RECENT ADVANCES IN THE STUDY OF
FISH EGGS AND LARVAE
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Spawning and nursery habitat of the wedge sole *Dicologlossa cuneata* (Moreau, 1881) in the Gulf of Cádiz (SW Spain)

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SUMMARY: Ichthyoplankton samples and hydrological data were obtained in an inshore area, between the mouths of the Rivers Guadalquivir and Guadiana (Gulf of Cádiz, SW Spain) during monthly surveys carried out from March 2002 to March 2003. Horizontal and temporal distributions of wedge sole (*Dicologlossa cuneata*) egg and larval abundances were analysed during this annual cycle in relation to environmental parameters. This area proved to be an important spawning and nursery ground for the species, which showed a winter-spring reproductive strategy with a long reproductive period lasting from autumn until early summer. Spawning areas were located in the shallowest waters (above 30 m depth) between the mouths of the Rives Guadiana and Tinto-Odiel, and to a lesser extent in the coastal zone between the mouths of the Rivers Tinto-Odiel and Guadalquivir. The spawning habitat was mainly determined by the distribution of the adults, the bathymetry and the temperature, and a preference for shallow and colder waters was observed. The inshore zone between the mouths of the Rivers Tinto-Odiel and Guadalquivir is the main nursery ground, with the greatest larval concentration and productivity in the area, due to the influence of the River Guadalquivir. The presence of recruits in this area may be linked to these favourable conditions for larval growth and survival.

Keywords: wedge sole, *Dicologlossa cuneata*, gulf of Cádiz, eggs and larvae, spawning, nursery, environmental conditions.

RESUMEN: HÁBITAT DE PUESTA Y CRÍA LARVARIA DE LA ACEDÍA *DICOLOGLOSSA CUNEATA* (MOREAU, 1881) EN EL GOLFO DE CÁDIZ (SO ESPAÑA). – Se tomaron muestras de ictioplancton y datos hidrográficos en una zona costera limitada por las desembocaduras de los ríos Guadalquivir y Guadiana (Golfo de Cádiz, SO de España) durante muestreos mensuales llevados a cabo desde marzo de 2002 hasta marzo de 2003. Se analizaron las distribuciones horizontal y temporal de las abundancias de huevos y larvas de acedía (*Dicologlossa cuneata*) durante este ciclo anual en función de parámetros ambientales. El área de estudio resultó ser una zona muy importante para la puesta y cría larvaria de la acedía. La especie mostró una estrategia reproductiva de carácter invierno-primaveral, con un largo periodo reproductivo que dura desde el otoño hasta el comienzo del verano. Las áreas de puesta se localizaron en las aguas más someras (por debajo de 30 m), entre las desembocaduras del Guadiana y del Tinto-Odiel y en menor medida en la zona costera entre las desembocaduras del Tinto-Odiel y del Guadalquivir. El hábitat de puesta estuvo determinado por la distribución de los adultos, la batimetría y la temperatura del agua, con preferencia por aguas someras y más frías. La principal zona de cría larvaria se localizó en el sector costero entre las desembocaduras del Tinto-Odiel y del Guadalquivir, con las mayores concentraciones larvarias y la mayor productividad del área, debido a la influencia del Guadalquivir. La presencia de reclutas en esta zona debe estar relacionada con las condiciones favorables para el crecimiento y supervivencia larvaria que se dan en la misma.

Palabras clave: acedía, *Dicologlossa cuneata*, golfo de Cádiz, huevos y larvas, puesta, cría, condiciones ambientales.

INTRODUCTION

The important fisheries in the Spanish waters off the Gulf of Cádiz are related to the bathymetric and oceanographic characteristics of its continental shelf and slope. In this area, the Gulf has a wide shelf with relatively warm waters that are enriched with nutrients and chlorophyll (Navarro and Ruiz, 2006). Several processes favour the entrance of nutrients in the coastal areas of the Gulf, such as upwelling events and river discharges. In addition, the alternation between westerlies and easterlies influences the biological production in the basin, since the former cause an increase in chlorophyll concentration. Rainfall and river discharges also have a marked effect on the chlorophyll concentration. Three important rivers, the Guadalquivir, the Guadiana and the Tinto-Odiel, influence this portion of the shelf. Most fishery production worldwide is confined to coastal regions and is associated with three main enrichment processes: coastal upwelling, tidal mixing and land-based runoff including major river outflow (Caddy and Bakun, 1994). Waters under riverine influence provide a rich environment where both physical and biological dynamics may enhance recruitment processes, and therefore the fishery production (Grimes and Kingsford, 1996; Grimes, 2001). Thus, the inshore region between the Guadiana and the Guadalquivir Rivers mouths constitutes a suitable habitat for the spawning and nursery of many species of commercial interest in the area (Baldó *et al.*, 2006; Ruiz *et al.*, 2006). Recent studies have evidenced the important role of the area near the Guadalquivir River mouth as a reproduction area for many commercially exploited species in the Gulf of Cádiz (Sobrino *et al.*, 2005). This spawning and nursery area is so important that it has recently been declared a fishing reserve. It is especially important for the wedge sole *Dicologlossa cuneata*, which constitutes one of the main target species exploited by bottom-trawl and gillnet fisheries in the Gulf of Cádiz (Sobrino *et al.*, 1994; Jiménez *et al.,* 1998). Indeed, the Guadalquivir River mouth has been traditionally considered as the main nursery area for *D. cuneata* in the Gulf of Cádiz (Muñoz, 1972), and recent studies have described this ecosystem as a major spawning, nursery and recruitment habitat for this species (García-Isarch *et al.*, 2003; Sobrino *et al.*, 2005). Apart from this limited area, the importance of the total coastal region between the Guadalquivir and the Guadiana Rivers in the life cycle of this species has been so far unknown.

