Reprinted from

THE JOURNAL of the Acoustical Society of America

VOL. 52, NO. 4 (Part 2) OCTOBER 1972

Bob, Hope to get together with you at Salton Sea this spring

Jim Fish

A 50-dB Increase in Sustained Ambient Noise from Fish (*Cynoscion xanthulus*)

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pp. 1266–1270

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A 50-dB Increase in Sustained Ambient Noise from Fish (*Cynoscion xanthulus*)

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(Received 6 April 1972)

Ambient noise was measured once a month in the Salton Sea, California, from January to August 1970 with a calibrated recording system. The nighttime spectrum level at 1000 Hz increased nearly 50 dB from January to May. The change in level resulted entirely from a chorus of sounds produced by a single species of fish—the orangemouth corvina, *Cynoscion xanthulus*. The seasonal peak of sound production coincided with their breeding season. This increase in ambient noise level is the greatest sustained effect ever reported from underwater natural causes.

Subject Classification: 16.6.

Although prehistoric man probably knew that some marine animals made sounds, and actual descriptions of fish sounds were reported by Aristotle as early as 350 B.C. (cited by Moulton),[1] it was not until the early 1940's that biological sound in the ocean became important to man. With the development of underwater sound detection devices came an almost immediate awareness that the ocean was not quiet, but rather noisy, especially in the shallow water areas.

Data on the contribution of biological organisms to the ambient noise of certain coastal regions were first presented in a series of U. S. government reports issued from 1942 to 1946.[2–15] Some of this information was published later in scientific journals.[16–21] In summary, these investigations revealed that various organisms increased the ambient noise spectrum level at certain frequencies by as much as 30 dB. The most important contributors to the noise were snapping shrimp, family Alpheidae, and fishes of the croaker family Sciaenidae. On rare occasions, very large concentrations of the tiny shrimp around pilings increased the ambient spectrum level nearly 40 dB in the 10–20-kHz range.[20] Most energy of the croaker sounds was much lower in frequency than the shrimp sounds, generally below 1500 Hz, and sound production occurred principally during the summer breeding season, after sunset.

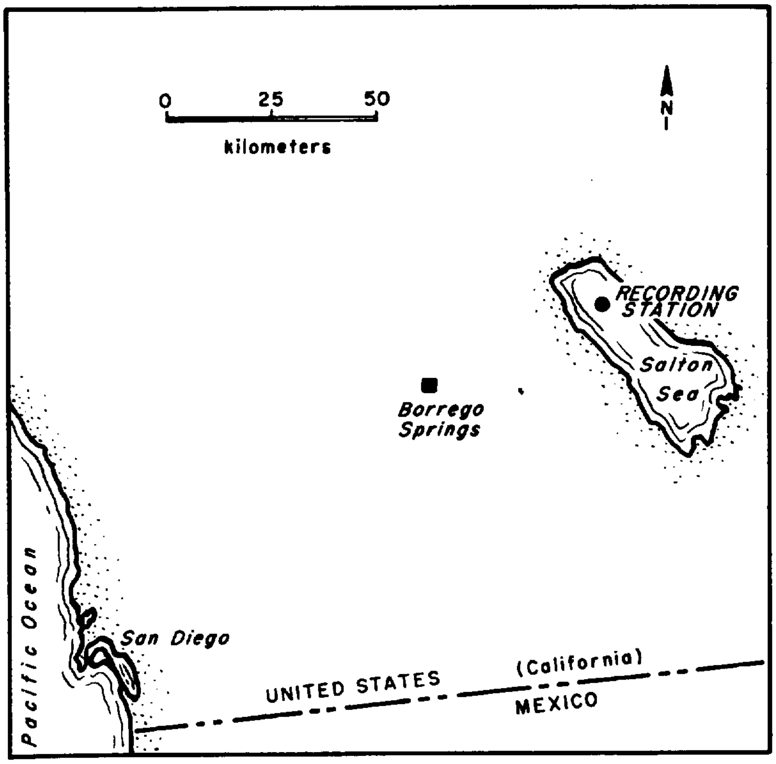

FIG. 1. Geographic location of the Salton Sea, Calif., with the station indicated where monthly ambient noise recordings were made.

Similar diurnal increases in ambient noise, of 10–25 dB, have been measured from unidentified biological sources.[22–26] Near the Great Barrier Island, New Zealand, a 25–30-dB increase in spectrum level in the 1200–1600-Hz range was thought to be caused by sounds from sea urchins, *Evechinus chloroticus*.[27] A 40-dB increase in the ambient noise level of Narragansett Bay from winter to early summer was due primarily to the toadfish, *Opsanus tau*.[28] However, other marine animals in the Bay also increase their acoustic activity in the summer, and boat noise increases, making it difficult to isolate and measure the contribution of toadfish.

