Scientia Marina

Acoustic observations in the Bay of Biscay: Schooling, vertical distribution, species assemblages and behaviour*

JACQUES MASSÉ

IFREMER, B.P. 1105, 44311 Nantes Cedex 03, France.

SUMMARY: Eight acoustic surveys were carried out in the Bay of Biscay, during 1989-94, to study the distribution and abundance of anchovy (*Engraulis encrasicolus*, L.) in that area. Acoustic data were stored using the INES/MOVIES acquisition and processing system. Species-specific distribution patterns were confirmed through complementary sampling with a mid-water trawl. This paper summarises the combination of technical procedures used for acoustic assessments, and the results of acoustic surveys in the Bay of Biscay that pertain to the dynamics of this stock. Information is presented on the distribution and abundance of anchovy and co-occuring species, and on the movement patterns detected within the pelagic fish community, in relation to environmental conditions. A comparative analysis of the vertical distribution of echo traces revealed some species-specific preferences. Beyond the stock-assessment possibilities, experiments showed that acoustic survey methods can provide considerable knowledge used for ecological research.

Key words: Acoustic, anchovy, *Engraulis encrasicolus*, schooling, pelagic, behaviour, Bay of Biscay.

RESUMEN: Observaciones acústicas en el golfo de Vizcaya: Bancos, distribución vertical, asociación de especies y comportamiento. – Entre los años 1989-1994 se llevaron a cabo ocho campañas acústicas en el Golfo de Vizcaya, para estudiar la distribución y abundancia de la anchoa (*Engraulis encrasicolus,* L.) en esa área. Los datos de acústica se almacenaron utilizando el sistema de adquisición y proceso INES/MOVIES. Se confirmaron los patrones de distribución de cada especie a partir de muestreos complementarios con una red pelágica. Este trabajo sumariza la combinación de procedimientos técnicos usados para evaluaciones acústicas, y los resultados de las campañas acústicas en el Golfo de vizcaya que pertenecen a la dinámica de ese estock. Se presenta información sobre la distribución y abundancia de la anchoa y las especies que co-habitan y sobre los patrones de movimiento detectados en la comunidad de peces pelágicos, en relación con las condiciones ambientales. El análisis comparativo de la distribución vertical de los ecogramas revela algunas preferencias específicas. Más allá de las posibilidades de evaluación de estocks, los experimentos muestran que las campañas con métodos acústicos proporcionan conocimientos considerables utiles para la investigación ecológica. (Traducido por los editores).

Palabras clave: Acústica, anchoa, *Engraulis encrasicolus*, bancos, pelágicos, comportamiento, Golfo de Vizcaya.

INTRODUCTION

Anchovy (*Engraulis encrasicolus*, L.) is characterised by a short life span, no clearly defined stock/recruitment relation and substantial year-to-

year variation in distribution and abundance. During the last ten years, anchovy became subject to intense investigation by fishery biologists in the Bay of Biscay and the Mediterranean Sea. Because of the difficulty of relying on commercial catch statistics for assessment purposes, direct assessment methods were used by French and Spanish scientists to determine stock size in the Bay of Biscay from 1989 to

1992. Annual acoustic and egg production surveys were carried out each year, and both indicated similar trends in abundance from year to year.

Ongoing acoustic surveys conducted since 1993 were designed to provide a better understanding of the pelagic system dynamics through the monitoring of fish and plankton distribution, hydrobiological conditions and biological productivity. One of the primary objectives was to identify factors responsible for variation in anchovy abundance and distribution.

Over the years, technological progress in acoustic methods lead to more accurate and complete information on the distribution and abundance of anchovy, and on the spatial organisation and behaviour of pelagic fish in relation to environmental conditions. The aim of this paper is to summarise all observations made during acoustic surveys in the Bay of Biscay that pertain to the dynamics of this stock.

THE ACOUSTIC SURVEYS

Medium term series

Since 1983, at least one acoustic survey was carried out each year in the Bay of Biscay (except in 1988) on board R/V THALASSA. Until 1987, the EIGAS surveys ('Echo-Intégration dans le golfe de Gascogne') were carried out to study the distribution of pelagic species in this area during different seasons, and to assess the reliability of multispecific acoustic assessments. The methodological and biological results of these surveys were synthesised by Massé (1988), who showed that the pelagic species distributions fluctuated substantially, but that coherent structures occured among certain assemblages of species.

