Spawning and Early Life History of Largemouth Bass (Micropterus salmoides) in Wahweap Bay, Lake Powell

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SPAWNING AND EARLY LIFE HISTORY OF LARGEMOUTH BASS (*MICROPTERUS SALMOIDES*) IN WAHWEAP BAY, LAKE POWELL

by

Kent D. Miller

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Kent D. Miller

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Spawning and Early Life History of Largemouth Bass

(Micropterus salmoides) in Wahweap Bay,

Lake Powell

by

Kent D. Miller, Master of Science

Utah State University, 1971

Major Professor: Dr. Robert H. Kramer
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Spawning time and habitat of largemouth bass, survival of embryos, and growth and food habits of fingerlings were studied in 1968 and 1969 at Wahweap Bay, Lake Powell. Spawning began in mid- to late-April, when mean daily water temperature at nesting depths was 14.4-15.0 Centigrade (58-59 Fahreheit), and continued until mid-June. Most spawning took place on the northeast shore of the bay. Sandstone rubble was the most commonly used bottom type for nesting, either at the base of ledges or around large sandstone boulders. Mean nest depth increased from 1.63 meter to 4.54 meters (5.36 feet to 14.90 feet) in 1968 and from 1.51 meter to 2.93 meters (4.96 feet to 9.60 feet) in 1969, because bass sought the protection of ledges and boulders covered by continually rising water. Nearly all embryos required 4 days to hatch, and survival to hatching was 80.4 percent and 92.2 percent for 1968 and 1969, respectively. Growth of fingerlings was similar in both years and most rapid prior to August 1 in both years. Fingerlings from the 1969 year-class were longer than those from the 1968 year-class before August 21. Total length of bass on August 21 was 68.0 millimeters in both years but 86.5 millimeters and 80.2 millimeters on October 1 in 1968 and 1969, respectively. Growth may have been influenced by total temperature experience during the early part of the growing season but not during the latter part. Fingerlings ate mostly crustaceans, insects, and fish. Size of organisms eaten increased with increase in fingerling length, and fingerling bass fed selectively on larger Crustacea. Numbers of nests located and numbers of young-of-the-year taken in beach-seine catches indicated that the 1968 year-class was stronger than 1969. Estimated numbers of bass per 92.9 meters^2 (1,000 feet^2) seined varied from 0.82 to 3.39 in 1968 and from 0.23 to 2.65 in 1969. An index to year-class strength may be obtained from seine catches at any time of the summer after brood dispersal, but indices obtained in this study must be validated by determing the contribution of each year-class to the creel.

(47 pages)

INTRODUCTION

Water impoundment in Lake Powell behind Glen Canyon Dam began in January, 1963. Largemouth bass fingerlings were stocked throughout the lake in 1963 and 1964. Since then, abundant stocks of bass have been maintained by natural reproduction, and an excellent sport fishery has developed. The purpose of the present study was to gain knowledge of largemouth bass reproduction and early life history in Wahweap Bay of Lake Powell so that fishery managers will be able to predict year-class strengths as early as possible. The objectives were:

1. To study the time of spawning, spawning habitat, and factors related to successful reproduction of largemouth bass.

2. To describe growth of largemouth bass during the first growing season.

3. To describe the food habits of young-of-the-year bass.

4. To study the feasibility of using numbers of young-of-the-year bass taken in beach-seine catches as an index to year-class strength.

STUDY AREA

Glen Canyon Dam is located on the Colorado River, 9.65 km (6 mi) south of the Utah-Arizona border. The base of the dam lies at an elevation of 956.42 m (3,138 ft). Maximum capacity of Lake Powell is 3,458,637 hectare meters (28,040,000 acre ft). Water surface elevation is 1,127.67 m (3,699.9 ft) at maximum capacity, resulting in a depth of 171.26 m (561.9 ft) at the dam. The reservoir is confined to the deep, narrow canyon of the Colorado River. Most of the shoreline is sandstone cliffs and sandstone talus slopes. Only a few side bays offer relief from the narrow canyon walls.

One such bay was selected for this study, Wahweap Bay, the lowermost on Lake Powell. The narrow entrance to Wahweap Bay is 1.61 km (1 mi) above the dam. Wahweap Bay is 10.45 km (6.5 mi) long and 4.83 km (3 mi) wide at its maximum width (Figure 1). The bay had a maximum depth of 48.80 m (160 ft) during the study period. The shoreline of Wahweap Bay is very irregular and is composed of gently sloping, smooth wind-blown sand beaches, gravel ledges and slopes, very rough steep cliffs, or slopes of broken sandstone boulders.

Shoreline vegetation was sparse, composed of mainly Russian thistle (*Salsola Kali tenuifolia*), big sage brush (*Artemesia tridentata*), and tamarisk (*Tamarix pentandra*). No rooted aquatic vegetation existed in Wahweap Bay.

