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HAKE, MACKEREL AND HORSE MACKEREL DISTRIBUTION OF EGGS AND LARVAE IN RELATION TO GEOSTROPHIC CIRCULATION IN THE BAY OF BISCAY

by

VALDES, L.[1], A. LAGO DE LANZOS[1], A. SOLA,[2] C. FRANCO[1], P. SANCHEZ[2] & P. ALVAREZ[3]

1. Instituto Español de Oceanografia
Laboratorio Oceanográfico de Santander
P.O. Box 240, Santander, Spain

2. Instituto Español de Oceanografia
Servicios Centrales
Avda. Brasil 31, Madrid, Spain

3. Instituto Tecnológico Pesquero y Alimentario
Avda. Satrústegui 8, Donostia, Spain

Abstract

Distribution of hake, mackerel and horse mackerel eggs and larvae in the Bay of Biscay was compared with the geostrophic circulation observed in the surveys carried out in the framework of SEFOS (Shelf Edge Fisheries and Oceanographic Studies) in 1995. Simultaneous observation of fish eggs and larval distribution, temperature, salinity, density fields, and derived geostrophic currents, suggests surface circulation as being the main factor controlling the drift of larvae away from spawning grounds to inshore nursery areas as well as to offshore oceanic waters. In contrast, eggs appear aggregated close to the shelf-break where the target species spawn. Also, other main hydrographic singularities, such as gyre structures associated to the shelf break, are discussed in relation to the possible consequences of retention of fish larvae in the inner platform and to the advection of larvae off the shelf break in the areas where these events were observed.

Introduction

A central theme in pelagic ecology is the identification of the spatial distribution pattern of the species and understanding the causal mechanisms that lead to them. This is particularly important in fish species that spawn offshore and recruit inshore, which is a major cause of variability in marine fish production (Cushing, 1972). The drift from spawning sites to the nursery areas where larvae are retained (Iles and Sinclair, 1982) have been associated to physical characteristics of a region, such as coastal fronts, mesoscale events, and features of circulation (Nakata, 1989; Campana et al., 1989; Herra, 1989; Heath, 1989, etc) and many authors have encouraged active collaboration between physical oceanographers and biologists to attain a better understanding of this field of marine ecology (Koutsikopoulos et al., 1991).

In the Bay of Biscay, the important dynamic features that determine the physical environment include Ekman currents, mesoscale rings, fronts, and the general circulation. This general circulation in the Bay of Biscay area suggests weak clockwise circulation (Pingree, 1993), with seasonal changes in surface layers over the continental shelf and coastal areas. Circulation over the continental slope is prone to become unstable, particularly in the southern part of the Bay of Biscay and over the Armorican shelf, where gyres and fronts develops (Díaz del Río et al., 1992; Sournia et al., 1990).

SEFOS target species (mackerel, horse mackerel, hake and blue whiting) spawn in the vicinities of the slope, and the postlarvae and early juveniles recruit inshore in some areas of the Bay of Biscay, so at some critical time in the early fish stages, eggs and/or larvae must be transported from the spawning areas to nearshore nurseries. Transport away from the spawning grounds to inshore as well as to offshore regions is not well understood, and one of the main aims of the SEFOS project was to detect the hydrographical features that determine the distribution of eggs, larvae, recruits and adults during the spawning season. In this contribution we compare distribution of eggs and larvae with geostrophic circulation in the Bay of Biscay.

Methods

SURVEYS

In 1995 three surveys were performed, the first of which (AZTI-LEBAL 295) took place from 22 to 30 of March, and covered the French coast of the Bay of Biscay, sampling 62 plankton stations. The second (IEO-MPH 395), from 25 March to 15 April, covered the area from Lisbon up to 45°N (Arcachon, France) and a total of 112 samples were collected. The third survey (IEO-SEFOS 595), from 28 May to 18 June, covered the northern Cantabrian area and the west of France, sampling 120 stations (figure 1). In both IEO surveys the sampling grid was designed in accordance with the procedure described by AEPM (Anon, 1994), with cross-shelf transects every 15-30 nm and plankton stations 15 nm apart. In the AZTI survey, plankton stations were located every 10 nm in parallel transects 30 nm apart.