To assess the abundance of anchovy stock in the Bay of Biscay, annual surveys were carried out from 1989 to 1992, during April at the beginning of the spawning season. These surveys were part of the DAAG program ('Distribution et Abondance de l'Anchois du golfe de Gascogne'). Within the framework of an EEC research program (FAR n° MA 2495), a collaboration was established between Spanish and French scientists to compare relative indices of abundance provided by acoustic and egg production surveys. These were conducted in April each year in the south end of the Bay of Biscay along transects perpendicular to the isobaths

between 25 and 200 m, with a spacing of ten nautical miles (Fig. 1). A midwater trawl was used to identify the echo traces whenever shoals shapes and distribution changed.

The major finding of this study concerned the coherence of the two methods. Similar abundance trends were observed, particularly in terms of the number of one year old anchovy, which is commonly considered as the recruitment index for this population (Motos, 1994; Motos and Santiago, 1990; Motos et al., 1991, 1992, 1993). Since the two methods indicated parallel trends, both methods were considered suitable to monitor stocks of anchovy. This study also confirmed that anchovy recruitment can fluctuate by a factor of 1 to 10, as had been hypothesized through the cursory examination of trends in commercial catches.
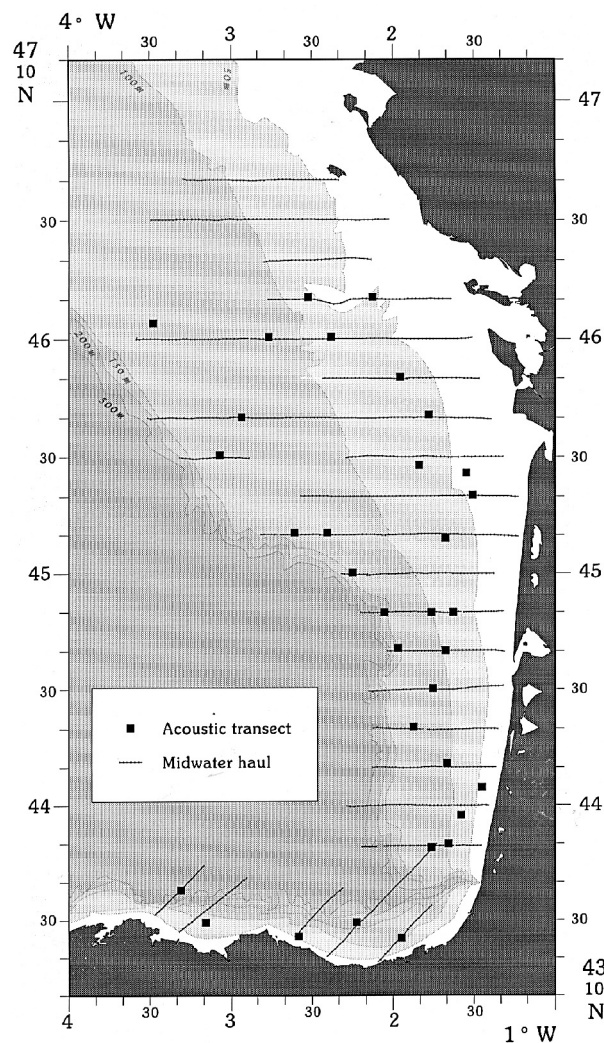

FIG. 1. – Approximate location of acoustic transects and midwater hauls conducted during the DAAG an ERAG surveys in the Bay of Biscay.

Two new surveys were carried out in June 1993 and 1994 during the peak of spawning. These surveys were part of the ongoing ERAG program (for Ecologie et Recrutement de l'Anchois dans le golfe de Gascogne). The main objective of this new program was to identify factors that could be responsible for recruitment variation through the monitoring of hydrobiological conditions in relation to adult and larvae distribution. The 1993 survey results were not used for this analysis since the sampling strategy was different than that of 1994 and not suitable for studying the detailed distribution patterns.

Methodology progress

Since the 1970s when acoustics began to be used to assess fish biomass, target strength (T.S.) definition has been the main concern of the scientific community. Several studies were conducted on this issue (see review by Mac Lennan and Simmonds, 1992) which lead to the development of sophisticated systems to get the best T.S. estimates. Nevertheless, it is possible to consider target-strength/length relations as constant when relative indices are concerned. Wrong target strength may induce considerable bias in absolute biomass assessments, but it is also recognised that a poor identification of echo-traces can be a major source of error.

