

Lake Powell Fisheries Investigations



Annual Performance Report
May 1, 1989 - April 30, 1990

Completion Report
May 1985 - April 1990
Dingell-Johnson Project F-46-R



UTAH
NATURAL RESOURCES
DIVISION

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LAKE POWELL FISHERIES INVESTIGATIONS

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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. 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. 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. Lake Powell Fisheries Investigations was redesignated as Project F-46-R in 1985.

Studies undertaken since 1971 included game fish food habits, benthic invertebrate studies, plankton studies, threadfin shad *Dorosoma pentenense* population dynamics and predator impacts, an annual gillnetting program to determine trends in game fish populations, and smallmouth bass *Micropterus dolomieu* stocking and population development studies. The study of fishing pressure and success has been continuing 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 salmoides*, black crappie *Pomoxis nigromaculatus* and rainbow trout *Oncorhynchus mykiss*, include the introduction of threadfin shad in 1968, introduction of striped bass *Morone saxatilis* in 1974, introduction of smallmouth bass in 1982 and the expansion of the walleye *Stizostedion vitreum* population which developed from stock present in the drainage prior to 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 filled in 1980, inundated brush decomposed and disappeared causing a decline in spawning and nursery habitat which greatly

reduced largemouth bass and crappie recruitment. To help alleviate these population declines and to provide more diversity, striped bass and smallmouth bass have been introduced.

Striped bass were found to be naturally reproducing in the Colorado River above Lake Powell in 1979. In 1981, striped bass reproduction was detected within the still water of the reservoir. This double dose of reproduction was more than the threadfin shad forage base could support. Striped bass predation eliminated threadfin shad from the pelagic zone of the reservoir. Striped bass physical condition and average size quickly declined without adequate pelagic forage. A search for a remedy to declining size and physical condition of striped bass has continued throughout the 1980's.

Despite the problems of the striped bass population, black bass, particularly smallmouth bass have flourished. The population of largemouth and smallmouth bass in the aggregate, has increased during the present five year report period due to the success of the smallmouth bass stocking program.

Findings of our research from 1985 to 1989 are given in this report along with detailed results of the 1989 sampling year. More detailed accounts of events occurring in any particular year, 1985 to 1988, can be found in Lake Powell annual progress reports for that year (Gustaveson et al. 1986, 1987, 1988 and 1989).

FORAGE CONDITION STUDY

JOB I

BACKGROUND

Threadfin shad have been stocked throughout the Southwestern United States as forage (Kimsey et al. 1957, LaRivers 1962, Beers and McConnell 1966, Burns 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 (yoy). Sampling in the winter of 1968-1969 revealed that shad had spawned their first summer in Lake Powell. Heidinger and Imboden (1974) found that yoy 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 the summer of 1970 (Gloss et al. 1971).

Threadfin shad quickly became the predominant food item of all major game species in Lake Powell (May et al. 1975; Hepworth and Gloss 1976; Gustaveson et al. 1980). Striped bass were introduced into Lake Powell in 1974 and utilized the dense pelagic shad population. As threadfin shad numbers have declined, crayfish *Orconectes virilis*, sunfish *Lepomis* spp, and zooplankton have become the predominant prey for most gamefish.

Threadfin shad population data collected from 1976-1979 formed a baseline for comparing impacts the expanding striped bass population exerted on threadfin shad abundance (Gustaveson et al. 1980). Data collected from 1980-1984 provided information on shad abundance following intense predatory pressure by striped bass. Data were collected from 1985-1989 to determine if shad populations could recover under intense predation caused by the presence of an established striped bass population with unlimited reproductive potential.

METHODS

Threadfin shad spawning was monitored from 1985 through 1989 with ichthyoplankton net collections. Ichthyoplankton sampling began in May and continued through September. Weekly samples were taken in the backs of bays at Wahweap Creek, Warm Creek, Bullfrog Creek and Hall's Creek. Biweekly samples were collected in the back of Navajo Canyon. Samples were also collected at Red and Ticaboo canyons during 1985, Piute Farms Wash (1985-1987), and from 1985 through 1988 at Piute Red Wall and the San Juan River inflow (Figure 1). Because of logistic and manpower requirements at these sites, sampling was discontinued after 1988.

A 1.0 m diameter ichthyoplankton net with 505 micron mesh was towed just below the water's surface. Three tows, each of a two minute duration sampling an average volume of 102 m³ of water per tow, were made at each station. 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. Water temperature (C) and clarity (Secchi disk) were collected at each station when possible.

All samples were preserved in the field with 10% buffered formalin. A biological stain, Phloxine B, was mixed with formalin to aid in separating larval fish from sample debris. Larval fish were picked from the debris and when possible identified to species. All threadfin shad were counted and a subsample of up to 25 larvae, juveniles and adults, was measured to the nearest mm. Larval and juvenile shad were differentiated by size after criteria presented by Barnes (1977). Mean number and total length of larval shad per tow were then calculated for all stations.

Midwater trawls to sample shad recruitment to the pelagic areas were conducted using a 7.32 m work boat outfitted with two Marco W050 hydraulic winches powered by Vickers hydraulic pumps. With dual controls, it was possible to run both winches in tandem or individually. The trawl was

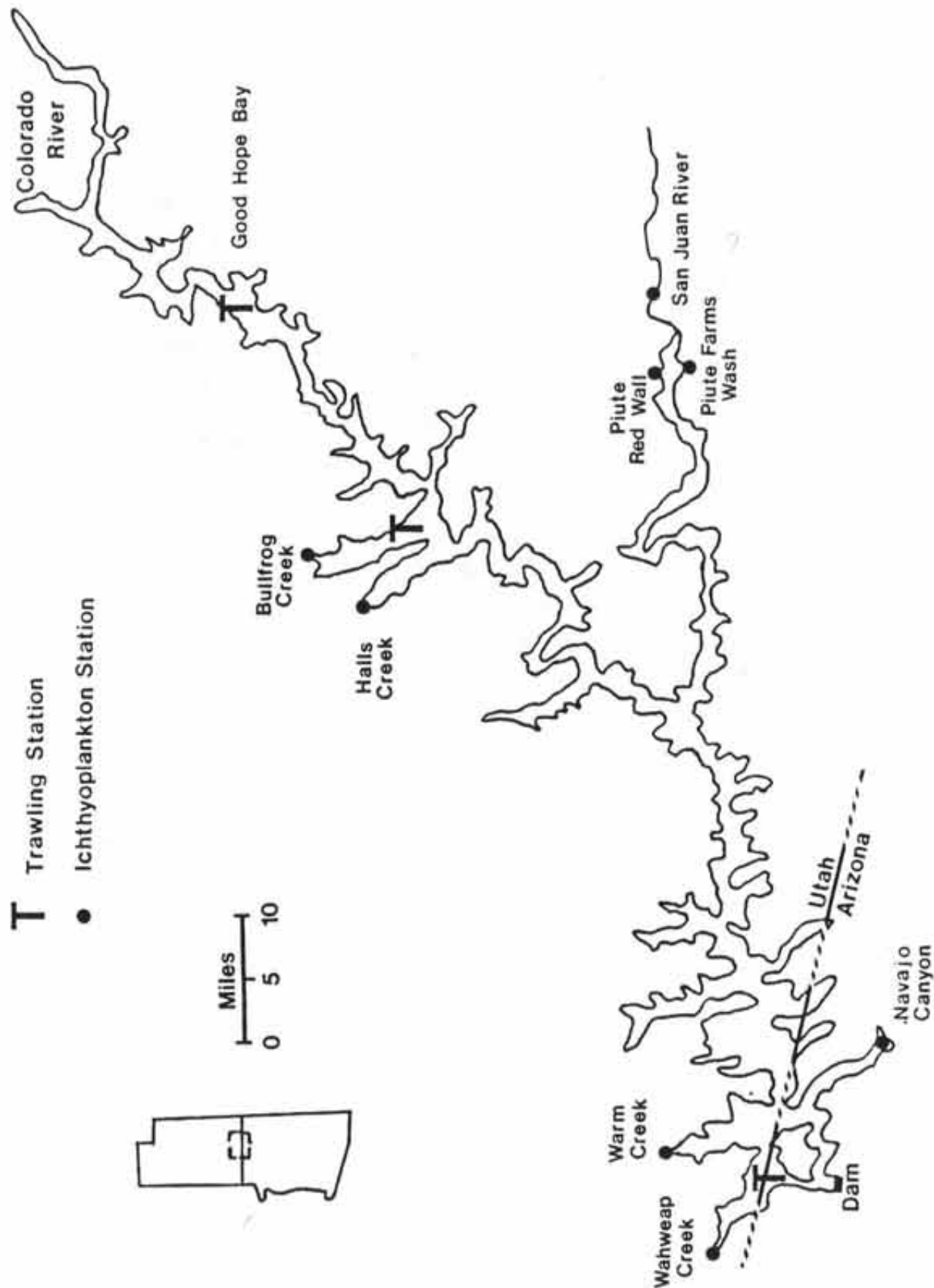


Figure 1. Map of Lake Powell showing trawling and ichthyoplankton netting stations for threadfin shad, 1985-1989.

designed after that described by von Geldren (1972). It measured 3.05 m x 3.05 m 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 cables (0.48 cm in 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, calculated using a T.S.K. flowmeter, was 8,178.44 m³ and the maximum depth fished was approximately 10.7 m, as measured by a Bendix T-1 bathythermograph. The oblique tow allowed 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 uniformly distributed instead of grouped in schools as found during the day (Houser and Dunn 1967, Netsch et al. 1971, Gustaveson et al. 1985). Sample nights were selected between new moon and first quarter to eliminate variability caused by moonlit nights. Once the net was retrieved, all fish were immediately removed from the net. All shad collected were preserved in the stained, buffered formalin solution. Mean shad number and total length were determined for each haul.

Trawling locations were selected to sample lake areas near the dam, midway uplake and near the Colorado River inflow in Wahweap, Bullfrog, and Good Hope bays, respectively (Figure 1). Each trawling location was sampled one night a month from July through September. The three areas of the lake were sampled on consecutive nights to allow comparison under approximately similar times and conditions. Three tows were made each sample night. Actual trawling transects were selected at random within each bay but they were in close proximity to previous transect sites.

Each night before trawl samples were taken, an 8-minute sonar transect was run over the trawling course using a Lowrance Model 1510C recorder with a LPT-101 transducer. The boat was operated at 800 rpm's during the sonar run. Echograms generated from these runs were used to supplement the trawl data.

RESULTS

Ichthyoplankton tows

Catches of shad peaked in June 1985 at both uplake sites, but neither reflected large numbers (Table 1). Shad reproduction at these sites declined in July as water temperatures exceeded 27 C. Increases in numbers to 6.3 shad/tow and a decrease in mean length to 10.3 mm in Red Canyon during August suggests resumption of spawning as temperatures declined. Secchi measurements in Red Canyon were consistently less than 1.0 m throughout the sampling period.

Samples were collected from the San Juan arm of the reservoir from 1985-1988 (Table 2). Catches at Piute Farms Wash and Piute Redwall generally peaked in June with very little reproduction from July through September (Table 2). The greatest catch at Piute Farms Wash (150.7 shad/tow) occurred in June 1987. Catches at Piute Redwall were greater than any other site sampled in the San Juan arm. During June of 1986 and 1987, catches averaged 227.3 and 472.9 shad/tow, respectively. Large numbers of shad were never collected from the San Juan River inflow site, suggesting either low reproduction or drift of newly hatched shad from the collection site. Water temperatures at these sites peaked during July and August corresponding to months of low reproduction, but unlike other lake sites reproduction showed little increase as temperatures cooled in September. Secchi measurements never exceeded 1.8 m throughout the sampling period and appeared not to be a limiting factor for shad reproduction in these areas.

The midlake sites, Bullfrog and Hall's creeks, have showed dissimilar patterns in shad catches from 1985-1989. Bullfrog Creek peaks in shad reproduction have shown a steady decline from 364.7 shad/tow in 1985 to 8.9 shad/tow in 1989 (Figure 2). Peaks in shad/tow occurred in May and June when water temperatures were increasing but still less than 27 C. Reproduction and catches declined as temperatures exceeded 27 C. Secchi measurements were consistently less than 2.0 m and did not appear to affect the magnitude of reproduction. Peak catches of shad in Hall's Creek remained fairly constant from 1985-1988, however, like Bullfrog Creek, peak catches in 1989 were the

Table 1. Monthly mean number and total length (mm) of larval threadfin shad collected during ichthyoplankton tows with corresponding mean temperature (C) and secchi (m) measurements for uptake stations, Lake Powell, 1985. (SE = Standard Error of the Mean)

Station	Year	Month	Shad/Tow	SE	Length	SE	Temp	Secchi
Red Canyon	1985	May	4.0	^a	9.3	^a	20.0	0.8
		Jun	26.5	1.56	9.5	0.18	24.7	0.6
		Jul	0.3	0.24	14.5		27.2	0.7
		Aug	6.3	3.66	10.3	1.44	25.9	0.5
		Sep	0.2	0.12	13.0		21.4	0.5
Ticaboo Canyon	1985	May	5.0		7.3		19.4	1.2
		Jun	8.5	5.80	9.4	3.11	24.7	1.9
		Jul	0.0	0.00			27.8	2.8
		Aug	0.4	0.24	9.5	3.18	26.1	1.7
		Sep	0.2	0.11	9.0		21.7	1.0

^a Blank indicates single sample with no SE.

Table 2. Monthly mean number and total length (mm) of larval threadfin shad collected during ichthyoplankton tows with corresponding mean temperature (C) and secchi (m) measurements for San Juan Arm, Lake Powell, 1985-1988. (SE = Standard Error of the Mean)

Station	Year	Month	Shad/Tow	SE ^a	Length	SE ^a	Temp	Secchi
Piute Farms Wash	1985	May	17.3		10.3		22.8	0.5
		Jun	6.0		8.8		23.9	0.5
		Jul	1.3		9.0		28.9	0.7
		Aug	0.0				26.7	0.6
		Sep	0.0				21.1	0.3
	1986	May	5.0		10.8		17.2	0.5
		Jun	128.9	65.87	8.7	1.17	25.0	0.5
		Jul	6.3	3.20	10.9	1.71	25.9	0.8
		Aug	0.0				27.2	0.5
	1987	May	3.3		9.3		18.9	0.5
		Jun	150.7	57.74	10.9	0.67	22.2	1.1
		Jul	0.0	0.00			28.1	1.4
		Aug	0.2	0.12	13.0		27.2	1.0
Piute Redwall	1985	May	68.7		8.4		23.3	0.5
		Jun	31.3		8.7		26.1	1.0
		Jul	0.7		11.5		27.8	0.6
		Aug	0.3		13.0		27.2	1.1
		Sep	4.7		7.8		21.1	0.5

Table 2. (Continued)

Station	Year	Month	Shad/Tow	SE	Length	SE	Temp	Secchi
Piute Redwall (Continued)	1986	May	28.3	^a	9.8	^a	19.4	0.3
		Jun	227.3	69.30	11.4	0.32	23.3	0.3
		Jul	23.0	6.80	13.3	1.28	26.5	0.5
		Aug	1.3		13.5		27.2	0.5
	1987	May	16.0		7.2		17.8	0.3
		Jun	472.9	48.19	11.3	0.25	21.1	0.8
		Jul	36.7	12.98	12.5	0.46	28.1	0.9
		Aug	5.9	1.31	13.1	0.74	26.1	0.5
	1988	May	3.7		10.0		23.9	0.9
		Jun	155.7		12.2		24.4	0.5
		Jul	23.5	16.62	5.5	3.89	28.1	0.8
		Aug	14.3		11.1		28.3	1.2
		Sep	5.7		17.6		21.7	0.2
San Juan River	1985	May	0.3		9.0		17.8	0.1
		Jun	1.0		4.0		17.2	1.8
		Jul	0.0				25.0	0.6
		Aug	0.0				26.7	0.3
		Sep	0.3		8.0		18.9	0.1
	1986	May	0.3		5.0		18.9	0.2
		Jun	0.9	0.11	4.2	2.02	20.8	0.2
		Jul	30.9	25.23	12.4		23.4	0.2
		Aug	0.7		10.0		28.9	0.2
	1987	May	0.0				15.6	0.3
		Jun	6.5	1.06	7.7	0.46	21.4	0.5
		Jul	3.0	1.91	8.3	1.63	26.9	0.7
		Aug	0.7	0.25	14.7	5.41	27.2	0.5
	1988	May	0.7		6.3		23.3	0.5
		Jun	0.0				22.2	0.5
		Jul	2.7	0.25	11.6	2.30	27.8	0.5
		Aug	24.7		17.0		27.5	0.3
		Sep	1.3		19.3		19.2	0.6