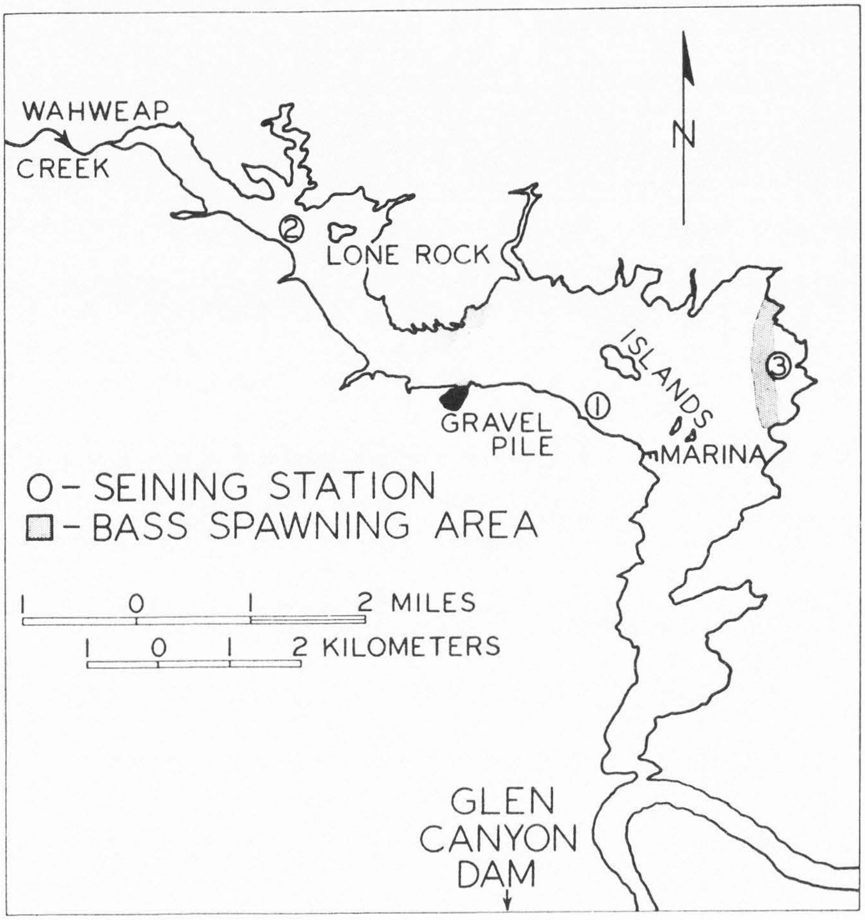

Figure 1. Wahweap Bay, Lake Powell, with largemouth bass nesting areas and seining stations shown.

Nineteen fish species were present in Lake Powell during the study period:

Game fish

- kokanee salmon (Onchorhyncus nerka)
- rainbow trout (Salmo gairdneri)
- brown trout (Salmo trutta)
- channel catfish (Ictalurus punctatus)
- largemouth bass (Micropterus salmoides)
- black crappie (Promoxis nigromaculatus)
- walleye (Stizostedion vitreum vitreum)

Nongame fish

- threadfin shad (Dorosoma petenense)
- carp (Cyprinus carpio)
- Utah chub (Gila atraria)
- bonytail (Gila elegans)
- red shiner (Notropis lutrensis)
- Colorado squawfish (Ptychocheilus lucius)
- flannelmouth sucker (Catostomus latipinnis)
- humpback sucker (Xyrauchen texanus)
- black bullhead (Ictalurus melas)
- yellow bullhead (Ictalurus natalis)
- green sunfish (Lepomis cyanellus)
- bluegill (Lepomis macrochirus)

METHODS AND MATERIALS

Field operations began April, 1968, and continued through October, 1969. Water temperatures at nesting depths were recorded with two Ryan model F-8 8-day recording thermometers and one Temp scribe recording thermometer. Surface water temperature, air temperature, and wind speed were obtained from a weather observation float maintained by the U. S. Bureau of Reclamation at mid-bay. Water temperatures were also determined with a pocket thermometer as a routine part of other field observations. Various water-quality measurements were made at mid-bay at 10-day intervals during the spring and summer of 1969. Visibility was measured with a secchi disk during the spawning seasons, and turbidity was measured in the nesting areas during 1969 with a Hach Company Engineers Kit, model number DR-EL.

Daily records of water surface elevations were obtained from the U. S. Bureau of Reclamation, Glen Canyon Project Office, Page, Arizona. Records of hourly weather observations were obtained at the Air West Airlines Office at Page, Arizona, about 8.05 km (5 mi) from the study area.

Daily observations on bass nests were made with the aid of a water scope and by SCUBA diving. Nests were marked with numbered floats. Location, bottom type, and depth were observed in 141 nests in 1968 and 68 nests in 1969. Nest depth was measured to the nearest

7.62 cm (.25 ft) when observations were made from the boat. During SCUBA observations, nest depth was measured to the nearest 30.48 cm (1.0 ft). Egg samples were obtained from the nests with a 1.27 cm diameter plastic tube when a boat was used. When nest depth and/or water turbidity necessitated use of SCUBA, eggs were obtained from the nests with a rubber bulb syringe. Mortality of embryos was estimated from 151 samples (79 nests) in 1968 and from 47 samples (28 nests) in 1969.

Food-habit analyses were made on 514 fry and fingerling bass samples in 1969. Plankton samples were taken at the surface of seining stations each sampling day in 1969 with a small Wisconsin-type plankton net towed parallel to shore behind the outboard-driven seining boat.

Three beach-seining stations were located on representative bottom types in Wahweap Bay (Figure 1). Each station was sampled weekly from June to October each year. The beach seine was 30.48 m (100 ft) long with 12.20-m-long wings of 6.35 mm-mesh. The wings tapered from 1.83 m (6 ft) deep at the ends to 3.66 m (12 ft) deep where they joined a 6.08-m-long center panel of 3.15-mm-mesh nylon bob-binette. All fish, egg, and plankton samples were immediately preserved in 10 percent formalin.

RESULTS

Physical and Chemical Characteristics

During the study period, Lake Powell contained from 965,556 hectare meters (7,828,000 acre ft) to 1,612,140 hectare meters (13,070,000 acre ft). The reservoir was about 274 km (170 mi) long and had a surface area of from 25,010 to 37,759 hectares (61,800 to 93,000 acres).

Total alkalinity at the surface in 1969 varied from 140 ppm (April) to 157 ppm (June). Hydrogen-ion concentration (pH) was 8.2 to 8.5. Total hardness was 254 ppm (June) and 310 ppm (September) in 1969. Phosphates varied from .30 ppm to .41 ppm, and total organic nitrogen content was .35 ppm to .40 ppm from April to July, 1967.

Secchi-disk readings at mid-bay ranged from 2.17 m (9 ft) to 8.84 m (29 ft) during the spring and summer of 1969. Wave action near loose sandstone beaches reduced secchi-disk visibility to 0.91 m to 1.22 m (3-4 ft) at times in late May. Turbidity ranged from 0 to 8 JTU at the surface and 7 JTU to 8 JTU at 2.74-3.05 m (0-10 ft) depths near the northeast shore.

Maximum water surface temperature during 1968 and 1969 was 31.7 C (89 F) on August 8, 1969, and minimum was 5.6 C (42 F) on February 4, 1969 (Figure 2).