Generally in the Bay of Biscay, as in Mediterranean sea, several species of pelagic fish are present in a same area. Even if precise specific target-strength/length relations are defined, it is essential to assign each echo to a given species. Therefore, the first priority was to focus on species identification from echo-traces rather than on T.S. analysis.

With this aim in view, a new echo-sounder data processing system (INES-MOVIES, see Diner *et al.*, 1989) was developed to digitise and store acoustic and navigation data during a survey and perform echo-integration in real time. Since 1989, all acoustic and navigation data collected during our surveys were stored, and it is now possible to re-analyse all data as new processing software becomes available. A first use of this system was to improve acoustic assessments by discrimination of pelagic shoal types according to species (Massé and Rouxel, 1991).

The OEDIPE custom software develloped by IFREMER was used to sort and map the computed acoustic data and the species distribution obtained from mid-water catches. This allowed for the strat-ification of the surveyed area by presence/absence of certain species and/or echo-traces, and estimate the mean scattered energies detected along the transects.

To optimise the species identification and sampling strategy, efforts were made to assess the effects of the number and location of trawl samples and acoustic transects on the estimates of abundance (Massé and Retière, 1995). When mixed populations are concerned, no objective method is available to identify the species from echo-traces, so mid-water trawl samples are generally obtained to determine the proportion of the total echo energy due to each species and their size composition (MacLennan and Simmonds, 1992).

Since acoustic data were available at a very fine spatial scale (one sample every 10 cm depth for each ping), new software (MOVIES-B, see Weill *et al.*, 1993) was developed to characterise fish aggregations and particularly shoals according to various morphological, energetic and temporal/spatial distribution factors. This software was then used to characterise fish aggregations in relation to species, and to identify shoals according to several factors (Scalabrin *et al.*, 1994). Independently of these particular uses, all these tools served to describe the pelagic fish community with regard to the availability of resources, their organisation in space, and their behaviour (Scalabrin and Massé, 1993).

