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Temporal and spatial variation in pelagic fish abundance in Lake Mead determined from echograms

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TEMPORAL AND SPATIAL VARIATION IN PELAGIC FISH ABUNDANCE IN LAKE MEAD DETERMINED FROM ECHOGRAMS [1]

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We scored echograms on a scale of 1 to 5 and used these scores as relative estimates of pelagic fish abundance in Lake Mead, Arizona-Nevada. Spatial and temporal patterns in fish abundance and the association between fish abundance and chlorophyll *a* concentration were tested with nonparametric statistical methods. We found no difference in fish abundance between years of our study ($p = 0.5017$), but there was significant seasonal ($p = 0.0068$) and spatial ($p < 0.0001$) heterogeneity in abundance. Fish abundance was positively correlated with chlorophyll *a* concentration ($r_s = 0.533$, $p < 0.0001$).

INTRODUCTION

Echograms have been used extensively to locate and estimate the relative abundance of marine fish stocks (Cushing 1973). In freshwater, echograms have been used to describe vertical (Netsch et al. 1971; Eggers 1978; O'Brien et al. 1984; Matthews et al. 1985), spatial (O'Brien et al. 1984; Wanjala et al. 1986) and temporal (Baker and Paulson 1983) patterns in fish abundance. Although most uses of echograms have been qualitative, Mullan and Applegate (1969) and Matthews et al. (1985) obtained relative estimates of fish abundance by counting targets (fish) on echograms. However, neither Mullan and Applegate (1969) nor Matthews et al. (1985) presented any statistical analysis of estimates obtained from echograms. Our purposes in this paper are to: 1) describe a procedure we have used for the scoring and statistical analysis of echograms as relative estimates of pelagic fish abundance; and 2) describe temporal and spatial variation in pelagic fish abundance in Lake Mead.

METHODS

As part of a limnological survey of Lake Mead, a large mainstem impoundment of the Colorado River, Arizona-Nevada, we conducted monthly echosounding surveys from March 1981 through December 1982. On each sampling date we echosounded transects, approximately 1km in length, with a Furuno Model FM 22-A recording echosounder. The echosounder has a beam angle of 28° and an operating frequency of 50 KHz; maximum and effective paper widths are 150 and 130 mm, respectively, and paper feeds at a rate of 10 mm/ min. We operated the echosounder with the depth range set at 100 or 50 m and gain (sensitivity) generally set at 4 (on a scale of 0 to 10). Transects were run

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between 0800 and 1300 hrs at a speed of 8 km/ h in the immediate vicinity of each of 13 sampling stations (Figure 1).

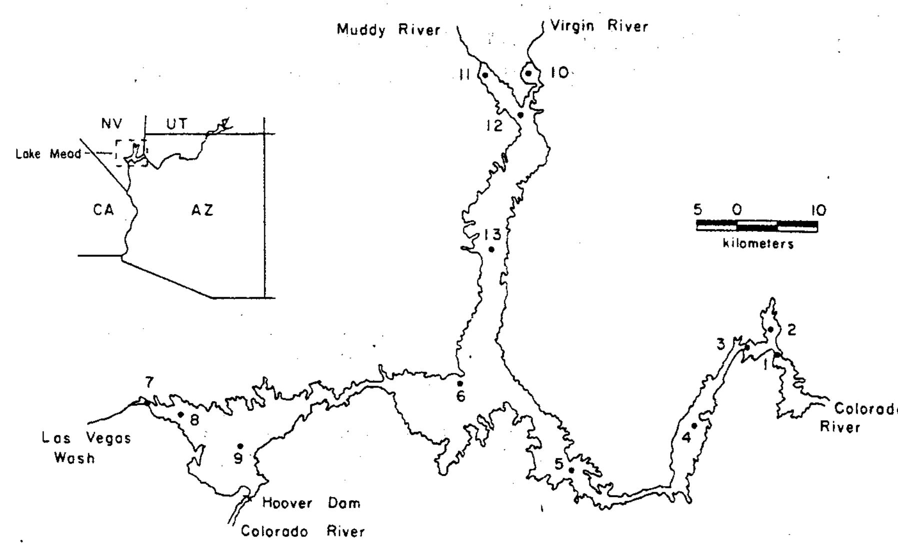

FIGURE 1. Lake Mead, Arizona-Nevada, with echosounding stations indicated by solid circles.

After all field work was completed, we assembled and ranked, 1 through 5, a reference set of echograms (Figure 2) that encompassed the range in target number and density observed in our sample echograms. Each sample echogram was compared with the reference series and scored 1 to 5. Changes in depth range affect the apparent number and density of targets in echograms; therefore, we also referred to a series of echograms in which depth range was alternately set at 50 and 100 m. To ensure consistency, all sample echograms were evaluated and scored in a single session by one person (GRW).

We used these scores as estimates of the relative abundance of pelagic fish in Lake Mead. To test differences in fish abundance between years we used a Mann-Whitney U-test; differences in fish abundance between seasons (winter= December through February; spring= March through May; summer= June through September; fall= October and November) and between sampling stations were tested with a Kruskal-Wallis one-way analysis of variance. We used Spearmans rank correlation (r_s) to test the association between fish abundance and chlorophyll *a* concentration; chlorophyll *a* data were obtained from Paulson and Baker (1983).

