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DISTRIBUTION AND ABUNDANCE OF PELAGIC FISH IN LAKE POWELL, UTAH, AND LAKE MEAD, ARIZONA-NEVADA

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ABSTRACT.—Pelagic fish communities (waters with depths >20 m) of Lakes Powell and Mead were examined quarterly from 1995 to1998 using vertical gill nets and a scientific echosounder. Nets captured a total of 449 fish consisting of striped bass (57%/45% [Lake Powell/Lake Mead]), threadfin shad (24%/50%), common carp (15%/4%), walleye (3%), channel catfish (2%), and rainbow trout (<1%). Each reservoir contained concentrations of pelagic species separated by expanses of habitat with few fish (<10 kg · ha^{-1}). Reservoirs experienced dramatic seasonal and annual fluctuations in pelagic biomass. Lake Powell's biomass peaked at the Colorado River at 709.7 (±46.5) kg · ha^{-1} and Lake Mead's reached 291.9 (±58.2) kg · ha^{-1} at Las Vegas Wash. These locations supported estimated fish densities of 124,668 fish · ha^{-1} and 15,131 fish · ha^{-1}, respectively. Maximum reservoir biomass peaked in August 1996, with Lake Powell supporting 10,852,738 ± 5,195,556 kg (27.6×10^7 fish) and Lake Mead 1,926,697 ± 892.994 kg (10.8×10^7 fish). Biomass ebbed in May (1996 and 1997), when Lake Mead supported 65% (296,736 kg vs. 453,097 kg) and 62% (101,016 kg vs. 162,262 kg) of biomass levels found in Lake Powell.

Key words: pelagic fisheries, striped bass, threadfin shad, biomass, densities, distribution.

Lake Powell and Lake Mead on the Colorado River represent the 2 largest (by volume) reservoirs in the Western Hemisphere. Both are in the arid southwestern United States and were created for water storage, flood control, and hydroelectric power generation. The reservoirs bracket Grand Canyon, with Lake Powell 400 km upstream of Lake Mead. Both support economically important striped bass (*Morone saxatilis*) fisheries, and combined annual harvest exceeds 1 million fish (Nevada Department of Wildlife [NDOW] unpublished data, Gustaveson et al. 1998). Fish distribution and production are influenced by limited nutrients in both reservoirs (Paulson and Baker 1984, Axler and Paulson 1987, LaBounty and Horn 1997). Unlike pelagic fisheries in more productive waters elsewhere (Axon and Whitehurst 1985, Boxrucker et al. 1995), little quantitative information is available regarding striped bass populations found in nutrient-limited reservoirs. The objective of this study was to examine distribution and biomass of the pelagic fish communities in these nutrient-limited reservoirs.

STUDY SITE

Lake Powell

Glen Canyon Dam is 7 km downstream of the Utah-Arizona border near Page, Arizona. Lake Powell has maximum surface area of 65,315 ha, depth of 171 m, and active storage of 3.33×10^{10} m^3. The reservoir reaches upstream more than 340 km into the Colorado, San Juan, Escalante, and Dirty Devil Rivers. It is often described as an inundated canyon having 2 large basins (Wahweap and Padre Bays), both at the lower end of the reservoir (Fig. 1). Principal inflows are the Colorado (88%) and San Juan (10%) Rivers. Water released from Lake Powell flows 385 km through Grand Canyon before entering Lake Mead.