^a Blank indicates single sample with no SE.

lowest (15.7 shad/tow) of any recorded period (Figure 2). Because of the close proximity of Hall's and Bullfrog creeks, temperatures varied little between the two sites. However, in 1989 secchi measurements differed at the two sites, although the difference was probably related to changes in accessibility caused by the drastic drop in reservoir level. Sand bars and trees which had been submerged but were above the water level in August and

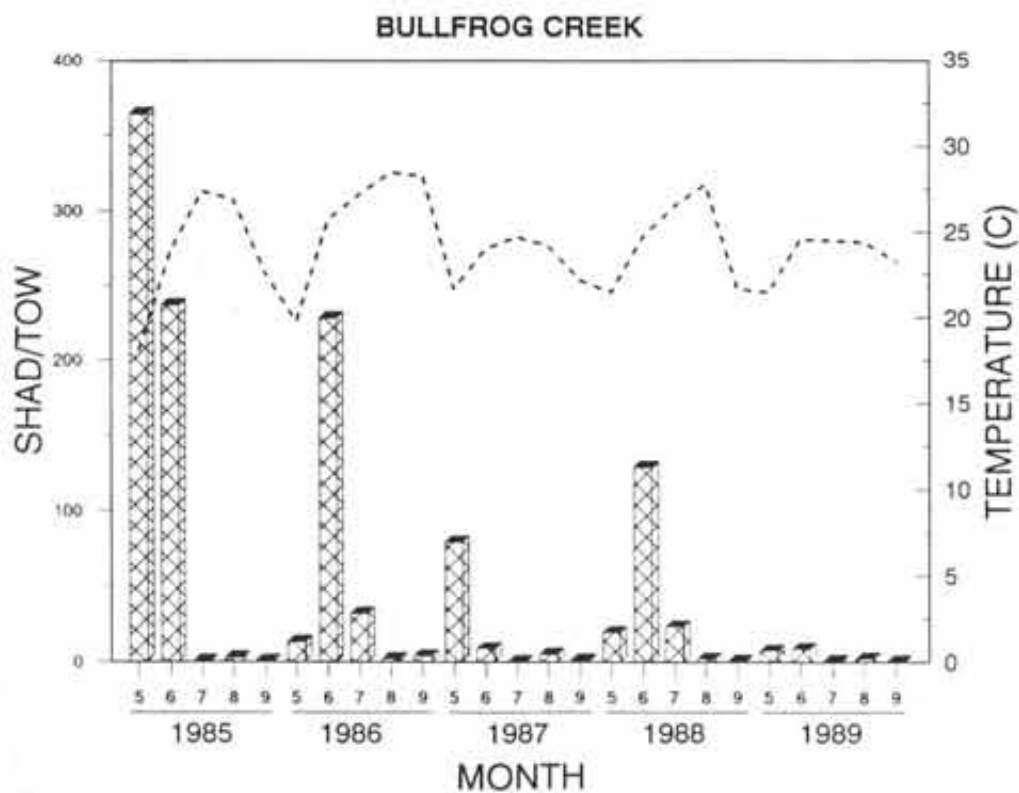
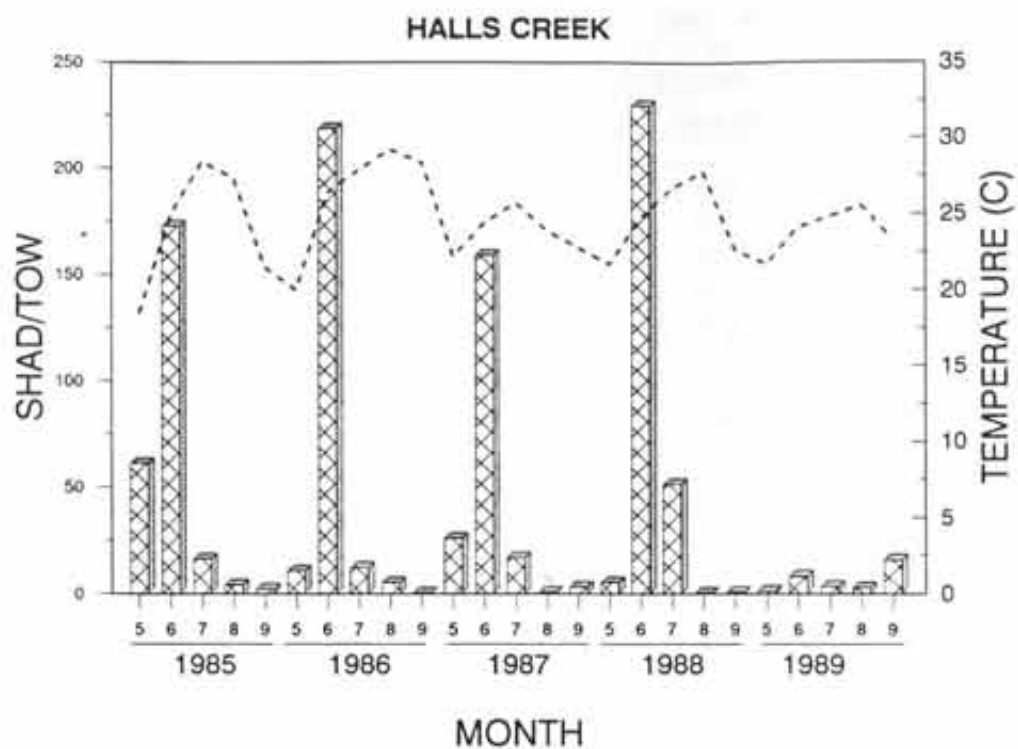


Figure 2. Mean number of larval shad collected per ichthyoplankton tow and mean water temperature, Hall's and Bullfrog creeks, mid Lake Powell, 1985-1989.

September limited access to the back of Hall's Creek.

Trends in shad catches in downlake sites at Wahweap and Warm creeks and Navajo Canyon varied by site. Peaks in shad/tow at Wahweap Creek have generally declined from 1985-1989 (Figure 3). The highest peak (131.2 shad/tow) was observed in 1985 with a peak of only 27.4 shad/tow in 1989. Similar to most other stations, mean fish length at Wahweap Creek increased through the summer and declined again in September. Water temperature patterns varied little from year to year, generally warming to highs between July and August and cooling in September. Secchi measurements have remained fairly constant, ranging from 0.4-0.9 m.

Warm Creek is the only site lakewide which has shown an increase in larval shad abundance from 1985-1989 (Figure 3). Peaks in abundance generally occurred in May and/or June, however, in 1989 a early summer peak was not observed. Rather, abundance peaked in September at 309.9 shad/tow. Shad reproduction appeared to decrease as summer water temperatures approached their apex. Except for an unusual secchi reading of 1.5 m in August of 1985, secchi measurements were always <1.0 m.

Navajo Canyon has also shown a decline in catch rates of larval shad from 1986-1989 (Figure 4). In 1989 there were peaks of 102.0 and 117.2 shad/tow in June and August, respectively. Although these peaks were less than most years for Navajo Canyon, they were well above peaks at most other Lake Powell sites during 1989.

Midwater trawls

Midwater trawl catches of threadfin shad in Lake Powell have steadily declined. Catches in 1989 were at their lowest level since monitoring began in 1977 (Figure 5). In 1989 pelagic shad were not captured from Wahweap or Good Hope bays and only a single adult shad was collected in 9 trawl hauls from Bullfrog Bay. Catches of shad in 1988 were only slightly better. The highest catches from 1985-1989 were just over 9 shad/trawl in Wahweap Bay in 1987 and 11 shad/trawl in Good Hope Bay during 1985 (Figure 5). These catches are well below those of previous years in which catches averaged near 131 shad/trawl in 1984 and over 1,250 shad/trawl prior to 1980.

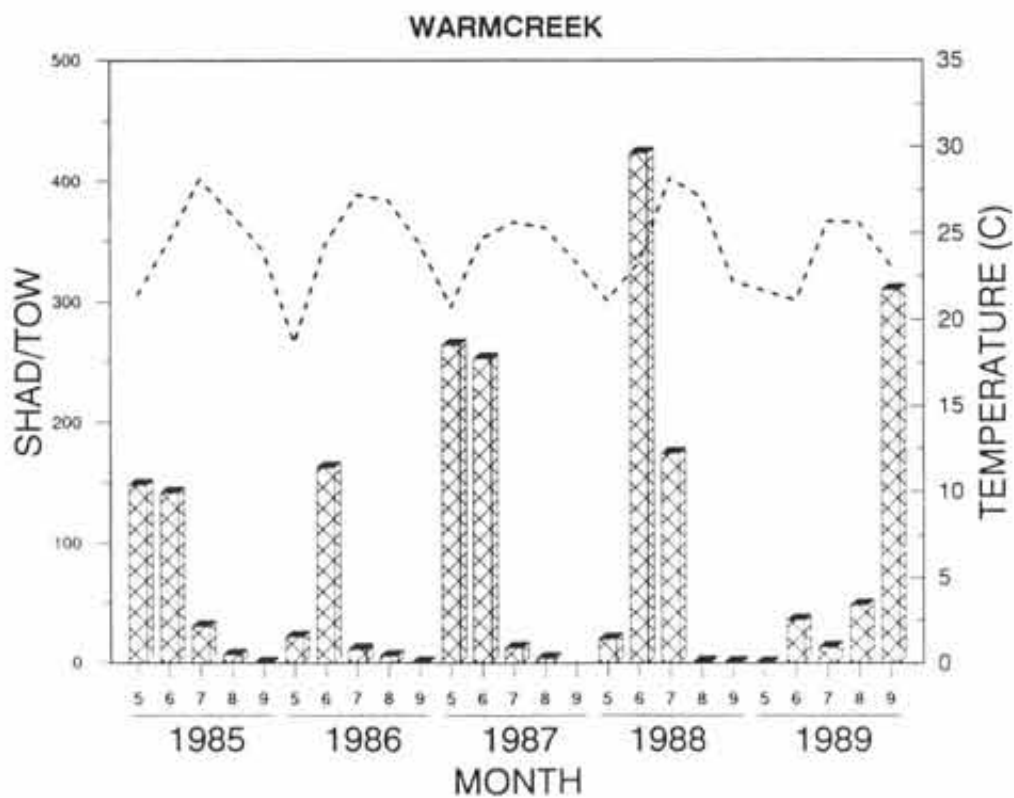
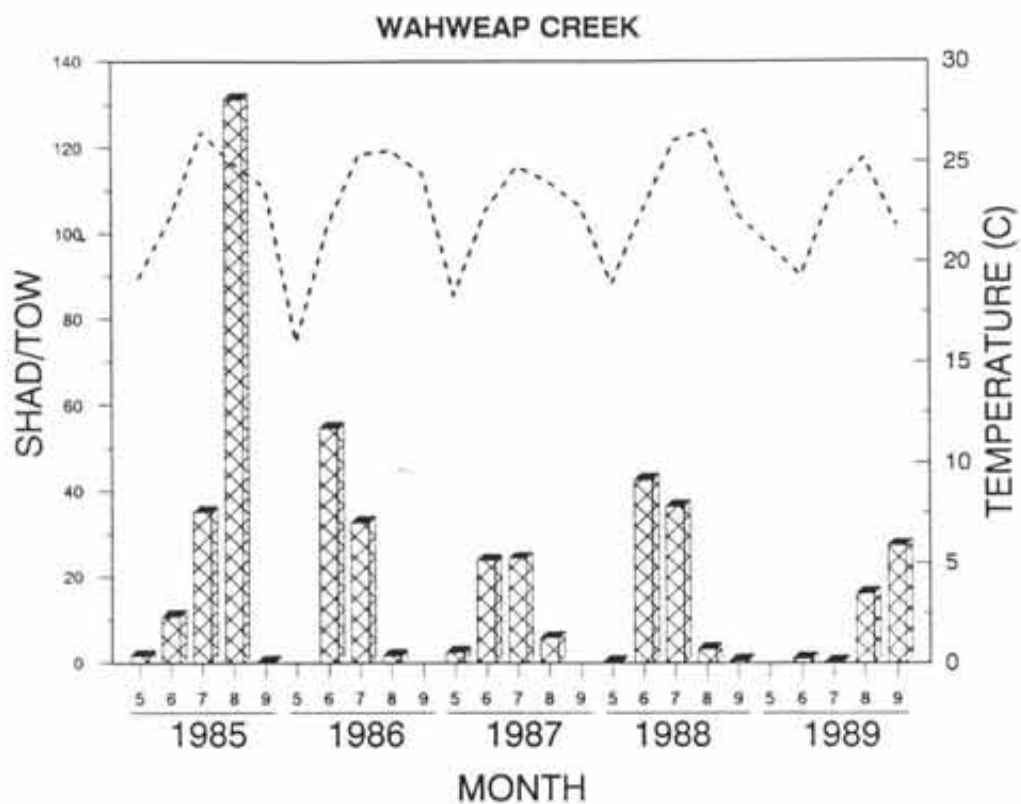


Figure 3. Mean number of larval shad collected per ichthyoplankton tow and mean water temperature, Wahweap and Warm creeks, lower Lake Powell, 1985-1989.