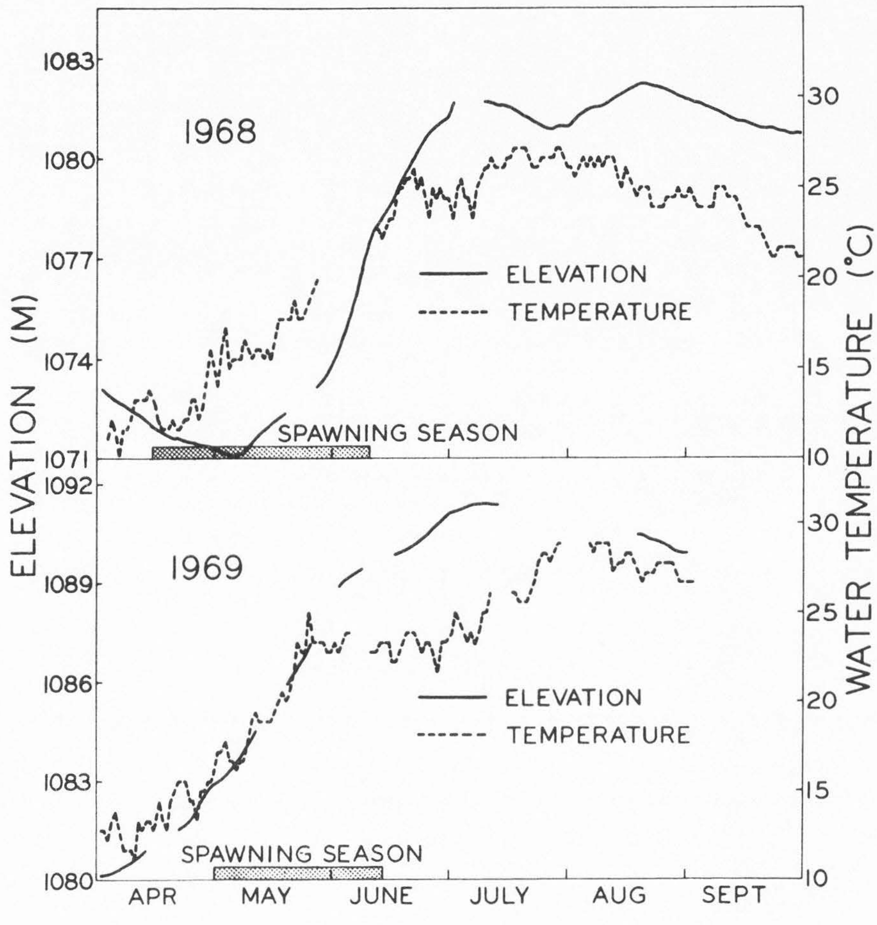

Figure 2. Water surface elevation (solid line), water surface temperature (dashed line), and largemouth bass spawning period (stippled area), Wahweap Bay, 1968 and 1969.

From May 5, 1968, until the end of spawning that year, the reservoir surface rose 6.99 m (22.94 ft) from elevation 1,070.80 m to 1,077.79 m (3,513.30 ft to 3,536.24 ft) at an average rate of 22 cm (0.72 ft) per day (Figure 2). The most rapid rise was between May 27 to June 13, when it averaged 32 cm (1.06 ft) per day.

Water surface elevation at the beginning of the 1969 spawning season was 1,080.57 m (3,545.36 ft), 8.77 m (28.79 ft) higher than the beginning of the 1968 season and 2.44 m (8.00 ft) higher than at the end of the spawning in 1968. By June 10, 1969, the lake level had risen 8.84 m (29.00 ft) to elevation 1,089.61 m (3,575.00 ft) at a mean rate of 15 cm (0.49 ft) per day. The most rapid rise was during the third week of May when the mean rate was 18 cm (0.6 ft) per day. Water level continued to rise until July 9 when it reached 1,091.44 m (3,581.02 ft).

Nesting and Spawning

Spawning dates and temperatures

The earliest nests were observed on April 14 in 1968 and on April 11 in 1969. These early nests were unattended and had no eggs. They were 0.60-0.91 m (2-3 ft) in diameter and were constructed in 0.91-1.52 m (3-5 ft) depths on the north and south shores of Wahweap Bay.

Mean daily water temperature during the first week of nest construction ranged from 11.7 C to 13.9 C (53 to 57 F) at the surface and nesting depths (Figure 2). Maximum daily air temperatures ranged from 20 C to 25 C (68 F to 77 F) during this period.

Voegele (1969) reported similar "test" nests constructed by spotted bass (Micropterus punctulatus) in Bull Shoals Reservoir. Carr (1942) stated that empty nests in 600-acre Bivans Arm in Florida were guarded longer early in the spawning season than later on, but she did not mention unattended nests.

Detailed observations on unattended nests were made in 1969. About 30 unattended nests without eggs were observed at 1.52-2.44 m (5-8 ft) depths on the north shore of the bay April 11-14, 1969. Two of these nests contained bass eggs on April 15-15, and within 1-2 days many of the nests were found guarded by black crappie. Mean daily water temperature at the surface ranged from 13.4 C (56 F) on April 11 to 12.8 C (55 F) on April 15, and at nest depths it ranged from 12.2 C to 15.6 C (54 F to 60 F). Maximum daily air temperature was 25 C (77 F) during this period.

The first eggs were observed in nests on April 30, 1968, and April 14, 1969. Spawning was continuous to June 13, 1968, and to June 10, 1969. During the 1968 spawning, mean daily water temperature at nesting depths rose from 14.4 C to 23.9 C (58 F to 75 F), and in 1969 it rose from 15 C to 23.4 C (59 F to 74 F). Mean daily surface water temperature at mid-bay ranged from 15.6 C to 22.2 C (60 F to 73 F) during the 1968 spawning season and from 13.4 C to 22.0 C (56 F to 73 F) in 1969. In both years, spawning began earliest on the shallower and more gently sloping north shore, where mean daily water temperature was 0.6-1.6 C (1-3 F) higher than on the south shore at this time.