Lake Mead

Hoover (Boulder) Dam is located in Black Canyon about 40 km south of Las Vegas, Nevada. At full pool the reservoir is 180 m deep, covers 165,815 ha, and holds 3.95×10^{10} m^3 of storage. Lake Mead is approximately 185 km long and inundates portions of the

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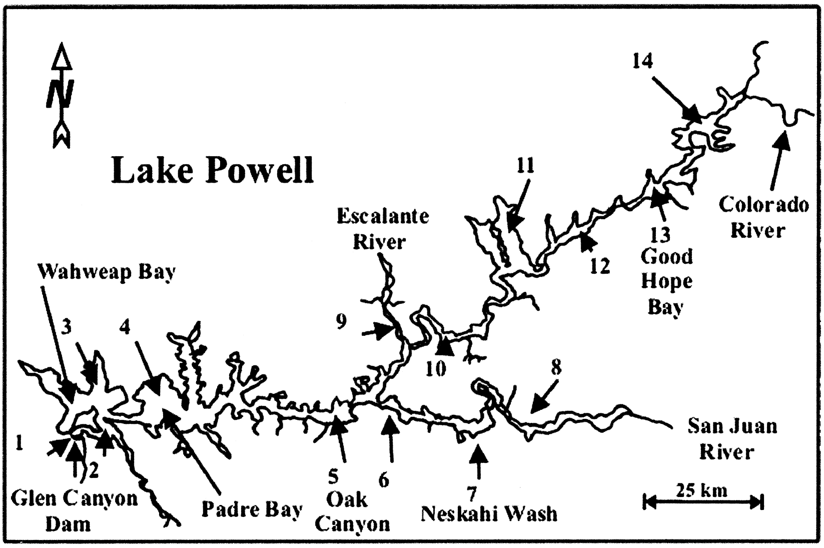

Fig. 1. General map of Lake Powell, Utah, showing the location of prominent features and the location of the 14 study sites.

Colorado and Virgin Rivers. Lake Mead has 4 large basins (Boulder, Virgin, Temple, and Gregg; Fig. 2). Principal inflows are the Colorado (98%) and Virgin (1%) Rivers and Las Vegas Wash (1%).

General Limnology

The Colorado River flows through relatively barren deserts and is fed primarily by snowmelt and surface runoff draining 630,000 km^2 from Arizona, California, Colorado, New Mexico, Utah, and Wyoming. Both reservoirs are phosphorus limited and are considered oligotrophic to mildly mesotrophic (Paulson and Baker 1984, LaBounty and Horn 1997). Primary production is greatest at nutrient input areas (rivers and treated sewage effluent) and diminishes with distance from the nutrient source. Chlorophyll-*a* often declines to $<2\ \mu g \cdot L^{-1}$, a level inadequate to support planktonic feeders such as threadfin shad (*Dorosoma petenense*) and age-0 fish. Water clarity often exceeds 15 m.

METHODS

We selected 25 monitoring sites (14, Lake Powell; 11, Lake Mead) to represent major habitat types (i.e., basins, main stem canyons, side canyons, and inflows; Figs. 1, 2). Field surveys were conducted quarterly, starting at Lake Powell (5–7 days) and finishing at Lake Mead (3–5 days).

Data Collection

Species composition was determined using a set of 6 vertical gill nets (2.5 m × 100 m), each having a different mesh size (12, 25, 31, 42, 50, 64 mm). We suspended nets from floating spools to depths >30 m and fished overnight at Good Hope Bay, Neskahi Wash, Oak Canyon, and Padre Bay on Lake Powell and at Boulder Basin, Gregg's Basin, Overton Arm, and Virgin Basin on Lake Mead. Each site was sampled once each field trip as wind permitted.

Fish biomass and densities were measured using a single-beam scientific echosounder (BioSonics^{TM} DT-4000) that was upgraded to a dual-beam system (DT-5000) in September 1996. Both models operated at 420 kHz using a 6° single-beam or 6.2°–13.6° dual-beam transducer. Data were thresholded at –60 dB and collected and stored on a laptop computer.