PLANKTON SAMPLING

In the AZTI-LEBAL 295 survey, a Bongo net of 60 cm diameter mounted on a 250 µm gauze was used for plankton sampling in oblique tows. In IEO surveys (MPH 395 and SEFOS 595), plankton sampling was carried out using a Bongo net (20 cm diameter and mesh size of 250 µm) hauled in double oblique tows. In the three surveys the net was hauled to a maximum depth of 200 m, or 5 m above the bottom in shallower water, and tows were made at a ship's speed of 2-3 knots. A depth recorder was fixed to the net cable in order to register the maximum depth reached. A General Oceanics flowmeter was used to determine the water volume sampled. Samples were immediately sorted and counted for target species. Samples were preserved in 4% buffered formaldehyde, and once in the laboratory all fish eggs and larvae were counted and classified to species level. Mackerel and horse mackerel eggs were staged according to Lockwood et al. (1977) and Pipe and Walker (1987) and the larvae of all target species measured to the nearest 0.1 mm for information on length frequency distribution. Abundances were converted to number by square metre following standard techniques (Smith and Richardson, 1977), assuming a 100% filtration efficiency for both nets.

PHYSICAL PROCEDURES

In the three surveys, CTD profiles were obtained at every plankton station using a CTD-SBE25 equipped with pressure, temperature and salinity sensors. 28 CTD casts were obtained in AZTI-LEBAL 295, 112 CTD in IEO-MPH 395, and 120 in IEO SEFOS 595. Water samples were taken for CTD salinity calibrations on every IEO cruise and the AZTI CTD was calibrated before and after the survey. Geostrophic circulation on each survey was derived from dynamic height, which was calculated for every station at 0.2 cm intervals in the 10/100 dbars.

Results

Spawning of SEFOS target species is spatially related to the shelf-break, and early life stages are found throughout the Bay of Biscay during the months of sampling. For this reason, larvae of these species can be used as good tracers for comparing spatial/temporal observations of hydrographic features and larval distribution.

A significant portion of the egg assemblages in the three surveys carried out in the Bay of Biscay in 1995 are made up of SEFOS target species, particularly mackerel and horse mackerel, which account for more than 50% of the total eggs counted in each survey (figure 2). The spatial distribution of eggs is closely related to the area where the females of each species spawn, this being the main reason why eggs appear aggregated close to the 200 m contour line (figure 3). Depending on the species some differences were observed. Mackerel, for example, spawn closer to 200 m depth than horse mackerel and hake, which spawn more over the shelf. This spatial distribution was coherent with the pattern observed by other authors for the same species in this geographical region (Franco et al., 1993; Lago de Lanzós et al., 1993).

As embryonic development of eggs occurs over a period of a few days, 3 to 5 depending on temperature (Ware, 1977; Coombs and Mitchell, 1982) even when residual currents are relatively strong in the Bay of Biscay (approximately 5 cm s^{-1} in March-April), no significant displacement from spawning sites can be observed during the life stand of this developmental stage (figure 4). With respect to this, we should consider that the resolution of our observations is determined by the sampling grid, which was designed with plankton stations 10-15 nm apart, a distance (18-27.8 km) which is in the limit of that expected in 5 days of drifting from the spawning sites at a speed of 5 cm s^{-1} (21.6 km in 5 days).

In contrast to eggs, larvae of the target species remain resident in the plankton until their metamorphosed to juvenile stage which, depending on the development rate, takes about 2 months. During this period larvae can drift away from spawning sites and this movement can be detected. In our results we observed that more than 50% of the larvae stay in the spawning areas and the remainder are transported to both inshore and offshore waters (figure 4). So, although the bulk of the population is retained in the spawning grounds, there is still a significant part of the larvae whose spatial distribution is determined by water displacement.

During the survey LEBAL 295, geostrophic circulation suggests some weak northwards along-shelf current, and hake larvae seem to be retained inshore over the Armorican shelf. Both the circulation and the pattern of larval distribution are coherent with the dominant winds in this region and in this season. Also, the length distribution of hake larvae conform to the observed circulation as the smaller (recently hatched) larvae were found close to the slope and larger larvae were found both in the inner platform and off the shelf break. This latter patch could be related to the mesoscale gyre identified over the Armorican shelf (Bartsch et al., 1996) (figure 4).