Nest sites

Nests usually appeared as light-colored cleared areas which contrasted with the surrounding dark undisturbed bottom. Adult bass, swimming or hovering near the nests, were often seen before the nest was identified. Black crappie spawned at the same time as bass during the study period, and the similarity of their nests to those of bass made it necessary to observe a bass guarding a nest before positive identification was made.

In 1968, nests were found around the shoreline, except in the lower 1.61 km (1 mi) near the narrow steep-walled entrance and in the shallow upper end where Wahweap Creek entered the bay. Throughout the 1968 spawning season, nests were located on all three islands in the bay (Figure 1). Nests were also found on these islands early in the 1969 spawning season before they were inundated. Nests were found on the north and south shore of the bay in 1968 but only on the north shore in 1969.

In 1968, 77 nests were found on the north shore, 30 on the south shore, and 34 nests were found on the three islands. In 1969, 65 nests were found on the north shore of the bay and three on the largest island. In both years, nests were most dense in a large relatively shallow bay midway along the north shore of Wahweap Bay (Figure 1). Forty-three nests were found there in 1968 and 30 in 1969.

Wind and wave action

Afternoon and evening winds from the northwest were frequent and strong during both spawning seasons. Three nests constructed on the east shore on unprotected sandstone rubble at 0.45-1.07 m (1.5-3.5 ft) depths were destroyed by strong wave action on May 6, 1968. In 1969, two nests constructed 0.76 m (2.5 ft) deep in the same area were destroyed in the same manner on April 24. Average afternoon wind velocities recorded at the Page, Arizona Airport on these days were 16.41 km/h and 32.89 km/h (10.20-20.44 mph), respectively. Nests constructed deeper than 1.53 m (5 ft) or at shallower depths but protected by ledges or boulders were not destroyed by wave action.

Bottom type

Largemouth bass nests were built on or under large broken sandstone boulders on sandstone rubble at the base of sandstone ledges, on talus slopes, and on gravel bottoms. Nests were often constructed to take advantage of protection offered by slopes, boulders, ledges, and submerged sagebrush or tamerisk.

Sandstone rubble was the most frequently used bottom type. It was most available in the large, relatively shallow bay on the north shore of Wahweap Bay. In 1968 and 1969, 73 nests (35 percent) were found in this area on sandstone rubble. An additional 86 nests

(41 percent) were found on this bottom type throughout the rest of the bay. All of the nests found on sandstone rubble were constructed at the base of 0.61-1.52 m (2-5 ft) high sandstone ledges, under or at the base of the large angular sandstone boulders or on steep talus slopes that gave protection to one side or above the nest. In 1968, 15 nests were constructed on top of smooth firm sandstone shelves or boulders; ten had no cover; four were constructed at the base of flooded sagebrush, and one was at the base of a submerged fence post.

Though uncommon, gravel was the second-most-heavily-utilized bottom type. All of the nests constructed on gravel were found on steep slopes or at the bottom of trenches or pits dug in the gravel deposits. The steep slopes provided protection to one side of the nest, and in some cases the trenches or pits provided protection to the nest from above. Gravel bottoms were restricted to the largest island, to a single pile dumped on the south shore during dam construction, and to a gravel borrow site on the north shore. The latter area (available only in 1969) was very rough and irregular because of many trenches and pits dug during dam construction. Seventy-three nests were found on gravel bottom in both years. Thirty-eight of these were found in 1968 at the base of the large gravel pile. No nests were found on the south shore gravel pile in 1969. This was attributed to higher water levels covering the rougher and more gently sloping base of the gravel pile that was utilized for spawning in 1968. In 1969, 35 nests were found on the gravel borrow sites.

Nest depth and location

Depth of water over largemouth bass nests in Wahweap Bay ranged from 0.46 m to 8.23 m (1.50 ft to 27.00 ft). In both years, mean nest depth increased as water rose during the spawning periods (Figure 2).

In 1968, mean nest depth during the first 10 days of spawning (April 26-May 5) was 1.63 m (5.36 ft) and ranged from 0.46 m to 2.88 m (1.50 ft to 9.45 ft). After May 5, nest depth increased steadily as the water rose. During the final 10 days of nest-occupation in 1968 (June 4-13), mean nest depth was 4.54 m (14.90 ft) and ranged from 2.74 m to 7.01 m (9.00 ft to 23.00 ft).

During the first 10 days of the 1969 spawing season (April 12-22), mean nest depth was 1.51 m (4.96 ft) and ranged from .76 m to 3.05 m (2.50 ft to 10.0 ft). Mean nest depth during the last 10 days of nest-occupation (June 1-10) was 2.93 m (9.60 ft) and ranged from 2.13 m to 3.66 m (7.0 ft to 12.0 ft).

In both years, many of the ledges, boulders, and talus slopes upon which nests were built during the start of the spawning season were covered by increasingly deeper water. In 1968, rising water came up over the ledges on the north shore spawning areas and spilled out over flat and unbroken terrain. As the water rose, bass appeared to seek the protection of ledges, boulders, and talus slopes at the greater depths. Because of higher water, the ledges and rough slopes on the north shore were not available in 1969 as they were in 1968, and no protected nesting areas were available on the south shore.

In 1968, no nests were found on the shallow, flat, and open areas of the bay after water began to rise rapidly. In 1969 when increased water depths made many of the ledges and slopes used for nesting in 1968 unavailable, fewer nests were located, but no nests were found on flat open areas in shallow water.

The trenches and irregular areas of the lower part of the large south shore gravel pile were also covered by rising water in 1969, leaving only smooth, very steep gravel slopes of loose gravel. However, the trenches and pits in the north shore gravel deposits were made available for bass spawning.

Hunsaker and Crawford (1964) indicated that largemouth bass selected deeper water in protected areas for spawning in a 3-acre pond in California; the most important factor in the selection of a spawning site was the availability of suitable protection in the immediate vicinity of the nest.

Embryo survival

All nests required 4 days to hatch, except two nests in 1968 and one in 1969 which required 5 days to hatch.