ACOUSTICS AND ECOLOGY

Ideally, to assist fishery managers, acoustic surveys should provide information on stock size, distribution, migration patterns, and the stock availability to the fishery. These four factors influence the susceptibility of the stock to exploitation, so better monitoring of such factors could in theory lead to better management practices. The acoustic method can be used to monitor these four factors in a very short time, and help to obtain an accurate picture of a pelagic fish community in a wide area. Data collected during the DAAG and ERAG surveys were processed rapidly by analysing the horizontal and vertical distribution of adults in relation to environmental conditions and species specific behaviour. Substantial effort was also made to understand how anchovy share space with other pelagic species through an analysis of aggregation patterns.
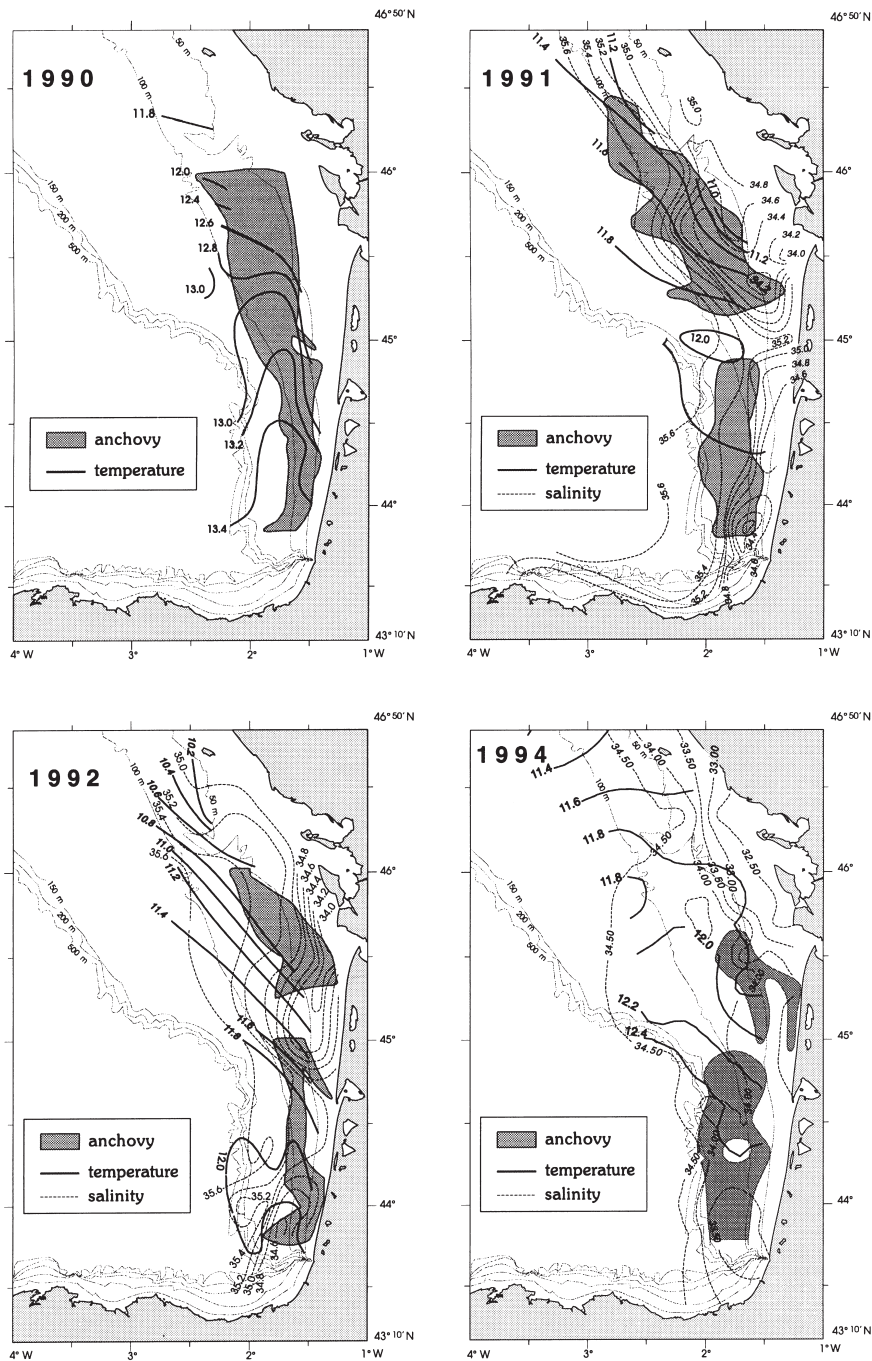
FIG. 2. – Horizontal distribution of adult anchovy based on acoustic survey and pelagic hauls results. Environmental data are surface salinities and temperatures at 50 m depth.

Horizontal distribution

From the DAAG and egg surveys carried out in the Bay of Biscay, three main spawning grounds were defined : the first one under the influence of Gironde freshwater plume, the second one close to the continental shelf break called "*Fer à cheval*" and the third one in the southern end of the Bay of Biscay near the Adour river.

Echo densities mapped along the transects were stratified with OEDIPE software according to species as observed in midwater trawl catches. Surface temperatures were continuously monitored and temperature/salinity profiles throughout the water column were monitored periodically with CTD sounding devices along each transect. Figure 2 presents the environmental isolines and the associated anchovy distribution.

Each year changes are observed in the distribution of adult anchovy, around 45° N where often a discontinuity appears (Massé *et al.*, 1995). This boundary generally corresponds to a temperature gradient between the Gironde brackish water and a southern water mass affected by the Adour River outflow. Adult anchovy seem to be preferentially concentrated under the Gironde River brackish water. This observation is less pronounced in the southern end near the Adour River.

Vertical distribution

Shoal shape and vertical distribution were studied to determine the influence of temperature, salinity, and shoal composition (Massé *et al.*, 1995). During day time, anchovy tend to remain below cold and brackish water, but rise to the surface, at night, perhaps to take advantage of high food concentrations (Fig. 3).

Anchovy aggregations are generally detected as small shoals, 5-15 m above the bottom. In 1992, anchovy were observed in the northern area as compact layers close (< 2 m) to the bottom. This behaviour had never been observed previously during acoustic surveys, nor reported by fishermen. However in 1992, the hydrological structure was particularly homogeneous with low salinity water from the surface to the bottom. Further investigations would be required to confirm if this particular structure is responsible for the fish distribution.