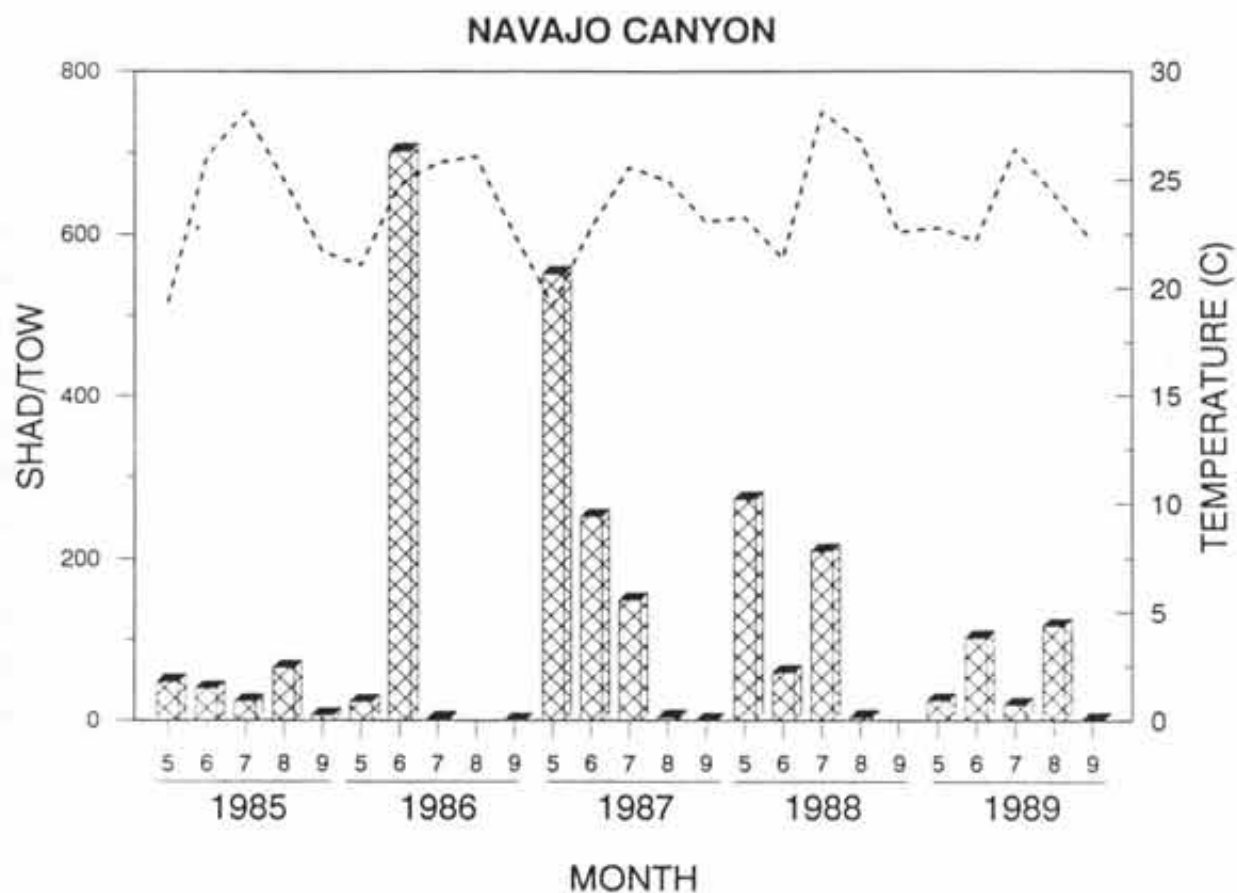
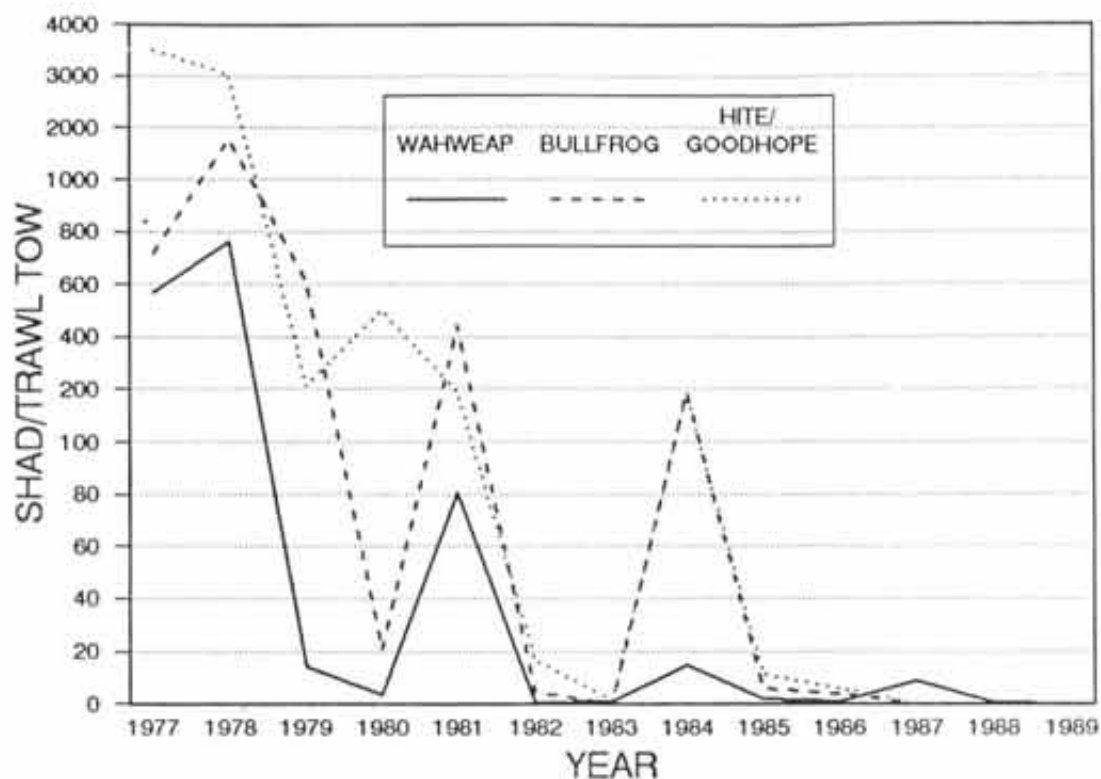


Figure 4. Mean number of larval shad collected per ichthyoplankton tow and mean water temperature, Navajo Canyon, lower Lake Powell, 1985-1989.



Shad trawls 1985-1989

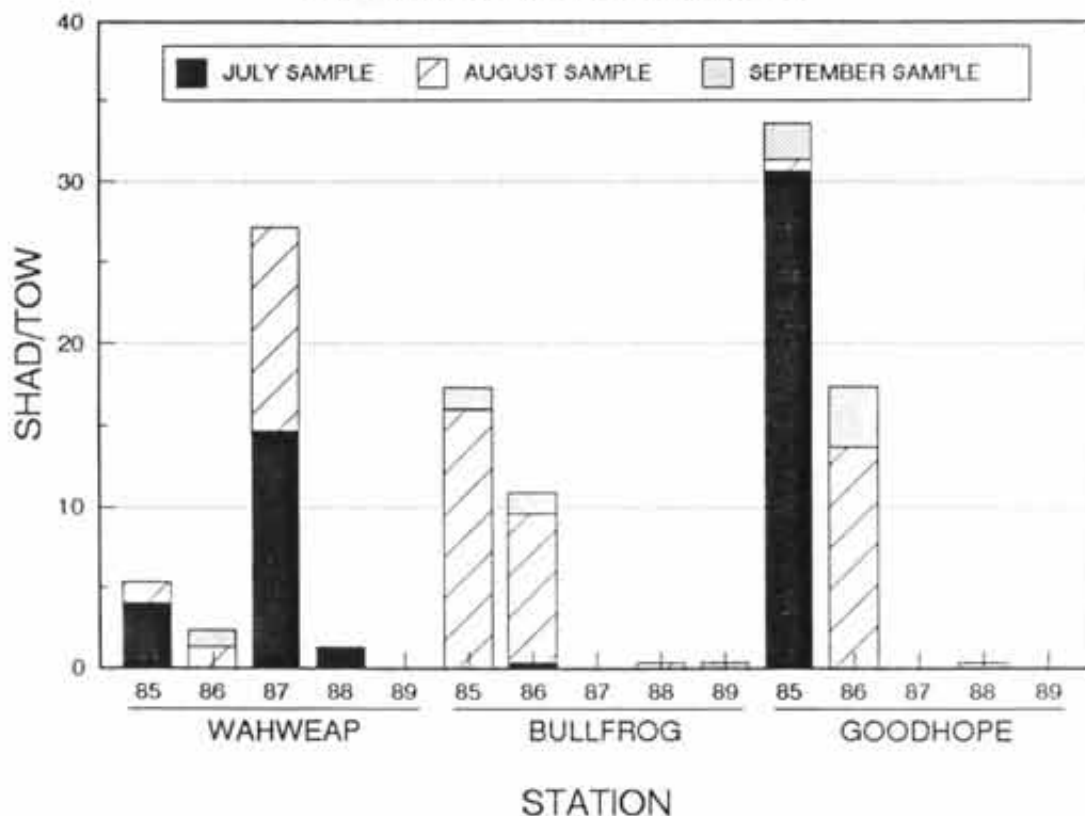


Figure 5. Mean number of shad collected per trawl tow by station and month, 1985-1989 (lower figure) and historic catch of threadfin shad collected per trawl tow at Lake Powell, 1977-1989 (upper figure).

DISCUSSION

In Lake Powell, shad generally spawn when water temperature at dawn is between 16 and 27 C. Spawning begins in early or mid-May, peaks during June and sometimes persists into September. Threadfin shad reproduction in the backs of canyons and yoy recruitment to the pelagic zone have been monitored with ichthyoplankton tows and midwater trawl sampling. Reproduction in the backs of Lake Powell's canyons has been verified and monitored since 1976 (Gustaveson et al. 1980, 1985). As yoy shad grow and densities increase, they become more pelagic and move to the open waters of the reservoir becoming less vulnerable to 1.0 m nets and more vulnerable to midwater trawls (Houser and Dunn 1967, Houser and Netsch 1971). Those recruited to the pelagic zone become available forage for striped bass and other open water predators (Morris and Follis 1978, Mosher 1984). Decreasing pelagic shad populations were first observed in Lake Powell in 1982-1983 and immediately resulted in reduced condition factors in striped bass (Gustaveson et al. 1985).

The larval shad peaks observed in September in Wahweap and Warm creeks may have resulted from yoy spawning which has been observed in other lakes (Johnson 1971; Heidinger and Imboden 1974; McHugh 1983). Yoy spawning may have been triggered by low population numbers reflected by low larval abundance in May and June. This perhaps serves as a mechanism for the population to maintain a level sufficient for survival. Anderson (1973) found spawning was affected by density dependent factors, including crowding and nutritional conditions.

Shad abundance in ichthyoplankton tows in 1989 were the lowest since monitoring began. Indications are that threadfin shad will not recover to their previous abundance and will probably provide little if any forage to striped bass in the pelagic zone. The shad that do migrate out of turbid waters are probably consumed before reaching open bays. Greater visibility in some canyons may contribute to low numbers of shad. Shad tend to spawn in shallow, turbid water along shorelines and in the backs of canyons and bays (Gustaveson et al. 1985). Turbidity also reduces predatory effectiveness and probably permits development of small populations within turbid zones.

Striped bass have been shown to be effective predators, eliminating or impacting shad in other systems (Combes 1978, Morris and Follis 1978). In lakes and reservoirs with sufficient productivity and ample prey species diversity, shad have suffered little or no impact from striped bass predation (Nash et al. 1987). Lake Powell, with a single pelagic prey species, offers little prey diversity to striped bass predation. It is likely that the threadfin shad population in Lake Powell will continue to exist in the turbid waters of the backs of canyons but will not provide enough forage under the intense predatory pressure of the existing striped bass population.

Although shad reproduction was confirmed in the backs of canyons, results from midwater trawls indicated that few if any of these fish recruited to the pelagic zone during the summer. 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. Pelagic shad were virtually absent at all trawl stations in Lake Powell since 1987.

Gustaveson et al. (1985) proposed that shad populations in Lake Powell were cyclic because peaks in trawl catches were observed in 1978, 1981, and 1984. If a 3-year cycle still existed on Lake Powell, 1987 would have been the next population peak. Wahweap Bay, the furthest site downlake had a slight peak in 1987 but no peaks were evident further uplake. However, decreases in the amplitude of each successive peak from 1978-1984 were noted by Gustaveson et al. (1985). It has been shown that density dependent factors, including crowding and food, affect shad spawning. The cycling observed in the shad population could be density related, whereas, the overall long-term decline in the population is probably predator related.

The near absence of pelagic shad in 1988 and 1989 suggests that shad numbers may be suppressed by predators to a level where the population cannot rebound under current conditions. In lake E.V. Spence, striped bass reduced the standing crop of gizzard shad and completely eliminated threadfin shad (Morris and 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 thus were eliminated. Threadfin shad are the only schooling forage fish in Lake Powell

to support the striped bass population. Striped bass in Lake Powell seemingly have unlimited reproductive potential (Gustaveson et al. 1985). Although larval shad collected from the backs of canyons are evidence of reproduction and a sustained population, predatory impact appears too great to allow reestablishment of a pelagic population. When threadfin shad were first introduced into Lake Powell, a lakewide population developed in just over one year. However, that took place in the absence of striped bass which had not yet been introduced into the reservoir.

Spawning in Lake Powell was directly related to water temperature. Threadfin shad at Lake Powell appear to spawn at water temperatures from 16-28 C. Heidinger (1983) found a thermal cut-off of spawning activity at approximately 30 C. He also found higher shad recruitment where optimum water temperatures for shad spawning occurred for longer periods of time without exceeding the thermal cut-off temperature. Sample temperatures never exceeded 30 C, however, these measurements were probably not taken when temperatures were at their daily apex. When sample temperatures exceeded 27 C larval shad catches declined to near zero. Water temperatures from May through September remained near optimum and accounted for the extended spawning season. Shad winter die-offs which occur in temperate lakes (Parsons and Kimsey 1954) are a rare occurrence at Lake Powell (Gustaveson et al. 1985) and do not appear to be a limiting factor on population numbers.

RECOMMENDATIONS

Monitoring since 1979 has documented continued shad existence even under extreme predatory pressure. Turbid water in the backs of some canyons provides rufugium for shad. Enough shad survive in these areas each year to spawn. However, successful reproduction does not mean recruitment to the pelagic zone or to the forage base for striped bass. From 1985 to the present, few shad have been collected from the pelagic zone. Because continued monitoring of shad at the present level of intensity will probably not reveal any further information under present predatory pressures it is, therefore, recommended that ichthyoplankton netting be reduced or discontinued and midwater trawling in Lake Powell be reduced to a one-month period. Larval

shad samples indicated peak spawning generally occurred from mid-May through June and yoy shad historically recruited to the pelagic areas in July and August. Sampling of the pelagic zone in July would maximize chances for capturing recruited shad.

Sampling intensity can be increased if shad recruitment to the pelagic zone reoccurs. Striped bass condition (K_{fl}) has been an immediate proxy for shad availability (Gustaveson et al. 1985). In addition, striped bass stomach contents have reflected when shad were present; shad being their preferred food. When shad are absent striped bass switch to plankton, crayfish, and sunfish. These indicators should allow for continued feedback on shad population levels.

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. 1980, 1985; Scott and Gustaveson 1989). In general, both total recreational boat use and angling pressure have increased steadily since 1965. However, a sharp reduction in angling pressure was observed in 1988. 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 (Scott and Gustaveson 1989). Since 1984, striped bass have been a major component of angler success and harvest.

METHODS

A scheduled creel census was conducted from April through October in 1985 and 1988. In 1985 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. However, in 1988 a new marina was opened at Piute Farms Wash and this new access area was added to the creel survey.

During 1985 each station was surveyed 4 random days/month. In 1988 Wahweap was surveyed 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 and a 2 days/month survey was added at Piute Farms. All creel survey days were 6 hours; generally 1400-2000 h. Data obtained during angler interviews 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, stomach samples were obtained from selected samples of game fish.

Pressure estimates were based on the total number (fishing and non-fishing) 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 launching ramps 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. 1980), creel surveys were not conducted during these months. However, pressure estimates were provided by the National Park Service for the entire year. Creel survey data presented in this report are based only on those months when a census actually occurred (April-October).

RESULTS AND DISCUSSION

Fishing pressure on Lake Powell increased from 1975-1982. Fishing pressure decreased in 1983-1984 when gas prices dramatically increased nationwide. Decreased fishing pressure during this period were observed elsewhere (Osburn et al. 1988). Fishing pressure increased in 1985 to 128,186 fishing boat-days but dropped again in 1988 to 104,482 fishing boat-days (Table 3). This drop corresponds to decreases in striped bass average size and condition (see Job IV). Average time fished/trip and mean number of fishermen/boat have remained fairly constant from 1975-1988.

Table 3. Fishing boat use (boat-days) by month, Lake Powell, 1975-1985 and 1988. 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	Jun.	Jul.	Aug.	Sep.	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
1985	997	1,208	3,382	17,217	14,873	18,369	8,798	18,858	18,184	17,467	6,631	2,182	128,186	4.3	2.5
1988	1,511	1,492	2,808	14,386	16,677	12,653	6,537	9,283	16,815	16,645	4,031	1,812	104,482	3.9	2.4
Average	567	988	3,626	13,046	15,658	12,440	7,010	8,199	9,601	8,564	4,031	1,061			
X	0.7	1.2	4.3	15.4	18.5	14.7	8.3	9.7	11.3	10.1	4.8	1.3			

Angler origin was different in 1988 than during previous creel years. Gustaveson et al. (1985) reported little change in angler origin from 1980-1984. Resident states (Utah and Arizona) showed slight gains in percent of angler representation (Table 4). The greatest changes in angler representation were in western non-resident states. Colorado anglers, who gained access to Lake Powell at Hite, Hall's Crossing, and Bullfrog marinas, declined 7.2%. New Mexico anglers, who normally come to Hall's Crossing, declined 1.9%. The largest increase was from California anglers who increased from 5.5% to 12.6% of total anglers.