Average survival of embryos to hatching was 80.4 percent in 1968 and 92.2 percent in 1969 (Table 1). This compares favorably with survival of largemouth bass embryos in Lake George, Minnesota (Kramer

Table 1. Survival of largemouth bass embryos, Wahweap Bay, Lake Powell, 1968 and 1969

Year	Percentage survival on successive days (Hatching) 1	2	3	4	Daily instantaneous mortality rates (%)
1968	90.6	81.8	81.0	80.4	3.7
1969	97.3	92.5	94.5	92.2	1.4

and Smith, 1962). Instantaneous daily embryo mortality rate, i, (Ricker, 1958) was .037 and .014 in 1968 and 1969, respectively (calculated as the slope of regression lines fitted by least squares to $\log_e$ daily percentage embryo survival and number of days).

Few dead sac fry were sampled. SCUBA observations indicated, that once this stage was reached, survival was good.

Hydra (Hydra utahensis) was observed throughout Wahweap Bay on all bottom types and over the range of bass spawning depths during both years. Examination of egg samples under a dissection scope and SCUBA observations revealed many instances of hydra polyps attached by their tentacles to bass embryos and fry still on the nest. Extent of mortality due to hydra was not estimated.

Eisler and Simon (1961) summarized many accounts of hydra preying on fish embryos and young fish. They found that recently-hatched larvae of Chinook salmon (Oncorhynchus tshawytscha) and silver salmon

(*O. kisutch*) were adversely affected by exposures to *Hydra oligactis* as short as 5 minutes and usually died within 5 days. Clady and Ulrikson (1968) attributed death of bluegill fry in nests in a metal tank with a gravity flow of water to hydra (probably *Hydra carnea*).

Angling mortality

Nests were marked with white styrofoam floats in 1968 to aid in relocating nests under conditions of rapidly rising water. Anglers soon located the floats, and some made special efforts to fish the nests marked by the floats. SCUBA observations indicated that anglers removed adult male bass from 34 nests (24 percent) located in 1968. All of these nests were unsuccessful, apparently due to predation by other fish on the embryos or sac fry. One carp was seen scavenging one of these nests, and carp scales were found in several others. To prevent anglers from fishing marked nests, marker floats were placed just beneath the surface during the last part of the 1968 spawning season and throughout 1969.

Growth

Young-of-the-year bass were measured to the nearest 1.0 mm total length and weighed to the nearest 0.01 g.

Growth of fingerlings was expressed in curves of total length fitted by eye to points, representing the average total length of fish taken before and after broods dispersed in both years (Figure 3, Table 5).

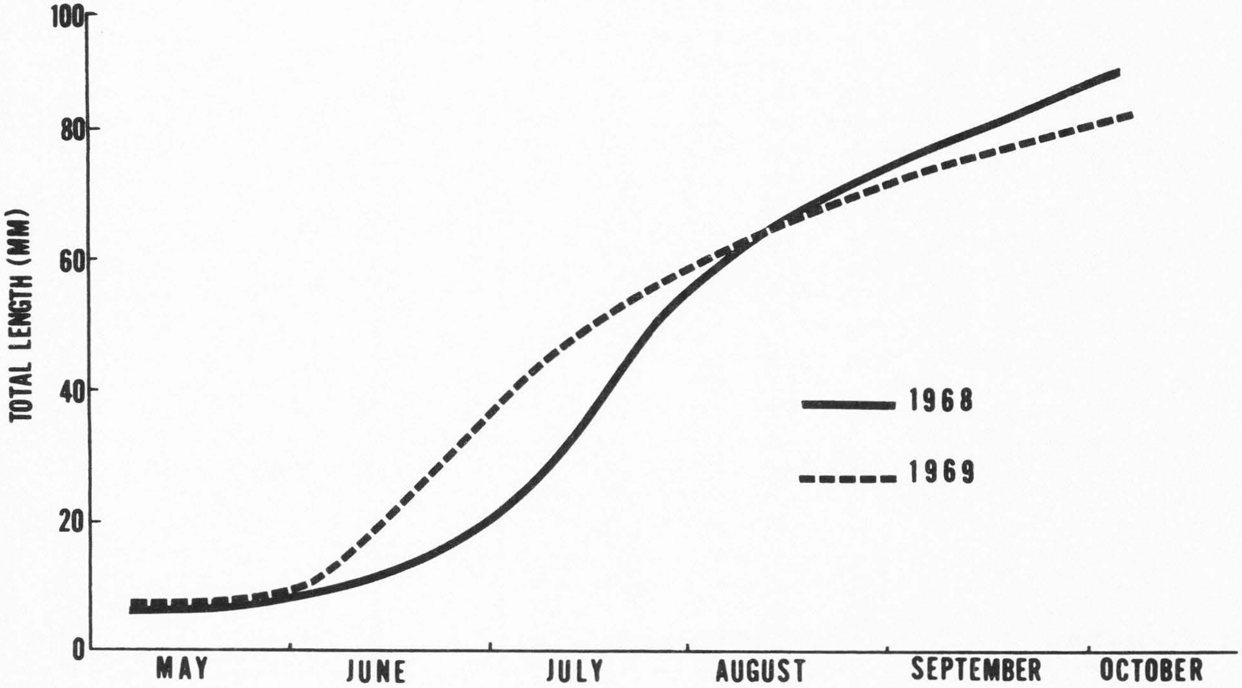

Figure 3. Growth of largemouth bass fingerlings during first growing season, 1968 and 1969.

Total length at the end of the growing season (October 1) and at the end of 2-week periods after May 1 of each year was estimated from the curves. Total length on October 1 was 86.5 mm in 1968 and 80.2 mm in 1969.

Growth between years was compared by expressing growth as g (Ricker, 1958) during each 2-week period and as the percentage increment to the total length at the beginning of each period (Table 2). The appearance of very slow growth during May of both years is because all the fish sampled that month were sac fry from nests. Growth patterns were similar in both years, rapid early growth, slowing through the latter part of the summer. In 1968, growth rate was greatest in the fourth and fifth 2-week periods and decreased steadily after that. In 1969, growth rate was fastest during the third and fourth 2-week periods.