Species organisation and behaviour

Survey data on approximately 5500 individual fish shoals detected during the 1994 ERAG survey were analysed with MOVIES-B software (Massé *et al.*, 1996) to determine species-specific preferences, and the influence of species assemblage on the shoal location and shape. Shoals characterisation was
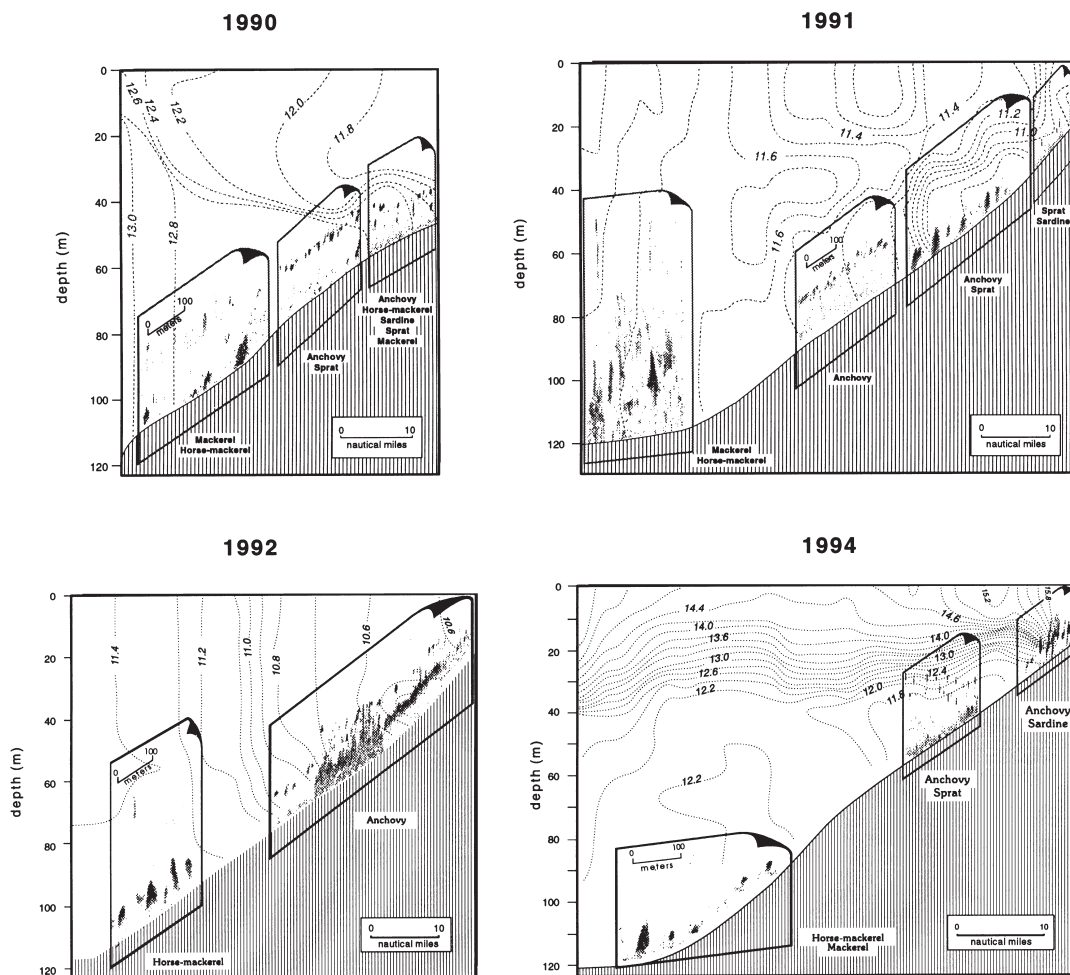

