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Estimation of Fishery Resources by Sonar Surveys

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The methodology adopted by the Pelagic Fishery Project, Cochin for surveying the surface fish schools with sonar equipment, is described. The estimates of the biomass arrived at from the surveys conducted during 1975-'78 are presented.

Estimation of fishery resources is important as the magnitude of the standing stock determines the fishing effort to be expended, as also the period and area for this purpose. In recent times electronic instruments are being extensively used in this estimation. Vessels fitted with the instruments scan the coasts to locate and estimate the different varieties of commercially important fishes. Echo integrator, echo sounder and scientific sonar are the acoustic instruments used in this endeavour. Of these, echo integrator along with echo sounder is used for estimating fish moving in lower strata, usually below 10 m to the bottom, while sonar is used for detecting the surface moving fish and estimating their abundance and echo sounder detects and records traces of moving fish well below the surface of the sea. Pelagic Fishery Project, Cochin has been making use of the above instruments and estimating the biomass of some of the important varieties of fish on the southwest and southeast coasts of India in different seasons since 1972. The details of estimates have been published in the various reports brought out by the Project (Anon 1974, '75, '76a, '76b). The method followed and the estimates arrived at in the course of recent surveys are presented in this communication.

Operation of sonar

The word sonar stands for sound navigation and ranging. It consists of transmitter, receiver, recorder, transducer with tilting and training mechanism and control cabinet. The block diagram of the operation of the sonar is given in Fig.1.

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Transmitter is the main source of oscillation. This has an oscillator section which oscillates at ultrasonic frequency range and pulsed at a predetermined frequency, on receiving command from the recorder. This oscillator output is fed to the transducer which is normally fitted on to the keel of the vessel facing side ways, producing horizontal beam. It converts the electrical oscillation into mechanical vibration. These vibrations or sound waves travel horizontally in the water and get reflected by any object. The reflected sound waves are picked up by the same transducer which converts them into electrical energy. This reflected and received energy known as 'echo' is given to the receiver. It amplifies the received echo signal and feeds it to the recorder as voltage signal. Recorder has an electric pen running over a recording paper which makes a definite mark as and when an electrical signal passes through the pen. Thus a marking is displayed on receipt of echo signal on the recorder paper. Also the recorder marks when the transmitter transmits. The distance between the transmitter signal's mark and the received echo's mark is visually a measure of the time lag of the echo and is calibrated to read the range directly. Control cabinet enables us to control the parameters of the equipment like pulse length, band width, power output, beam width, range, training, tilting etc. Tilting mechanism is used to tilt the transducer to detect surface fish or deep water fish and training mechanism to rotate the transducer around 360° and to obtain the direction of the fish school with respect to the bow of the vessel.

The shape of the fish echo recorded on the paper depends on beam width, pulse length, range, tilt angle and paper speed. When the beam width is greater, the fish school is within the beam for a longer period giving the echotrace the shape of a bigger school. Also if two or more schools are seperated by a small distance vertically, they will appear as one school on the recorder. Pulse length is having similar effect on the horizontal resolution. For the longitudinal length of the school (parallel to the track of the ship) the echogram for the same size of the school becomes smaller at short range and greater at long range as the beam is conical in shape. The range selector is changed from long range to short range when the school appears at a fixed distance and the paper speed is increased. The exactly opposite effect is produced when the range selector is changed from short range to long range. The echo picture is enlarged when the paper speed is increased and *vice versa*. Also for estimation of fish abundance the shape and dimension of the echo appearing on the recording paper is made use of. Hence the parameters affecting the shape of the echo should be controlled and accounted for estimation purposes. The sonar equipment used in R. V. Rastrelliger for the regular surveys of the Pelagic Fishery Project was Simrad Survey Sonar s.u. The parameters normally used during the sonar surveys are as follows:

Frequency	:	24 KHz
Pulse length	:	4 milliseconds corresponding to 6 m
Tilt angle	:	0°
Beam angle (2A)	:	8°
Range	:	500 m
Training angle	:	Fixed at 90° or 270° (Port or star board)

Method of estimation

In the acoustic surveys the vessel followed a grid of parallel tracks. A typical track is given in Fig. 2. The area surveyed was between 9°N on the east and 17°N on the west coasts.