Circulation in the central region of the Cantabrian Sea during the survey MPH 395 suggests some eastward transport along-shore and some limited transport offshore. Larval distribution with respect to depth shows some advection of larvae offshore, and the spatial distribution of mackerel larvae also shows a major advection of larvae in the area covered by the Cantabrian Sea, mainly off Asturias. As above, dominant winds during this season conform to the observed circulation and distribution of the larvae in the Cantabrian area. The length distribution of mackerel reflects the main features observed in geostrophic circulation, thus according to the direction of water transport the larger larvae are found offshore. An area of retention is detected in the inner part of the Bay of Biscay, which can also be seen in the geostrophic circulation chart (figure 5).

During SEFOS 595, circulation in the Bay of Biscay is characterized by the gyre structures that cover the whole French platform and the Armorican shelf-break. The gyres determine a retention of larvae within the structures and a displacement of particles in a circular movement. As most of the gyres are located over the shelf, most of the larvae of both mackerel and horse mackerel also appear in inshore waters and the larvae that appear in offshore waters correspond to the plankton stations located off the Armorican shelf-break. The spatial distribution of the abundance of horse mackerel larvae reflects the retention of most of the larvae in inshore waters. Also, the length distribution reproduces the hydrographical structures, and a good agreement between both data sets was found in the Armorican shelf, where the two anti-clockwise gyres are characterized by a distribution of the smaller larvae in the outer boundary of the gyre and the larger ones in the centre of the gyre, which is the contrary than expected. This spatial distribution imply an additional difficulty for the larvae to escape from these structures (figure 6).

Summary

Variability in the distribution of larvae and eggs observed in SEFOS surveys in 1995 can be explained by both the geostrophic circulation dominant during these surveys and by the biological behaviour of the spawning stock, whose eggs appear aggregated close to the 200 m contour line where the females of the target species spawn. This pattern of spatial distribution has been reported previously in the literature. More than 50% of the larvae were found in the vicinities of the spawning areas, and the remainder were found in both offshore and inshore waters depending on the season. The results described above show a good coupling between larval distribution (in terms of both abundance and length distribution) and geostrophic circulation in this geographic region and is also in accordance with the dominant winds in the month of sampling.

Displacement by water currents is a fact of life for all pelagic larvae and has been recognised as one of the major driving forces in fish distribution and recruitment. An inshore distribution of larvae was found in the French area of the Bay of Biscay in both LEBAL 295 and SEFOS 595, where the circulation had retained larvae over the shelf, thus good survival rates can be expected. Meanwhile, off the Armorican shelf and in the Cantabrian area, some larvae are advected from the spawning areas to the open ocean, where high mortality is expected and they may be lost to the population. Nevertheless, these distribution patterns refer to a single year and it must be borne in mind that currents may depend on the season, large scale environmental processes affecting current systems, and local hydrographical conditions. Therefore, more research is required in order to confirm the patterns observed in the SEFOS projects.

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Figure captions

Figure 1.	Surveys carried out in 1995 by Spain within the framework of SEFOS.
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Figure 6.	Mackerel larvae distribution, dynamic heights and larvae sizes in MPH 0395 survey.
Figure 7.	Horse mackerel larvae distribution, dynamic heigth and larvae size in SEFOS 0595 survey.