Each of the 25 monitoring sites had 3 transects that paralleled (distances >200 m) each other from opposite shorelines. Exceptions were at dams and narrow canyons where transects (1–2 km long) zigzagged from opposite shorelines. Transect coordinates were programed into a GPS navigational system that

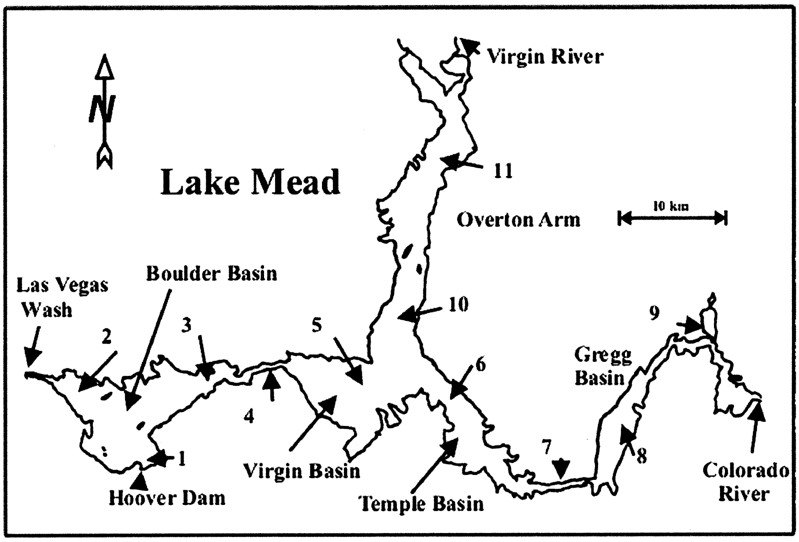

Fig. 2. General map of Lake Mead, Arizona-Nevada, showing the location of prominent features and the location of the 11 study sites.

allowed for repetitive monitoring. We conducted surveys both day and night, but night surveys were reserved for inflow areas that we suspected would support higher fish densities. Night surveys improved density resolution because schooling fish disperse at night to feed (Luecke and Wurtsbaugh 1993). Surveys started and ended near (5 m) shore and were conducted at speeds of 8–10 km · h^{-1}.

From each of the monitoring sites (25), we collected data during 8 quarterly field surveys for a total of 541 (some equipment/weather failures) transect files. Cumulative transect distance was 70.9 km for Lake Powell and 95.0 km for Lake Mead; in total, we collected 1326 km of transect data during the study.

Acoustic Data Analysis

Electronic echograms were edited, and only reaches where depths exceeded 20 m were used in the analysis. Fish biomass is a direct fish-weight-to-water-volume ratio based on reflective energy readings. Fish densities were estimated by echo-counting, which involves counting individual targets for specific strata volume and converting fish · m^{-3} to fish · ha^{-1}.

Fish biomass (kg) and densities (numbers) per surface area were calculated and averaged to provide a transect value. Surface area (full pool) of each habitat type was measured from topographical maps. Biomass and density were multiplied by the surface area of each habitat type to determine total reservoir biomass and numbers of fish. The 3 transect values were averaged and 90% confidence limits were calculated for each of the 25 monitoring sites.

RESULTS

Pelagic netting produced 449 fish representing 6 species. We suspected that large-mesh monofilament nets would contribute a high bias toward larger species. Striped bass (56%) dominated the Lake Powell gill-net catch, followed by threadfin shad (24%), common carp (*Cyprinus carpio* [15%]), walleye (*Stizostedion vitreum* [3%]), and channel catfish (*Ictalurus punctatus* [2%]). Threadfin shad comprised 50% of the Lake Mead gill-net sample, followed by striped bass (45%), common carp (4%), and a rainbow trout (*Oncorhynchus mykiss* [<1%]).

Pelagic biomass and densities varied seasonally, peaking in August and reaching lows just prior to spawning in May. Geographically, both peaked at the confluence of the Colorado (P014) and San Juan Rivers (P08) in Lake Powell, and in Lake Mead at the Colorado River (M09) and Las Vegas Wash (M02; Table 1, Figs. 3, 4). Maximum biomass was 709.7 and 291.9 kg · ha^{-1}, and fish densities reached 144,668

TABLE 1. Pelagic fish biomass ($kg \cdot ha^{-1}$, CL = 90%) measured with single- and dual-beam acoustical technology in Lakes Powell and Mead, Arizona-Nevada-Utah, from November 1995 through January 1998.