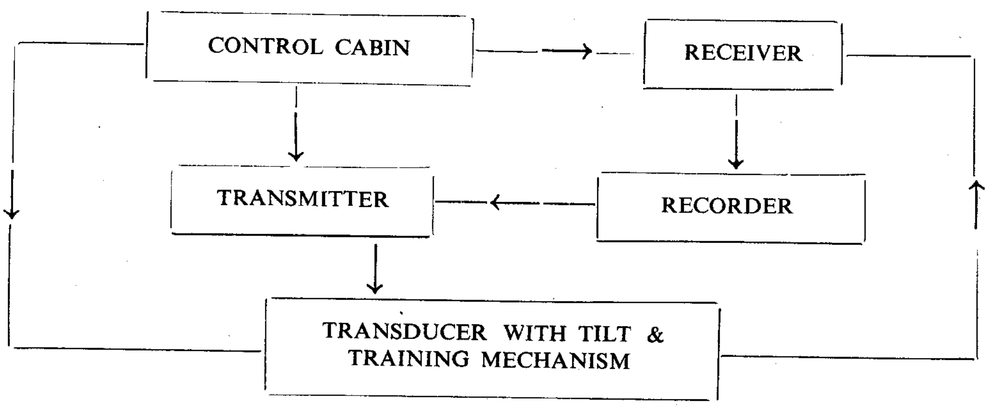

Fig. 1. *Block diagram of sonar*

After completion of a survey, the recorded paper from the sonar was suitably marked to tally with the areas of survey. Then the recordings on the paper pertaining to the schools of fish are isolated. The distance of the mid-point of the school from the vessel was measured and a frequency table of the number of schools in class intervals of 20 m was prepared. The extreme

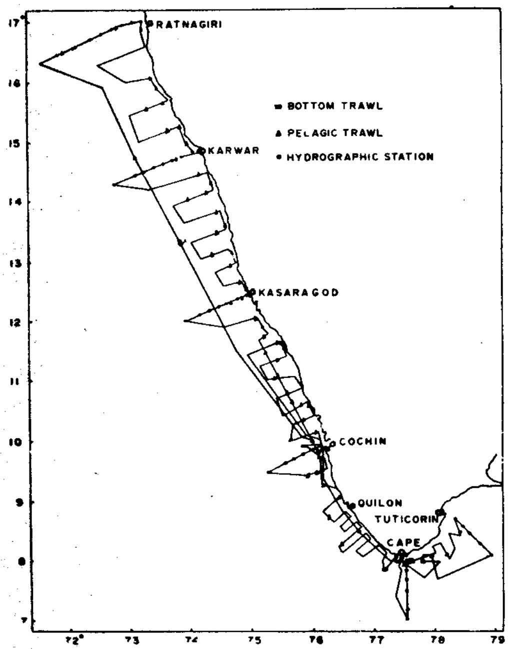

Fig. 2. Typical cruise track of the vessel

ends of the histograms show variations in the numbers of recorded schools from the rest, because of the difference in the effectiveness of the beam with the distance from the vessel. Deleting such extreme ones, the range over which the beam was effective, was determined which forms the basis for estimation of the number of schools along with track of the vessel. Thus if 20 to 220 m is found to be the effective range of the sonar and if 4 schools are recorded in one nautical mile of the track, the number of schools in one nautical mile square (one nautical mile along the track and one nautical mile across the track) is estimated by $\frac{4 \times 1852}{200}$, that is, 37 schools, where 1852 is the number of metres in one nautical mile, 200 is the length of the effective range in metres.

