NOISE PRODUCTION BY MARINE LIFE

N. V. NĀRAYANA PILLAI

(Indian Naval Physical Laboratory, Cochin)

A B S T R A C T

IT HAS been known for more than 2000 years that various kinds of fishes are capable of producing sound. Aristotle, Pliny, Pherecrates and the Greek Authology all contain reference to the sounds of fishes. The matter of fish sound production received relatively little attention until the time of Second World War. It was found that in the working of instruments such as ASDIC and SONAR the results were often vitiated by interference due to noise made by submarine life. In order to distinguish the submarine sound from noises made by marine organisms a great deal of work has been done and is still in progress in the United States, United Kingdom and Japan. In India so far no work has been attempted along these lines.

I N T R O D U C T I O N

IT IS generally believed that in the subsurface ocean there exists an all pervading lull which is undisturbed by the rush of winds or the roar of waves. Experiments, however, have shown that this is far from the fact and these vast depths of the oceans are full of sounds of varied character. The predominant constituent of this underwater noise is now known to be produced by a variety of animals. Although this fact appears to have been known even at the time of Aristotle, the subject did not receive much attention till the early thirties of this century. It was realised only during the second world war that underwater noises made by marine animals interfered with the operation of listening devices used for the detection of enemy crafts. Subsurface listeners, reported undefinable contacts running the entire gamut, with various types of noises such as "mild beeping, clicking, whistling, grunting, hammering, moaning, mewing, dragging of heavy chains, of coal rolling down a metal chute, fat frying in a pan, simulated propeller noises and the pings of echo ranging". Intensive study was since then carried out chiefly in U.K., U.S.A. and Japan on the analysis of under-water noise made by marine animals with a view to identifying particular sounds with the species that produced them resulting in the accumulation of considerable literature on this subject as well as interesting phonographic records. The present paper reviews the work done on the sound produced by marine life and the mechanism of noise production.

NOISE MAKERS AND NOISE MAKING MECHANISM

Marine animals which are responsible for sound production in the sea may be classified into three groups viz., *Crustacea* (Shrimps, Crabs and Lobsters), *Fishes* and *Cetacea* (whales and porpoises). A list of these noise makers is given in Table I which also provides a summary of the noise characteristics and the noise producing mechanism.

I. Crustacea

(*i*) *Snapping Shrimps.*—Among crustaceans the most important and most widely distributed noise producers are the Snapping shrimp of the genera *Crangon* and *Synalpheus*[1]. They are found mainly in tropical and subtropical waters, less than 55 m deep where the bottom is composed of rock, coral or other sheltering material and where the

water temperature is more than 11°C for the greater part of the year. Knudsen, Alford and Emling[2] conducted a survey of underwater ambient noise due to marine life in the Bahamas and along the eastern coast of U.S.A. from Florida to Cape Charles with particular reference to geographical distribution, diurnal variation, variation with water depth, type of bottom and distance from the shore. Their work has shown that the northern limit of the occurrence of large concentrations of shrimp at inshore stations along the U.S. Atlantic Coast is marked by the 26° and 27°N. latitude. Shrimp may however, be found in the northern latitudes in off shore areas at the edge of the Gulf stream where water temperatures, depth and bottom conditions offer a favourable habitat. It was also found that within the range of depth at which shrimp commonly occur the maximum concentration is determined not by depth but by local bottom conditions which provide a favourable habitat.

Fig. 1 shows the average ambient noise over a shrimp bed together with the water noise for seastate-1 for comparison. It is seen that while at lower frequencies the latter determines the ambient noise, at higher frequencies especially above 10 Kc/s the shrimp noise is predominant.

The level of the shrimp noise reaches a maximum just before sunrise and after sunset indicating increased activity of the shrimp during these periods (Fig. 2). A study of the frequency analysis of the noise shows that the spectrum extends from 0·1 Kc/s to 25 Kc/s with a broad peak around 4 to 6 Kc/s (Fig. 1).