Table 4. Change in angler origin by percent from the period 1980-1984 and 1988, Lake Powell.

<u>ORIGIN</u>	<u>1980-1984</u>	<u>1988</u>	<u>% CHANGE</u>
Utah	29.8	30.9	+ 1.1
Colorado	28.6	21.4	- 7.2
Arizona	26.8	27.5	+ 0.7
New Mexico	5.6	3.7	- 1.9
California	5.5	12.6	+ 7.1
Other	3.7	3.9	+ 0.2

Changes in angler fish preference were observed between 1985 and 1988. In general, anglers on Lake Powell were less discriminating and not targeting specific species (Table 5). In a national survey (U S Fish Wildlife Service 1988), 20% of the anglers responded that they fished for any species of fish available. This is well below the 45% of Lake Powell anglers responding that they fished for any fish. Declines in the largemouth bass and black crappie fisheries, and the reduction in size and condition of the striped bass fishery may have discouraged some anglers (see Jobs III and IV). Wahweap was the only area where fishermen were more discriminating in 1988 than 1985. This was primarily due to an increase in anglers targeting juvenile striped bass. Anglers who normally seek a specific game fish (i.e. trophy striped bass or black crappie) may travel elsewhere to fish when these fish were not available at Lake Powell. This may account, in part, for the decline in total fishing pressure at Lake Powell witnessed during 1988.

Table 5. Species sought (%) by anglers, Lake Powell, April-October, 1985 and 1988. Trace (t) = < 1%.

Species	<u>Hite</u>		<u>Bullfrog/Hall's</u>		<u>Wahweap</u>		<u>Total</u>	
	1985	1988	1985	1988	1985	1988	1985	1988
Largemouth Bass	28	13	12	13	12	13	14	13
Black Crappie	5	0	1	t	2	0	2	t
Striped Bass	20	24	47	42	40	45	41	37
Walleye	2	2	3	2	3	2	3	2
Channel Catfish	1	3	t	t	2	2	1	3
Bluegill	0	1	t	t	1	t	t	1
Smallmouth Bass	0	t	0	t	t	1	t	1
Any	44	56	37	41	40	36	39	45

Striped bass have become a major component of the Lake Powell fishery in the 1980's. Striped bass accounted for 64% and 60% of all fish creeled in 1985 and 1988, respectively (Table 6). Largemouth bass and black crappie which once combined for over 90% of all fish harvested now account for only 10%. Smallmouth bass were first observed in the creel in 1988 but represented only 1% of all fish creeled.

The total creel rate in 1988 remained the same as it was in 1985. Although changes in species composition of the creel have occurred, total creel rate was 0.41 fish/h (Table 7). Increases in total creel rate above 1984 levels could have been influenced by a peak in striped bass population size and a change in striped bass daily creel limits from 4 to 10 fish. Creel rates of striped bass increased to near 0.20 fish/h in 1985 and 1988 (Table 8). This represents a substantial increase from <0.04 fish/h at all sites in 1984.

Table 6. Species composition by percent (t = <1%) of the total recorded creel census for Lake Powell, 1964-1985 and 1988.

Year	Largemouth Bass	Black Crappie	Rainbow Trout	Striped Bass	Walleye	Channel Catfish	Bluegill	Smallmouth Bass	Other
1964	60	--	25	--	--	9	--	--	6
1965	61	--	27	--	--	7	--	--	5
1966	62	--	27	--	--	8	--	--	3
1967	69	1	5	--	--	20	3	--	2
1968	47	9	1	--	--	21	17	--	5
1969	42	16	10	--	--	11	19	--	2
1970	37	34	4	--	--	8	14	--	3
1971	34	50	1	--	--	4	10	--	1
1972-73	29	50	2	--	--	8	10	--	1
1974	37	48	1	--	--	5	8	--	1
1975	48	44	t	--	--	3	4	--	t
1976	42	47	t	--	--	2	7	--	t
1977	32	49	t	t	t	10	7	--	1
1978	38	40	t	1	t	12	7	--	t
1979	48	36	t	3	2	6	4	--	t
1980	29	24	t	15	10	12	10	--	t
1981	39	18	t	12	10	13	8	--	t
1982	26	16	t	33	9	13	2	--	t
1983	19	23	--	30	7	10	10	--	1
1984	34	18	--	15	8	11	12	--	2
1985	10	7	--	64	10	5	2	--	t
1988	9	1	--	60	3	11	13	1	2

Table 7. Total creel rate for all species by month and year for Lake Powell, 1964-1985 and 1988.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mo/Ave ^a	Mt/Ave ^b
1964	--	--	--	--	--	--	.73	.48	.62	.56	.75	.81	.66	.61
1965	.51	.66	.59	.69	.61	.47	.52	.57	.52	.69	.74	.67	.60	.59
1966	.69	.43	.61	.58	.51	.72	.82	.86	.51	.49	1.16	.71	.67	.61
1967	.40	.29	.45	.42	.40	.46	.57	.38	.38	.40	.36	.51	.42	.42
1968	.04	.17	.34	.42	.52	.35	.32	.47	.65	.46	.27	.28	.33	.41
1969	.25	.08	.34	.52	.71	.44	.41	.60	.54	.71	.75	.36	.48	.54
1970	.17	.37	.53	.69	.68	.59	.53	.62	.56	.29	.43	1.19	.55	.60
1971	.50	.64	1.58	1.28	1.14	1.28	.76	.81	.48	.45	.63	.28	.82	1.05
1972	.39	--	--	1.47	.90	.67	.49	.39	.34	.47	.40	--	.61	.53
1973	--	--	.56	.62	.68	.47	.29	.21	.18	--	--	--	.43	.43
1974	--	--	.84	.59	.43	.37	.17	.41	.31	--	--	--	.45	.45
1975	--	--	.35	.58	.67	.53	.52	.22	.15	--	--	--	.30	.55
1976	--	--	--	.58	.54	.38	--	--	--	--	--	--	.50	.51
1977	--	--	--	.47	.34	.31	.17	.29	.17	--	--	--	.29	.37
1978	--	--	.14	.28	.21	.23	.34	.19	.19	--	--	--	.23	.23
1979	--	--	.41	.54	.54	.43	.20	.31	.24	--	--	--	.38	.45
1980	--	--	--	.54	.43	.34	--	--	--	--	--	--	.44	.47
1981	--	--	--	.50	.34	.26	.30	.48	.29	--	--	--	.36	.34
1982	--	--	--	.31	.38	.26	.30	.52	.35	.31	--	--	.35	.28
1983	--	--	--	.25	.23	.21	.16	.14	.11	.44	--	--	.22	.21
1984	--	--	--	.15	.20	.19	.23	.11	.18	.22	--	--	.18	.18
1985	--	--	--	.24	.40	.31	.30	.84	.42	.42	--	--	.42	.41
1988	--	--	--	.29	.42	.45	.35	.35	.38	.38	--	--	.37	.41

^a Average of monthly creel rates.^b Total fish caught divided by total hours.

Table 8. Striped bass creel rates (fish/angler hour) by access area, Lake Powell, 1980-1985 and 1988.

Location	1980	1981	1982	1983	1984	1985	1988
Hite	0.002	0.005	0.015	0.023	0.024	0.118	0.180
Bullfrog/Hall's	0.004	0.008	0.026	0.031	0.032	0.320	0.320
Wahweap	0.007	0.034	0.083	0.154	0.023	0.219	0.240

RECOMMENDATIONS

The creel survey should continue every third year to assess changes in Lake Powell's sport fishery. The survey will follow the same methods so that the data will be comparable between years and so trends can be readily identified. The 1991 creel census should document the expanding smallmouth bass fishery and predict how important that fishery will be to the future of Lake Powell.

INDEX TO ANNUAL POPULATION TRENDS

JOB III

ANNUAL NETTING

BACKGROUND

Standardized spring gill net sampling has been used to describe gross changes in fish population densities and species composition at Lake Powell since 1971 (Gloss et al. 1974; May and Hepworth 1976; Gustaveson et al. 1980, 1985). The gill net sampling has been most effective in describing changing trends in the largemouth bass and walleye populations.

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

Gill net sampling was conducted during March 1985-1988 at Padre Bay, San Juan Arm, Rincon, and Good Hope Bay (Figure 1). Spring netting was not conducted in 1989 due to personnel changes and time constraints. Gangs of ten 30.5 m diving experimental gill nets with four 7.62 m panels (mesh sizes 25, 38, 51, and 76 mm) were fished for two consecutive days at each station. On rare occasions, 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 each morning, weighed and measured, scales taken for age and growth analysis, and stomach contents classified.

RESULTS AND DISCUSSION

The 1988 total spring gillnetting catch rate (1.62 fish/net day) was the lowest since netting began in 1971 (Table 9). The catch rates for individual species have varied over time corresponding to changes in the reservoir and the fishery. The highest catch rates were in 1972 and 1975 corresponding to peaks in largemouth bass abundance. However, largemouth bass catch has remained at a stable, though relatively low level since 1983.

As largemouth bass abundance declined after 1975, walleye abundance increased (Figure 6). Walleye abundance peaked in 1981 at 4.99 fish/net-day (Table 9). Walleye catches have also stabilized at a low level near 0.70 fish/net-day since 1986. Striped bass numbers increased in the gill net catch, peaking in 1985 at 3.07 fish/net-day and then declining to 0.18 fish/net-day in 1988. The decrease in overall catch from 2.18 fish/net-day in 1987 to 1.62 fish/net day in 1988 was primarily caused by a decrease in striped bass catch.

Some species which were represented in early gill net catches have disappeared from Lake Powell. Flannelmouth sucker *Catostomus latipinnis*, the one Colorado River system native species which was once abundant in Lake Powell, has not been collected since 1984. Rainbow and brown trout *Salmo trutta*, sport fish once common in areas of Lake Powell, have also disappeared.

Channel catfish *Ictalurus punctatus* and common carp *Cyprinus carpio* catches have remained fairly constant from 1971-1988. Smallmouth bass were collected in the 1988 gill netting and should become more abundant as this population develops. Smallmouth bass harvest has surpassed largemouth bass harvest in other reservoirs dominated by rocky substrate (Rideout and Oates 1975).

Despite low threadfin shad abundance in Lake Powell (Job I) shad remain the predominant food item for walleye (Table 10). Crayfish appear infrequently in walleye stomach samples although they are the most common food item in largemouth bass (Table 11). Some dietary overlap exists between walleye and largemouth bass, but analysis of stomach contents suggested that interspecific competition for food may be low. Low sample size in 1989 made comparisons to previous years unreliable.

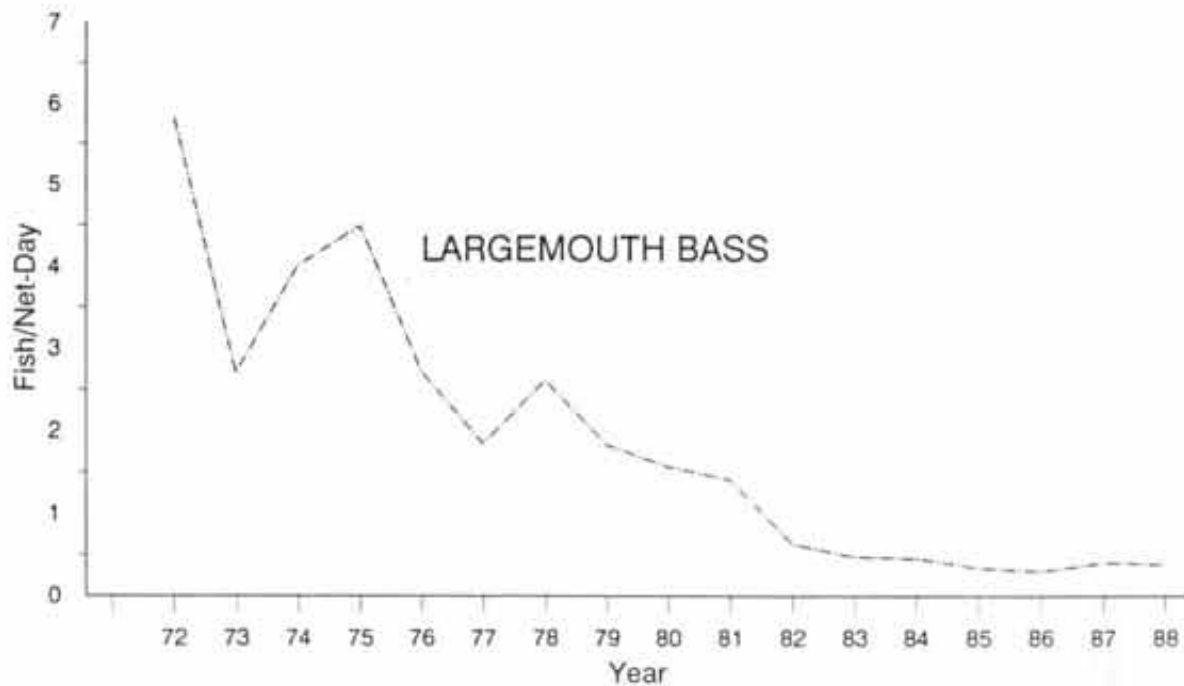
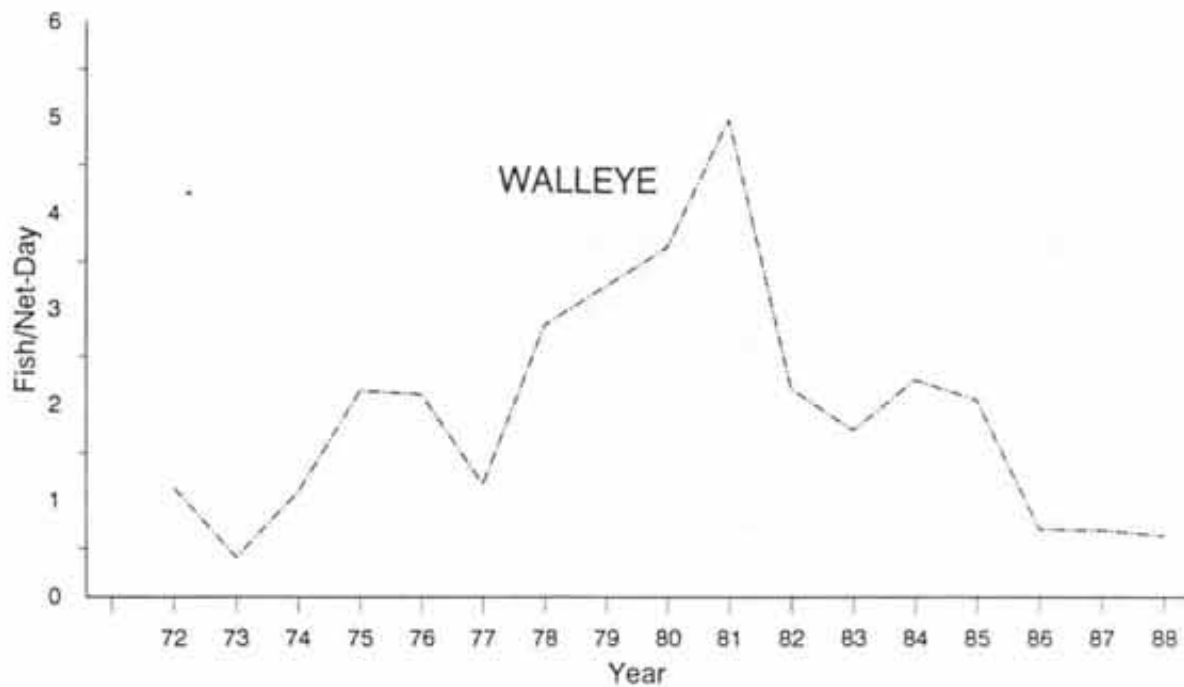


Figure 6. Catch rates (fish/net day) for walleye and largemouth bass from annual netting, Lake Powell, 1972-1988.