	1995		1996		1997			1998
	Nov.	Feb.	May	Aug.	May	Aug.	Oct.	Jan.
LAKE POWELL								
1	0.1 (0.2)	7.2 (12.3)	24.2 (21.0)	136.4 (21.6)	1.3 (–)	0.5 (0.4)	0.9 (–)	4.0 (4.3)
2	0.1 (–)	3.8 (8.1)	2.3 (1.9)	21.3 (9.5)	0.0 (–)	1.7 (1.9)	0.1 (0.1)	0.6 (0.6)
3	—	63.8 (15.7)	10.7 (4.4)	172.2 (48.8)	1.9 (0.6)	2.7 (1.1)	11.2 (9.2)	1.9 (1.3)
4	10.2 (5.1)	4.4 (4.5)	4.1 (2.9)	78.2 (15.7)	1.2 (2.1)	1.1 (0.9)	0.2 (0.3)	0.5 (–)
5	20.5 (13.4)	13.8 (12.9)	3.1 (2.1)	80.0 (14.6)	0.5 (0.7)	3.1 (3.1)	1.2 (0.7)	0.2 (0.1)
6	4.6 (6.2)	63.3 (98.5)	5.5 (7.9)	170.6 (36.1)	0.4 (0.1)	1.2 (1.4)	1.3 (1.2)	0.9 (0.5)
7	132.3 (37.6)	—	1.2 (0.5)	54.2 (6.7)	1.0 (0.7)	4.5 (3.7)	107.5 (76.3)	4.6 (0.8)
8	—	—	0.8 (0.5)	240.1 (61.7)	2.3 (0.5)	162.0 (121.0)	59.7 (11.1)	10.5 (5.5)
9	6.5 (4.8)	24.4 (1.1)	5.2 (4.9)	132.9 (4.6)	4.6 (1.1)	4.6 (6.3)	1.2 (0.8)	1.5 (0.6)
10	59.3 (17.1)	3.0 (1.6)	1.3 (1.3)	272.3 (46.3)	0.5 (0.3)	9.4 (–)	1.0 (0.5)	1.3 (0.4)
11	91.3 (78.1)	185.7 (142.2)	11.6 (15.1)	33.7 (20.5)	0.2 (0.0)	24.9 (8.9)	6.0 (2.9)	1.6 (2.0)
12	204.5 (90.5)	15.3 (3.7)	2.8 (2.7)	316.4 (223.9)	11.8 (5.8)	38.1 (30.0)	25.4 (12.9)	2.2 (0.5)
13	403.3 (266.0)	10.2 (4.7)	10.1 (9.8)	344.2 (55.2)	10.5 (7.6)	98.5 (22.4)	26.4 (14.2)	12.2 (6.1)
14	295.7 (148.8)	41.5 (11.4)	16.4 (9.1)	709.7 (46.5)	1.6 (1.7)	366.4 (33.3)	61.1 (31.6)	5.1 (3.5)
Total[a]	5231. (9766)	2176. (2590)	453. (577)	10,852. (5196)	162. (209)	2229. (1325)	910. (943)	149. (148)
LAKE MEAD								
1	0.0 (–)	1.5 (1.0)	4.0 (4.4)	27.5 (8.2)	0.5 (0.8)	53.0 (2.7)	0.0 (–)	0.1 (–)
2	29.9 (10.2)	65.7 (10.0)	16.1 (10.9)	62.0 (31.6)	8.6 (6.7)	291.9 (58.2)	16.9 (23.0)	2.9 (0.4)
3	0.4 (0.6)	0.2 (0.3)	1.9 (2.1)	31.5 (16.9)	0.0 (0.0)	3.8 (1.3)	0.1 (–)	0.5 (0.1)
4	0.8 (0.7)	0.5 (0.7)	3.5 (0.5)	30.1 (27.4)	0.2 (–)	41.0 (32.0)	0.2 (0.3)	0.0 (–)
5	0.6 (0.8)	0.1 (0.2)	1.9 (1.5)	4.2 (3.1)	0.1 (–)	3.3 (2.3)	0.1 (–)	0. 7 (0.9)
6	0.6 (0.8)	0.1 (0.0)	0.6 (0.4)	15.4 (8.1)	0.1 (0.1)	2.0 (1.5)	0.9 (0.9)	0.1 (–)
7	1.2 (0.7)	2.9 (1.2)	2.6 (1.9)	7.3 (0.7)	0.4 (0.4)	6.7 (5.9)	5.3 (1.7)	1.2 (0.8)
8	39.3 (56.4)	8.6 (0.7)	1.2 (0.8)	27.7 (5.8)	1.6 (0.8)	21.8 (0.9)	17.0 (3.9)	4.4 (1.1)
9	22.7 (25.0)	4.8 (4.1)	30.9 (11.0)	82.2 (2.0)	11.1 (8.8)	81.9 (58.8)	41.4 (13.7)	9.4 (5.6)
10	1.5 (2.0)	0.8 (0.3)	1.0 (0.9)	5.6 (2.8)	2.1 (2.5)	2.8 (2.4)	0.1 (–)	—
11	51.9 (16.4)	9.8 (2.9)	5.9 (2.4)	13.0 (2.6)	1.8 (0.1)	4.7 (2.5)	9.6 (5.0)	0.6 (0.6)
Total[a]	803. (1073)	378. (169)	297. (288)	1927. (1477)	101. (1055)	1455. (948)	393. (374)	85. (86)