Fingerlings from the 1969 year-class were longer than those from the 1968 year-class before August 21 (Table 2). On that date, total length of each year-class was 68 mm, after which the 1969 fish grew faster. Total temperature experience (degree-days greater than 10 C) for each year-class after the mid point of spawning (May 12) was greatest throughout the 1969 growing season. Linear regression lines fitted to weight of fingerlings and accumulated centigrade degree-days at each 2-week interval for each growing season were not significantly different at the 10 percent level. The lines suggest that growth may have been influenced by total temperature experience during the early part of the

Table 2. Growth and temperature experience of largemouth bass fry and fingerlings at successive 2-week periods after May 15, Wahweap Bay, Lake Powell, 1968 and 1969; growth expressed as total length, percentage increment, and daily instantaneous growth rate; temperature experience expressed as accumulated centigrade degree days above 10 C after May 12.

	1968				1969			
Date	Accumulated centigrade degree days	Total length (mm)	Percentage increment	Daily instantaneous growth rate	Accumulated centigrade degree days	Total length (mm)	Percentage increment	Daily instantaneous growth rate
May 15	--	5.0[a]	--		--	5.5[a]	--	
May 29	--	8.3[a]	66.0		--	6.5[a]	18.2	
June 12	294.48	12.0	44.6		392.22	15.0	130.8	
				.064				.183
June 26	509.48	17.0	41.7		577.10	31.0	106.7	
				.126				.089
July 10	716.68	30.0	76.5		769.97	45.0	45.2	
				.108				.044
July 24	949.46	49.5	65.0		987.76	54.5	21.1	
				.044				.029
Aug. 7	1180.03	60.2	21.6		1235.54	61.7	13.2	
				.025				.023
Aug. 21	1399.49	68.0	13.0		1453.33	68.0	10.2	
				.020				.016

Table 2. Continued

Date	1968 Accumulated centigrade degree days	1968 Total length (mm)	1968 Percentage increment	1968 Daily instantaneous growth rate	1969 Accumulated centigrade degree days	1969 Total length (mm)	1969 Percentage increment	1969 Daily instantaneous growth rate
Sept. 4	1599.47	74.7	9.8		1689.47	72.8	7.1	
				.018				.012
Sept. 18	1795.02	81.0	8.4		1903.93	76.6	6.1	
				.014				.012
Oct. 2	1934.48	87.0	7.4		2083.38	80.7	5.3	
Oct. 16	--	92.2	6.0		--	--	--	

[a]Represents length of sac fry still on nest.

growing season but not during the latter part. Kramer and Smith (1960) found total temperature experience to be strongly associated with largemouth bass fingerling growth rate before August 1 in Lake George, Minnesota, but not after that date. Food habits of the 1968 year-class were not analyzed, but differences in quality or quantity of food may have accounted for growth differences between years in the latter part of the growing season.

Length-weight relationship

A log plot of the average lengths and weights of bass fingerlings in 10-mm groups from 10 mm to 129 mm total length indicated that one straight line could be used to describe the length-weight relationship during the first growing season of both years in the present study. Regression lines were computed by the method of least squares from logarithms of mean lengths and mean logarithms of weights of 1,019 fingerlings taken in 1968 and 1,691 fingerlings in 1969. Regression lines were:

$$1968 \quad \text{Log } W = 3.03942 \text{ Log } L - 5.02880$$

$$1969 \quad \text{Log } W = 3.29188 \text{ Log } L - 5.49019$$

where W = weight in grams and L = total length in millimeters. These compare favorably with regression lines computed by Kramer and Smith (1960) for largemouth bass fingerlings in Lake George, Minnesota.

Food Habits

Stomachs were taken from bass fry and fingerlings from 6 mm to 155 mm total length captured in 1969 and examined by 10-mm length groups. Food was not found in bass less than 8 mm total length.

Food items changed through the first growing season from entirely Crustacea in the smallest fingerlings to predominately insects and fish in the largest fingerlings (Table 3). Crustacea (cladocerans and copepods) occurred in over 90 percent of the stomachs from bass up to 39 mm long. Occurrence of Crustacea decreased with size of bass as percentage occurrence of insects increased. Mean number of Crustacea per stomach increased from 54 to 95, until bass reached a size at which they began to eat insects.

Insects and fish began to be eaten when bass reached 20 mm long. Percentage occurrence of insects, mainly chironomid larvae and pupae, increased from 7 percent to 100 percent as fingerlings grew from 20 mm to 99 mm long. Mean number of insects per stomach increased from 0.3 to 72 with size of fingerling up to 59 mm and then decreased. This decrease reflected a change from nearly all chironomid larvae and pupae in the diet to increasing numbers of larger insects--adult Diptera and damsel-fly nymphs (Coenagrionidae)--and to increased numbers of fish in the diet.

Fish (largemouth bass, black crappie, bluegill sunfish, and threadfin shad) were eaten by bass over 20 mm long. Percentage

Table 3. Utilization of crustaceans, insects, and fish by largemouth bass, Wahweap Bay, Lake Powell, 1969--expressed as percentage occurrence and mean number per stomach of fish containing food

Total length (mm)	Percentage empty stomachs	Crustaceans		Insects		Fish	
		Percentage occurrence	Mean number per stomach	Percentage occurrence	Mean number per stomach	Percentage occurrence	Mean number per stomach
8-10	0.0	100.00	54.00	0.00	0.00	0.00	0.0
10-19	0.0	100.00	53.00	0.00	0.00	0.00	0.0
20-29	0.0	96.30	94.30	7.41	0.30	3.70	--[a]
30-39	0.0	94.59	95.30	59.46	8.10	21.62	0.5
40-49	0.0	58.14	39.50	90.70	30.50	6.98	0.7
50-59	1.1	43.18	21.40	96.59	71.80	9.09	0.1
60-69	3.0	28.87	13.50	94.85	59.90	3.08	--[a]
70-79	3.9	17.81	22.70	90.24	52.80	14.63	0.1
80-89	4.6	2.44	.07	90.24	52.80	14.63	0.1
90-99	12.0	4.55	6.80	100.00	18.60	4.55	0.4
100-70	28.6	0.00	0.00	60.00	18.30	40.00	0.5

[a]Less than 0.05.

occurrence of fish increased with fingerling size, but it was never greater than 40 percent.