The number of schools estimated in each square nautical mile was referred to as 'school density'. The estimated school densities were noted in each of the divisions of the vessel track in a chart covering the surveyed area. The division corresponding to a nautical mile, was referred to as elementary sampling distance unit or briefly 'ESDU'. Boundary lines are drawn on the chart to distinguish the distribution areas of fish. The type of fish for the distribution areas (mackerel and oil sardine) was made out by visual observations of surface moving schools or from the fishing conducted by the vessel for identification of the traces. The distribution areas are further divided into four strata.

Stratum 'a'	:	0—50 schools per square nautical mile
Stratum 'b'	:	51—100 schools per square nautical mile
Stratum 'c'	:	101—200 schools per square nautical mile
Stratum 'd'	:	201 and more schools per square nautical mile

Fig. 3 shows distribution areas of some of the surface fish schools in one of the surveys.

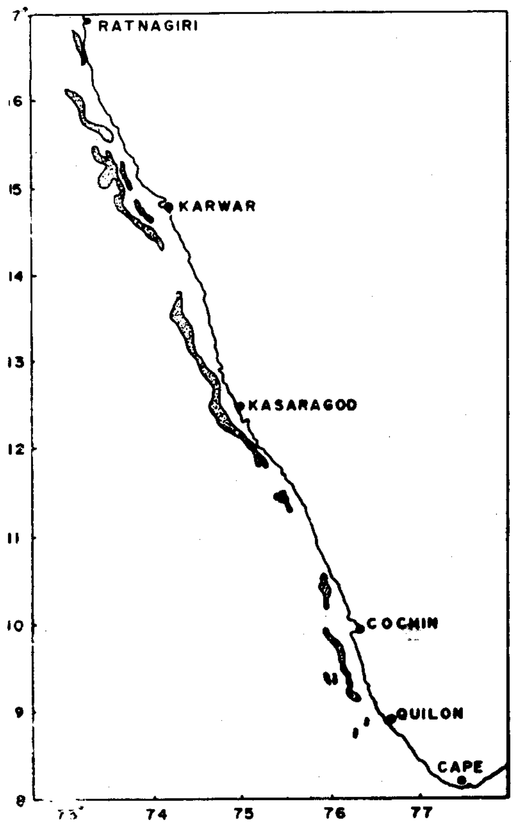

Fig. 3. Distribution of surface fish schools based on sonar observations (Sept. / Oct. 1975)

The estimations for biomass are done for 30′ latitude intervals. The strata in each of the distribution areas, already mentioned were worked out separately for each 30′ interval which is called a 'sub area'.

The schools covered within the effective range only were considered for the biomass estimation. Each of these schools was measured for the length axis of the school (L) parallel to the track of the ship, the breadth axis (B) perpendicular to the track of the ship and for the distance of the nearer end of the school from the vessel (D). The original measurements obtained from the sonar paper were converted into actual measurements. The apparent length of the school 'L', following Forbes & Nakken (1972), is given by L=CSI, where C, is the speed of the paper in seconds per mm; S, the speed of the ship in metres per sec. and I, the measured width of target on chart in mm.

Breadth of the school was obtained from the width of the sonar paper corresponding to the range of the sonar. The true measurements of the dimensions of the school were obtained as follows:

$$L_c = L-2\left(D + \frac{B}{2}\right) \tan A$$

$$B_c = B\text{–Pulse length}/2$$

where 2A was the beam angle

The shape of the school was considered to be either elliptical or circular and the corresponding length and breadth of the school, L_c and B_c form the two axes of the ellipse in the former case, whereas in the latter the corrected breadth, B_c was the diameter.

The surface area of a schools of elliptical shape A_e is $\frac{\pi}{4} L_c B_c$ and for a school of circular shape area A_c is $\frac{\pi}{4} B_c^2$. The area of each stratum of distribution in a sub-area was measured by a planimeter and was converted to the actual area surveyed in square nautical miles by multiplying with a suitable raising factor. The area thus obtained was denoted by 's'. The vertical extension of the school h, in the sub-area was estimated from the echo recordings. If $\bar{d}$ is the average number of schools in a stratum of the sub-area, the volume of school is $a\bar{d}A_c h$ or $a\bar{d}A_e h$ depending on the assumption of the shape of the school. The estimates of various strata from a sub-area were added up to obtain a single estimate for a sub-area. The first estimate of biomass, was thus obtained as total volume of schools in sub-area.

