ICES Fisheries Acoustic Science & Technology (FAST)
Working Group Meeting, Ostende, Belgium, 19-22 April, 1988.

INFLUENCE OF FISH BEHAVIOUR ON FISH STOCK ABUNDANCE ESTIMATIONS

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Keywords: Fish behaviour, Stock assessment.

Abstract

A new methodology is proposed for studying fish school behaviour, allowing to quantify its influence on stock abundance estimations. Observations are collected in open sea or inside a large net set in shallow waters. Preliminary results concerning fish reactions show a modification of the school structure under a research vessel using acoustic devices for abundance measurements. The school structure, even when the fish is not disturbed, shows an irregular density distribution in opposition to the common belief.

Fish behaviour studies in relation with fisheries started many years ago with the aim of improving fishery technology. Avoidance and escapement observations have been carried out for several decades making it possible to build more efficient or more selective fishing gears, according to the needs of fishermen or fishery managers. Nevertheless, as far as fishery biology is concerned, the influence of the numerous behavioural parameters has been considered either very recently or not at all, while it is predominant in three main fields:

(1) Changes in behaviour can be induced by the scientific observer and/or his observation tools. This field mainly

concerns the acoustic survey method: the interpretation of data requires in this case to quantify the behaviour effect with respect to the oceanographic vessel as first described by Olsen[1] and more recently by various participants to the International Symposium on Fisheries Acoustics in Seattle[2]. The main parameters to identify and to measure are in this case: the fish avoidance caused by the stress from the vessel (noise, light, shadow ...) as shown in figure 1, and the fish tilt angle inside the acoustic beam, induced by these stimuli.

(2) Natural behaviour quantitatively influences the scientific observations or the fishery activity, and then the validity of production models. The structure of schools and concentrations must be known, as well as their time and space variations. Studies have already been carried out on this topic[3,4] but few, as far as we know, from the quantitative point of view, except on small schools in tanks. However, when designing and processing acoustic surveys, it is necessary to have a good enough knowledge on the tridimentional school and concentration structure, but also on their time evolution. Such data provide a better estimation of the biomass and of its confidence limits, as mentioned by Aglen[5] and Gerlotto & Stequert[6]. As shown in recent works[7] it seems that the density inside large schools is not homogeneous, contrary to the common belief resulting from visual observations on small schools. Our preliminary studies indicate that a vertical density gradient is frequently observed, as well as discontinuities inside the school.

The precise knowledge and quantification of this natural behaviour is also highly required for the adaptation and correction of observations or conclusions in the fishery biology research field, as shown in the following two examples.

The first one concerns the interspecific relationships in schools and concentration. In tropical areas at least, fish concentrations and schools may regroup several species presenting some affinities or similarities with respect to their size, body shape, alimentation, etc[8]. Therefore, it is obvious that one cannot consider those species separately when studying their biology with the aim of fishery management.

Second, the formation and dispersion of schools and concentrations must be considered. Fishery biology uses mainly statistical data from the fisheries as representative of the exploited stocks. In the case of pelagic species, the sampling unit is usually related to a gear set (pelagic trawl, purse seine, surrounding gill-net, beach seine) and then concerns a single school or part of a concentration in most of the cases. In fact, the sum of these observations does not necessarily represent the sum of the exploited cohorts.

The dispersion of the fish during certain periods of its life (reproduction, search for scattered food, etc.) may make it unavailable for such fishing gears[9]. Otherwise, when the Petersen method is used for studying growth, an unappropriate sampling method or data processing can lead to a confusion between school and cohort modal length.

Thus it is essential to know precisely the mechanism of formation of shoals and concentrations, its determinism and its periodicity, in order to estimate the different biases induced by this natural behaviour.

(3) Behaviour can be modified by learning in relation with a fishery. Until now, most fishery biologists used to assume that biological parameters in general (growth, reproduction, natural mortality, etc.) as well as fish behaviour in particular (migrations, catchability, availability, etc.) were genotypic constants. This is obviously a simplification of a complex reality, made necessary in the first step of the fishery biology development. Nowadays we must needs improve our knowledge on this topic: fishermen observe that many species become rapidly unavailable to a fishing gear although they are not overexploited. Fish will learn and then change its behaviour when the known gear or fishing boat is detected. Learning may introduce a serious bias in the results of production models based on the assumption that fishing yields are proportional to abundance.

With the goal of estimating the effect of fish behaviour on the results of fishery research, and particularly on stock assessment in tropical areas, the program EICHOANT was developed in 1986 in the Caribbean area. For the time being, EICHOANT (Evaluation of the Behaviour Influence on Fishery Biology and Acoustic Observations in Tropical Open Sea) concerns the island of Martinique (French West Indies) and the oriental part of Venezuela where the program is developed in cooperation with FLASA (La Salle Foundation of Natural History).