[a] Total = reservoir total in metric tons.

and 15,131 fish $\cdot$ ha^{-1} in Lake Powell and Lake Mead, respectively. Fish densites in Lake Powell during August (1996 and 1997) averaged 26,188 and 2605 fish $\cdot$ ha^{-1} compared to 2394 and 1840 fish $\cdot$ ha^{-1} for Lake Mead.

Biomass generally decreased with distance downstream (Figs. 3, 4). Biomass levels <10 $kg \cdot ha^{-1}$ were found at 53% ($n = 108$) and 72% ($n = 87$) of Lake Powell's and Lake Mead's monitoring stations, respectively. There were some exceptions; 1 occurred when biomass (>20 $kg \cdot ha^{-1}$) extended throughout Lake Powell during August 1996 (Table 1, Fig. 3), at which time biomass averaged 197 $kg \cdot ha^{-1}$ compared to 28 $kg \cdot ha^{-1}$ measured in Lake Mead. Another exception occurred during the November surveys when it appeared that shallow-inflow communities moved down-reservoir to deeper habitats for winter (Table 1).

Total reservoir biomass for Lake Powell ranged from 453,097 kg (May 1996) to 10,852,738 kg (August 1996). Seasonal trends were similar for Lake Mead, while biomass was less, ranging from 296,736 kg to 1,926,697 kg for the same period. We also noted annual declines between August 1996 and 1997 when estimated average fish densities dropped from 26,188 to 2605 fish $\cdot$ ha^{-1} in Lake Powell and from 2394 to 1840 fish $\cdot$ ha^{-1} in Lake Mead. This represented a decline from 276 million to 90 million fish in Lake Powell and from 108 million to 66 million fish in Lake Mead.