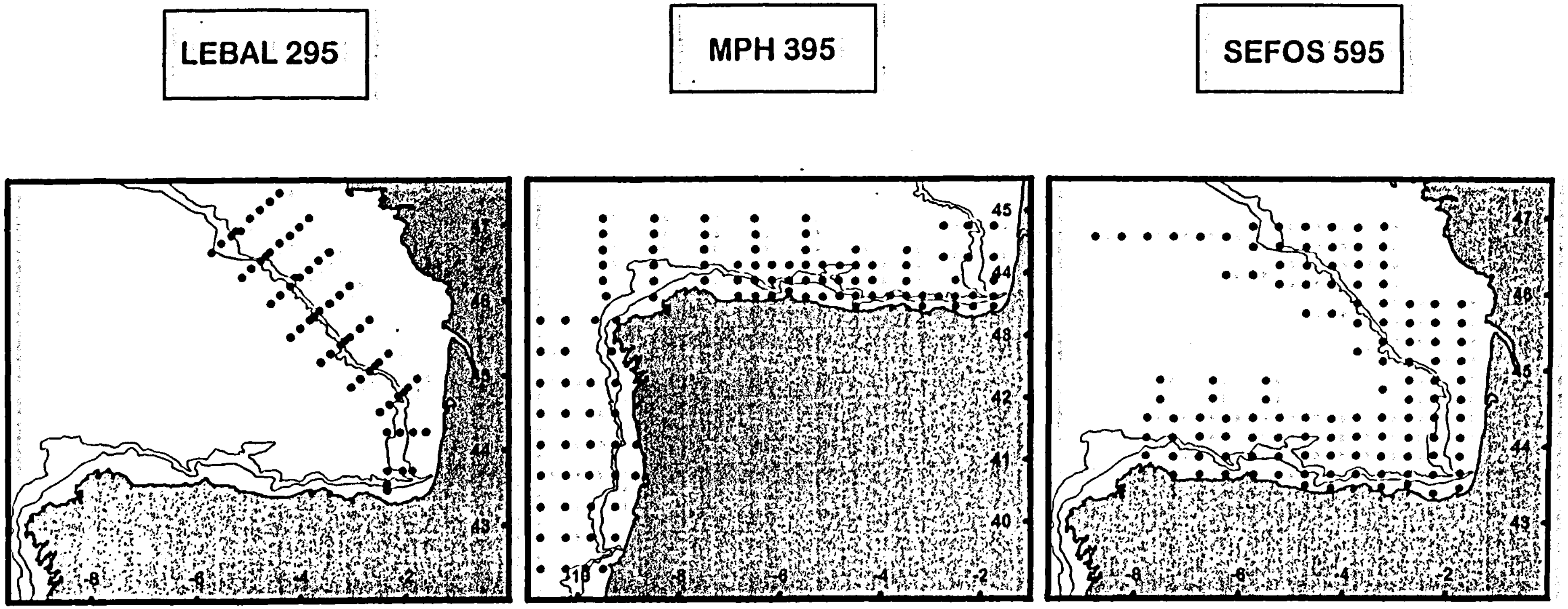

LEBAL 295
MPH 395
SEFOS 595
47
46
45
44
43
-8
-6
-4
-2
45
44
43
42
41
40
-10
-8
-6
