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

by

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Abstract

A method using a multibeam sonar and density calculation was applied to ivestigate schools 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 close to the biggest anchovy school ever captured during trial fishing with a purse seine. The method is an alternative to the conventional one of echo integration to estimate the biomass in schools.

Introduction

A fish school appears as a compact unit with individuals in polarized and syncronized swimming (Pitcher 1983). The organized behaviour enables estimation of the fish density if the length of the schooling individuals is known (Serebrov 1976). As the school dimensions can be measured by a multibeam sonar (Misund 1987), the school biomass can be calculated by multiplying the dimensions and the 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 obtained as the actual species seemed to appear exclusively in rather small schools (Beltestad, Misund & Sørensen 1988).

Materials and Methods

The investigation was conducted from M/V "Atløy Viking" on the shallow shelf (< 50 m depht) off Mozambigue in May 1987. The 70 feet vessel was rigged with a pelagic capelin trawl, 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 (Fig. 1).

Recorded schools were measured in daylight only. In darkness the schools dispersed in midwater shoals (Pitcher 1983), too scattered to give distinct sonar recordings. To minimize bottom reverberation in shallow waters, the sonar search range chosen was 200 m. Midwater schools were classified as anchovy *(Stolephorus punctifer)*, and bottom schools as other small pelagic species according to the usual vertical distribution of different species in daylight (Sætre & Silva 1979). The pelagic trawl was aimed at abundant recordings to investigate the catch potential and test the classification.

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

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

c : speed of sound (~ 1500 m/s)
2B : beamwidth of the sonar (6° at the transmitter)
t_s, t_e : pulselengths of sonar and sounder (2.8 and 1.6 ms)
s_s, s_e : scaling of sonar and sounder recordings respectively

The most common pelagic species in the catches were length measured to the nearest 0.5 cm, and average weight (W) calculated by length-weight relations (Brinca et. al. 1983, 1984). According to Serebrov (1976), 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 (Serebrov 1976). 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 in the assumed lognormal distribution of school areas of anchovy was 36 m^2 (Table 1), and not significantly less than of other species ($p > 0.05$, Mann-Whitneys-test). The crosswise and lengthwise extension of the schools were about equal, as indicated by their proportions and strong correlations (Table 1). The average vertical extension of anchovy schools was only 1.8 m, giving an average school volume of 43 m^3. The school dimensions of other species were bigger both both with regard to vertical extension and volume (Table 1).

Length distributions of anchovy *(Stolephorus punctifer)* from different areas (Fig. 4) were rather similar with an average of 6.1 cm (Table 2). *Decapterus russelli* and *Thryssa vitrirostris* were the most abundant of other species in the catches on the Sofala Bank. Based on the estimated density and measured school volume, the average biomass of anchovy schools was calculated to only about 15 kg. Assuming that the other recorded schools were formed by *Thryssa vitrirostris* or *Decapterus russelli*, their average school biomass was about 111 and 163 kg respectively (Table 2). The maximum school biomass of these species was from 12.7 to 18.6 tonnes, while the maximum school biomass of anchovy was only about 0.5 tonnes.

Discussion

The maximum recorded school biomass of 540 kg anchovy was close to the biggest anchovy school captured during previous trial fishing with purse seine which was 750 kg (Beltestad, Misund & Sørensen 1988). Average recorded school biomass of anchovy was only 15 kg. These results support the small school size explanation of 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 (Radakov 1973). Depending on season, the mean school area of

Engraulis mordax outside the coast of California varied from 772 to 1683 m^2 (Smith 1981). The average school area of the other small pelagic species was about one third of sardine and mackerel schools off India (Anon 1975). Maximum school biomass of these species was from 13 to 19 tonns, but only a few schools of that size were recorded during the cruise.