Table 9. Catch rate (fish/net day) by species and year, annual gill netting, Lake Powell, 1971-1988.

Species	Catch Rate																	
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
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	0.34	0.30	0.40	0.39
Smallmouth bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
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	2.05	0.70	0.69	0.63
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	3.07	0.70	0.49	0.18
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	0.06	0.00	0.00	0.00
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	0.06	0.01	0.11	0.04
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	0.04	0.01	0.05	0.04
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	0.17	0.16	0.13	0.13
Common 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	0.35	0.22	0.31	0.21
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	0.00	0.00	0.00	0.00
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	0.00	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	0.00	0.00	0.00	0.00
Yellow perch	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	0.01	0.05	0.00	0.01
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	6.16	2.16	2.18	1.62

Table 10. Percent occurrence of food items in walleye collected in gill nets and during creel census, Lake Powell, 1985-1989. (Percentage based on number of stomachs containing food.)

	YEAR				
	1985	1986	1987	1988	1989
Sample size (n)	218	56	55	50	11
Empty stomachs	201 (92%)	36 (64%)	36 (65%)	21 (42%)	6 (55%)
Stomachs w/food	17	20	19	29	5
<u>Food item</u>					
Crayfish	1 (6%)	0	0	0	0
Plankton	0	0	0	0	0
<u>Fish</u>					
Threadfin shad	5 (29%)	5 (25%)	12 (63%)	22 (76%)	1 (20%)
Bluegill	0	0	0	0	0
Green sunfish	2 (12%)	1 (5%)	4 (21%)	1 (3%)	0
Centrarchids	1 (6%)	0	0	4 (14%)	2 (40%)
Other fish	1 (6%)	0	1 (5%)	0	0
Unknown fish	7 (41%)	14 (70%)	4 (21%)	3 (10%)	2 (40%)

Table 11. Percent occurrence of food items in largemouth bass collected in gill nets and during creel census, Lake Powell, 1985-1989. (Percentage based on number of stomachs containing food.)

	YEAR				
	1985	1986	1987	1988	1989
Sample size (n)	49	24	32	31	7
Empty stomachs	26 (53%)	3 (13%)	11 (34%)	8 (26%)	3 (43%)
Stomachs w/food	23	21	21	23	4
<u>Food item</u>					
Crayfish	18 (79%)	14 (67%)	19 (90%)	22 (96%)	1 (25%)
Plankton	0	0	0	0	0
<u>Fish</u>					
Threadfin shad	0	1 (5%)	1 (5%)	2 (9%)	1 (25%)
Bluegill	1 (4%)	1 (5%)	1 (5%)	0	0
Green sunfish	2 (9%)	1 (5%)	3 (14%)	3 (13%)	0
Centrarchids	1 (4%)	0	0	2 (9%)	2 (50%)
Other fish	0	0	0	0	0
Unknown fish	1 (4%)	5 (24%)	0	0	0

SUMMARY AND RECOMMENDATIONS

Largemouth bass and walleye catches have stabilized at low levels. Striped bass have reached their lowest level since they peaked in 1985. Only channel catfish and carp catches have remained constant since 1971. Smallmouth bass were sampled for the first time during spring gill netting in 1988 and should increase in the future.

Annual gill netting catch rates have corresponded with fishermen creel rates for largemouth bass and walleye. Netting should continue to determine if a relationship between smallmouth bass relative abundance and sport fishery catch rate exists. Monitoring of other fish species comprising the Lake Powell fishery with gill nets should also continue.

ELECTROFISHING

BACKGROUND

An annual program of electrofishing was initiated in 1977 to obtain information on the relative abundance of yoy largemouth bass and black crappie which were inadequately sampled by gill nets. More recently, this survey has been used to assess smallmouth bass population development.

METHODS

A 5.5 m specially fabricated aluminum boat was used for electrofishing. An Onan 7.5 kw generator provided electrical power for the lighting system and a Coffelt Model VVP-15 electroshocker. The positive array consisted of two dropper electrodes. The negative electrodes were 2.0 m long sections of 13 mm cable, one on each side of the boat. The output to the entire positive array was 5-8 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, Stanton Creek, and Good Hope Bay) were sampled each year (Figure 1). Similar shoreline habitat was electrofished at each transect. Electrofishing 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 were summations of all fish captured during the four 15 minute sessions at each station.

RESULTS AND DISCUSSION

Electrofishing catch rates by site in 1989 appeared similar to previous years. Stanton Creek had the highest mean catch rate (107 fish/h) whereas, the San Juan arm had the lowest (28 fish/h) (Table 12). This ranking also occurred during the 1988 electrofishing survey (Gustaveson et al. 1989). Converting catch rates to percent of catch allowed annual comparisons of

largemouth and smallmouth bass relative abundance (Figure 7). Prior to smallmouth bass introduction into Lake Powell in 1982, largemouth bass were the only black bass (Gustaveson et al. 1985). Since their introduction, smallmouth bass have represented an increasing portion (97% in 1989) of the electrofishing black bass catch (Figure 7).

Table 12. Mean catch rate^a (fish/h) of fish collected by electrofishing, Lake Powell, September 1989.

Species	Good Hope Bay	Stanton Creek	Rincon	San Juan	Warm Creek	% of Total Catch
Young-of-the-year largemouth bass			1			0.3
Age I and older largemouth bass		1	1			0.6
Young-of-the-year smallmouth bass	15	11	2	5	3	10.8
Age I and older smallmouth bass	17	69	7	12		31.4
Young-of-the-year black crappie						0.0
Young-of-the-year striped bass	4					1.2
Age I and older striped bass		2				0.6
Channel catfish			4	5	14	6.9
Green sunfish	50	21	29	6	27	39.8
Bluegill	9	3	2		14	8.4
Total ^b	95	107	46	28	58	

^a Total fish divided by total hours of electrofishing

^b Due to rounding total will not always equal sums of all species

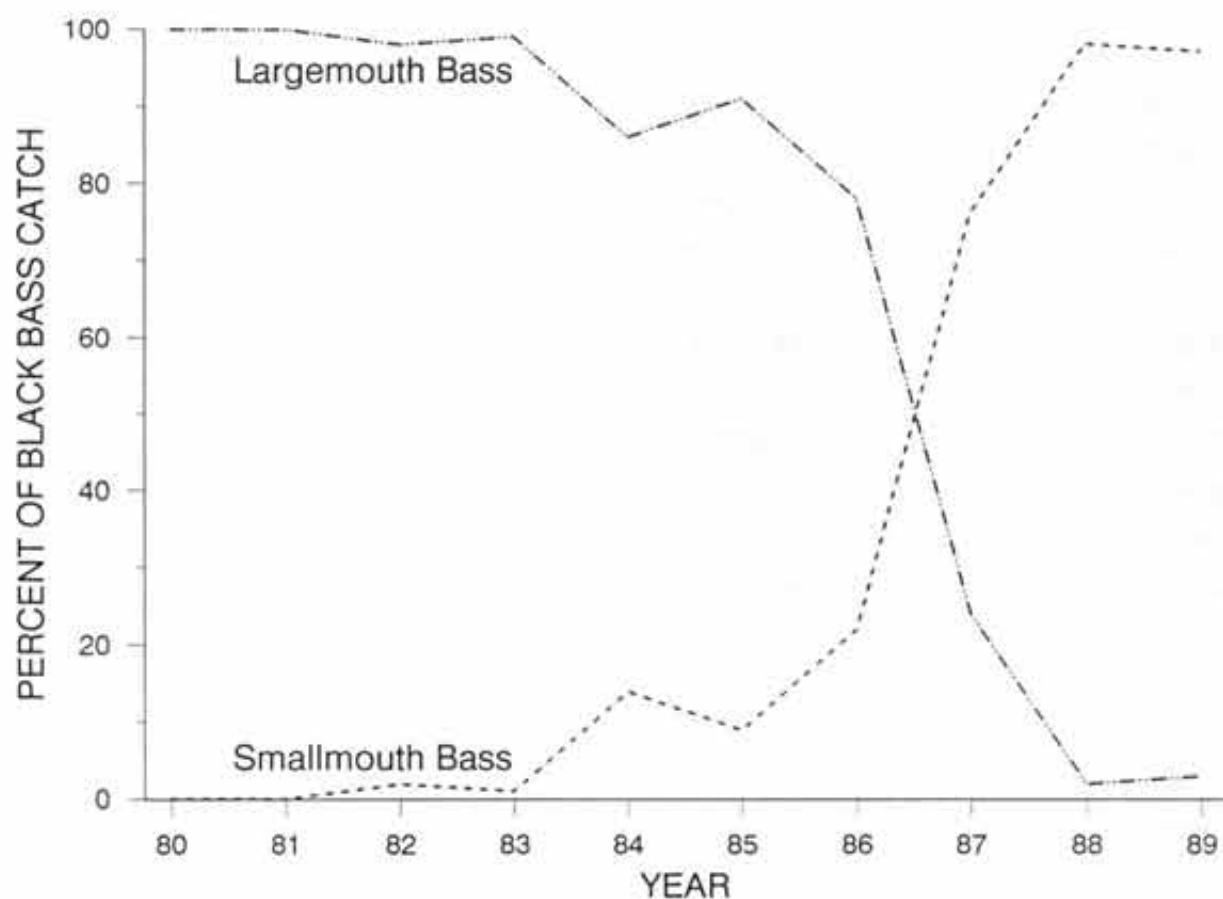


Figure 7. Percent of black bass electrofishing catch represented by largemouth and smallmouth bass, all sites combined, Lake Powell, 1980-1989.

Current electrofishing sites, however, are also the locations of smallmouth bass stockings. Thus, the data presented on changing largemouth bass abundance may represent a phenomenon occurring in the stocking areas rather than a lakewide population decline. Current electrofishing sites of talus and rubble shoreline habitat are preferred by smallmouth bass but not necessarily by largemouth bass (Carlander 1977). In a Massachusetts reservoir with predominantly rocky habitat and a developing smallmouth bass fishery, smallmouth harvest exceeded that of largemouth bass and eventually increased to 5 times the historic largemouth bass harvest. However, at the same time largemouth bass harvest was unaffected and remained constant (Rideout and Oatis 1975). It is unclear what effect the expanding smallmouth bass population will have on the existing largemouth bass population.

SUMMARY AND RECOMMENDATIONS

Sampling sites may need to be added or changed as present sites represent smallmouth bass stocking sites. Past electrofishing proved valuable in monitoring smallmouth bass population development but may not meet our needs to monitor other species including largemouth bass. Habitat preference and use by smallmouth and largemouth bass at Lake Powell need to be determined. These data can then be used to select sampling sites more representative of each or both species.

Electrofishing gear can be variable from year to year. Methods of reducing variation between years needs to be examined. Alternative gears and methods should also be examined to obtain less biased data than currently collected through electrofishing.

Table 13. Mean catch rate^a (fish/h) of fish collected by electrofishing, Lake Powell, 1985-1989.

Species	1985	1986	1987	1988	1989
Young-of-the-year largemouth bass	127	99	27	2	<1
Age I and older largemouth bass	6	3	2	1	<1
Young-of-the-year smallmouth bass	13	23	73	154	9
Age I and older smallmouth bass	<1	5	19	30	26
Young-of-the-year black crappie	22	3	11	2	0
Young-of-the-year striped bass	150	1	26	11	1
Age I and older striped bass	<1	0	0	0	<1
Channel catfish	26	12	14	23	7
Green sunfish	208	180	281	140	33
Bluegill	203	165	104	26	7
Total ^b	754	491	555	390	84

^a Total fish divided by total hours of electrofishing

^b Due to rounding total will not always equal sums of all species

STRIPED BASS POPULATION DEVELOPMENT

Job IV

BACKGROUND

Striped bass fingerlings were stocked into Lake Powell annually from 1974-1979 (Table 14). Natural reproduction was detected in 1979 at which time stocking was curtailed so that impact of that reproduction could be fully evaluated. Yoy striped bass were found only in 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 present in the lower reservoir during this same time. Collection of yoy striped bass near Glen Canyon Dam annually since 1981 indicated striped bass had successfully spawned within the reservoir despite the absence of current to suspend the eggs during incubation. It was determined that the oligotrophic nature of the reservoir allowed the fertilized eggs to settle on highly oxygenated sandy substrate where they hatched instead of being smothered by an oxygen poor environment as occurs in most eutrophic lakes. (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 pelagic threadfin shad forage base. An excellent sport fishery emerged in 1979 and 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. Unlimited striped bass natural reproduction placed extreme predatory pressure on the single pelagic forage fish, threadfin shad, in Lake Powell. In 1982-1983, the progeny of the first generation of stocked striped bass declined in physical condition as forage became scarce. Adult striped bass were most affected because they were forced into deep, cool water strata by ontogenetic thermal requirements (Schaich 1979) where forage was absent. Adult fish (> 500 mm) declined in abundance due to lack of shad forage, angling harvest and natural mortality. Old adults, originally stocked in the 1970's, survived by foraging on carp in the pelagic zone. New adults, spawned in the 1980's, could not thrive without a pelagic shad population. Smaller juvenile fish were present in the warm surface layers and subsisted by eating the annual shad crop and then reverting to a pelagic plankton diet.

Table 14. Stocking history of Lake Powell, Utah-Arizona, 1963-1988.

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 Crsng-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-----				

Table 14. Continued.

Year	Species	Number	Size	Area	Method
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
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
1985	Smallmouth Bass	13,289	2-4"	Wahweap Creek	Truck
	Smallmouth Bass	12,389	2-4"	Antelope Canyon	Truck
	Smallmouth Bass	22	10-15"	Antelope Canyon	Truck
	Smallmouth Bass	31,995	2-4"	Rincon	Aerial
	Smallmouth Bass	19,390	2-4"	Good Hope Bay	Aerial
	Smallmouth Bass	26,328	2-4"	Neskahi Canyon	Aerial
	Smallmouth Bass	702	10-15"	Hite-Dirty Devil River	Truck

Table 14. Continued.

Year	Species	Number	Size	Area	Method
1986	Smallmouth Bass	12,758	2-4"	Escalante River	Aerial
	Smallmouth Bass	8,136	2-4"	Piute Farms Wash	Truck
	Smallmouth Bass	6,123	2-4"	Wahweap Creek	Truck
1987	Smallmouth Bass	220	3-6"	Wahweap-Warm Creek	Truck
	Smallmouth Bass	24,200	2-3"	West Canyon	Aerial
	Smallmouth Bass	7,200	2-3"	Nokai Canyon	Truck
		3,150	2-4"	Piute Farms	Truck
1988	Smallmouth Bass	20,536	2"	Knowles/Cedar Canyon	Aerial
	Smallmouth Bass	24,643	2"	Llewellyn/Cottonwood	Aerial
	Smallmouth Bass	4,307	2"	Middle Rock Creek	Aerial
	Smallmouth Bass	10,745	2"	San Juan (mouth)	Aerial
	Smallmouth Bass	10,800	2"	Navajo Canyon	Aerial
1989	Smallmouth Bass	21,002	2"	Trachyte Canyon	Aerial
	Smallmouth Bass	2,394	2"	Warm Creek (mouth)	Boat

A relatively few older individual fish have survived and attained large size. To date the largest fish taken by an angler weighed 40 pounds and was 10 years old. More of these large fish die from persistent summer mortality than are captured by anglers. Most of the dead fish found floating on the surface weigh 20-50 pounds and are 9-10 years old. It appears that 10 years may be the life expectancy of Lake Powell striped bass when forage is not limiting survival.