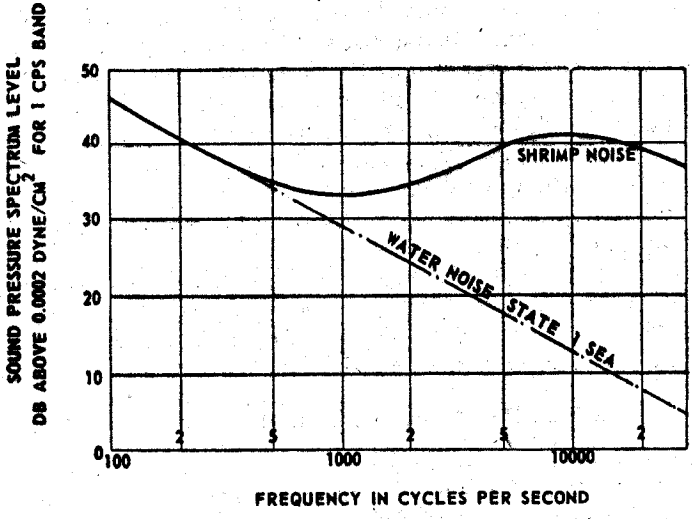

Fig. 1—Average Ambient Noise Spectrum over Shrimp Bed

The snapping shrimp are about $\frac{3}{4}$ to $1\frac{1}{2}$ inches along with an enlarged claw carrying terminal pincers (Fig. 3). In some species this is nearly as large as the body of the animal itself. The movable finger (C) is jointed near the outer end of the palm of the claw forming a pincer like arrangement with the immovable thumb (F). The sound is produced when the movable finger strikes on the opposing tip of the thumb[3]. The tips of these structures are either heavily calcified (*Crangon*) or are tipped with a heavy formation of chitin

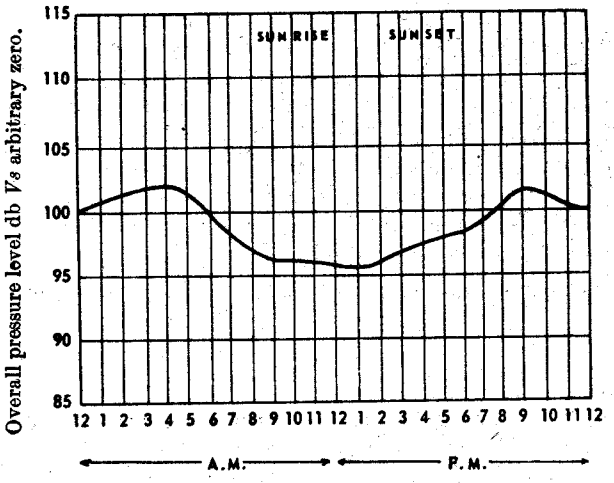

Fig. 2—Diurnal Variation of Ambient Noise from Snapping Shrimp

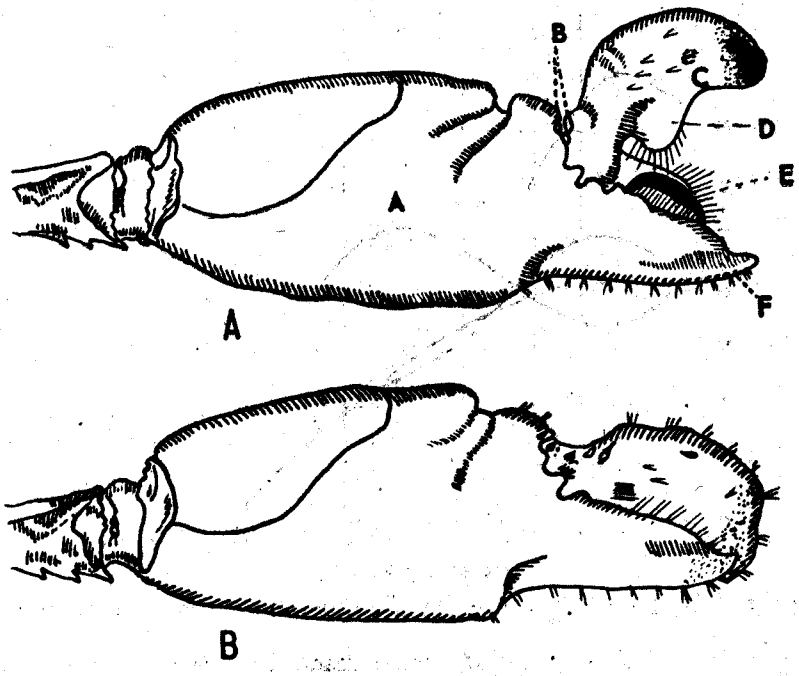

Fig. 3—Crangon Californiensis). Snapping mechanism. A. Snapperopen B. Snapperclosed.
A. PALM. B. SUCKERS. C. MOVABLE FINGER. D. PLUNGER. E. SOCKET. F. THUMB.