Described in this paper is a 50-dB increase in sustained ambient noise from the sounds of a single marine species landlocked in an inland salt-water lake. This impoundment offered a unique opportunity for such a study. Generally, in the shallow ocean there are several soniferous species present at one time. Also, the nonbiological contribution to ambient noise is frequently quite high and variable. Under these circumstances, it is impossible to determine how much the ambient noise level is affected by a particular species.

The Salton Sea, located in the desert of southern California (Fig. 1), was formed in 1905–1907 by flood waters from the Colorado River.[29] It is ~57 km long by 14–24 km wide, making it the largest inland body of water in California. The maximum depth is near 14 m. Waste water from agricultural irrigation, high in salts, has fed the sea over the years. During the period 1950–1956, the salinity varied from 33 to 39 parts per thousand and a variety of marine fishes were transplanted from the Gulf of California with the intent of forming a sport fishery. However, only three of these species thrived and now exist in significant numbers—the orangemouth corvina, *Cynoscion xanthulus*; the gulf croaker, *Bairdiella icistius*; and the sargo, *Anisotremus davidsoni*.[29,30] The latter two are small fish, but the corvina can attain a weight of 14 kg.

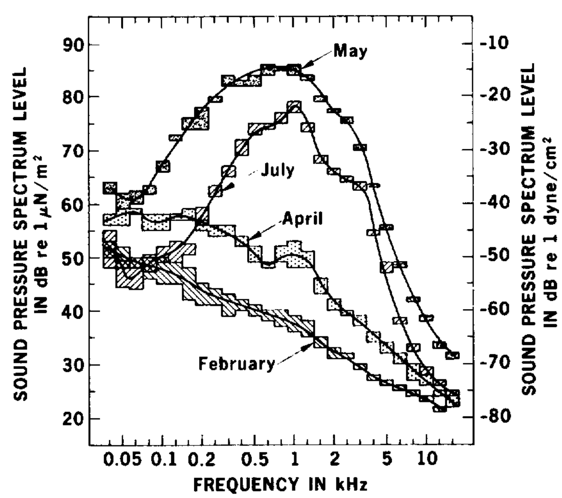

FIG. 2. Sound-pressure spectrum levels (⅓-oct SPLs reduced to bands 1 Hz wide) measured at the Salton Sea from Feb. to July, 1970. Variation in level over 128 sec is indicated by the width of the curves (see "methods" for explanation).