The sonar projection of a school is distorted and overestimated (Misund 1987), but this can be corrected by compensating forthe beamwidth and pulselength of the sonar (Smith 1971, Anon 1975). However, as reported by Halvorsen (1985), the corrections may exclude small recordings. By use of multibeam sonar, the average beamwidth compensation is valid for schools projected over several beams, but must be halved for projections occuring in a single beam. Nevertheless, the results might be biased by sonar limitations causing a decreasing school projection at shorter horizontal distances (Misund 1986).

Depth measurement by a horizontal guided sonar can be very inaccurate (Misund 1987), and the method of classifying sonar recordings according to species by their depth has great uncertainty. However, because the schools occurred in concentrated areas where either anchovy or the other species dominated the catches it is conceded that this method of classification was relied on with some confidence. Some of the measured schools might have been bigger pelagic species like *Thunnus albacares* or *Caranx sexfaciatus*, observed in surface schools.

In calculating the dimensions, the schools were considered ellipsoid. Schools are claimed to be amorphous (Radakov 1973), but there are reports of elliptical sardine, mackerel and anchovy schools (Anon 1974, Squire 1978). However, the crosswise-to-lenghtwise proportions indicates a nearly circular school shape which gives correct school area estimates by the applied equation (Pitcher & Partrigde 1979).

The Serebrov equations 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 (Pitcher and Partridge 1979). The calculated density in schools of *Thryssa vitrirostris* is the same as observed in schools of South-African pilchard of about the same length (Anon 1974). However, the equations are based on the assumption that schools are organized in a cubic lattice (Serebrov 1976). Even if this is the approximate organization of herring schools (Partridge et. al. 1980), measurements of capelin schools have revealed a lower density than predicted (Serebrov 1984). Especially if there exist lacunas between sub-units in schools (Pitcher & Partridge 1979), the overall fish density in schools may be predicted too high (Serebrov 1984). This may have caused overestimation of the actual school biomass.

The school size of pelagic species in the Northern Hemisphere usually have large seasonal variations (Radakov 1973). Such variations were scarcely reflected in the trial fishing catches, even if a few unusually large anchovy schools were recorded in the Boa Paz area during full moon periods in June-July 1987 (Beltestad, Misund & Sørensen 1988).

A basic assumption of the applied method is that recorded schools are organized with individuals in polarized and syncronized swimming (Pitcher 1983), resulting in an approximately constant interfish distance. Below a certain light level, schools resolves in looser organized shoals (Hunter 1968, Class, Wardle & Mojsiewicz 1986), for which the applied method is invalid. However, as evaluated by this investigation, in situ measurements by multibeam sonar 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 shape of anchovy and other pelagic species ($\bar{X}$: average value, N: number of measured schools, CW: crosswise extension, LW: lengthwise extension, r_s: Spearmans correl. coeff.).

	Area		Shape			Vertical ext.		Volume	
	$\bar{X}(m^2)$	range(m^2)	CW:LW	r_s	N	$\bar{X}$(m)	range(m)	$\bar{X}(m^3)$	N
Anchovy	35.7	1.0-364	0.8:1	0.47	99	1.8	0.1-4.2	42.8	40
Other species	67.4	2.5-2320	1.2:1	0.64	45	5.7	0.3-12.6	256.1	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	15.2	542.0
Decapterus russelli	11.2	13.0	49.0	163.1	18620.8
Thryssa vitrirostris	14.4	18.8	23.1	111.1	12686.7