(*Synalpheus lockingtoni*)

(*ii*) *Crabs and Lobsters*: According to Moulton[4] the sound production in the Spiny lobster (*Panulirus argus*) is effected by a stridulating mechanism placed at the basal joints of the large antennæ. Noise making in crabs such as *Pseudozius* and *Ocypoda* is effected by rubbing the uropods against the undersurface of the telson[5]. The male fiddler crab (*Gelasimus*), a common inhabitant of sandyshores produces a kind of clapping noise with its large chelipeds during the breeding season. Others like *Cancer* and *Portunus* are known to produce noise only while feeding. No literature is available on the acoustical characteristics of the noise produced by crabs and Lobsters.

It is said that the barnacles (*Balanus* sp.) can also produce occasional clicks of low intensity[6].

II. Fishes

Some species of fish are surprisingly vocal and Fig (4) shows the frequency range of the sound produced by some of these fishes. A convenient way to describe and classify them is by their sound making method[7]. It is believed that the noises are produced either by stridulation, that is, by moving parts of the skeleton against one another or by using the swim bladder. Although the role of swim bladder in sound production is not known with definiteness, the following mechanisms have been suggested.

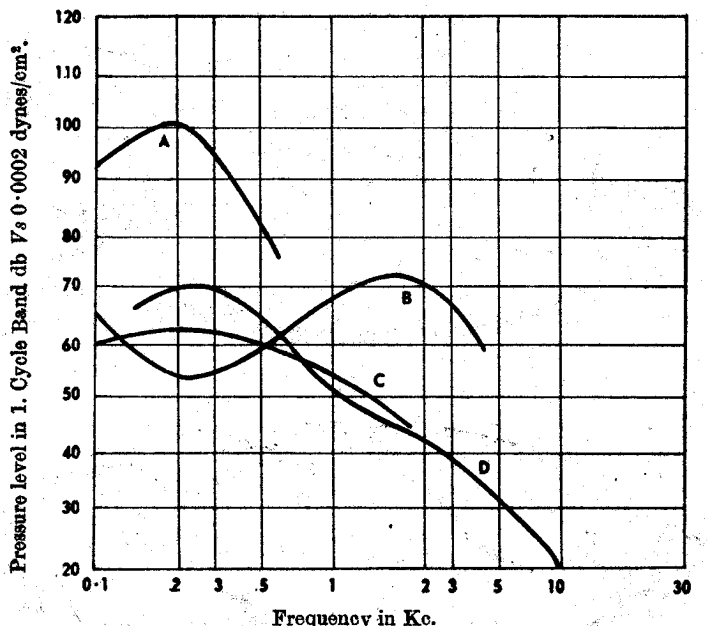

Fig. 4—Ambient Noise Spectum for (A) Toad Fish, (B)—Drum Fish, (C) Sea Robin (D) Croakers

(*i*) As a resonator which amplifies the noises made by adjacent structures (e.g. in *Balistes*, *Hœmulon*).

(*ii*) As an intrinsic sound generator which is set into resonant vibration by the contraction of the muscles in the bladder wall (e.g. as in Gurnards, Toadfish).

Another possible mechanism of noise production is by the expulsion of air from the air bladder through the pneumatic duct.[8] The grunting as well as gurgling noise made by fishes including the 'bark' of the Conger cel may perhaps be due to this cause. The characteristic murmuring sounds made by the *Loaches* (Cobitidæ) are probably due to the rapid expulsion of air bubbles through the anus.

(iii) Croakers (Micropognon undulatus)

Croakers are a variety of drum fish belonging to the family sciænidæ. This species, perhaps the most numerous of the sonic fishes attain; a length of 8—12". The individual fish produces a rapid burst of drumming noise, each pulse lasting about 1—1½ sec. The sound spectrum ranges from 100 to 10,000 c/s with a peak around 200 c/s and rapidly falling off at higher frequencies. Diurnal variation of noise level has been observed with the maximum occurring immediately after sunset. The period of noise production seems to coincide *with the feeding time.* The noise is produced by the contraction of drumming muscles attached to the walls of the swim bladder. The rapid contraction and expansion of the muscle causes the walls of the bladder to vibrate[9] (Fig. 5).