Percentage composition of six groups of Crustacea in plankton samples was compared with percentage composition of Crustacea in fingerling stomachs. Correlation coefficients (*r*) between percentage composition of Crustacea in plankton samples and in fingerling stomachs were .02 in June, -.27 and .14 in July, -.47 in August, and -.12 in September. No correlation coefficients were significant at the 10 percent level.

These results indicate that bass fingerlings fed on crustaceans selectively instead of in relation with their abundance. Selection was toward the larger plankton organisms, *Daphnia* and copepods. *Daphnia* made up only 1 percent to 21 percent of early July plankton samples but comprised 16 percent to 87 percent of the Crustacea in fingerling stomachs sampled in early July. After late July, selection appeared to be toward two copepods, *Diaptomus* and *Cyclops*, which comprised from 0.5 percent to 42 percent of crustaceans in plankton samples but made up 50 percent to 100 percent of the crustaceans in stomachs sampled in August and September. Nauplii made up 14 percent to 67 percent of all plankton samples but were occasionally taken only by fingerlings less than 10 mm total length.

Abundance of Bass Fingerlings

As part of the Lake Powell Fishery Investigations, efforts were begun during this study to develop an index to year-class strength from the beach-seine catches. Average weekly catch per haul was plotted against number of days after July 15, the estimated date of brood dispersal each year for each area. (See Appendix, Table 6.) Straight lines were fitted to all six sets of data, and no slopes of the linear regressions were significantly different from zero at the 90 percent level. Since there was no significant slope to these regression lines, the mean number of bass fingerlings per seine haul made any time during the first growing season after brood dispersal could be used as an index to year-class strength.

Estimated numbers of fingerling bass present after brood dispersal per 92.9 m^2 (1,000 ft^2) ranged from 0.82 to 3.39 in 1968 and from 0.23 to 2.65 in 1969 (Table 4). Mean number of fingerlings per haul was greatest in 1968 for all areas. Differences between years for Area 2 and Area 3 were insignificant at the 90 percent level. In Area 1, though mean number of fingerling per seine haul was considerably lower than in Area 2 or Area 3 in both years, the difference between 1968 and 1969 catches was significant at the 99 percent level. Area 1, a blown sand beach, appeared to be less favorable bass fingerling habitat because of sparse vegetation and lack of other cover. Area 3, which had the highest mean number per haul in both years, was on smooth sandstone rubble in the

Table 4. Abundance of largemouth bass fingerlings, Areas 1, 2, and 3, Wahweap Bay, July 15-October, 1968 and 1969--expressed as mean number per haul and number per 92.9 m^2 (1,000 ft^2)

Area	Year	Number of hauls	Mean number per haul	Standard error of mean	Number per 92.9 m^2 (1,000 ft^2)
1	1968	16	4.12	0.67	0.82
	1969	44	1.14	0.22	0.23
2	1968	15	6.80	1.53	1.36
	1969	48	5.12	0.68	1.02
3	1968	31	16.94	2.98	3.39
	1969	48	13.27	1.56	2.65

large bay on the northeast shore immediately above the ledges and broken boulders preferred for spawning.

It appeared that Area 1 would be the best area for seining in future evaluations of year-class strength, because (a) its less favorable habitat would not attract disproportionately high numbers of fingerling bass, and (b) fluctuating water levels in the bay will not change the character of the habitat.

SUMMARY AND CONCLUSIONS

Largemouth bass began to spawn in Wahweap Bay when daily mean water temperature reached 14.4 C to 15.0 C (58 F to 59 F) at nesting depths. Spawning was continuous from mid- or late-April until mid-June. Most spawning (55 percent of nests) in 1968, and all spawning in 1969, was on the northeast shore. Preferred bottom type for nesting was sandstone rubble at the bases of ledges or large sandstone boulders. Mean nest depth ranged from 1.6 m (5.4 ft) to 1.5 m (5.0 ft) at the beginning of the spawning seasons and increased to 2.93 m (9.60 ft) to 4.50 m (14.90 ft) as water level rose during the spawning season. Nest depth increased as each spawning season progressed as bass sought protection of ledges and boulders which were covered by increasing water depths. Strong winds and wave action destroyed nests constructed shallower than 1.53 m (5 ft). Deeper water or protection by boulders and ledges prevented other nests from being destroyed by effects of wave action.

Eggs hatched in 4 to 5 days. Average survival of embryos was 80.4 percent and 92.2 percent at hatching in 1968 and 1969, respectively.

Fingerling from the 1969 year-class were larger than those from the 1968 year-class before August 21. Total length of bass on August 21 was 68.0 mm in both years but was 86.5 mm and 80.2 mm on October 1 in 1968 and 1969, respectively. Growth may have been influenced by total temperature experience during the early part of the growing season but not during the latter part.

Fingerling bass ate crustaceans, insects, and fish. They fed on larger Crustacea selectively rather than in relation to their relative abundance in the zooplankton. Size of organisms eaten increased as fingerlings grew larger.

Beach-seine catches in 1968 and 1969 indicated that the 1968 year-class was the larger. Estimated numbers of bass fingerlings per 92.9 m^2 (1,000 ft^2) seined ranged from 0.82 to 3.39 in 1968 and from 0.23 to 2.65 in 1969. An index to year-class strength in Wahweap Bay can be obtained at any time during the summer after brood dispersal from seine hauls made in Area 1. Validation of predicted strong or weak year-classes shown by beach-seine estimates, however, must await determination of each year's class contribution to the creel.

LITERATURE CITED

Carr, Marjorie H. 1942. The breeding habits, embryology, and larval developments of the largemouth black bass in Florida. Proc. New. Eng. Zool. Club 20:43-77.

Clady, Michael D., and Gerald U. Ulrikson. 1968. Mortality of recently hatched bluegill fry as a result of Hydra. Prog. Fish. Cult. 30(1):39-40.

Eisler, Ronald, and Raymond C. Simon. 1961. Destruction of salmon larvae by Hydra oligactis. Trans. Amer. Fish. Soc. 90(3): 329-332.

Hunsaker, Don, II, and R. W. Crawford. 1964. Preferential spawning behavior of the largemouth bass, Micropterus salmoides. Copeia 1:240-241.