-4
-2
47
46
45
44
43
-8
-6
-4
-2

Figure 1

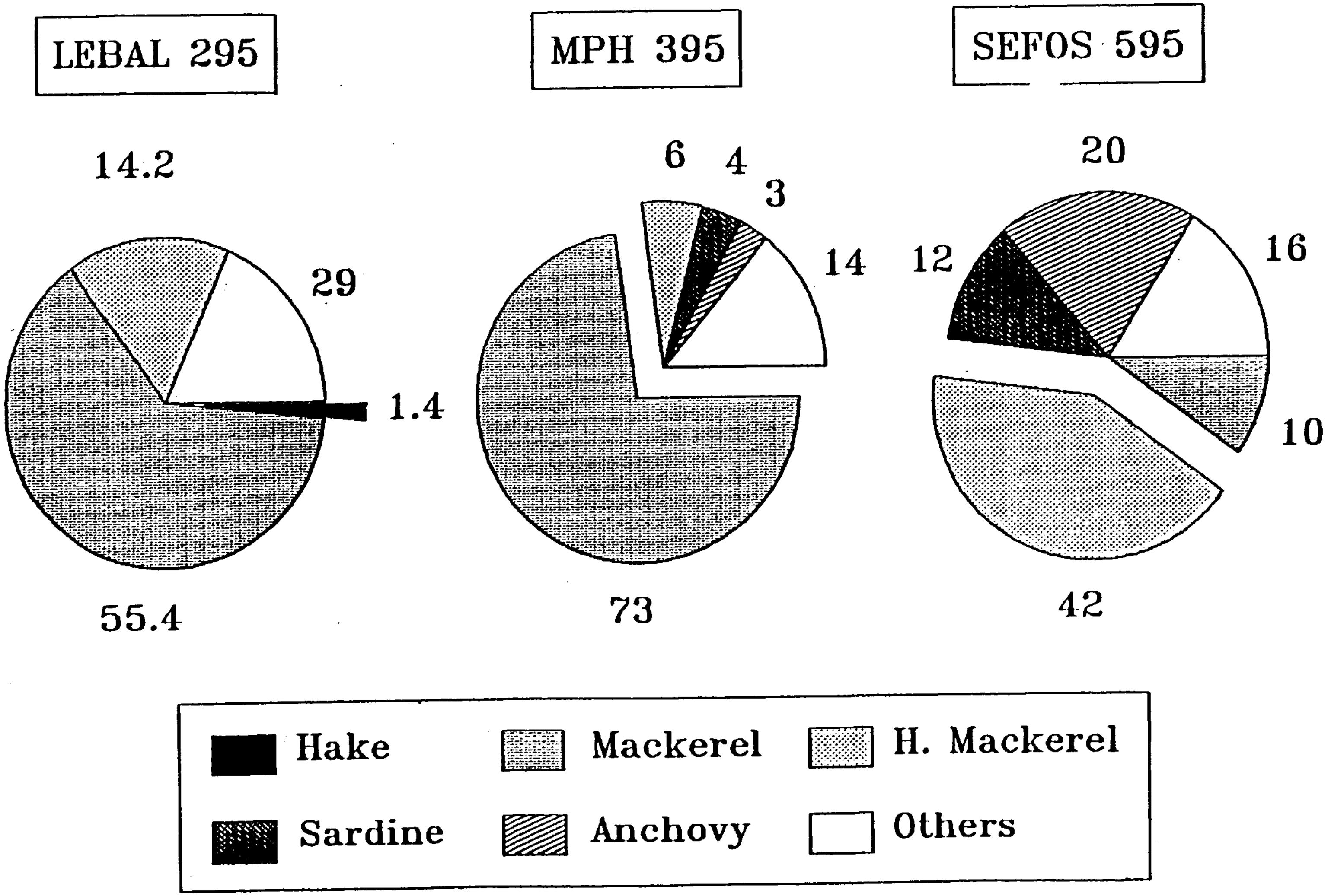
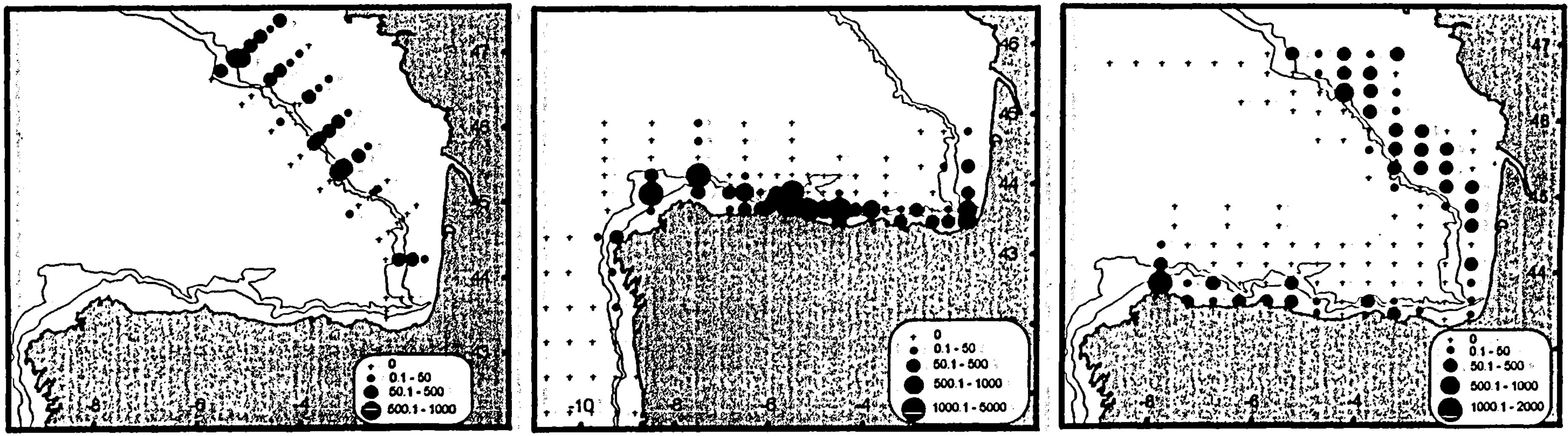