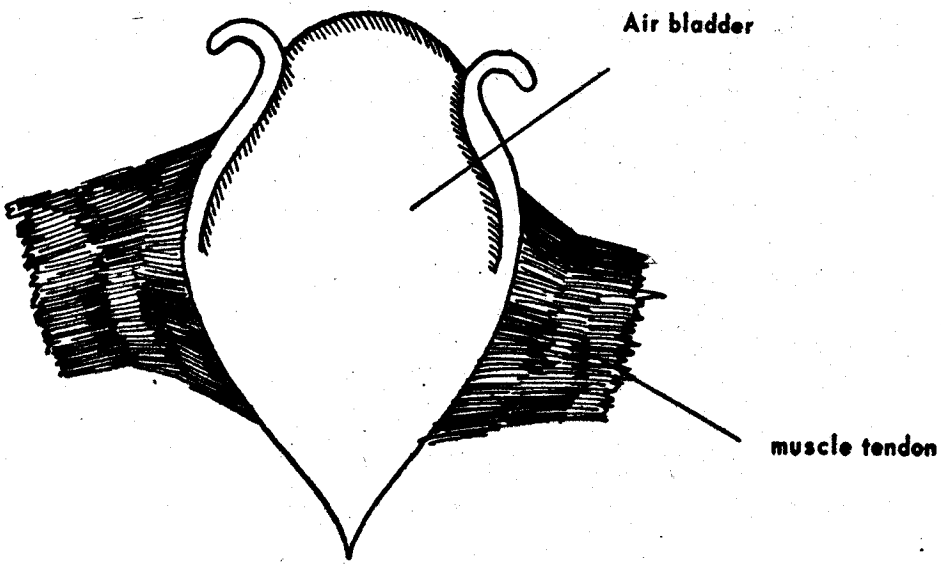

Fig. 5—Air Bladder of a Sciaenid (*Micropognon undulatus*)

(iv) Trigger Fish (Balistes carolinensis)

The trigger fish which belongs to the family *Balistidæ* is also a common inhabitant of coral reefs. The noise spectrum ranges between 50 and 4,800 c/s with the principal frequency at 2,400—4,800 c/s. The noise is believed to be generated by the beating of the rays of the pectoral fin on a taut membrane, a kind of outer window of the air bladder, like drum sticks producing a humming noise[10]. It can also produce a metallic

scratching by the grinding of the *pharyngeal* teeth, the air bladder in this case acting as a resonator.

(*v*) *Sea Horse* (*Hippocampus hudsonius*)

The sea horse belongs to the family Hippocampidæ. It is usually found taking shelter among seaweeds or coral growth. The frequency spectrum of the clicks lie below 4,800 c/s with the principal frequency lying in the region of 400—800 c/s. A study of the behaviour of these fishes has shown that the noises made by both the sexes are frequent and intense during the breeding season. The soundmaking is effected by the stridulation of the posterior margin of the skull and the coronet and the noise thus produced is amplified by the air bladder giving rise to a series of clicking sound.

(*vi*) *Other Species of Sonic Fishes*

The sound producing mechanism in the Indian cat-fish (Callomystax) consists of a most elaborate stridulating organ involving the vertebral column and the dorsal fins. The first interspinous bone of the dorsal fin is scraped between two ridged plates representing the fourth and fifth vertebræ producing harsh grating noises. Some of the sonic catfishes (Siluroidea) possess an apparatus known as the *elastics spring mechanism* which causes the vibration of the air bladder. The expanded end of the 'springs' (modified portions of the 4th vertebra) are attached to the front part of the air bladder. The vibration of the air bladder is effected by the contraction of two strong muscles which run from the 'springs' to the hinder portion producing the humming noise.