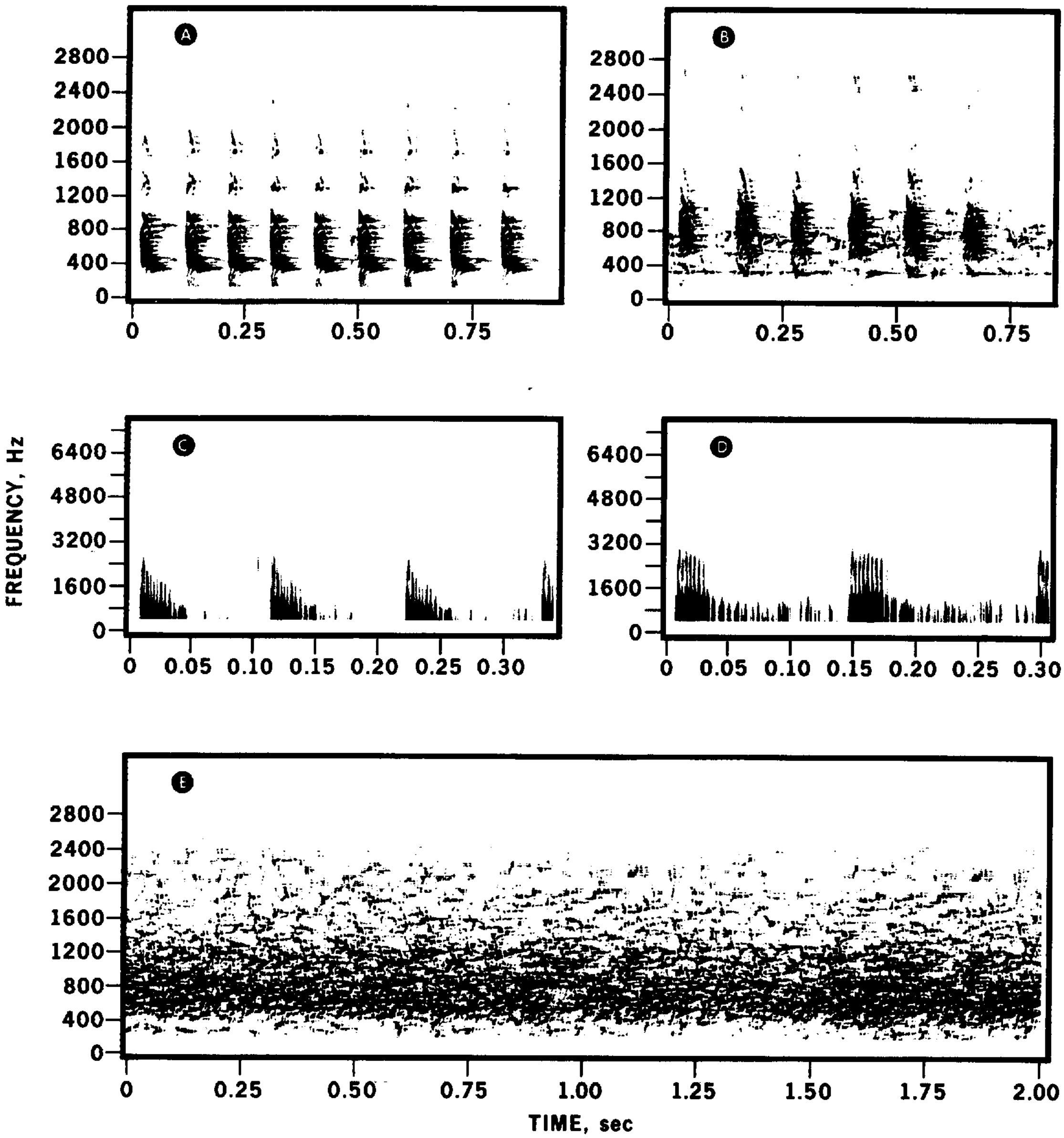

FIG. 3. Spectrograms of sounds produced by corvina, *Cynoscion xanthulus*. (A) Sound composed of nine "knocks" recorded from a fish close to the hydrophone at the Salton Sea; effective analyzing filter bandwidth—24 Hz. (B) Sound composed of six "knocks" from a corvina in a tank; effective analyzing filter bandwidth—24 Hz. (C) Wide-band analysis of three "knocks" from field recording (A) above; effective analyzing filter bandwidth—800 Hz. (D) Wide-band analysis of two "knocks" from tank recording (B) above; effective analyzing filter bandwidth—800 Hz. (E) chorus of corvina sounds recorded at the Salton Sea; effective analyzing filter bandwidth —24 Hz.

Presently, the corvina population is estimated at 1–3 million.[31] Preliminary recordings made throughout the Sea, and in the presence of the three different species, showed that the corvina was the only species producing sound in the deeper offshore areas. Also, in contrast to the ocean, there are no noisy invertebrates in the Salton Sea. Hence, the corvina "chorus" could be measured easily, without interference from other sonic organisms.

I. METHODS

Ambient noise was measured near the center of the deepest basin in the northern part of the Sea, 8 km offshore (Fig. 1), at least once a month from January to August, 1970. Only data taken from 2100 to 0100 h are considered here since the corvina did not make sound until evening. On the days selected for recording, the wind velocity was near zero after 2100 h and the Sea was glassy smooth. There were no detectable nonbiological sounds, such as boat noise, on any of the recordings analyzed for spectral content.

A calibrated recording system, similar to that described by Calderon and Wenz,[32] was used for all recording. It consisted of a bottom resting hydrophone (Wilcoxon M-H90-A), a sound system calibrator[33] for inserting calibration signals of known level through the entire recording system and onto magnetic tape, a sound and vibration analyzer (General Radio, Type 1564-A), and a magnetic tape recorder (Uher Model 4200). The frequency response of the system was ±3 dB from 40 Hz to 16 kHz. Sound pressures were measured in $\frac{1}{3}$-oct bands, in the field, with the sound and vibration analyzer. These data were later converted to spectrum levels and used as a check on the calibrated tapes analyzed in the laboratory.

Spectral analysis was performed in the laboratory with a real-time analyzer (General Radio Type 1921) consisting of: a $\frac{1}{3}$-oct multifilter (Type 1925), a multichannel rms detector (Type 1926), and a storage display unit (Type 1921-P1). The "pink" noise calibration, supplied by the sound system calibrator and recorded on tape at the start of each field recording session, was played back through the analyzer before the data. While the curve of this "pink" random noise (spectrum level slope of −3 dB/oct) was appearing on the screen of the storage display unit, the dials on the multifilter were adjusted for each $\frac{1}{3}$-oct band from 40 Hz to 16 kHz to correct for deviations from "flatness" in the recording system response. The noise data were then analyzed and converted from $\frac{1}{3}$-oct levels to spectrum levels.

Four 32-sec sections of tape were selected from each 30-min, monthly tape recording and played through the analyzer which was set to integrate sequentially 8-sec sections of data and display a complete curve from 40 Hz to 16 kHz at the end of each integration. Consequently, for each 128-sec sample, 16 overlapping curves were displayed on the screen of the storage display unit, representing the sixteen 8-sec integrations. The width of this cumulative curve, in each $\frac{1}{3}$-oct band, represented the variation in level for the 128-sec composite sample. The analysis was restricted to those sections of the tape where individual fish could not be heard above the background chorus.