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.

Physical condition of striped bass varied in direct relation to the abundance of pelagic threadfin shad, their primary food source. Growth was rapid in the 1970's when shad were abundant and has since slowed considerably.

The introduction of striped bass has been a qualified success. An exciting, highly sought after fishery developed but subsequently declined. Angling pressure decreased on declining populations of largemouth bass and crappie as anglers pursued striped bass. However, the elimination of shad from the pelagic zone has created a striped bass population imbalance with a stockpiling of juvenile striped bass and elimination of the highly sought adult fish. The correction of this population imbalance is our management task for the 1990's.

METHODS

Biological information was obtained from striped bass sampled during normal field collections with experimental gill nets, by angling, electrofishing, seining, and during creel census interviews. Data necessary to determine age and growth, food habits, maturity, and condition (KFI) were routinely taken. Stomach contents were qualitatively examined in the field and recorded as percent occurrence of food items. Scales were taken from below the lateral line and near the tip of the pectoral fin. Scale impressions were made in acetate cards with a heated press. Impressions were read on a Micron XL-20 microfiche reader at a magnification of 24X.

The relative abundance and distribution of yoy and juvenile striped bass was assessed with a combination of beach seines, electrofishing gear (Job II), and experimental gill nets. During November, an annual survey of striped bass abundance was conducted by fishing 10 experimental gill nets for 40 consecutive hours (two nights and one day) at each of four stations. The sample sites closely approximate those used during the spring netting survey (Job II). Nets were attached to the shore in similar talus rock and rubble habitat and stretched from shore to an average depth of 20 m. Experimental gill nets were 30.5 m long by 1.8 m deep, with four panels of 1.9, 2.5, 3.8, and 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).

RESULTS AND DISCUSSION

Spawning

Striped bass spawning has been detected annually since 1979. Striped bass were anadromous spawners historically and still exhibit a spawning migration in fresh water. Mature fish run up the Colorado River tributary and spawn annually between the headwaters of Lake Powell and Cataract Canyon. Spawning in the river is triggered by increasing water temperatures between 15-18 C. Striped bass eggs and larvae spawned in the river are transported to the lake on the spring flood and annually populate the upper third of the reservoir with striped bass.

Striped bass apparently intrude less than 20 km of river above Lake Powell since no fish have been collected above Cataract Canyon during the spring spawning period (Persons et al. 1981). Only two striped bass have ever been collected above Cataract Canyon. These fish were both juveniles and collected in the summer during periods of low flow (Valdez 1990).

Each spring an aggregation of mature prespawning striped bass has been observed near Glen Canyon Dam. Fish arrive as early as mid-February or as late as mid-April. They are apparently attracted to the current created as water is drawn through the penstocks for power generation. These fish remain in large schools until spawning is triggered by a calm weather period which allows rapid warming of the water surface layers in a short time. A five degree surface temperature rise in one day induces spawning activity. Spawning was observed at temperatures ranging from 16-22 C. Windy conditions which mixed the lake and cooled surface temperatures curtailed spawning activity. Spawning was observed as early as April 13th and as late as June 1st in some years. Riverine spawning is usually 2-3 weeks later than lake spawning because the lake warms earlier than the river.

Spawning fish leave the staging area to spawn when conditions are right. Striped bass have historically moved to the long points projecting out from Antelope Island to spawn. Males stage off these long points awaiting the arrival of females. Spawning normally occurs at night with fish becoming active at dusk and spawning activity peaking about 2 hours after dark. Striped bass spawn on or near the surface and can be seen and heard thrashing

the water in the shallow coves (1 m) out to fairly open water where the depth is 10-20 m. The fertilized eggs settle on the oxygen rich substrate where they incubate for 2-3 days and then hatch (Gustaveson et al. 1984).

As size and condition of striped bass declined the abundance of spawning fish also decreased. During 1989 only three ripe males were collected by anglers and from gill net sampling from the historically identified spawning area near Antelope Island in Wahweap Bay. Striped bass continued to spawn successfully despite poor physical condition and small size. Striped bass eggs were collected in ichthyoplankton tows on 1 June 1989 in the back of Warm Creek, a location where spawning has not been detected previously. On 2 June four ripe males were collected in the back of Navajo Canyon. There may be a shift in spawning locations occurring.

Young-of-year striped bass were expected to be scarce in 1989 due to the poor condition of brood fish. But yoy striped bass were qualitatively sampled by seining lakewide in July and August. The large numbers of yoy striped bass found during seine sampling were not detected in September electrofishing. Only 4 yoy striped bass were captured in Good Hope Bay during the entire electrofishing survey (Table 13).

Recruitment

Striped bass abundance has been estimated by sampling annually since 1981. Trends in striped bass numbers collected in gill nets set during November at standard sites have shown a wide variation in age composition and number of fish captured. Yearly variation in weather patterns, food availability and environmental factors probably caused some annual differences in catch but the survey seems reliable enough to detect gross changes in striped bass population structure. The nets seem most efficient in capturing 200-400 mm striped bass which are typically one year old fish. Abundance of yoy and older fish was probably underestimated but these age groups were still sampled effectively and consistently each year.

Striped bass abundance was lowest in 1985 (Figure 8) following the extremely high angling harvest during that summer (Job III). Abundance then increased and peaked in 1988. Finally in 1989 total numbers of fish declined to 1985 levels but older fish were sampled more often than yearlings.

Yearlings and yoy were collected in the lowest abundance since 1981.

The large population of juvenile striped bass was advancing in age but not in size. Total length of striped bass collected during this survey has declined annually until 1989 when total length increased slightly. Average size of fish sampled has decreased from 555 mm, to 423 mm, 393 mm, and 348 mm over the past four years before recovering to 353 mm in 1989. It appears that the plankton diet presently consumed does not allow the average striped bass to grow much larger than 350 mm. The population cannot maintain more body mass unless pelagic forage fish become available.

Food Habits

The 1985-1989 period has been marked by a scarcity of shad in the pelagic zone. Over this period of time, almost 50% of striped bass sampled had empty stomachs (Table 15). Striped bass have a very restrictive prey search image. Once a food item is identified striped bass feed on that item until it becomes scarce. They do not easily switch from one food item to another. The dominant food item has consistently been zooplankton in each of the past five years (Table 15). Crayfish and threadfin shad were the only other important food items found in striped bass stomachs. Striped bass are not effective predators on centrarchids which live near shore and hide in cover. These fish make up only an incidental portion of food eaten by striped bass.

There was evidence of striped bass cannibalism in years when shad were scarce (Figure 5) and yoy abundant at certain locations (Table 13). During 1989 many yoy striped bass were collected in seines during the summer but were collected only occasionally in electrofishing and gill net sampling. Juvenile striped bass may have reduced the 1989 striped bass year class by predation.

In Lake Powell carp often school in the pelagic zone as they feed on plankton and debris. Adult striped bass over 4.5 kg consistently had carp remains in their stomachs. These large striped bass were the only fish able to successfully use carp as forage.

Over the past 5 years the incidence of ulcerous lesions in striped bass stomachs has remained near 10%. When forage was abundant in the 1970's no ulcerous lesions were found.

Striped Bass Relative Abundance

Fall netting - all stations combined

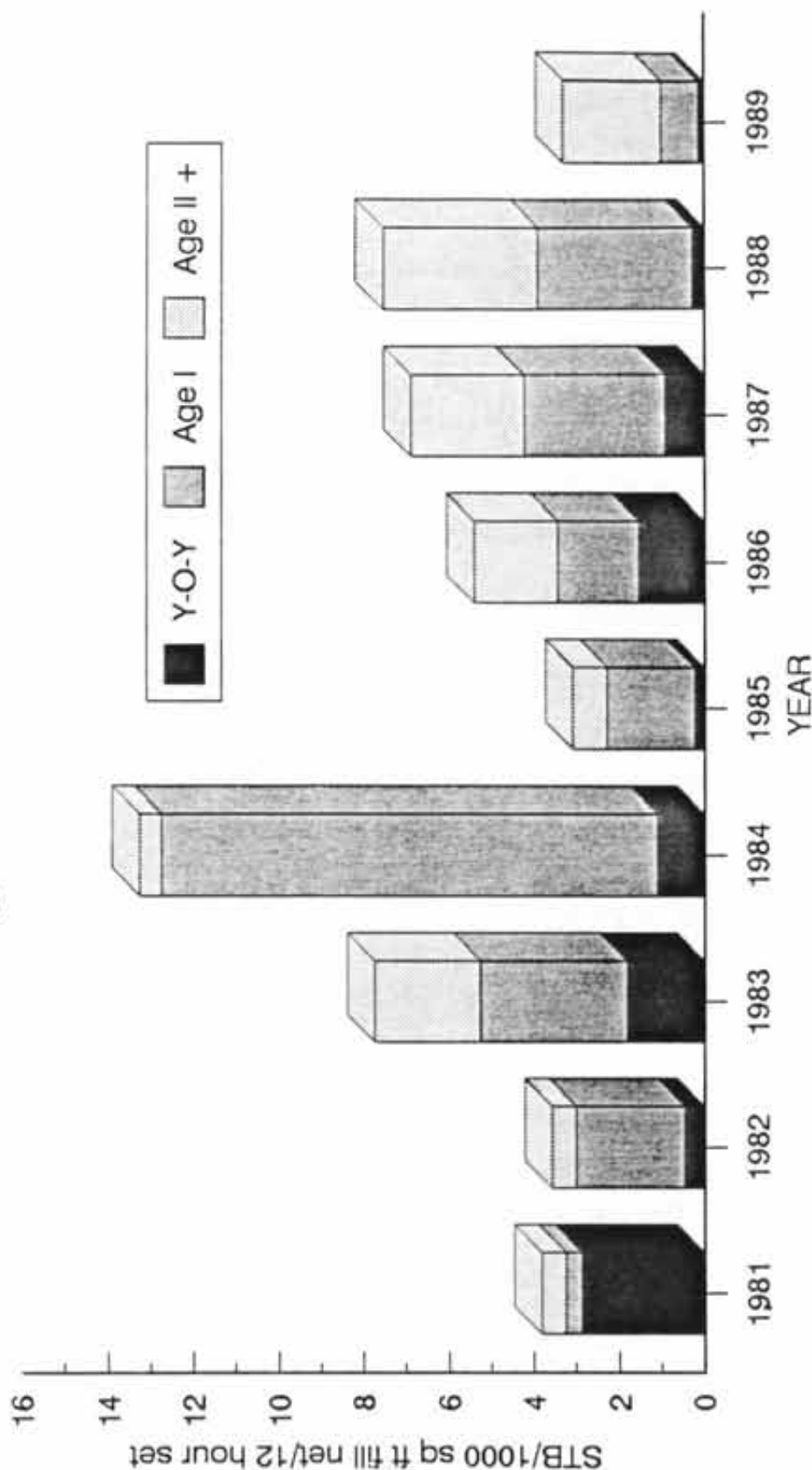


Figure 8. Average number of striped bass caught during fall netting (fish/100 ft² of net/12 h), Lake Powell, 1981-1989.

Table 15. Percent occurrence of food items in striped bass collected in gill nets and during creel census, Lake Powell, 1985-1989. (Percentage based on number of stomachs containing food.)

	YEAR				
	1985	1986	1987	1988	1989
Sample size (n)	830	54	493	987	245
Empty stomachs	442 (53%)	39 (72%)	225 (46%)	364 (37%)	109 (44%)
Stomachs w/food	388	15	268	623	136
<u>Food item</u>					
Crayfish	58 (15%)	4 (27%)	56 (21%)	101 (16%)	16 (12%)
Plankton	163 (42%)	7 (47%)	95 (35%)	300 (48%)	73 (54%)
<u>Fish</u>					
Threadfin shad	66 (17%)	3 (20%)	113 (42%)	65 (10%)	48 (35%)
Bluegill	4 (1%)	0	0	0	0
Green sunfish	4 (1%)	1 (7%)	3 (1%)	0	0
Striped bass	4 (1%)	0	2 (1%)	0	0
Carp	4 (1%)	0	0	0	0
Centrarchids	4 (1%)	0	1 (<1%)	1 (<1%)	1 (1%)
Unknown fish	30 (8%)	0	21 (8%)	75 (12%)	16 (12%)
Bait (Anchovy)	74 (19%)	0	2 (1%)	177 (28%)	0

Physical Condition

Striped bass physical condition reached its low point in 1985 (Figure 9). A large carryover striped bass population from 1984 combined with poor shad recruitment in 1985 (Figure 5) caused a drastic decline in condition of all striped bass. Adult (>500 mm) condition factor (Kf1) declined to 0.90. These adult fish have failed to recover their body weight over the past 5 years and have progressively become less numerous. Evidence of a large scale winter dieoff was seen during March 1988 with most fish larger than 500 mm disappearing from the population. Adults over 4.5 kg that utilized carp as

forage were not affected by the forage shortage. These large adults become less numerous each year since few fish have recently achieved a size large enough to allow carp utilization.

Juvenile striped bass rebounded from a low average K Factor of 1.05 in 1985 to maintain a K Factor near 1.15 for the rest of the period. The recovery rendered juvenile striped bass acceptable to anglers who usually rejected fish, with K Factors less than 1.0, as too emaciated. Striped bass between 1.0 and 1.1 are marginal and may or may not be accepted depending on the individual angler.

Juvenile striped bass maintained body weight by foraging on the annual shad crop and then shifted their diet to pelagic zooplankton once the shad were gone or became unavailable. Striped bass up to 350 mm seemed to maintain good condition on a plankton diet while larger fish apparently did not obtain enough nourishment from plankton alone.

Age and Growth

Growth of striped bass has been historically variable due to changes in available forage. Fish sampled in 1975-1979 from a fast growing population with unlimited forage grew at tremendous rates. Growth slowed somewhat during 1980-1984 but was still satisfactory and near that seen in the earlier period. But from 1985-1989 growth has slowed dramatically. Total length at each age class is now 105-225 mm less than seen in earlier years (Tables 16 and 17). Striped bass are growing slower and not living as long.

There was some variation in growth between lake areas. Striped bass collected in the San Juan Arm and at Wahweap were consistently larger than peers captured at Rincon and Good Hope Bay (Table 18).