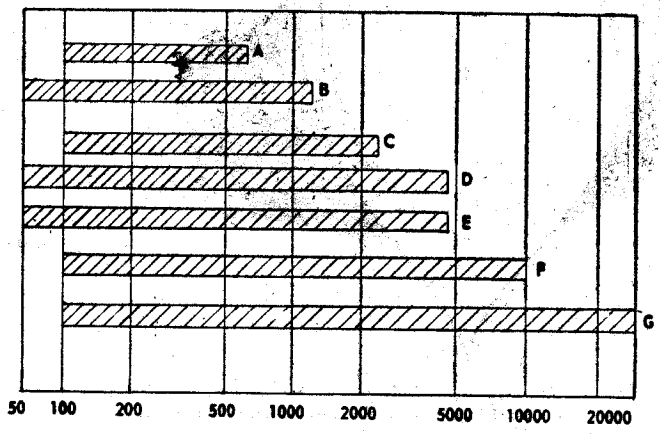

Fig. 6—Frequency Range of Noise Produced by some Marine Animals

A. Toad fish
B. Eel
C. Sea robin
D. Sea horse
E. Trigger fish
F. Croakers
G. Snapping shrimp.

The common Eel (*Anguilla rostrata*) produces a peculiar type of noise referred to as "dull-thud-thumb" caused by the escape of air bladder gas through the pneumatic duct and the branchial aperture. The frequency spectrum ranges between 50 and 1,200 c/s. The puffer fish (*Tetrodon*) as well as the porcupine fish (*Diodon*) are capable of making a 'nasal rasp' by grating the incisor teeth. Its frequency range lies between 200 and 1,600 c/s. The Horse Mackerel (*Trachurus*), the sunfish (*Mola*) and certain species of the trigger fish (*Balistes*) produce harsh noises by grating together the upper and lower pharyngeal teeth.

III. *Cetacea* (*Marine mammals*)

The most important underwater noise producers among marine mammals are the whales and the porpoises. The porpoise (*Tursiops truncatus*) produces two types of noises viz. the 'porpoise clicks' and the 'porpoise whistle'. The latter has an approximate duration 0·5 second and frequency range between 7,000 and 15,000 c/s. The former which is by far the more common consists of a series of rapid clicks or pings. The rate of occurrence may vary from as low as five per second to several hundred per second. The vibrations are mostly in the sonic range although frequencies far above the limits of audibility are also present. The frequency spectrum extends from 20 to 120 kc/s. It has been suggested that the valve in the blow hole of the porpoise plays an important role in sound production.[11]

Underwater sound recordings conducted at the U.S. Navy SOFAR station in the Dahu Islands revealed the fact that whales also contribute to the underwater noise due to marine life[12]. No information is however available on their acoustical characteristics or to the mode of generation.

CONCLUSION

The above list of sonic marine life is by no means complete and it is possible that there may be other marine animals capable of producing noise. Although different types of noises are known to be produced by marine animals, their significance has not been clearly understood. Fish sounds seem to form part of the normal behaviour of many fishes and it is likely that they play an important part in their life, for instance in shoal formation. In some cases (as in the Toad fish) these are recognition signals to attract the sexes during the breeding season. In some others (as in croakers) they indicate the feeding time. The porpoises are known to make use of their clicks for navigation and the Seahorses for orientation. Competition and the approach of a natural enemy also serve as stimulii to sound production.

Apart from its usefulness to understand the behaviour of these marine animals a systematic study of these noises is useful in other aspects too. Recordings of underwater noise at different stations and periods and laboratory analysis of the same will serve to chart the distribution of sonic marine life. They will further provide an independent method of identifying shoals of fish at sea that may not be normally visible. Artificial simulation of these sounds may help the fishermen to obtain a larger catch. Since these noises interfere with the sonar signals of the naval ships, used for submarine detection, an exact knowledge of the intensity and frequency characteristics will also be of great use to the sonar operators in classifying the sonar echoes.

TABLE I.

NOISE PRODUCING MARINE LIFE

Name	Noise producing mechanism	Description of sound	Frequency range c/s	Principal Frequency c/s
INVERTEBRATES				
Crustacea				
(*a*) Snapping shrimp (Crangon and synalpheus).	Snapping of the larger claws	Crackling ..	100–25,000	..
(*b*) Mantis shrimp ..	Do.	Sharp click ..	..	..
(*c*) Crabs: (1) Cancer & Portunus	Noise only while feeding	..	..	..
(2) Pseudozius & Ocypoda ..	Rubbing the Uropods against the undersurface of the telson.	..	..	..
(3) Gelasimus	Chelipeds	Clapping noise ..	..	..
(*d*) Barnacles (Balanus sp:)	..	Occasional clicks of low intensity.	..	..
(*e*) Spiny Lobster (*Panulirus* argus) ..	By means of the stridulating mechanism placed at the basal joints of the large antennæ.	Grating noise ..	..	..
VERTEBRATES				
Fishes				
(*a*) Common Eel (Anguilla rostrata)	Air bladder, escape of air bladder gas through the pneumatic duct and branchial apertures.	Dull-thud-thump ..	50–1,200	75–150 or 150–300
(*b*) Sea Horse (Hippocampus hudsonius)	Stridulation of posterior margin of the skull and coronet.	Loud click similar to snap of finger against thumb. ..	50–1,600	400–800
(*c*) Common trigger fish (Balistes car olinensis)	Pharyngeal teeth and air bladder	Metallic scraching and spitting.	50–4,800	2400–4800
	(2) Stridulation of Pectoral arch	Hissing and heavy humming ..	..	..