The analysis had a high degree of variance caused by sparsely populated areas where fish detections were rare. These detections, if made, generally occurred in large schools, and as a result, CLs of 90% were used. This problem is intrinsic to schooling fish found in large bodies of water and is most evident in daytime surveys (Argyle 1992). However, sample variance for more densely populated areas ranged from 20% to 30%, similar to levels reported for

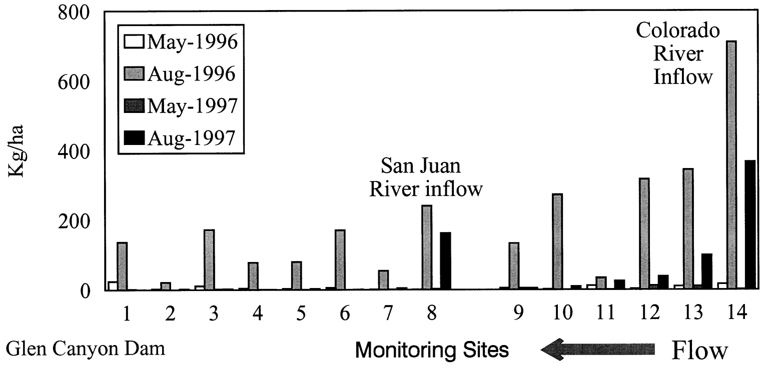

Fig. 3. Average biomass (kg · ha^{-1}) distribution in Lake Powell during May and August 1996 and 1997.

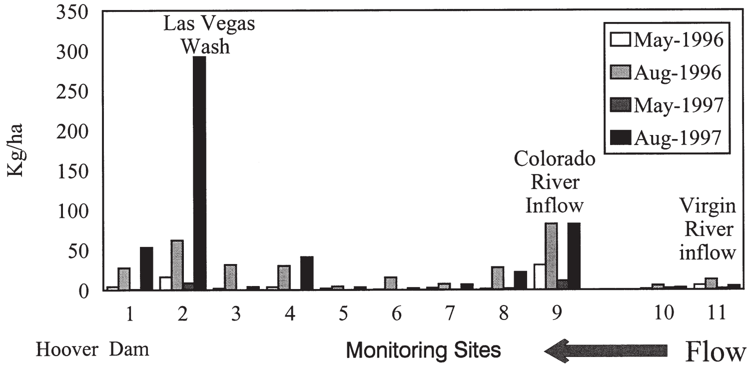

Fig. 4. Average biomass (kg · ha^{-1}) distribution in Lake Mead during May and August 1996 and 1997.

other acoustical studies (Hansson 1993, Vondracek and Degan 1995).

DISCUSSION

Portions of Lakes Powell and Mead support impressive threadfin shad and striped bass populations that can rival those found in more productive southern reservoirs (Degan and Wilson 1995). However, vast portions of pelagic habitat contain few or no fish. Having a simple prey base, this type of fishery suffers from boom and bust cycles (Axon and Whitehurst 1985, Persons and Dreyer 1987). Primary production is another factor limiting fish biomass and distribution (Paulson and Baker 1984, Persons and Dreyer 1987, LaBounty and Horn 1997).

Lake Powell's biomass exceeded 350 kg · ha^{-1} at the Colorado River inflow but dropped to <10 kg · ha^{-1} (53%, n = 57/108) for downreservoir monitoring sites. Lake Mead's biomass was typically lower, but its distribution was similar with the exception of Las Vegas Wash, the source of treated sewage effluent from Las Vegas Valley. Seventy-one percent of Lake Mead's monitoring sites (n = 62/87) had biomass levels <10 kg · ha^{-1} while nearly half of those (n = 28/87) had <1 kg · ha^{-1}.

Limnological studies reported primary production (chlorophyll-a) at these same sites to be <2 µg · L^{-1}, which is inadequate to support planktonic feeders such as threadfin shad (Paulson and Baker 1984, Labounty and Horn 1997). State agencies have experimented with nutrient-enrichment programs ranging from small cove experiments to an application of 114,000 L ammonium phosphate to 12,000 ha of Lake Mead (Morgensen and Padilla 1982, Axler and Paulson 1987). Fertilization increased productivity but benefits were short-lived and deemed economically nonviable. State agencies have since liberalized creel limits on striped bass to reduce the frequency and severity of emaciated fish or fish die-offs.