RESULTS AND DISCUSSION

Only in exceptional situations (e.g., Wanjala et al. 1986) is it possible to identify individual species in echograms. However, electrofishing, fish trapping and midwater trawls (Deacon et al. 1972; Paulson and Espinosa 1975; Allan and Roden 1978) have shown that pelagic fish populations in Lake Mead are almost exclusively composed of threadfin shad, *Dorosoma petenense*. Also, a concurrent series of meter-net tows and echogram transects made at seven locations in Lake Mead on 21 June 1987 showed that estimates of pelagic fish abundance obtained from echograms were highly correlated (r_s = 0.847, p= 0.0162) with meter-net catches composed entirely of threadfin shad. Estimates of fish abundance derived from echograms appear to be specific for threadfin shad in Lake Mead; however, we refer to these as estimates of total pelagic-fish abundance because large fish (e.g., striped bass, *Morone saxatilis*, and carp, *Cyprinus carpio*) frequently occur in our echograms.

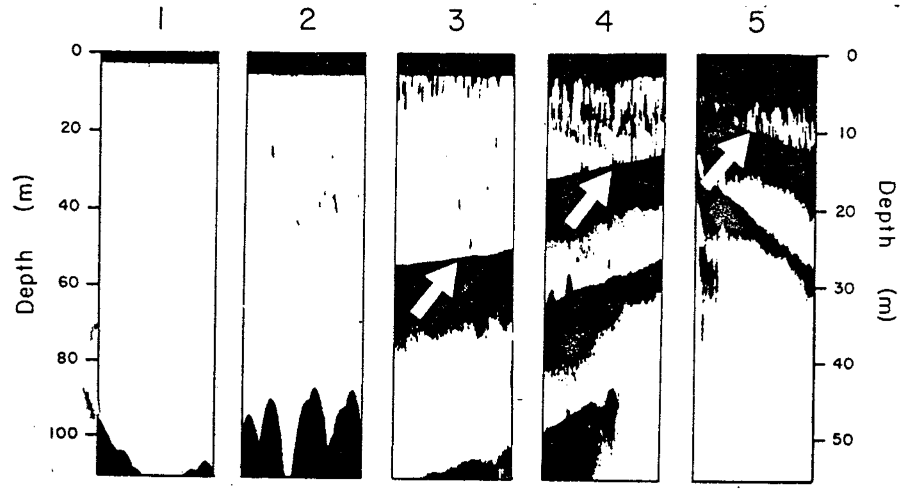

FIGURE 2. Reference series of echograms. Numbers indicate relative abundance of pelagic fish: 1- no targets (fish) present; 2- few; 3- several; 4- abundant; 5- dense, over-lapping targets. Arrows indicate lake bottom. Echograms 1–4 are from a transect made between stations 7 and 9 on 6 August 1982; echogram 5 was made at station 9 on 13 July 1982. Depth-range setting was 0–100 m for echogram 1 and 0–50 m for echograms 2–5.

Pelagic fish abundance exhibited considerable temporal and spatial variation in Lake Mead during 1981 and 1982 (Table 1). There was no difference in abundance between years (p= 0.5017) so data were pooled. Seasonal variation in fish abundance was highly significant (p= 0.0068). Fish abundance was greatest in the summer, following the threadfin shad spawn in May–June; abundance declined during fall and winter, but there was no change from winter to spring. Seasonal abundance of threadfin shad in Lake Mead shows a similar pattern based upon electrofishing results (Deacon et al. 1972) and occurrence in stomachs of striped bass (Wilde and Paulson 1989).

There was a highly significant spatial variation in fish abundance (p < 0.0001) that was not attributable to variation in water temperature, dissolved oxygen concentration, pH and conductivity (Wilde 1984). Fish abundance was greatest near the inflows of the Colorado (Stations 1–3), Virgin (Station 10) and Muddy (Station 11) rivers and the Las Vegas Wash (Station 7) and decreased downstream from these inflows. Chlorophyll *a* concentration, a measure of phytoplankton abundance, exhibited a similar distribution (Wilde 1984) and was positively correlated with fish abundance (r_s = 0.533, p < 0.0001). This correlation is based upon 256 station-date observations and is a measure of both the seasonal and spatial association between chlorophyll *a* and fish abundance.

Table 1. Relative Abundance of Pelagic Fish in Lake Mead, 1981–1982, determined from Echograms. Station Numbers are as in Figure 1.