LEBAL 295
MPH 395
SEFOS 595
14.2
29
1.4
55.4
6
4
3
14
73
20
12
16
10
42
Hake
Mackerel
H. Mackerel
Sardine
Anchovy
Others

Figure 2



LEBAL 295

MPH 395

SEFOS 595

Hake egg /10m2

Mackerel egg / m2

Horse mackerel egg / m2

Figure 3

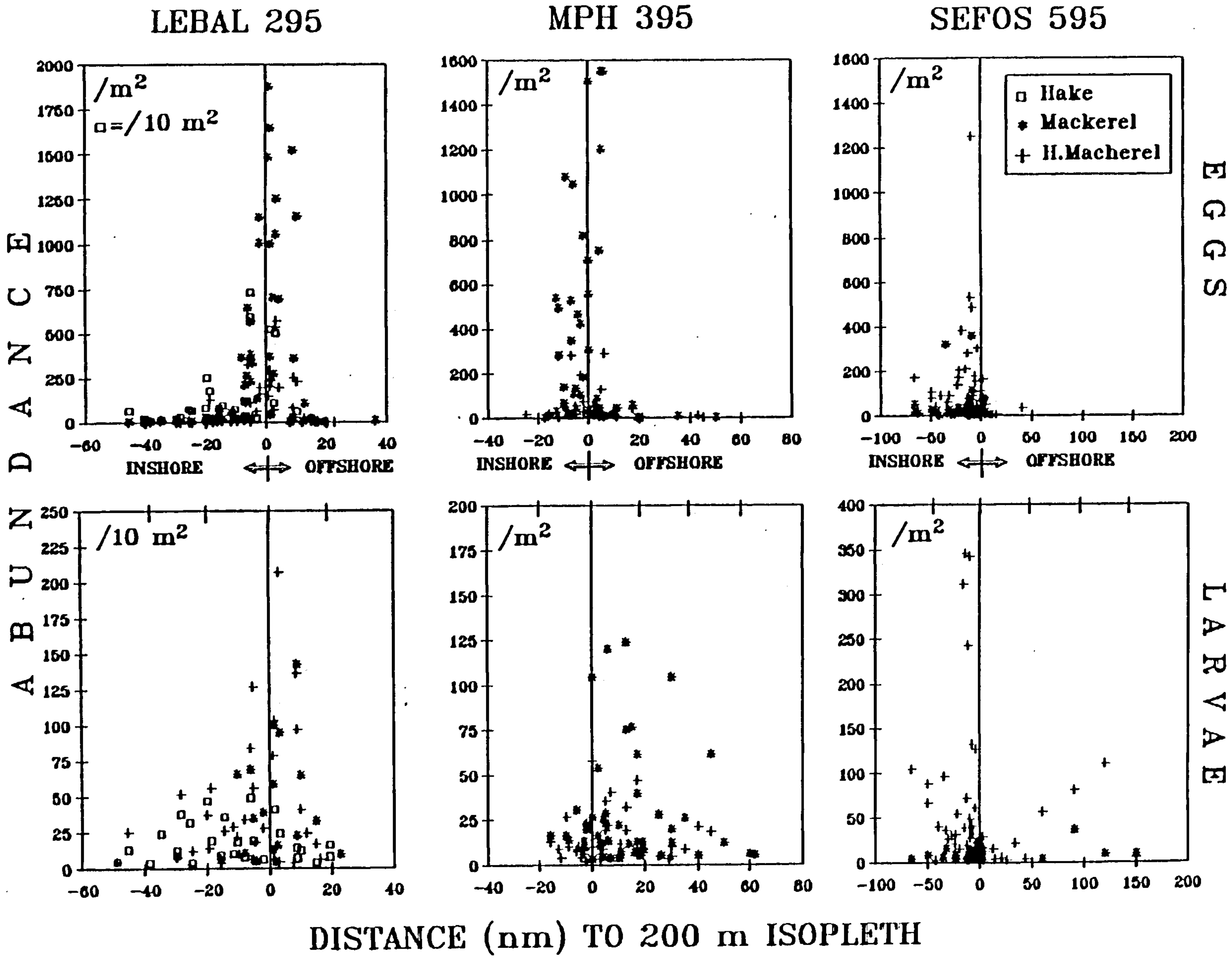

LEBAL 295
MPH 395
SEFOS 595
A B U N D A N C E
E G G S
L A R V A E
/m²
□=/10 m²
/10 m²
□ Hake
✱ Mackerel
+ H.Macherel
INSHORE
OFFSHORE
2000
1750
1500
1250
1000
750
500
250
0
1600
1400
1200
1000
800
600
400
200
0
250
225
200
175
150