Sounds of individual corvina close to the hydrophone in the field and sounds of those in laboratory test tanks were analyzed with a Kay Electric Company vibralyzer.

II. RESULTS

From January through mid-March, 1970, recordings from the Salton Sea were extremely quiet. No biological sounds were observed until the end of March. The low spectrum levels for February, representative of this three-month period, are shown in Fig. 2. By early April, numerous fish sounds were heard, but the sustained chorus had not yet reached its peak. At 1 kHz, the spectrum level increased almost 15 dB over the January–March level (Fig. 2). By May, the noise increased to a loud roar and remained that way through mid-June. The spectrum level at 1 kHz was nearly 50 dB higher in May than during the winter season, with most of the energy in a band from 400 to 1200 Hz. The chorus gradually declined from late June through July, and by August (the last month the Sea was monitored) the levels were reduced to those noted in February with only an occasional fish sound recorded at the offshore station. A survey of the Sea in August showed that the corvina had moved inshore and were distributed over a wide area. In these regions, some sounds were recorded from individual fish, but a loud chorus was not apparent.

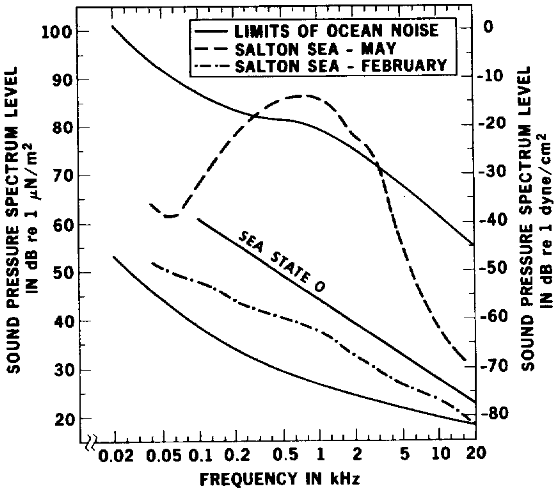

FIG. 4. Sound-pressure spectrum levels ($\frac{1}{3}$-oct SPLs reduced to bands 1 Hz wide) for the Salton Sea in Feb. and May 1970 are compared with Wenz's empirical limits for ocean noise[34] and Knudsen's Sea State 0 curve.[20]

Sound production of the orangemouth corvina appeared to be associated with breeding, as the sounds were emitted only during the reproductive season.

The orangemouth corvina, *Cynoscion xanthulus*, was identified as the species responsible for the chorus by catching these fish in areas where the sounds occurred and transporting them to a laboratory tank where their sounds were recorded. The tank recordings differed slightly from the field recordings presumably because of the acoustic properties of the small (2 m wide by 1 m deep) metal tank. Figure 3(A) shows a corvina sound, composed of nine "knocks," recorded at the Salton Sea, and Fig. 3(B) illustrates a sound with six "knocks," recorded in the tank. The number of "knocks" in a sound varied from four to 13 with seven or eight being most common. The repetition rate varied from six to 12 "knocks"/sec. Each "knock" was composed of eight to ten short pulses with a repetition rate of about 240/sec [Figs. 3(C) and 3(D)]. The chorus at the Salton Sea is shown in Fig. 3(E).

III. DISCUSSION

In Fig. 4, the spectrum level curves for February and May at the Salton Sea are presented along with the empirical upper and lower limits of ambient noise shown by Wenz[34] and the "Knudsen curve" for Sea State 0.[20] During the winter, ambient noise levels of the Salton Sea were 5–10 dB below the Sea State 0 condition over most of the measuring band. It would be most unusual to encounter such a quiet condition in the ocean. When the sound production of Salton Sea corvina reached a peak in May, the ambient-noise spectrum level exceeded Wenz's empirical upper limit by about 5 dB in the region from 500 to 1500 Hz. Thus, not only was the Salton Sea exceptionally quiet during the winter, it was extremely noisy during the spring. The resulting seasonal change of nearly 50 dB is believed to be the greatest sustained increase in underwater ambient noise level yet reported for any natural cause in either fresh or salt water.

ACKNOWLEDGMENTS

The authors would like to thank Dr. I. Haydock for his invaluable help with the field work; D. Crear and J. A. Hoke for their field assistance; P. O. Thompson, J. C. Brown, and M. A. Calderon for analyzing much of the data; and R. S. Gales, Dr. R. W. Young, and F. G. Wood for their interest in the study and their comments. The research was supported by independent Research funding of the Naval Undersea Center during J. Fish's appointment as a NRC–NUC Postdoctoral Research Associate.

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