FIG. 3. – Vertical distribution of adult fish based on acoustic surveys and pelagic hauls, and temperatures as observed during surveys along a transect perpendicular to the isobaths, in front of the Gironde.
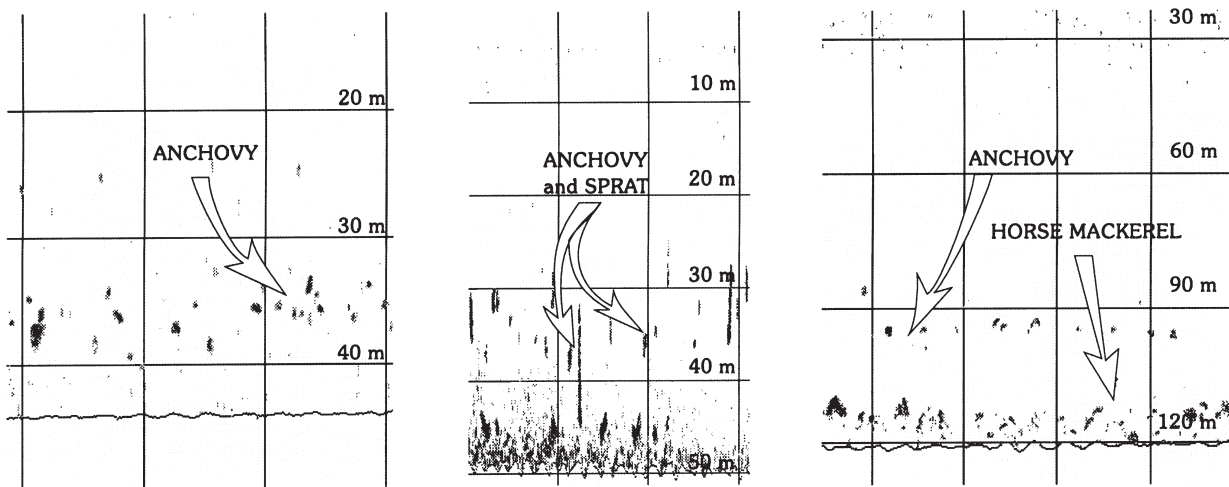
FIG. 4. – Typical echo-traces of mono and multi-species assemblages produced by the INES/MOVIES system using acoustic survey data for the Bay of Biscay.

based on size, morphology, back-scattered energy and spatial distribution. A comparative analysis of the vertical distribution of echo-traces and catch composition revealed some species-specific preferences (Fig. 4).

In the absence of other species, horse mackerel were found predominantly close to the bottom (< 10 m), while anchovy tended to be aligned horizontally approximately 15 m above the bottom.

When horse mackerel and anchovy occupied the same area, they were in separate vertical clusters : horse mackerel still occupy a layer close to the bottom, but anchovy are found 10 m further up than

when alone, or about 25 m above the bottom (Fig. 5). Under such conditions, the back-scattered energy reflected by anchovy shoals is lower. It is hypothesised that this is an indication of greater stress levels within the anchovy shoal.

When anchovy and sprat occupied the same area, no important modification of the vertical distribution was detected. These species have similar mean size and trophic requirements, and most likely exhibit competitive interactions instead of predator-prey interactions. No evidence was obtained to indicate the presence of mono-species shoals, and it is hypothesised that both species can exist in the same shoal.
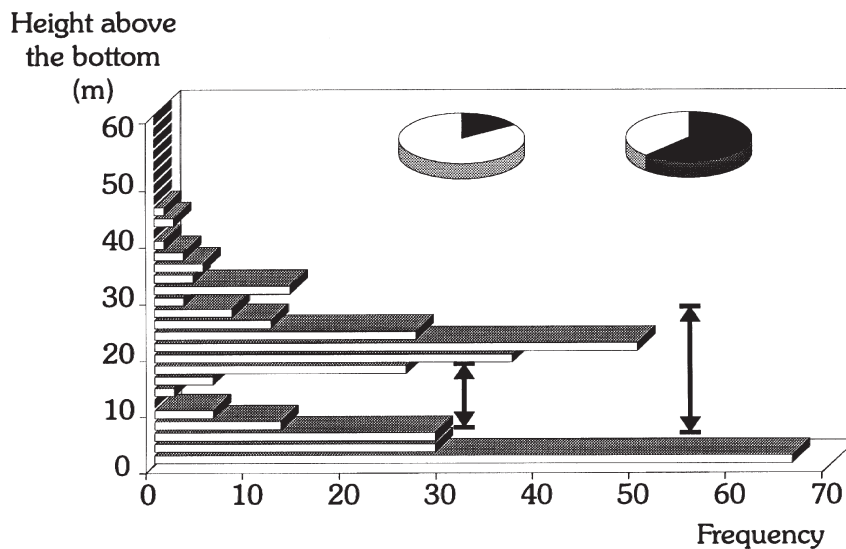