Off the coast of Venezuela, a seasonal upwelling allows the presence of a large stock of *Sardinella aurita*, but induces a low water transparency permitting only observation with acoustic devices. Around Martinique, some bays provide good working conditions (high transparency, low current, protection from the wind) allowing the installation of a "mesocosm" for visual and acoustical observations. This installation (fig. 2) consists of a 70 m diameter, 15 m height circular net, set on shallow grounds. Small pelagic schools, from 100 kg to 5 metric tons, are encaged in the net. Underwater camera, aerial camera as well as vertical and horizontal sonars are used to observe and quantify school behaviour.

Preliminary information has been collected on a small school (100 kg) of *Harengula jaguana* and *Decapterus punctatus* in Martinique. In Venezuela, the same equipment has been used to observe a 5 ton school of *Sardinella aurita*. The sound attenuation within schools mentioned by Olsen[10] can be studied in detail from specific schools already well-described. Otherwise, this installation can be used to study the influence of external parameters related to scientific surveys or to fisheries, and to quantify them.

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Fig. 1 Measured changes of relative densities inside a fish school due to avoidance from a research vessel.

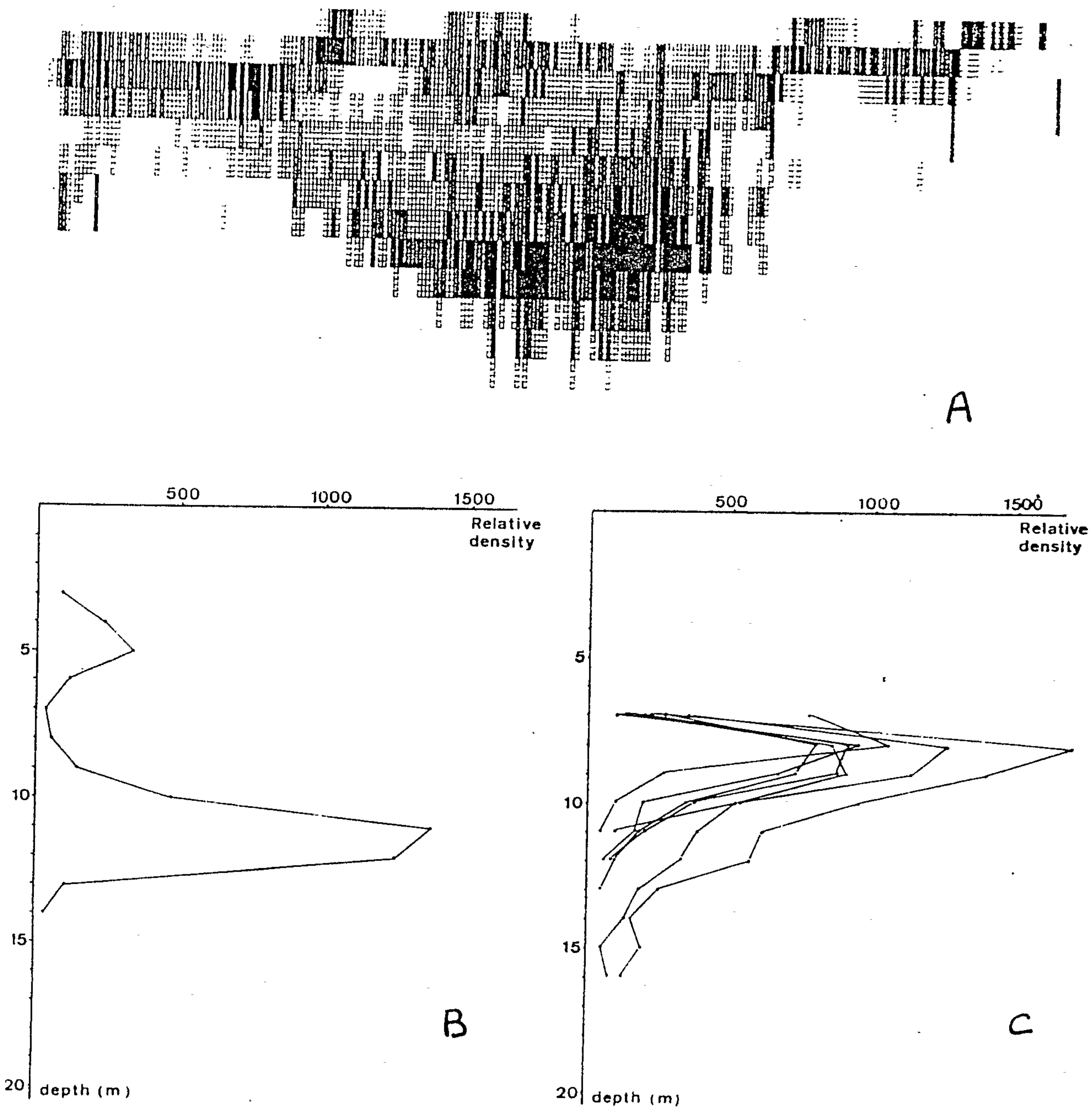
a, Diagram of the vertical structure of density in a non-disturbed school of sardine, Sardinella aurita. The image of the school is obtained by a 70 khz vertical echo-sounder fixed on a small drifting raft, each transmission of the sounder is processed separately through an echo-integrator. The 265 successive transmissions were recorded during the passage of the school beneath the transducer. They are presented on the figure from right to left. Up to 13 horizontal one meter layers are individualized.

b, Mean densities in one meter horizontal layers (relative values) for the same non disturbed shool as in a.

c, Mean densities in one meter horizontal layers of several sardine schools disturbed by a vessel passage.

