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SCHOOL SIZING OF SMALL PELAGIC SPECIES OFF MOZAMBIQUE BY DENSITY ESTIMATION AND ACOUSTIC DIMENSIONING

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ABSTRACT

A method of acoustic dimensioning and density calculation was developed to estimate the school biomass of anchovy and other pelagic species off Mozambique in May 1987. The school sizes of both anchovy and other species were rather small. Maximum recorded school biomass of anchovy was comparable to the biggest anchovy school captured during trial fishing with purse seine. The method is an alternative to conventional echo-integration for estimating school biomass.

INTRODUCTION

A fish school appears as a compact unit with individuals in polarized and syncronized swimming (12). The organized behaviour enables estimation of fish density if the length of the schooling individuals is known (15). Since school dimensions can be measured acoustically, school biomass can be calculated by multiplying dimension with estimated density.

These principles were applied to investigate the schools of small pelagic species outside the coast of Mozambique. Trial fishing with pelagic trawl and purse seine was conducted in the area in 1985 - 1987. Only low catches (< 1000 kg/hour) were made, and the actual species seemed to appear exclusively in rather small schools (3).

MATERIALS AND METHODS

The present investigation was conducted from M/V "Atløy Viking" on the shallow shelf (< 50 m depth) off Mozambigue in May 1987. The 70 feet vessel was rigged with a pelagic capelin trawl (3), equipped with sonar (150 kHz Furuno CH-12), and echo-sounder (50 kHz Furuno FE 881). About 80 % of the schools were recorded on the Sofala Bank, the rest off Boa Paz and in Maputo Bay (Fig. 1).

To minimize the bottom reverberation in the shallow waters, the sonar search range chosen was 200 m. In accordance with (20), midwater schools were classified as anchovy *(Stolephorus punctifer)*, and bottom schools as other small pelagic species. The pelagic trawl was aimed at abundant recordings to investigate the catch potential and test the species classification. Recorded schools were measured in daylight only. In darkness the schools dispersed in midwater shoals (12), too scattered to give distinct sonar recordings.

The school projection on the sonar display was measured perpendicular to the beam (cw) and along the beam (lw) by a ruler (Fig. 2). Only the larger sonar recordings were considered in areas with many schools. The sonar marker was used to measure the horizontal distance vessel-school (R), and the depth of the school (D). The vertical extent (h) of some of the sonar measured schools were recorded by the echo-sounder. The schools were assumed ellipsoid and dimensioned by:

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Crosswise school extent	$CW = cw\ s_s - 2R \tan (BW/2)$ (m)
Lengthwise school extent	$LW = lw\ s_s - (c\ t_s)/2$ (m)
Horizontal school area	$A = (CW\ LW/4)\ \pi$ (m^2)
Vertical school extent	$H = h\ s_e - (c\ t_e)/2$ (m)
School volume	$V = 4/3\ (A\ H/2)$ (m^3)

c: speed of sound (~ 1500 m/s)

BW: beamwidth of the sonar (6° at the transmitter)

t_s, t_e: pulselengths of sonar and echo-sounder (2.8 and 1.6 ms)

s_s, s_e: scaling of sonar and echo-sounder recordings, respectively

The most abundant pelagic species in the catches were length measured to the nearest 0.5 cm, and their average weight (W) calculated by length-weight relations (4, 5).

According to Serebrov (15), the density (p) in a school can be estimated by an approximate constant ratio (K) between average interfish distance (r) and average fish length (LT):

Fish density: $p = 1/r^3 = 1/(LT\ K)^3$ (n/m^3)

The numerical value of K is 2.44 as determined in freeswimming schools of anchovy, capelin, cod, herring and grenadier (15). The school biomass was calculated by:

School biomass: $B = V\ p\ W$ (kg)

RESULTS

The great majority of the sonar recordings were small, and difficult to sort out from noise reverberation. Typically, numerous small spots projected in single sonar beams were recorded when cruising in areas with school concentrations. Most of the measured schools amounted < 100 m^2 (Fig. 3). The average area of anchovy schools was 80 m^2 (Table 1), but not significantly less than of the other species ($p > 0.05$, Mann-Whitney test). The crosswise and lengthwise extent of the schools were about equal, as indicated by their proportions and strong correlations (Table 1). The average vertical extent of anchovy schools was only 1.8 m, giving an average volume of 95 m^3. Both the vertical extent and volume of the schools organized by other species were significantly bigger ($p < 0.05$, Table 1).

Length distributions of anchovy *(Stolephorus punctifer)* from the trawl catches averaged 6.1 cm (Table 2). Based on the estimated density and measured school volume, the average biomass of anchovy schools was calculated to only about 35 kg. *Decapterus russelli* and *Thryssa vitrirostris* were the most abundant of other species in the catches on the Sofala Bank, and assuming that all bottom schools were formed by these species their average school biomasses were estimated at 560 and 380 kg respectively (Table 2). The maximum school biomass of these species was from 8.5 to 12.2 tonnes, while the maximum school biomass of anchovy was only about 0.4 tonnes.