Date	Station 1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
March 19–21, 1981	2	3	2	1	1	1	3	2	1	5	2	2	NS'	2.1
April 14–16	4	2	3	3	1	1	4	3	1	5	3	3	1	2.6
May 13–15	3	2	3	1	1	1	3	2	1	1	1	1	1	1.6
June 22–24	2	3	4	2	2	1	3	3	1	4	2	2	1	2.3
July 21–23	2	2	2	1	1	1	4	3	1	3	3	2	1	2.0
August 18–20	3	3	3	1	1	1	3	2	1	2	2	1	1	1.8
September 15–17	2	2	2	1	1	1	2	2	1	2	2	1	1	1.5
October 19–21	2	2	2	1	1	1	3	2	1	2	2	1	1	1.6
November 23–27	2	1	1	1	1	1	2	1	1	2	2	2	1	1.4
December	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
January 18–22, 1982	2	2	2	1	1	1	4	2	1	2	2	2	2	1.8
February 17–19	2	2	2	1	1	2	2	1	1	2	2	1	1	1.5
March 23–25	2	1	2	1	1	1	2	2	1	2	2	1	1	1.5
April 20–23	3	3	3	2	2	1	3	2	2	3	2	2	1	2.2
May 10–12	2	2	2	1	1	1	2	2	1	2	1	1	1	1.5
June 20–24	2	2	2	2	1	2	4	3	2	4	2	2	1	2.2
July 13–15	3	2	3	1	2	2	5	2	2	4	2	2	1	2.4
August 10–12	3	2	4	1	1	1	5	2	2	3	4	2	2	2.5
September 8–10	2	2	3	2	1	1	3	2	2	2	2	2	1	1.9
October 6–8	2	2	3	1	1	1	4	2	2	3	3	2	1	2.1
November 9–12	2	3	3	1	1	2	3	2	1	2	2	2	1	1.9
December 14–16	2	2	2	1	1	1	4	1	1	2	2	1	1	1.6
Station means	2.3	2.1	2.5	1.3	1.1	1.1	3.2	2.0	1.3	2.7	2.1	1.7	1.1	

' NS = not sampled

Annual means (for each station) for fish abundance and chlorophyll *a* (Figure 3) which reflect only spatial trends were highly correlated ($r_s = 0.850$, $p < 0.0001$). Positive relationships between the spatial distributions of threadfin shad and chlorophyll *a* have been reported by Rinne et al. (1982) and Siler et al. (1986).

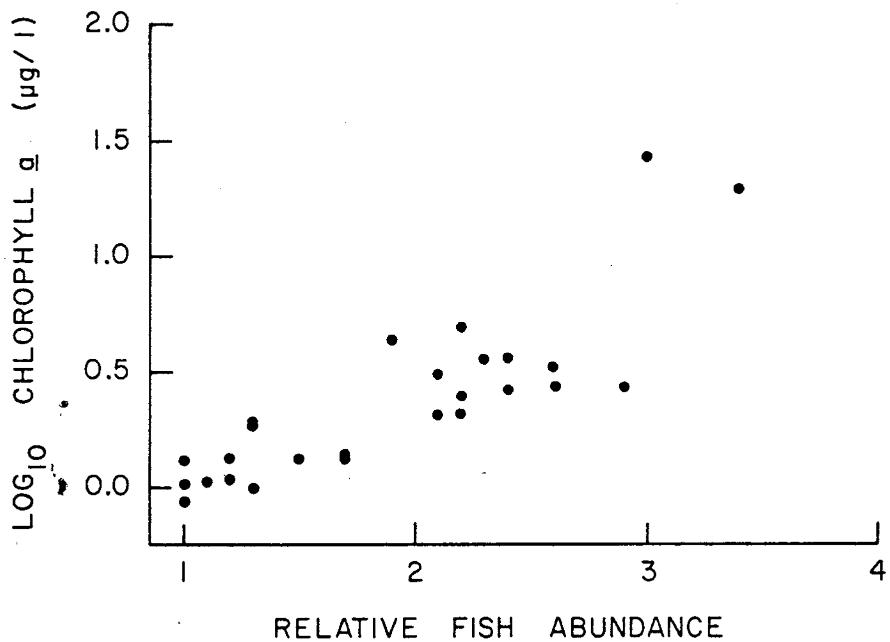

FIGURE 3. Scatterplot of annual means of relative fish abundance and log chlorophyll *a* concentration ($r_s = 0.850$; $p < 0.0001$; $N = 26$). Note, r_s is unaffected by log transformation of chlorophyll *a*.

Mullan and Applegate (1969) suggested that echograms could provide information on temporal, vertical and spatial patterns in fish abundance. Estimates of fish abundance derived from echograms are relative; however, these estimates meet the requirements and assumptions of many commonly used nonparametric methods and can be used to test hypotheses concerning trends in fish abundance. Our scoring scheme is only one of many possible; for example, fewer or more than five ranks could be used. Counts of individual targets or output from an optical digitizer could also be analyzed as relative estimates of fish abundance.

Echosounding requires a minimal investment of manpower and money compared with conventional sampling techniques (gill netting, electrofishing, etc.). More advanced hydroacoustic systems that supply quantitative estimates of fish abundance also require a small investment of manpower; however, such systems are expensive. Thorne (1983) estimated that the minimum cost for a hydroacoustic system with signal integration that produces data of scientific quality was $50,000; recording echosounders can be obtained for as little as 1 to 2% of that amount.

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