Kramer, Robert H., and Lloyd L. Smith, Jr. 1960. First-year growth of the largemouth bass, Micropterus salmoides (Lacepede), and some related ecological factors. Trans. Amer. Fish. Soc. 89(2): 222-233.

Kramer, Robert H., and Lloyd L. Smith, Jr. 1962. Formation of year classes in largemouth bass. Trans. Am. Fish. Soc. 91(1):29-41.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. 119. 300 p.

Vogele, Louis E. 1969. Progress in sport fishery research, 1968. Bureau of Sport Fisheries and Wildlife, Resource Publication 77: 75-76.

APPENDIX

Table 5. Mean total length of largemouth bass fingerlings at date of capture, Wahweap Bay, Lake Powell, 1968 and 1969

1968		1969	
Date	Total length (mm)	Date	Total length (mm)
May 8	5	May 7	7
May 11	6	May 11	7
May 13	6	May 12	6
May 17	6	May 15	6
May 17	7	May 26	6
June 10	20	June 10	9
June 16	17	June 10	6
June 17	21	June 15	20
June 18	11	June 25	29
June 20	11	June 31	39
June 20	13		
June 26	12		
July 10	20	July 10	48
July 19	43	July 16	55
July 31	57	July 22	56
		July 28	58
August 8	58	August 5	55
August 15	64	August 17	68
		August 27	70
September 5	79	September 3	68
September 14	78	September 9	76
		September 17	73
		September 23	75
October 4	84	October 5	80
October 23	93		

Table 6. Number of largemouth bass fingerlings, taken per beach-seine haul, Wahweap Bay, Lake Powell, July-October, 1968 and 1969

1968					1969				
Date	Haul no.	Area 1	Area 2	Area 3	Date	Haul no.	Area 1	Area 2	Area 3
July 18	1	4	0	-	July 18	1	-	1	-
	2	3	7	-		2	-	3	-
	3	8	2	-		3	-	3	-
	4	1	-	-		4	-	10	-
July 20	1	-	-	9	July 21	1	1	-	9
	2	-	-	6		2	0	-	9
	3	-	-	21		3	0	-	16
	4	-	-	-		4	0	-	1
July 31	1	9	-	13	July 23	1	-	6	-
	2	6	-	7		2	-	3	-
	3	3	-	9		3	-	9	-
	4	-	-	-		4	-	3	-
August 2	1	-	-	12	July 28	1	0	-	19
	2	-	-	35		2	0	-	3
	3	-	-	10		3	0	-	7
	4	-	-	-		4	1	-	4

Table 6. Continued

1968					1969				
Date	Haul no.	Area 1	Area 2	Area 3	Date	Haul no.	Area 1	Area 2	Area 3
August 6	1	0	13	-	July 30	1	-	0	-
	2	3	22	-		2	-	12	-
	3	7	0	-		3	-	1	-
	4	-	-	-		4	-	5	-
August 9	1	-	-	45	August 4	1	0	-	15
	2	-	-	49		2	1	-	11
	3	-	-	73		3	0	-	1
	4	-	-	-		4	1	-	4
August 13	1	3	8	-	August 6	1	-	0	-
	2	3	5	-		2	-	9	-
	3	6	4	-		3	-	8	-
	4	-	-	-		4	-	4	-
August 16	1	-	-	35	August 15	1	3	-	20
	2	-	-	1		2	3	-	28
	3	-	-	21		3	2	-	10
	4	-	-	-		4	5	-	8

Table 6. Continued

1968					1969				
Date	Haul no.	Area 1	Area 2	Area 3	Date	Haul no.	Area 1	Area 2	Area 3
September 4	1	4	7	-	August 18	1	-	1	-
	2	0	5	-		2	-	5	-
	3	6	0	-		3	-	11	-
	4	-	0	-		4	-	5	-
September 6	1	-	-	2	August 20	1	0	-	1
	2	-	-	5		2	0	-	36
	3	-	-	19		3	2	-	0
	4	-	-	6		4	0	-	11
September 11	1	-	-	4	August 25	1	-	3	-
	2	-	-	17		2	-	0	-
	3	-	-	18		3	-	1	-
	4	-	-	-		4	-	6	-
September 18	1	-	-	6	August 28	1	2	-	5
	2	-	-	10		2	0	-	2
	3	-	-	21		3	2	-	28
	4	-	-	9		4	0	-	1

Table 6. Continued

1968					1969				
Date	Haul no.	Area 1	Area 2	Area 3	Date	Haul no.	Area 1	Area 2	Area 3
October 4	1	-	-	3	September 2	1	-	3	-
	2	-	-	3		2	-	12	-
	3	-	-	5		3	-	2	-
	4	-	-	36		4	-	5	-
October 23	1	-	-	14	September 5	1	0	-	13
	2	-	-	4		2	3	-	39
	3	-	-	6		3	0	-	13
	4	-	-	20		4	0	-	14
					September 8	1	-	4	-
						2	-	2	-
						3	-	21	-
						4	-	13	-
					September 10	1	0	-	12
						2	3	-	20
						3	0	-	12
						4	4	-	7

Table 6. Continued

1968					1969				
Date	Haul no.	Area 1	Area 2	Area 3	Date	Haul no.	Area 1	Area 2	Area 3
					September 15	1	-	2	-
						2	-	7	-
						3	-	4	-
						4	-	5	-
					September 19	1	3	-	14
						2	3	-	20
						3	1	-	19
						4	4	-	11
					September 22	1	-	5	-
						2	-	0	-
						3	-	3	-
						4	-	5	-
					September 24	1	-	-	15
						2	-	-	25
						3	-	-	10
						4	-	-	10

Table 6. Continued

1968					1969				
Date	Haul no.	Area 1	Area 2	Area 3	Date	Haul no.	Area 1	Area 2	Area 3
					September 30	1	-	0	-
						2	-	0	-
						3	-	11	-
						4	-	18	-
					October 1	1	0	-	34
						2	1	-	48
						3	0	-	21
						4	3	-	8
					October 9	1	-	0	-
						2	-	2	-
						3	-	5	-
						4	-	8	-
					October 10	1	0	-	12
						2	2	-	13
						3	0	-	3
						4	0	-	1

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