Nutrient loading from the Colorado River into Lake Mead has declined since Glen Canyon Dam was constructed in 1964 (Paulson and Baker 1984, Persons and Dreyer 1987). Our data suggest that by late summer Lake Powell can support nearly 6 times the biomass of Lake Mead; however, actual carrying capacity during early spring appears lower and possibly less variable. Lake Mead's biomass during May was 65% (296,736 kg vs. 453,097 kg) and 62% (101,016 kg vs. 162,262 kg) of Lake Powell levels. These pelagic fish communities appear highly vulnerable to shifts in nutrient loading and predator-prey interactions.

Hydroacoustics provides the only practical method of measuring fish biomass in large reservoirs. However, in sparsely populated environments measurements of schooling species can be highly variable. We recommend that future efforts consider conducting all surveys at night and increasing the number of transects where fish distribution is suspected to be patchy (Argyle 1992, Degan and Wilson 1995).

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LITERATURE CITED

ARGYLE, R.L. 1992. Acoustics as a tool for the assessment of Great Lakes forage fishes. Fisheries Research 14: 179–196.

AXLER, R.P., AND L.J. PAULSON. 1987. Preliminary nutrient enhancement studies in Lake Mead. Technical Report 19, Lake Mead Limnological Research Center, University of Nevada, Las Vegas.

AXON, J.R., AND D.K. WHITEHURST. 1985. Striped bass management with emphasis on management problems. Transactions of the American Fisheries Society 114:8–11.

BOXRUCKER, J., P. MICHALETZ, M.J. VAN DEN AVYLE, AND B. VONDRACEK. 1995. Overview of gear evaluation study for sampling gizzard shad and threadfin shad populations in reservoirs. North American Journal of Fisheries Management 15:885–890.

DEGAN, D.J., AND W. WILSON. 1995. Comparison of four hydroacoustic frequencies for sampling pelagic fish populations in Lake Texoma. North American Journal of Fishery Management 15:924–932.

GUSTAVESON, A.W., G.L. BLOOMER, L. BERG, AND D. ARCHER. 1998. Summary of sport fisheries harvest, pressure and success, 1964 to 1997, measured by creel survey at Lake Powell, UT/AZ. Publication 98-15, Utah Division of Wildlife Resources, Salt Lake City. 22 pp.

HANSSON, S. 1993. Variation in hydroacoustic abundance of pelagic fish. Fisheries Research 16:203–222.

LABOUNTY, J.F., AND M.J. HORN. 1997. Influence of drainage from the Las Vegas Valley on the limnology of Boulder Basin, Lake Mead, Arizona-Nevada. Lake and Reservoir Management 13:95–108.

LUECKE, C., AND W.A. WURTSBAUGH. 1993. Effects of moonlight and daylight on hydroacoustic estimates of pelagic fish abundance. Transactions of the American Fisheries Society 122:112–120.

MORGENSEN, S.A., AND C.O. PADILLA. 1982. The status of the black bass fishery in Lake Mead and a program toward restoration and enhancement. Submitted to U.S. Bureau of Reclamation, Boulder City, NV, Contract 7-07-30-X0028. Arizona Game and Fish Department, Phoenix.

PAULSON, L.J., AND J.R. BAKER. 1984. The limnology in reservoirs on the Colorado River. University of Nevada–Las Vegas. Submitted to U.S. Bureau of Reclamation, Contract 14-34-0001-1243, Boulder City, NV. Lake Mead Limnological Research Center, UNLV, Las Vegas.

PERSONS, W.R., AND R. DREYER. 1987. Relationship between striped bass (*Morone saxatilis*) and threadfin shad (*Dorosoma petenense*) in Lake Mead. Dingell-Johnson Project F-14-R-20, Arizona Game and Fish Department, Phoenix.

VONDRACEK, B., AND D.J. DEGAN. 1995. Among- and within-transect variability in estimates of shad abundance made with hydroacoustics. North American Journal of Fisheries Management 15:933–939.

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