Figure 2. Diagram of the field experimental installation.

1 multibeam sonar
2 aerial video camera (blue-print stage)
3 vertical sonars and video cameras
4 horizontal video cameras
5 boat (12 m) for assistance and observation
6 instrumented raft (6x3 m)
7 helium balloon (blue-print stage)
8 purse-seine (diameter: 70 m; height: 15 m; mesh-size: 10 mm)


A
500
1000
1500
Relative density
5
10
15
20
depth (m)
B
500
1000
1500
Relative density
5
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15
20
depth (m)
C

Fig. 1.

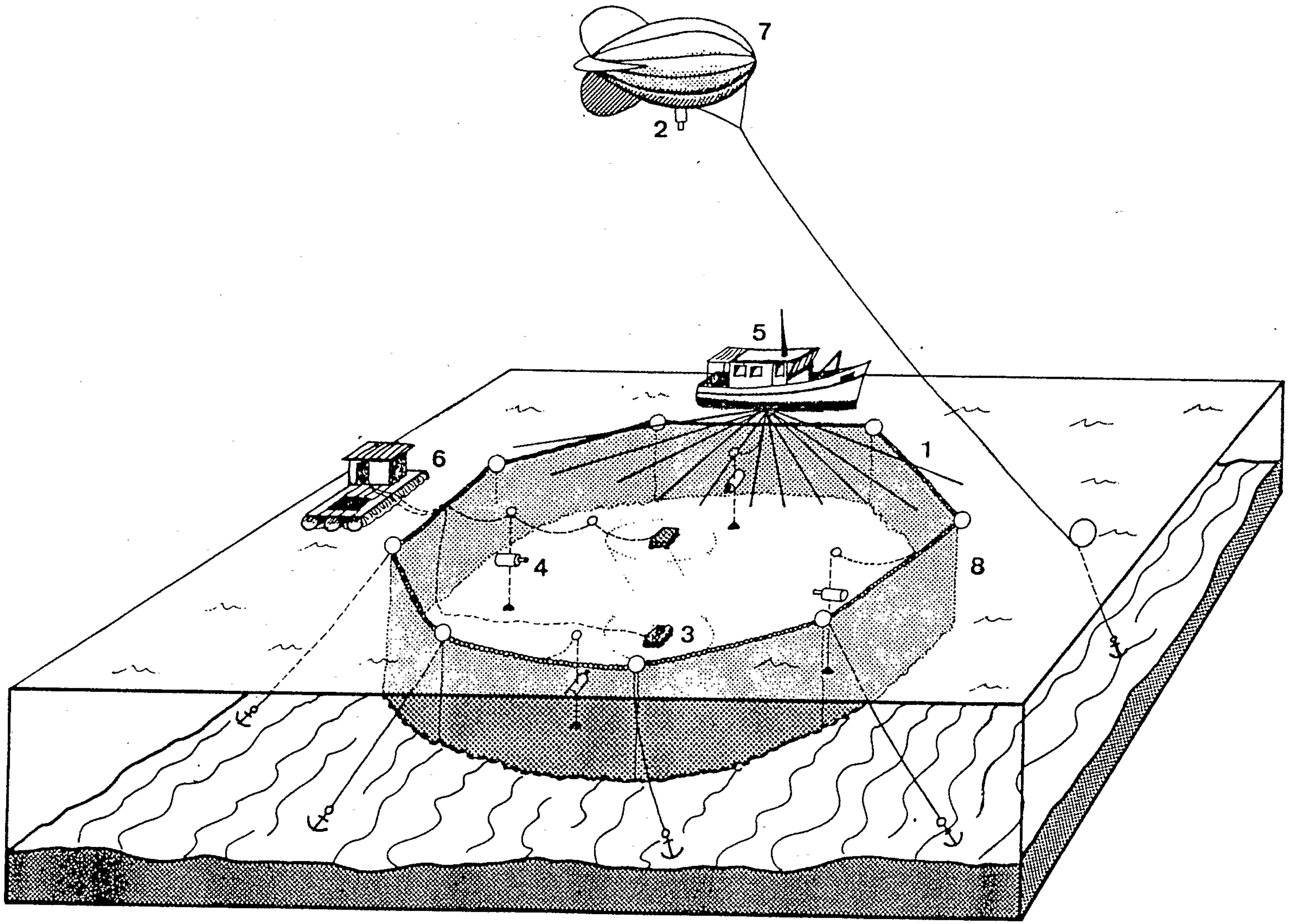

Fig. 2.