TABLE—*concld.*

NOISE PRODUCING MARINE LIFE

INVERTEBRATES

Name	Noise producing mechanism	Description of sound	Frequency range c/s	Principal Frequency c/s
	(3) Pectoral fin rays drumming against taut membrane above air bladder.	Humming ..	..	..
	(4) First dorsal fin ..	Clicking ..	..	..
(*d*) Toad fish (Opsanus tau)	Air bladder and intrinsic muscles	Intermittant boops	100–600	200
(*e*) Sea Robin (Prionotus carolinus)	Air bladder and intrinsic muscles	Rhythmic Squak or crackle	100–2,500	..
(*f*) Croakers (Micropogn-on undulatus)	Drumming muscles on air bladder on	Rapid burst of drumming noise	100–1,00,000	200 cps
(*g*) Fool fish (Monacanthus hispidus)	(1) Specially adapted incisor tooth and air bladder	Sharp whining Swish	50–800	150–300
	(2) First dorsal spine ..	Low click ..	50–800	150–300
	(3) Extrinsic feeding ..	Considerable Chirping	..	..
(*h*) Puffer fish (spheroides maculatus)	Grating of incisor teeth	Nasal rasp ..	200–1,600	300–800
(*i*) Orange file fish (Aleutera Schoepfii)	Specially adapted incisor teeth and air bladder	Toothy scraching. whesing.	50–4,800	700
(*j*) Thread herring (opistonema oglinum)	Air bladder	Hollow knock of low intensity	50–1,600	75–150
(*k*) Hard tail (Caranx crysos) ..	Pharyngeal teeth and air bladder	(1) Low thump with electric shock	20–850	150–300
		(2) Very loud rasps as with a rough file when netted	325–1,100	500
(*l*) Rudder fish (Seriola zonata) ..	Pharyngeal teeth and air bladder	Sharp knock ..	50–1,200	150–300
Porpoise				
Tursiops truncatus ..	Valve in the blow hole	(1) Clicks ..	20,000—1,20,000	..
	Valve in the blow 'hole'	(2) Whistle ..	7,500–15,000	..

Acknowledgement—The author thanks Dr. C. C. John Retd. Professor of Marine Biology and Fisheries, University of Kerala and Dr. D. Srinivasan, Officer-in-Charge, I.N. Physical Laboratory, Cochin for their valuable suggestions and comments in the preparation of this paper.

REFERENCES

1 EVEREST, F. ALTON, YOUNG, R. W. AND JOHNSON, M. W., *J. Acoust. Soc. Amer.*, **20**, 137 (1948).

2 KNUDSEN, V. O., ALFORD, R. S. AND EMLING, J. W., *'Survey of Underwater Ambient' Noise* Office of the Scientific Research and Development, National Defence Research Committee, Washington, D.C.

3 JOHNSON, M. W., EVEREST, F. ALTON AND YOUNG, R. W., *Biol. Bull.* **93**(2), 122, (1974).

4 MOULTON, JAMES M. 'The Sounds of Fishes' "Oceanus" (1956-57).

5 NICOL, J. A., 'The Biology of Marine Animals', Sir Isaac Pitman & Sons., Ltd., London 1960, pp. 405-408.

6 KNUDSEN, V. O., Alford, R. S. and Emling, J. W., *J. Mar. Res.*, **7**, 410, (1948).

7 FISH, M. P., *Scientific American*, **93—102** April (1956).

8 NORMAN, J. R., "A History of Fishes" Ernest Benn Ltd., 6th Edition—pp. 194 (1960).

9 DONALD LOYE, P. and, PROUD, Foot Don. A. *J. Acoust. Soc. Amer.*, **18**, 446 (1946).

10 FISH, M. P., KELSEY, A. S. AND MOWBRAY, W. H., *J. Mar. Res.*, **II.**, 180 (1952).

11 WINTHROP N. KELLOGG, 'Porpoises and Sonar', The University of Chicago Press, Chicago (1961).

12 SEHREIBER, O. W., *J. Acoust. Soc. Amer.* **24**, 116, (1952).