The packing density to convert volumes of schools to weight has been worked out on certain assumptions in each case separately. One method was to consider the distance between each fish in the school as one and a half times its length. In the surveys of 1975 and 1976, this procedure was adopted. A second method available was to consider the integrator deflection on the echo integrator for the surface schools recorded in the echo sounder. The integrator deflection was converted into total quantity and the volume of the surface school from echo recordings was obtained. By equating these two quantities, an estimate of the packing density was obtained. The method was followed in the surveys conducted in 1977 and 1978. As the packing densities differed in certain areas by this procedure, separate estimates of packing densities were obtained for different areas.

Sonar surveys

Sonar surveys have been conducted by the Project since 1975, mostly for the biomass estimates of mackerel and sardine. The surveys were arranged to cover the peak period of the fishing season. Only one survey each was conducted in 1975 and 1978 while in 1976 and 1977, 3 and 2 surveys were conducted respectively. The number of surveys in each year, the periods of the survey and the survey areas are given in Table 1.

The details of estimates are given in Tables 2 to 8. Though the original estimates were made for 30′ interval, they are reproduced here for 1° interval.

Table 1. *Details of sonar surveys conducted by the Pelagic Fishery Project*

Year	No. of surveys	Period	Surveyed area
1975	1	September to October	17° to 8°
1976	3	(i) June to July	16° to 9°*
		(ii) July to August	16°30′ to 8°30′*
		(iii) October	17° to 8°*
1977	2	(i) September	17° to 12° 45′
		(ii) November to December	17° to 9°*
1978	1	September to October	17° to 9° *

* Survey extended to east coast also

Table 2. *R/75-17 biomass (tonnes) latitude wise September to October* 1975

Latitude	Surface schools biomass
West coast	
17° to 16°	20,201
16° to 15°	159,758
15° to 14°	85,335
14° to 13°	240,374
13° to 12°	89,789
12° to 11°	54,148
11° to 10°	20,839
9° to 8°	72,662
8° to 7°	—
East coast	
7° to 8°	—
8° to 9°	—
Total	743,106

Note: — data not available

Table 3. 4/76-08 7 09 *biomass (tonnes) latitude wise June to July* 1976

Latitude	Surface schools Oil Sardine & mackerel	Others	Total
West coast			
17° to 16°	—	—	—
16° to 15°	2,691	0	2,691
15° to 14°	2,347	25	2,372
14° to 13°	1,210	0	1,210
13° to 12°	30,632	58	30,690
12° to 11°	125,731	762	126,493
11° to 10°	2,475	2,385	4,860
10° to 9°	15,077	2,085	17,162
9° to 8°	9,425	6,343	15,768
8° to 7°	0	3,181	3,181
East coast			
7° to 8°	0	6,142	6,142
8° to 9°	0	44,598	44,598
Total	189,588	65,579	255,167

Note: 1. — data not available
2. Biomass by sonar methodology from surface to 14 m depth

Table 4. *R/76-11 & 13 biomass (tonne)s latitude wise July to August* 1976

Latitude	Surface schools Oil Sardine & mackerel	Others	Total
West coast			
16° 30′ to 16°	1,024	247	1,271
16° to 15°	46,744	54	46,798
15° to 14°	201,764	7,261	209,025
14° to 13°	81,716	62,135	143,851
13° to 12°	111,715	3,101	114,816
12° to 11°	68,180	17,253	85,433
11° to 10°	67,459	10,703	78,162
10° to 9°	24,626	58,390	83,016
9° to 8°	321	0	321
8° to 7°	0	0	0
East coast			
7° to 8°	0	15,242	15,242
8° to 8°30′	0	643	643
Total	603,549	175,029	778,578