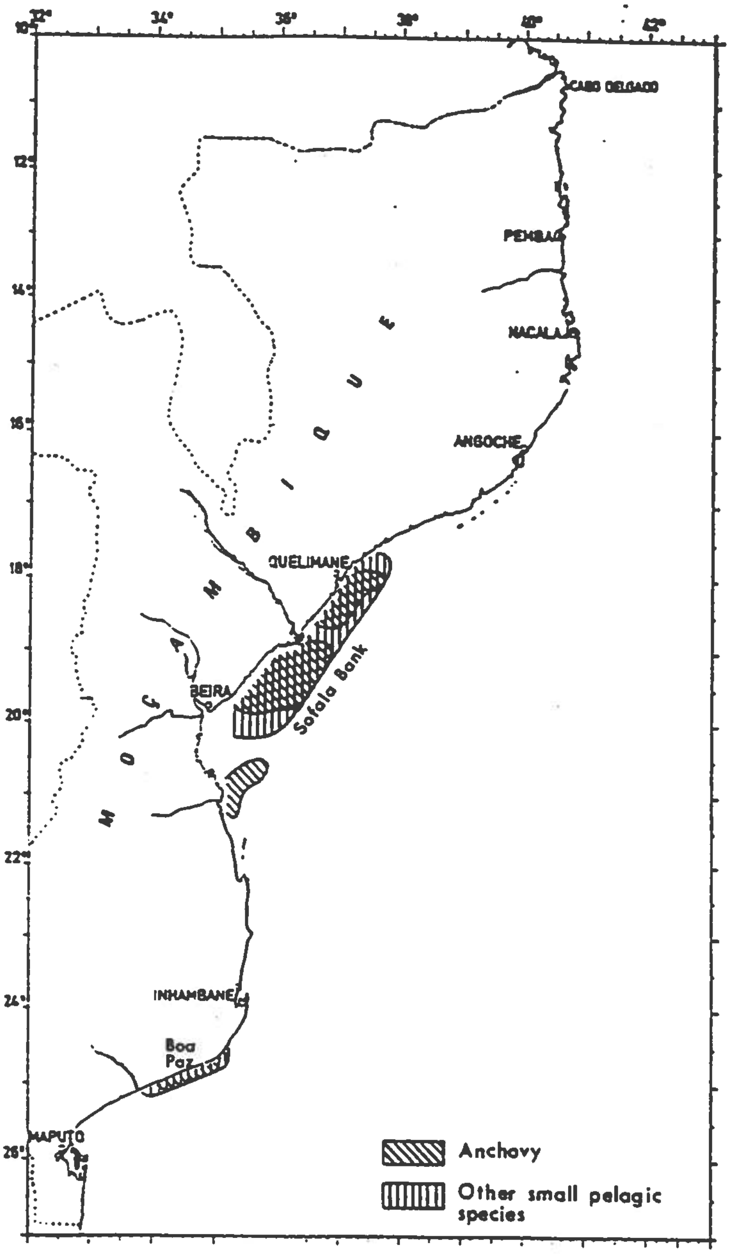

Fig. 1. Distribution of anchovy *(Stolephorus punctifer)* and other small pelagic species May 1987.

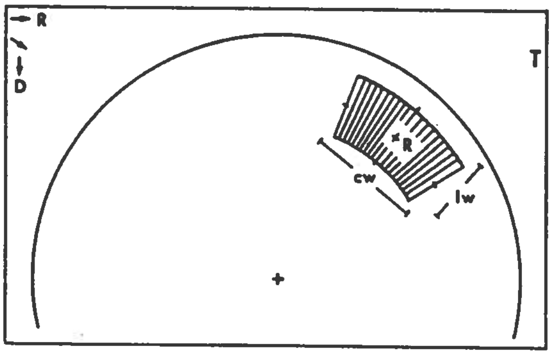

Fig. 2. Measurement of the horizontal dimensions of a school recording on the sonar display (R: horizontal distance vessel-to-school, cw: crosswise extension, lw: lengthwise extension, D: school depth, T: tilt angle).