125
100
75
50
25
0
175
150
125
100
75
50
25
400
350
300
250
200
150
100
50
-60
-40
-20
0
20
40
60
80
-100
-50
50
100
150
200
DISTANCE (nm) TO 200 m ISOPLETH

Figure 4

LEBAL 295

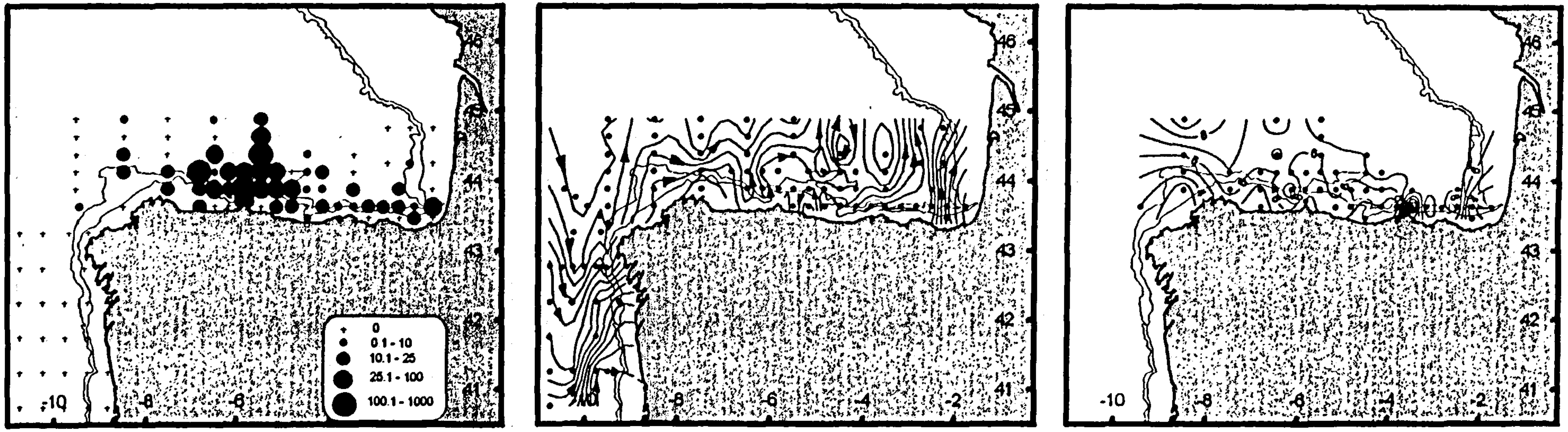
Hake larvae 10/m2

Dynamic heights 10/100 dbars

Hake larvae size (mm)

Figure 5

MPH 395



Mackerel larvae / m2

Dynamic heigths 10/100 dbars

Mackerel larvae size (mm)

Figure 6

SEFOS 595

Horse mackerel larvae / m2

Dynamic heigths 10/100 dbars

Horse mackerel larvae size (mm)

Figure 7