FIG. 5. – Frequency distribution of shoal depths. The deepest mode corresponds to horse mackerel shoals, the shallower one to that of anchovy shoals. Pie diagrams represent the species composition of pelagic hauls made at depth indicated by the arrows underneath each pie. Anchovy and horsemackerel contributions are represented by black and white respectively (from Massé *et al.*, 1996).
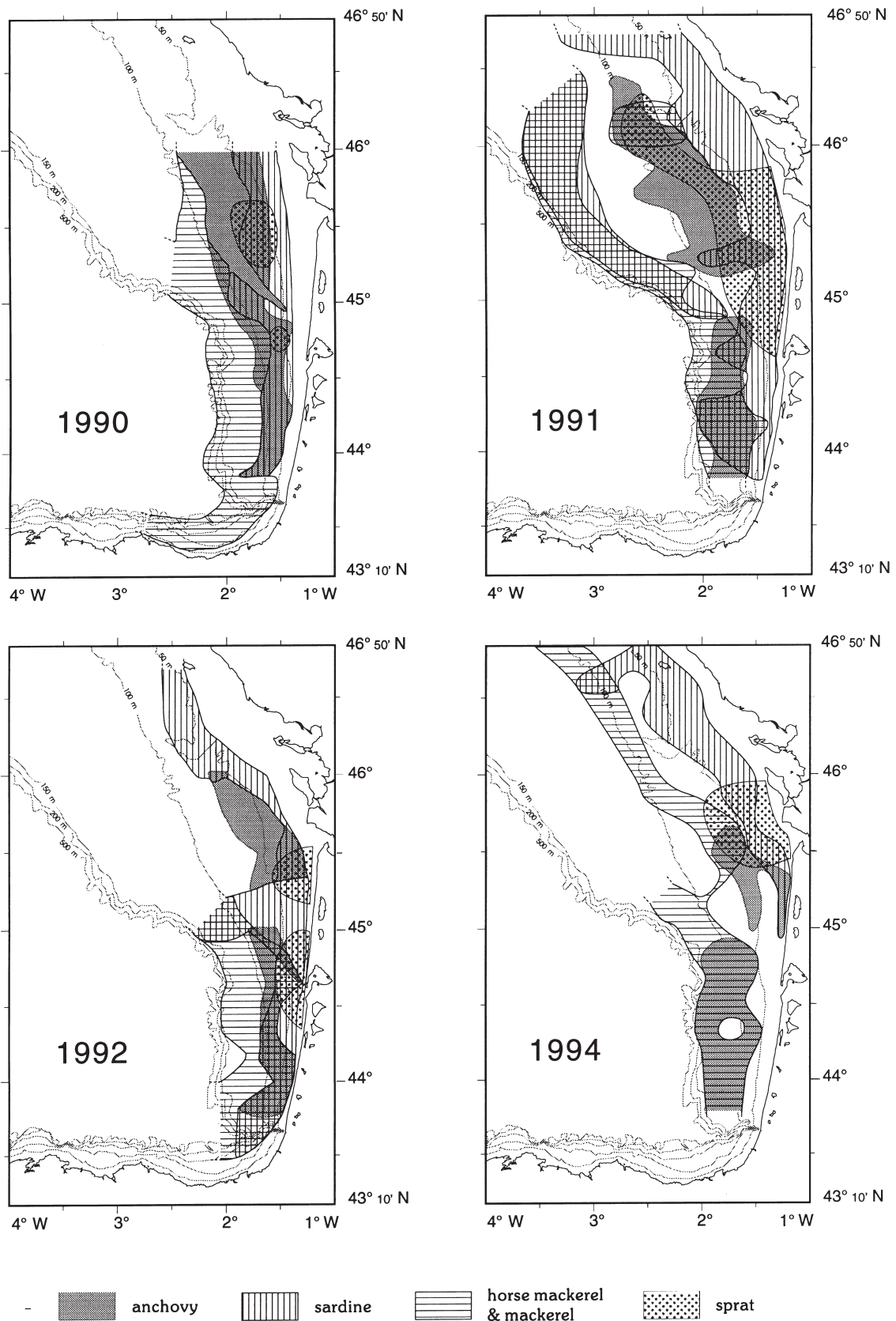
FIG. 6. – Horizontal distribution of sardine, anchovy, mackerel, horse mackerel and sprat as observed during the DAAG and ERAG surveys conducted in the Bay of Biscay.

From the horizontal distribution of species (Fig. 6), geographical space seems to be shared differently from year to year. South of 45° N, anchovy often have to share space with mackerel and horse mackerel. North of 45° N, the distribution of mackerel and horse mackerel varied considerably, and different degrees of overlap were observed. Sardines seem to be present each year along the coast, whereas horse mackerel and mackerel move about to a greater extent. As a result, anchovy may have to share space with other species, and adapt to new conditions by sharing food or defend themselves against predators.