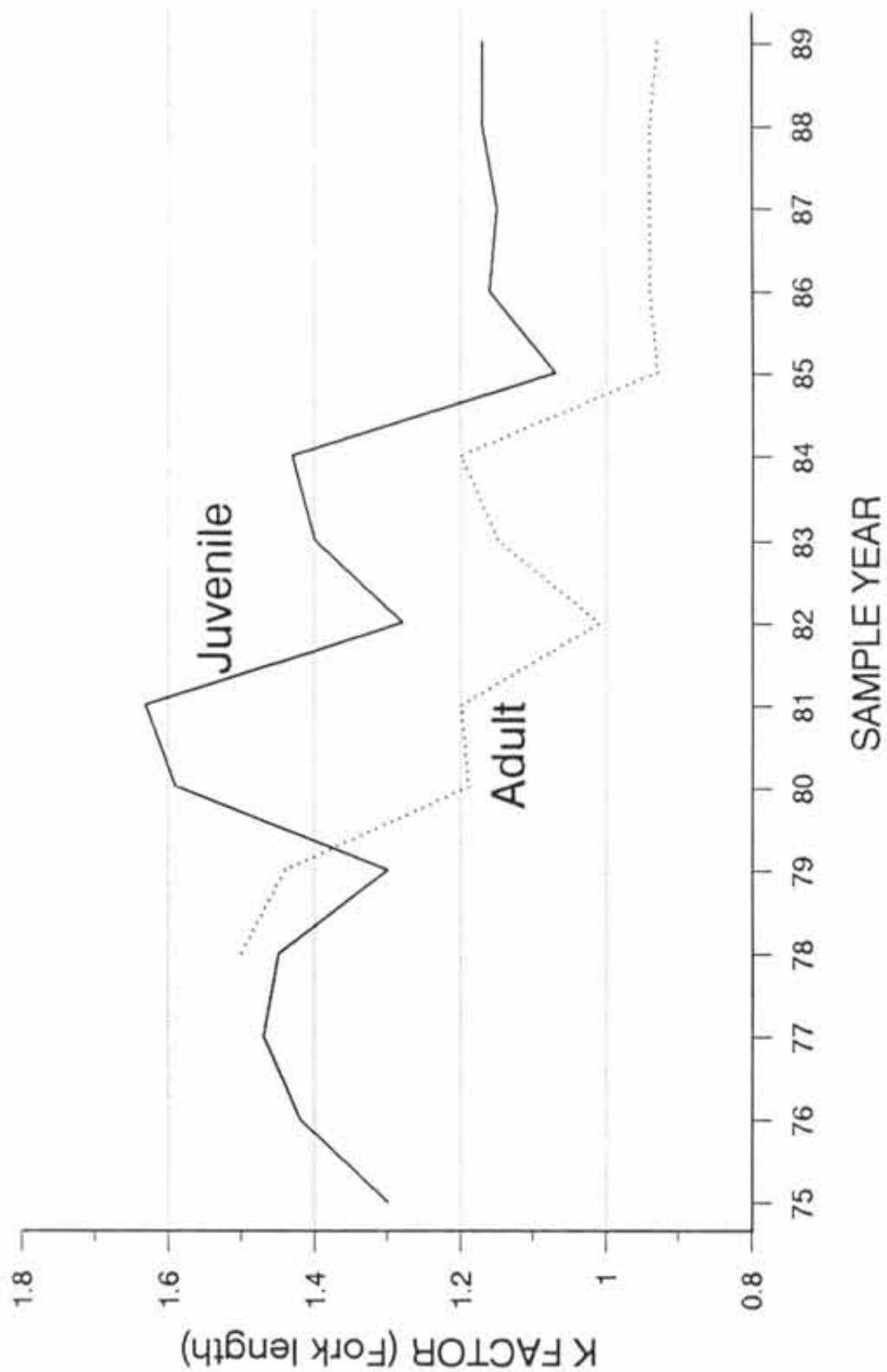


Figure 9. Annual condition factor (K) of adult and juvenile striped bass, Lake Powell, 1975-1989.

Table 16. Mean back-calculated lengths (mm) for each year class of striped bass, captured at Lake Powell during 1985-1989.

Year Class	Age	N	Mean back-calculated lengths (mm) for each age class						
			1	2	3	4	5	6	7
1988	1	124	129						
1987	2	128	132	263					
1986	3	166	161	312	385				
1985	4	129	157	301	380	428			
1984	5	39	163	297	386	448	497		
1983	6	10	186	351	447	509	549	594	
1982	7	1	232	411	553	636	652	698	707
All Classes			148	296	385	438	511	604	707
N		642	597	473	345	179	50	11	1

RECOMMENDATIONS

We need to continue studying the ever changing dynamics of the striped bass population. With food supplies expected to remain scarce, growth and condition of striped bass will remain depressed. The effect of smaller size and poor condition on brood stock should ultimately reduce spawning and

Table 17. Back-calculated growth of striped bass at Lake Powell, 1975-1989. Mean estimated total length (mm), with age classes not separated.

Year Interval	Age									
	1	2	3	4	5	6	7	8	9	10
1975-1979	253	440	564	663	690					
(n)	(939)	(324)	(111)	(41)	(1)					
1980-1984	227	429	555	634	673	702	735	815	967	946
(n)	(865)	(786)	(680)	(587)	(442)	(285)	(112)	(22)	(4)	(3)
1985-1989	148	269	386	438	511	604	707			
(n)	(597)	(473)	(345)	(179)	(50)	(11)	(1)			

Table 18. Back-calculated lengths (mm) of striped bass captured during November gill netting at Lake Powell. Lengths for each age class are combined and averaged for 1985-1989 and compared among four lake areas. Sample size (n) in parentheses.

Age Class	Wahweap Area 1	Rincon Area 4	Good Hope Area 5	San Juan Area 7
I	159 (188)	137 (124)	131 (143)	170 (126)
II	305 (144)	289 (108)	291 (107)	335 (102)
III	404 (100)	368 (76)	382 (71)	411 (85)
IV	451 (52)	428 (33)	418 (35)	460 (43)

recruitment. This has not been the case in Lake Mead where recruitment continues to be high despite forage limitations. We need to determine the long term effect of poor forage on recruitment as this is the key to the future success of the fishery.

We will continue to monitor age and growth, food habits, distribution and fishing success to document changes in the fishery. Fall netting should be continued to quantify trends in population structure and distribution. A new tagging study should be initiated to define growth in fish that are getting older but not necessarily increasing in length. Tagging would also help determine the extent of migration in fish that are not sexually maturing. This information could be important in providing information on the striped bass fishery to the angling public.

SMALLMOUTH BASS POPULATION DEVELOPMENT

JOB V

BACKGROUND

After the creation of Lake Powell in 1963, the fishery developed around largemouth bass and black crappie. The largemouth bass population increased during the filling stage of Lake Powell. Fish population surveys conducted annually since 1972 showed a decreasing trend in abundance of largemouth bass. Maturation of the reservoir, decomposition of inundated terrestrial vegetation used as escape and nursery cover, and competition with other fish species (particularly walleye) combined to reduce the largemouth bass population. Lake Powell at full pool does not have a large proportion of littoral zone with rooted aquatic vegetation that is favored by largemouth bass. The prospect of largemouth bass regaining their former population numbers is not good considering the morphology and available habitat in Lake Powell.

After the decline of largemouth bass, which were historically the most popular sport fish in the reservoir, it was decided to supplement warmwater fish numbers by introducing smallmouth bass in 1982. Smallmouth bass were acceptable to bass anglers and better adapted to utilize the steep rocky habitat so ubiquitous in Lake Powell. Smallmouth bass use rocky substrate for spawning and cover (Mraz 1964, Carlander 1977). They have been able to coexist with walleye in many instances (Fedoruk 1966) and grow to sizes similar to largemouth but at a slower rate (Carlander 1977). From 1982-1989 smallmouth bass have been reared in ponds near Lake Powell and stocked throughout the lake.

METHODS

Smallmouth bass were spawned and reared at the Wahweap Warmwater Hatchery, near Big Water, Utah. Fish were harvested at approximately 50 mm and then stocked. Culture methods are described in the Smallmouth Bass Culture Summary section contained within this report. Stocking of uplake

sites was generally done using a small plane outfitted with fish holding tanks capable of releasing fish from the air. Beach seining of areas stocked by air showed good survival (Gustaveson et al. 1985). Less remote areas were stocked by hauling fish either by truck or boat.

Development of the smallmouth bass population was monitored through collections made in Jobs I-IV. Smallmouth bass nest observations were made using snorkel and SCUBA surveys in areas of suspected spawning. In July and August various locations were beach seined to document the presence or absence of yoy smallmouth and largemouth bass. The habitat usage by lifestage of smallmouth and largemouth bass was experimentally examined during electrofishing surveys to determine if electrofishing could be used to study habitat overlap between smallmouth and largemouth bass. Habitat was categorized as either sand, sand/rubble, rubble, sand/boulder, sand/terrestrial vegetation, sand/aquatic vegetation, or boulder/rubble. Rubble was used as a general category representing size categories of rock larger than gravel and smaller than boulders. Sheer walls and the pelagic zone were the only major habitats on Lake Powell excluded because of electrofishing gear inefficiency in these areas. Lifestages were yoy (25-100 mm), juvenile (101-225 mm), and adult (>225 mm).

RESULTS AND DISCUSSION

A total of 23,396 fingerling smallmouth bass was stocked in Lake Powell during 1989 (Table 14). New release sites included the main channel at the mouth of Trachyte Canyon and the narrows between Warm Creek and Padre Bay. Since 1982, when smallmouth bass were first stocked in Lake Powell, a total of 294,372 fish has been stocked in 21 different lake locations. The reason for multiple stocking was to establish as many satellite populations of smallmouth bass as possible to facilitate quicker development of the fishery throughout the lake. Although smallmouth bass reportedly have restricted home ranges in lakes and do not move even modest distances (Coble 1975), during 1989 they were collected from most areas of Lake Powell (Figure 10). Natural reproduction and emigration from original stocking sites have resulted in establishment of smallmouth bass almost lakewide.

Natural reproduction of smallmouth bass was first observed at Lake Powell in 1985 and 23 active nests were located during 1986 (Gustaveson et al. 1986, 1987). In May 1989 black fry were observed in Crosby Canyon (Warm Creek) near the original planting site. Ten smallmouth bass nests were also located in Wahweap Bay on June 1, 1989. Nests were located at depths of 1-4 m, generally deeper than reported elsewhere (Carlander 1977, Sztramko 1985). Sztramko reported spawning beginning on Lake Erie from late May to early June depending on annual variations in water temperature. In the Southeast spawning occurs from April to early May (Carlander 1977). Spawning generally begins when temperatures reach 15 C and ceases as temperatures exceed 21 C (Mraz 1964, Carlander 1977). The spawning season in Lake Powell appears to begin in April and continue through May. During seining in July, 35 smallmouth bass (mean TL = 66.4 mm) were collected from areas of suspected spawning.

A total of 141 smallmouth bass was collected during the 1989 electrofishing survey whereas 735 were collected in 1988 and 368 in 1987 (Table 19). Differences in yoy numbers indicated a smallmouth bass year class strength for 1989 that was less than that of 1987 and 1988. However, differences may also reflect changes in shoreline habitat at the presently reduced lake level or may reflect changes in electrofishing efficiency. The lake level in September 1989 was 5 m below the September 1988 level. This resulted in more sand type habitat within the depth of electrofishing efficiency. It appears that strong year classes developed in 1987 at Good Hope and San Juan, whereas, the 1988 year class at Stanton Creek was strong. As in 1988, a majority of the fish sampled in 1989 were from the Stanton Creek site.

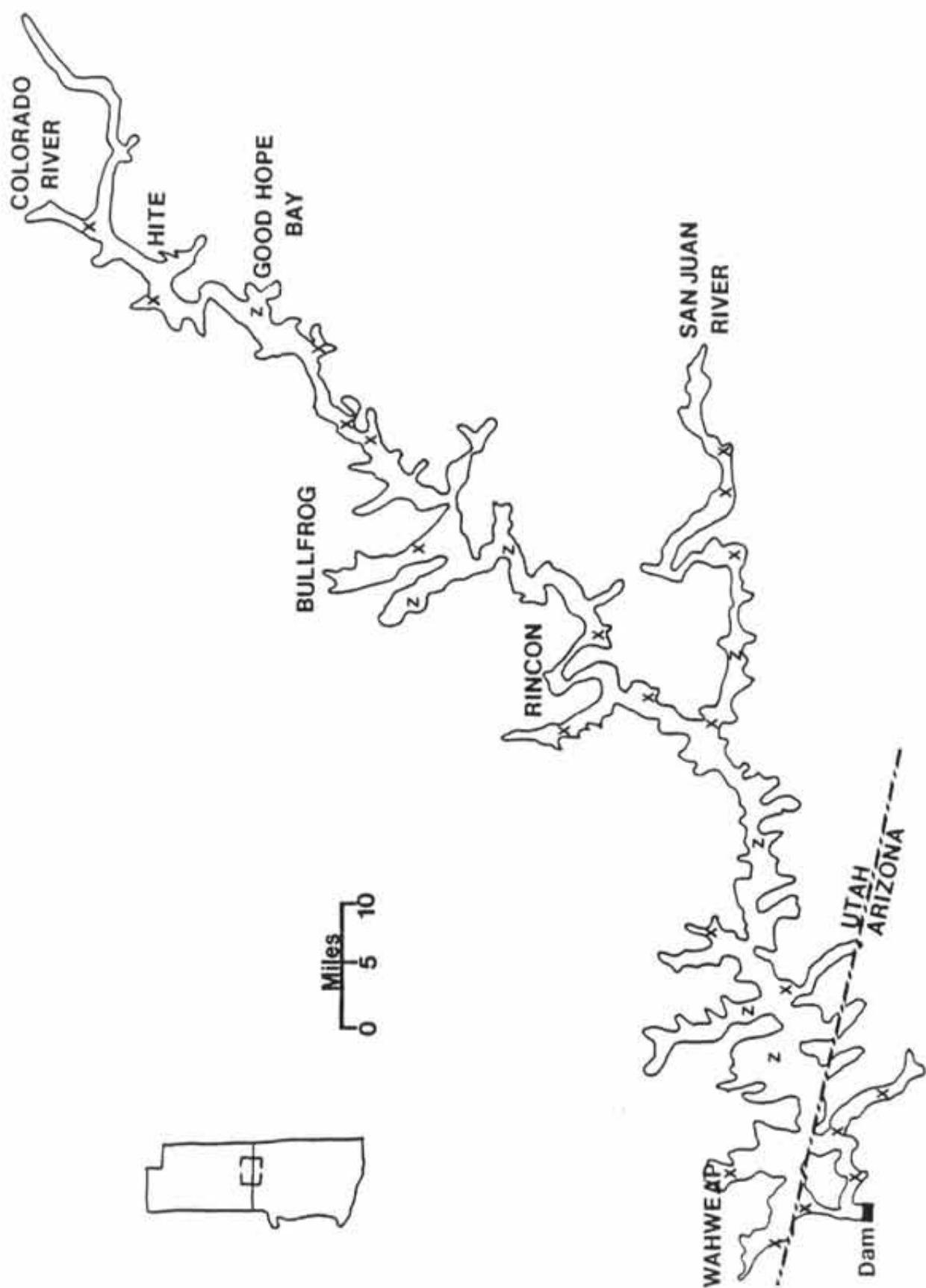


Figure 10. Map showing stocking sites (x) (1982-1989) and 1989 capture locations (z) for smallmouth bass, Lake Powell.

Table 19. Average catch rate^a (fish/h) of young-of-the-year smallmouth bass collected by electrofishing, Lake Powell, 1982-1989. (1+ and older fish denoted by parentheses)

Year (Stocked)	Good Hope Bay (1985)	Stanton Creek (1984)	Rincon (1985)	San Juan (1985)	Warm Creek (1982)	Total yoy & adult
1982	0	0	0	0	22	22
1983	0	0	0	0	0 (3)	3
1984	0	5	0	0	46	51
1985	4	0 (1)	36	5	5 (1)	52
1986	1 (2)	81	0 (2)	0 (17)	10	113
1987	134 (1)	33 (41)	67 (8)	37 (19)	21 (7)	368
1988	61 (49)	407 (26)	71 (25)	17 (20)	58 (1)	735
1989	15 (17)	11 (69)	2 (7)	5 (12)	3	141

^aTotal fish divided by total hours of electrofishing.

The first natural reproduction at each electrofishing site occurred 2 years after stocking. Smallmouth generally mature at 3-4 years but spawning at 2 years has been observed (Carlander 1977). Warm Creek which was stocked in 1982 showed no peak in yoy catches from 1985-1989. However, a peak did occur in 1984, and since then the population appears to have remained fairly stable in this area. The low catch in Warm Creek in 1989 may reflect lack of suitable shoreline habitat at the present lake level.

Smallmouth bass collected during electrofishing were generally associated with rock structure. Yoy were associated with a wider variety of habitats than other lifestages (Table 20). However, of the habitats sampled, yoy smallmouth bass were most often (36%) collected from the sand/rubble habitat. Fifty-eight percent of the juveniles were collected from the boulder/rubble habitat type. Most adults (91%) were associated with boulder being collected from either the sand/boulder or the boulder/rubble habitats.