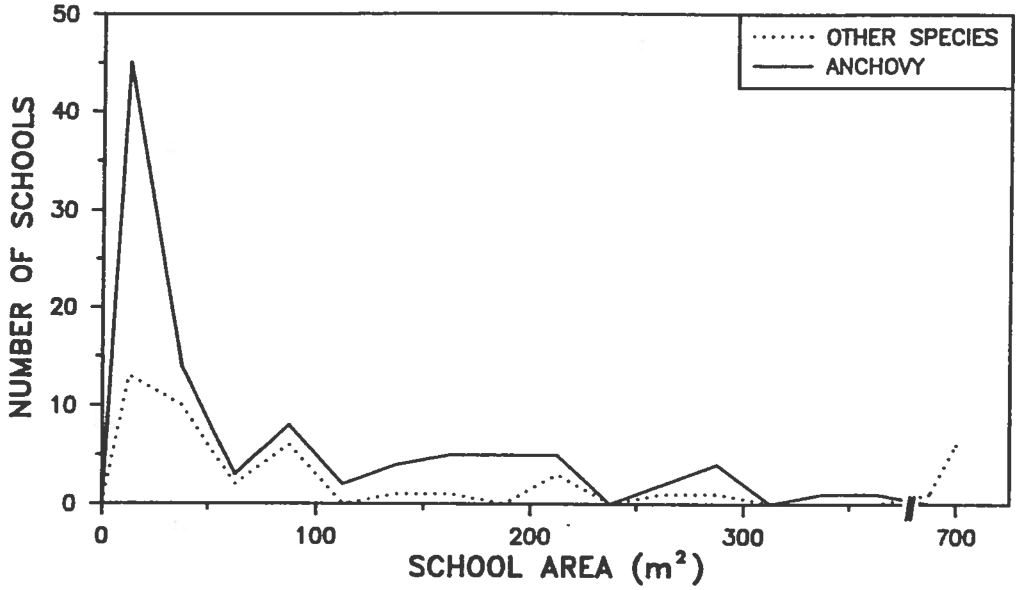

Fig. 3. Distribution of recorded school areas of anchovy (*Stolephorus punctifer*) and other small pelagic species.

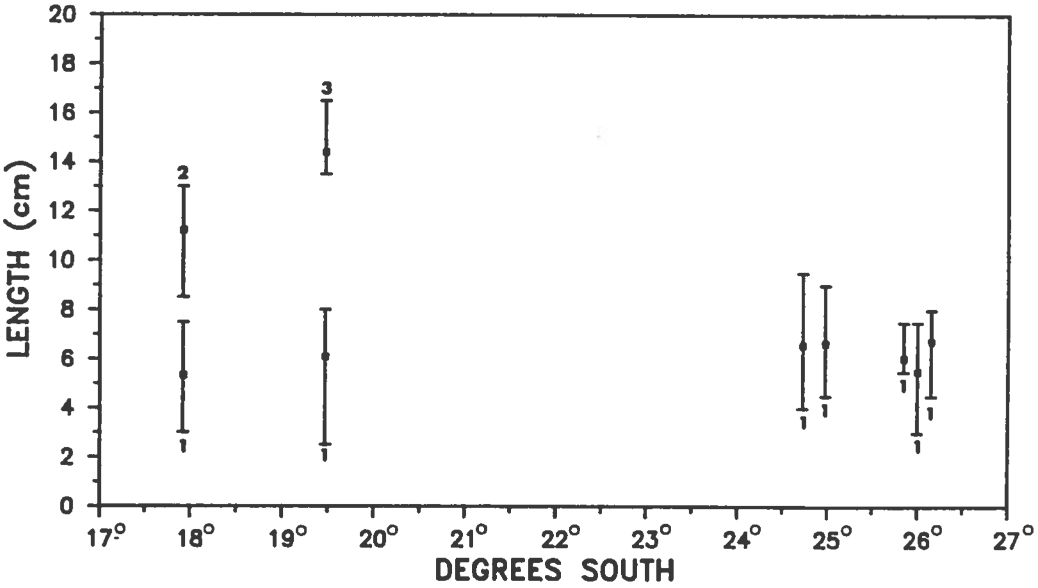

Fig. 4. Interval of variation (vertical bars) and average length of *Stolephorus punctifer* (1), *Decapterus russelli* (2), and *Thryssa vitrirostris* (3) in the trawl catches.