CONCLUSION

Beyond the stock assessment possibilities, these last few surveys showed that acoustic methods can be used to provide considerable knowledge for fishery management purposes. Acoustic methods can be used to make direct observations of the three dimensional structures of populations, and monitor their response to changes in environmental conditions. Acoustic survey methods can also provide census data collected over a large area in a short period with a very fine resolution. It is thus possible to subsequently analyse trends in the demographic traits of a population under different levels of resolution.

Acoustic observations, combined with environmental data collected in different areas or times can be used to compare the characteristics of similar species assemblages under different conditions. This provide more insight into the nature of the factors that govern the distribution of pelagic species during key periods in their life history (such as during spawning events). This approach may lead to a better understanding of the relation between a population distribution and its evolution compared to its environment. Detailed observations of individuals throughout their range may also lead us to adopt alternative views of the pelagic ecosystems structure.

ACKNOWLEDGEMENTS

REFERENCES

Diner, N., A. Weill, J.Y. Coail and J.M. Coudeville. – 1989. INES/MOVIES : A new acoustic data acquisition and processing system. *ICES, C.M. 1989/B:45*

Mac Lennan, D.N. and E. J. Simmonds. – 1992. *Fisheries acoustics*. Chapman and Hall, London.

Massé, J. – 1988. Utilisation de l'écho-intégration en recherche halieutique (analyse des campagnes effectuées dans le golfe de Gascogne de 1983 à 1987). *Rapport IFREMER - DRV-88030*, 155 pp (mimeo).

Massé, J., C. Koutsikopoulos and W. Patty. – 1996 - The structure and spatial distribution of pelagic fish schools in multispecies clusters : an acoustic study. *ICES, J. Mar. Sci.*, 53 : 155-160

Massé, J., C. Leroy, D. Halgand and P. Beillois. – 1995. Anchovy (*Engraulis encrasicolus*, L.) adult and egg distribution in the Bay of Biscay, in relation to environmental conditions, as observed during acoustic surveys (1990, 1991, 1992). *Actas del IV Coloquio Internacional sobre Oceanografia del Golfo de Viscaya*, 1995, pp. 281-283.

Massé, J. and N. Retière. – 1995. Effect of the number of transects and identification hauls on acoustic biomass estimate under mixed species conditions. *Aquat. Living Resour.*, 8: 195-199

Massé, J. and C. Rouxel. – 1991. Improvement in acoustic assessments by discrimination of pelagic schoals with INES/MOVIES system. *ICES,C.M. 1991/B:26.*

Motos, L. – 1994. *Estimación de la biomasa desovante de la población de anchoa del Golfo de Vizcaya,* Engraulis encrasicholus *L., a partir de su producción de huevos. Bases metodológicas y aplicación.* Ph. D. Thesis. UPV/EHU, Leioa.

Motos, L. and J. Santiago. – 1990. An egg production estimate of biomass of the Bay of Biscay anchovy (*Engraulis encrasicholus*, L.) in 1989. *ICES C.M., 1990/H:26.*

Motos, L. and A. Uriarte. – 1991. An egg production estimate of biomass of the Bay of Biscay anchovy in 1990. *ICES CM 1991/H:32.*

Motos, L. and A. Uriarte. – 1992. An egg production estimate of biomass of the Bay of Biscay anchovy in 1991. *ICES CM 1992/H:23.*

Motos, L. and A. Uriarte. – 1993. An egg production estimate of biomass of the Bay of Biscay anchovy in 1992. *ICES CM 1993/H:25.*

Scalabrin, C., N. Diner and A. Weill. – 1994. Automatic shoal recognition and classification based on MOVIES-B software. In: *OCEANS Conference Proceedings, "Oceans engineering for today's technology and tomorrow's preservation"*. Vol. II: 319-324, Brest - France.

Scalabrin, C. and J. Massé. – 1993. Acoustic detection of the spatial and temporal distribution of fish shoals in the Bay of Biscay. *Aquat. Living Resour.*, 6: 269-283.

Weill A., C. Scalabrin and N. Diner. – 1993. MOVIESB: An acoustic detection description software. Application to shoal species classification. *Aquat. Living. Resour.*, 6: 255-267.