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DISCUSSION

The maximum recorded school biomass of anchovy was comparable to the biggest anchovy school of 750 kg captured during previous trial fishing with purse seine (3). Average recorded school biomass of anchovy was only 35 kg. These results compare well with the low anchovy catches obtained by both purse-seine and pelagic trawl in daylight.

The anchovy schools off Mozambique were considerably smaller than for other commercially exploited anchovy species (14). Depending on season, the mean school area of *Engraulis mordax* outside the coast of California varied from 772 to 1683 m^2 (18). With regard to the other small pelagic species, the average school area was about the same as that of sardine and mackerel schools off India (2). Maximum school biomass of these species were from 8.5 to 12.2tonnes, but only a few schools of that size were recorded off Mozambique.

The sonar projection of a school is distorted and overestimated (10), but this is supposed to be corrected by compensating for the beamwidth and pulselength of the sonar (17, 2). However, as reported by Halvorsen (7), the corrections may exclude small recordings. Especially an average correction of the beamwidth is rather uncertain as the distortion due to the beamwidth (BW) at a certain distance vessel-to-school (R) will be arbitrary within the interval (0, 2 R tan BW). The results might also be biased by sonar limitations causing a decreasing school projection at shorter horizontal distances (9).

In calculating the dimensions, the schools were considered ellipsoid. Schools are claimed to be amorphous (14), but there are reports of elliptical sardine, mackerel and anchovy schools (1, 19). The proportions and the correlations between the crosswise and lengthwise dimensions, however, indicates a nearly circular school shape.

Depth measurement by a horizontal guided sonar can be very inaccurate (10), and the method of classifying sonar recordings according to species by their depth has great uncertainty. Because the schools occurred in concentrated areas where either anchovy or the other species dominated the catches, it is considered that this method of classification was fairly reliable. Some of the measured schools might, however, have been bigger pelagic species like *Thunnus albacares* or *Caranx sexfaciatus*, observed as surface schools.

The Serebrov equations (15) for calculating density are reasonable because the school volume is proportional to the number of individuals multiplied by the cube of the average body length (13). The calculated density in schools of *Thryssa vitrirostris* is the same as observed in schools of South-African pilchard of about the same length (1). The equations are based on the assumption that schools are organized in a cubic lattice (15). Even if this is the approximate organization of herring schools (11), measurements of capelin schools have revealed a lower density than predicted (16). Especially if lacunas exists between sub-units in schools (13), the estimated overall fish density in schools will be too high (16). This may have caused overestimation of the actual school biomass.

A basic assumption of the applied method is that recorded schools are organized with individuals in polarized and syncronized swimming (12), resulting in an approximately constant interfish distance. Below a certain light level, schools usually resolve in looser organized shoals (8, 6), for which the applied method is not valid. However, as evaluated by this investigation, in-situ measurements by multibeam sonar and echo-sounder combined with calculated densities may be used to estimate the biomass of schools. The method can be especially suitable in the absence of an adequate echo-integration system.

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Table 1. School dimensions and school shape of anchovy and other pelagic species (X: average value, N: number of measured schools, CW: crosswise extent, LW: lengthwise extent, r_s: Spearman's rank correlation coefficient).

	Area		Shape			Vertical ext.		Volume	
	X(m^2)	range(m^2)	CW:LW	r_s	N	X(m)	range(m)	X(m^3)	N
Anchovy	79.4	1.0-364	0.8:1	0.47	99	1.8	0.1-4.2	95.3	40
Other species	230.9	2.5-2320	1.2:1	0.64	45	5.7	0.3-12.6	877.4	38

Table 2. Length, weight, density and school biomass of the most common small pelagic species.

	Average length (cm)	Average weight (g)	Average density (n/m^3)	School biomass average (kg)	School biomass maximum (kg)
Stolephorus punctifer	6.1	1.2	303.0	34.7	370.6
Decapterus russelli	11.2	13.0	49.0	558.9	12216.8
Thryssa vitrirostris	14.4	18.8	23.1	381.0	8463.2