Note: Biomass by sonar methodology from surface to 14 m depth

Table 5. *R/76-16 biomass (tonnes) latitude wise October* 1976

Latitude	Surface schools: Oil Sardine & mackerel	Others	Total
West coast			
17° to 16°	78,838	44,168	123,006
16° to 15°	29,743	9,536	39,279
15° to 14°	24,068	0	24,068
14° to 13°	20,367	504	20,871
13° to 12°	15,556	4,763	20,319
12° to 11°	121,799	8,788	130,587
11° to 10°	27,657	7,610	35,267
10° to 9°	16,932	625	17,557
9° to 8°	15,097	1,197	16,294
8° to 7°	1,159	26,240	27,399
East coast			
7° to 8°	0	12,812	12,812
8° to 9°	—	—	—
Total	351,216	116,243	467,459

Note: 1. — data not available

2. Biomass by sonar methodology from surface to 17 m depth

Table 6. *R/77-13 biomass (tonnes) latitude wise September* 1977

Latitude	Surface schools
17° to 16°	15,998
16° to 15°	6,550
15° to 14°	3,915
14° to 13°	8,390
13° to 12° 45′	764
Total	35,617

Table 7. *R/77-14 biomass (tonnes) latitude wise November to December* 1977

Latitude	Surface schools
West coast	
17° to 16°	11,721
16° to 15°	7,034
15° to 14°	13,335
14° to 13°	1,124
13° to 12°	1,535
12° to 11°	333
11° to 10°	22
10° to 9°	119
9° to 8°	1,491
8° to 7°	169
East coast	
7° to 8°	31
8° to 9°	977
Total	37,891

Table 8. *R/78-15, 16 & 17 biomass (tonnes) latitude wise September to October* 1978.

Latitude	Surface schools: Oil sardine	Mackerel	Others
West coast			
17° to 16°	7,667	—	383
16° to 15°	11,054	—	—
15° to 14°	7,679	9,314	—
14° to 13°	59,065	16,474	4,783
13° to 12°	—	15,111	1,113
12° to 11°	1,944	12,140	769
11° to 10°	3,167	242	667
10° to 9°	—	2,554	2,064
9° to 8°	—	—	12,623
8° to 7°	—	—	948
East coast			
7° to 8°	—	—	2,038
8° to 9°	—	—	213
Total	90,576	55,835	25,601

The schools of mackerel and sardine could not be separated in some of the surveys as they occurred together. Besides, some other pelagic schools were also recorded by the sonar. These were mostly the schools of horse mackerel, tuna and lesser sardines and the estimates were given in the Tables 2 to 8. The estimate of combined stock of mackerel and oil sardine was 700 thousand tonnes in 1975. In 1976 the three surveys gave estimates varying between 190 and 600 thousand tonnes. In 1978, sardines were estimated at 91,000 and mackerel 56,000 tonnes. The above shows high fluctuations in the biomass. The estimates are to be considered as applicable for the period of surveys. They undergo tremendous variation over the period. Past experience is an indication in the matter of mackerel and oil sardine fishery in this respect. The surveys can be made at suitable periods of time so that the estimates of biomass can be utilised for a proper exploitation of the resources. With proper coordination between the different agencies, the sonar surveys can be taken advantage of, for augmenting the fishing effort to obtain improved catch.

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References

Anon (1974) *UNDP/FAO Pelagic Fishery Project, Cochin. Progress Report No.* 6

Anon (1975) *UNDP/FAO Pelagic Fishery Project, Cochin. Progress Report No.* 11

Anon (1976a) *UNDP/FAO Pelagic Fishery Project, Cochin. Progress Report No.* 12

Anon (1976b) *UNDP/FAO Pelagic Fishery Project, Cochin. Progress Report No.* 13

Forbes, S. T. & Nakken, O. (1972) *'Manual of Methods for Fisheries Resources Survey and Appraisal., Part 2. The Use of Acoustic Instruments for Fish Detection and Abundance Estimation' FAO Man. Fish. Sc.* 5