Sample size of largemouth bass during electrofishing was insufficient to make comparisons of habitat use. However, of the five fish collected, one adult was in boulder/rubble and another in sand/terrestrial vegetation. Juveniles were collected from rubble (67%) and sand/rubble (33%). The one yoy largemouth bass captured was on barren sand.

Table 20. Habitat use (%) by smallmouth bass during nighttime electrofishing surveys, Lake Powell, September 1989.

Habitat	LIFESTAGE		
	YOY	Juvenile	Adult
Sand	6.1	3.3	-
Sand/Terrestrial Vegetation	6.1	-	-
Sand/Aquatic Vegetation	-	-	-
Sand/Rubble	36.4	6.5	9.1
Sand/Boulder	12.1	13.0	45.5
Rubble	18.2	18.5	-
Boulder/Rubble	21.2	58.7	45.5

Smallmouth bass in 1989 contained a greater variety of food items than in 1988 (Table 21). Stomachs examined in 1989 contained primarily crayfish (56%), which along with plankton (19%), threadfin shad (9%), and unknown fish (9%) combined for the contents of over 93% of the stomachs containing food items. Plankton was primarily found in fish <165 mm.

Smallmouth bass in Lake Powell probably begin entering the fishery at age II. Growth of smallmouth bass is somewhat slower than largemouth bass; generally lagging one year behind (Table 22). Growth of age-I fish was less than the combined average of various waters reported by Carlander (1977). This may be attributed to differences in first year growth rates or related to size of fish at stocking. By age III and IV, growth in Lake Powell is similar to the combined averages of other waters. Condition factors (K_{tl}) ranged from 0.75-2.22 (mean=1.30). Fish >300 mm had a mean K_{tl} of 1.35. These are within the ranges reported from other areas of the United States (Carlander 1977). It appears that for Lake Powell smallmouth bass condition factors increase as fish get larger.

Table 21. Percent occurrence of food items in smallmouth bass collected from gill netting, electrofishing, and creel census, Lake Powell, 1988-1989. (Percentage based on number of stomachs containing food.)

	YEAR	
	1988	1989
Sample size (n)	36	47
Empty stomachs	15 (42%)	15 (32%)
Stomachs w/food	21	32
<u>Food item</u>		
Crayfish	17 (81%)	18 (56%)
Plankton	2 (10%)	6 (19%)
<u>Fish</u>		
Threadfin shad	0	3 (9%)
Bluegill	0	2 (6%)
Green sunfish	0	1 (3%)
Centrarchids	1 (5%)	1 (3%)
Other fish	3 (14%)	0
Unknown fish	2 (10%)	3 (9%)

Table 22. Mean back-calculated lengths for smallmouth bass (SMB), Lake Powell, 1986-1989, with comparisons to other waters and largemouth bass (LMB) from Lake Powell.

Mean back-calculated lengths with age-classes separated					
Age	Number	Back-calculated Length at Annulus			
1	30	96			
2	31	90	197		
3	29	92	209	284	
4	5	81	175	240	301

Mean estimated length comparisons by age					
	1	2	3	4	
Lake Powell (SMB) 1986-1989	92	201	278	301	
Flaming Gorge (SMB) ^a	51	111	176	230	
Other Waters (SMB) ^b	166	227	267	302	
Lake Powell (LMB) ^c 1963-1972	176	276	344	400	

^a Pettengill et al. 1984

^b Combined averages by age class from Carlander 1977

^c Hepworth and Pettengill 1979

SUMMARY AND RECOMMENDATIONS

Stockings and subsequent natural reproduction have been successful in establishing smallmouth bass in most areas of Lake Powell. Stocking should be discontinued until their distribution can be more fully assessed and the impact of future fishing pressure can be determined. As smallmouth bass become a more popular game fish at Lake Powell, future management changes may be necessary.

The effects of smallmouth bass population development on other game fish species are inconclusive. Future studies should address habitat and diet overlap between smallmouth and largemouth bass and the impact on their prey (crayfish and sunfish).

LITERATURE CITED

- Anderson, R. O. 1973. Application of theory and research to management of warmwater fish populations. *Trans. Am. Fish. Soc.* 102(1):164-171.
- Barnes, J. M. 1977. The sustained swimming ability of larval and juvenile gizzard shad and threadfin shad as related to entrainment and/or impingement by water intake structures of power stations. M. S. Thesis, Univ. of Arkansas. 141 pp.
- Beers, G. D., and W. J. McConnell. 1966. Some effects of threadfin shad introduction on black crappie diet and condition. *J. Ariz. Acad. Sci.* 4(2):71-74.
- Burns, J. W. 1966. Threadfin shad. Calhoun, A. ed. *Inland fisheries management*; California Department of Fish and Game. 481-488 pp.
- Carlander, K. D. 1977. *Handbook of freshwater fishery biology*. Vol. I. The Iowa State University Press. Ames, Iowa. 431 pp.
- Coble, D. W. 1975. Smallmouth. Stroud, R. H. and H. Clepper. eds. *Black Bass Biology and Management*. Sport Fishing Institute, Washington, D. C. 21-23 pp.
- Combes, D. L. 1978. Food habits of adult striped bass from Keystone Reservoir and its tailwaters. *Proc. Ann. Conf. S. E. Assoc. Fish and Wildlife Agencies.* 32:571-575.
- Fedoruk, A. N. 1966. Feeding relationship of walleye and smallmouth bass. *Journal of Fishery Research Board of Canada.* 23:941-943.
- Gloss, S., V. Starostka, C. Thompson, and A. F. Regenthal. 1971. Glen Canyon Reservoir postimpoundment investigation. *Prog. Rept. No. 7*, Utah Fish and Game. 21 pp.
- Gloss, S., B. E. May, and R. Stone. 1974. Colorado River reservoir and tailwaters fisheries management investigations and surveys. *Annual Prog. Rept., Federal Aid in Fish Restoration, F-28-R-2*. Utah Division of Wildlife Resources, Publ. No. 74-11. 10 pp.
- Gustaveson, A. W., T. D. Pettengill, M. J. Ottenbacher, and J. E. Johnson. 1980. Lake Powell Fisheries Investigations. 5-year completion and 1979 Annual Performance Report. Dingell-Johnson Project F-28-R-8. Pub. No. 80-11. Salt Lake City, Utah Division of Wildlife Resources. 75 pp.
- Gustaveson, A. W., T. D. Pettengill, M. J. Ottenbacher and J. E. Johnson. 1981. Lake Powell Fisheries Investigations. 1980 Annual Performance Report. Dingell-Johnson Project F-28-R. Pub. No. 80-9. Salt Lake City, Utah Division of Wildlife Resources. 35 pp.

- Gustaveson, A. W., T. D. Pettengill, J. R. Wahl and J. E. Johnson. 1982. Lake Powell Fisheries Investigations. 1981 Annual Performance Report. Dingell-Johnson Project F-28-R. Pub. No. 82-6. Salt Lake City, Utah Division of Wildlife Resources. 41 pp.
- Gustaveson, A. W., T. D. Pettengill, S. J. Scott and J. E. Johnson. 1983. Lake Powell Fisheries Investigations. 1982 Annual Performance Report. Dingell-Johnson Project F-28-R-11. Pub. No. 84-05. 41 pp.
- Gustaveson, A. W., T. D. Pettengill, J. E. Johnson and J. R. Wahl. 1984. Evidence of In-reservoir spawning of striped bass in Lake Powell, UT-AZ. North Am. Jour. Fish. Management 4:540-546.
- Gustaveson, A. W., B. L. Bonebrake, S. J. Scott and J. E. Johnson. 1985. Lake Powell fisheries investigations. 5-year Completion and 1984 (Segment 13) Annual Performance Report. Dingell-Johnson Project F-28-R. Pub. No. 85-12. Salt Lake City, Utah Division of Wildlife Resources. 73 pp.
- Gustaveson, A. W., B. L. Bonebrake and K. Christopherson. 1989. Lake Powell Fisheries Investigations. 1988 Annual Performance Report. Dingell-Johnson Project F-46-R-4. Salt Lake City, Utah Division of Wildlife Resources. 35 pp.
- Gustaveson, A. W., B. L. Bonebrake, S. J. Scott and J. E. Johnson. 1986. Lake Powell Fisheries Investigations. 1985 (segment 14) Annual Performance Report. Dingell-Johnson Project F-28-R. Pub. No. 86-8. Salt Lake City, Utah Division of Wildlife Resources. 40 pp.
- Gustaveson, A. W., B. L. Bonebrake, S. J. Scott and J. E. Johnson. 1987. Lake Powell Fisheries Investigations. 1986 (segment 2) Annual Performance Report. Dingell-Johnson Project F-28-R. Pub. No. 87-9. Salt Lake City, Utah Division of Wildlife Resources. 26 pp.
- Heidinger, R. C. 1983. Life History of gizzard shad and threadfin shad as it relates to the ecology of small lake fisheries. Proceedings of Small Lakes Management Workshop - "Pros and Cons of Shad." Iowa Conservation Commission and Sport Fishing Institute, Des Moines, IA. p. 1-18.
- Heidinger, R. C., and F. Imboden. 1974. Reproduction potential of young-of-the-year threadfin shad in southern Illinois lakes. IL State Acad. Sci. 67:397-401.
- Hepworth, D. K., and S. P. Gloss. 1976. Food habits and age and growth of walleye in Lake Powell, Utah-Arizona, with reference to introduction of threadfin shad. Utah Division of Wildlife Resources, Pub. No. 76-15. 13 pp.
- Hepworth, D. K. and T. D. Pettengill. 1979. Age and growth of largemouth bass and black crappie in Lake Powell, Utah-Arizona, with reference to threadfin shad introduction. Lake Powell Fishery Investigations, Utah Division of Wildlife Resources, Pub. No. 80-22. 20 pp.

- Houser, A., and D. A. Dunn. 1967. Estimating the size of the threadfin shad population in Bull Shoals Res. from midwater trawl catches. Trans. Am. Fish. Soc. 96(2):176-184.
- Houser, A. and N. F. Netsch. 1971. Estimates of young-of-year shad production in Beaver Reservoir. Hall, J. ed. Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Pub. No. 8:359-370.
- Inslee, T. D. 1975. Increased production of smallmouth bass fry. Stroud, R. H. and H. Clepper ed. Black Bass Biology and Management. Sport Fishing Institute, Washington, D. C. p. 357-361.
- Johnson, J. E. 1971. Maturity and fecundity of threadfin shad, (Dorosoma pentenense) (Günther), in central Arizona reservoirs. Trans. Am. Fish. Soc. 100:74-85.
- Kimsey, J. B., R. H. Hagy, and G. W. McGammon. 1957. Progress report of the Mississippi threadfin shad in the Colorado River. California Department of Fish and Game. Inland fish. Admin. Report 57-23. 48 pp.
- LaRivers, I. 1962. Fishes and fisheries of Nevada. Nevada Fish and Game Commission. 782 pp.
- May, B. E., C. Thompson, and S. P. Gloss. 1975. Impacts of threadfin shad introduction of food habits of four centrarchids. Utah Division of Wildlife Resources, Pub. No. 76-3. 42 pp.
- May, B. E. and D. Hepworth. 1976. Lake Powell post-impoundment investigations Annual Prog. Rept., Fed. Aid in Fish Restoration, F-28-R-3. Utah Div. of Wildl. Resour., Pub. No. 76-3. 42 pp.
- McCloskey, K. 1980. Striped bass investigations. Federal Aid in Fish Restoration F-15-R-12-15. Study No. 050. Fish and Game Commission. Pratt, KS. 74 pp.
- McHugh, J. J. 1983. Evaluation of threadfin shad stocking in two Virginia lakes. Proceedings of Small Lakes Management Workshop - "Pros and Cons of Shad." Iowa Conservation Commission and Sport Fishing Institute, Des Moines, IA. p. 124-132.
- Miller, K., S. P. Gloss, C. Thompson, K. Summers, and A. F. Regenthal. 1969. Glen Canyon Post-impoundment investigation. Prog. Rept. No. 6. Utah Fish and Game. 16 pp.
- Moczygemba, J. H. and D. J. Morris. 1977. Statewide striped bass study, Texas Parks and Wildlife Dept. Federal Aid Proj. F-31-R-3. Final Report. 30 pp.
- Morris, D. J. and B. J. Follis. 1978. Effects of striped bass predation upon shad in Lake E. V. Spence, TX. Proc. Annu. Conf. S. E. Assoc. Fish and Wildlife Agencies. 32:697-702.

- Mosher, T. D. 1984. An evaluation of threadfin shad introduction in Kansas. Comprehensive Planning Option Project FW-9-P-2. Kansas Fish and Game. 54 pp.
- Mraz, D. 1964. Observations on large and smallmouth bass nesting and early life history. Research Report No. 11 (Fisheries). Wisconsin Conservation Department. 13 pp.
- Nash, V. S., W. E. Hayes, R. L. Self, and J. P. Kirk. 1987. Effect of striped bass introduction in Lake Wateree, South Carolina. Proc. Annu. Conf. S. E. Assoc. of Fish and Wildlife Agencies. 41:48-54.
- Netsch, N. F., G. M. Kersch, Jr., A. Houser, and R. V. Kilambi. 1971. Hall, J. ed. Distribution of young gizzard shad and threadfin shad in Beaver Res. Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Pub. No. 8:95-105.
- Osburn, H. R., M. F. Osborn, and H. R. Maddux. 1988. Trends in finfish landings by sport-boat fishermen in Texas marine water, May 1974-May 1987. Management Data Series No. 150. Texas Parks and Wildlife Department, Coastal Fisheries Branch. Austin, TX. 573 pp.
- Parsons, W. R., and J. B. Kimsey. 1954. A report on the Mississippi threadfin shad. Prog. Fish-Cult. 16(4):179-181.
- Persons, W. R., R. V. Bulkley, and W. R. Noonan. 1981. Movements and feeding of adult striped bass, Colorado River inlet, Lake Powell, 1980-81. Utah Coop. Fish. Res. Unit. Logan, UT. 30 pp.
- Pettengill, T. D., S. B. Brayton, and J. J. Johnson. 1984. Flaming Gorge Reservoir fisheries investigations. 1983 (Segment 12) Annual Report. Dingell-Johnson Project F-28-R. Pub. No. 84-07. Salt Lake City, Utah Division of Wildlife Resources. 55 pp.
- Rideout, S. G. and P. H. Oatis. 1975. Population dynamics of smallmouth and largemouth bass in Quabbin Reservoir. Stroud, R. H. and H. Clepper. eds. Black Bass Biology and Management. Sport Fishing Institute, Washington, D. C. p. 216-221.
- Schaich, B. A. 1979. A biotelemetry study of spring and summer habitat selection by striped bass in Cherokee Res., TN 1978. M. S. Thesis. Univ. of TN, Knoxville, TN. 206 pp.
- Scott, S. J. and A. W. Gustaveson. 1989. A creel census summary of twenty-two years at Lake Powell, Utah 1964-1985. Utah Division of Wildlife Resources. Pub No. 89-10. 32 pp.
- Snow, J. R. 1975. Hatchery propagation of the black basses. Stroud, R. H. and H. Clepper. eds. Black Bass Biology and Management. Sport Fishing Institute, Washington, D. C. p. 344-356

- Sztramko, L. K. 1985. Effects of a sanctuary on the smallmouth bass fishery of Long Point Bay, Lake Erie. North Am. Jour. Fish. Management 5:233-241.
- U. S. Fish and Wildlife Service. 1988. 1985 National survey of fishing, hunting, and wildlife associated recreation. U. S. Fish and Wildlife Service, Washington, D. C. 167 pp.
- Valdez, R. A. 1990. The endangered fish of Cataract Canyon. Final Report. U.S. Department of Interior, Bureau of Reclamation, Salt Lake City, Utah. Bio/West Report No. 134-3. 94 pp + appendices.
- von Geldren, C. E. 1972. A midwater trawl for threadfin shad. California Fish and Game 58(4):268-276.