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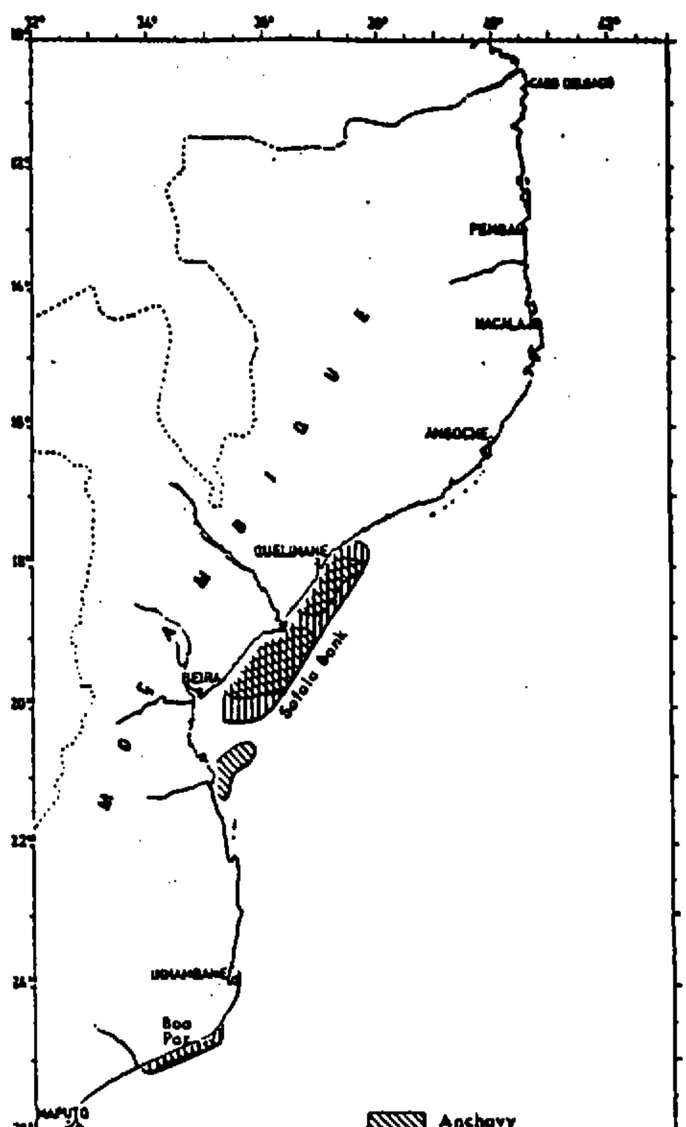

Fig. 1. Distribution of anchovy *(Stolephorus punctifer)* and other small pelagic species May 1987.

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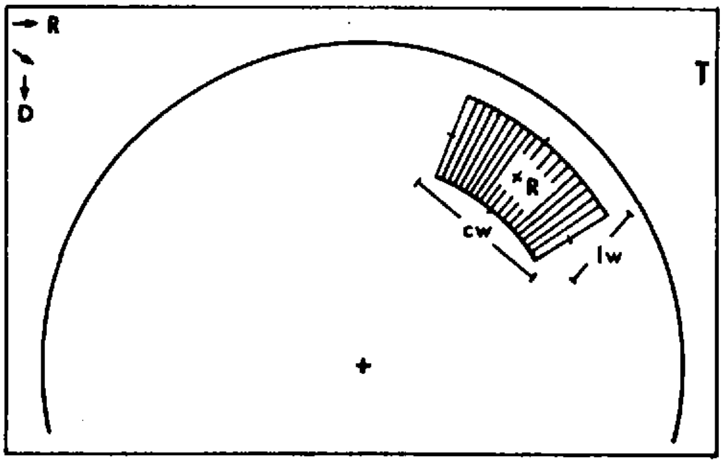

Fig. 2. Measurements of the horizontal dimensions of a school recording on the sonar display (R: horizontal distance vessel-to-school, cw: crosswise extent, lw: lengthwise extent, D: school depth, T: tilt angle).

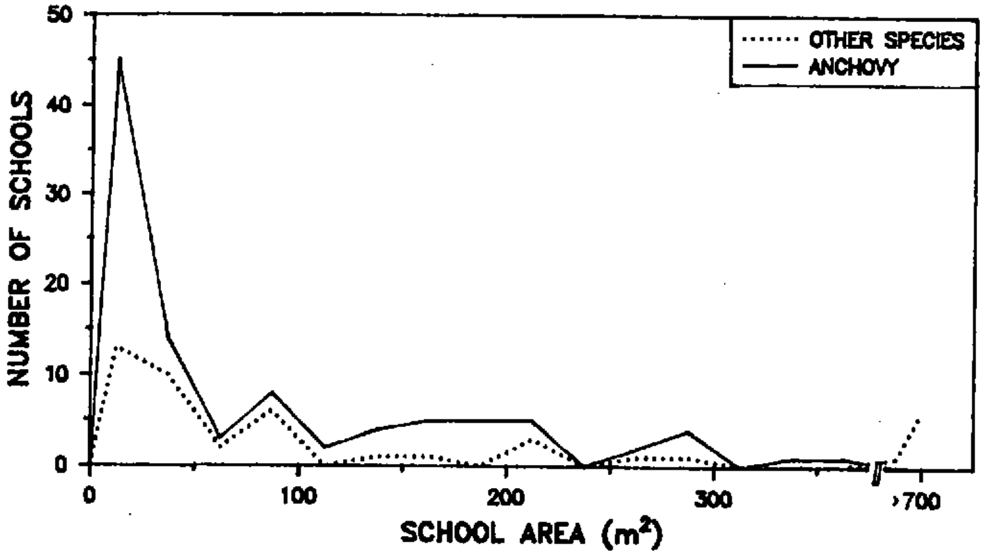

Fig. 3. Distribution of recorded school areas of anchovy *(Stolephorus punctifer)* and other small pelagic species.