The spatial and temporal distribution and survival of early life stages of fishes, mainly affected by the environmental conditions, greatly influences their recruitment. Both biotic and abiotic factors are considered to have an influence on the survival of ichthyoplankton, and therefore on the fishery recruitment size.

In this study, we analysed the ichthyoplankton samples collected in the inshore area between the Rivers Guadalquivir and Guadiana during a complete annual cycle in order to describe the horizontal and temporal distribution patterns of wedge sole eggs and larvae and to determine the locations and seasons for spawning and nursery of *D. cuneata* in this area. The aim of the study was to understand how the environmental conditions influence the early life stages of wedge sole during its reproductive season.

MATERIAL AND METHODS

Monthly surveys were carried out from March 2002 to March 2003 on board the vessel *Regina Maris* from the Consejería de Agricultura y Pesca of the Junta de Andalucía. Monitoring consisted of a grid of fixed stations distributed over an inshore area (from 6 to 90 m depth) between the mouths of the Rivers Guadalquivir and Guadiana (Fig. 1). The 26 stations sampled for ichthyoplankton were located in a design of ten transects quasi-perpendicular to the coastline, alternating short transects with 2 stations with longer ones with 3 stations (4 in the case of the transect at the River Guadalquivir mouth). Exceptionally, in the area between the mouths of the Rivers Guadiana and the Tinto-Odiel, two short transects were located between two longer ones, one at each river mouth. Twenty of these stations were at depths above 30 m, in order to achieve a complete sampling of the coastal zone of the study area. Four additional offshore hydrological stations completed transects 1, 3, 5 and 8 (from east to west), constituting a regular sampling grid of 30 hydrological stations.

At every ichthyoplankton station, double-oblique plankton hauls were carried out with a bongo net with a 40 cm mouth diameter and a 200 μm mesh size. All tows were performed at a vessel speed of 2-2.5 knots and to a maximum depth of approximate-

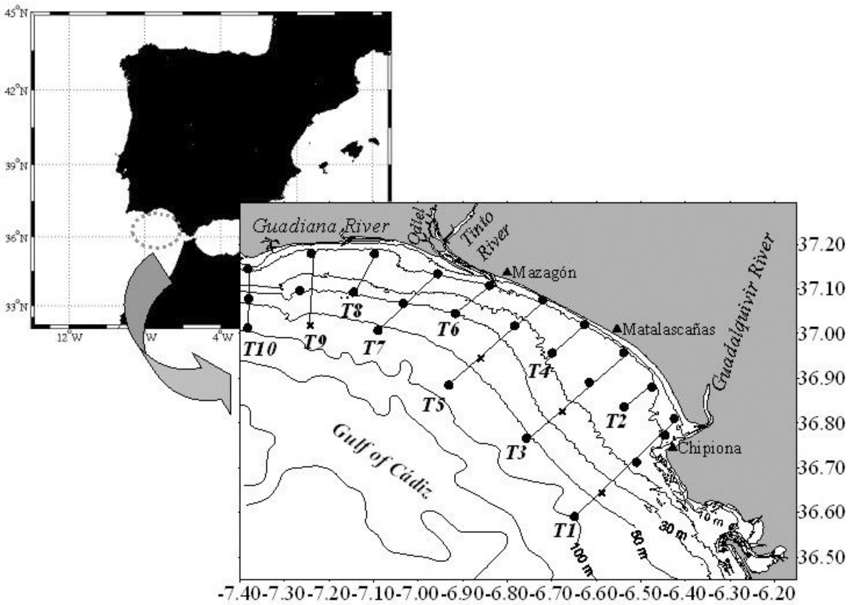

FIG. 1. – Study area in the Gulf of Cádiz showing the sampling stations: (•) stations sampled for ichthyoplankton and hydrology and (×) stations sampled for hydrology.

ly 5 m above the bottom. Two independent "General Oceanics 2030" flowmeters installed in each mouth of the net measured the volume of water filtered. Zooplankton samples were immediately preserved in a 4% buffered seawater formaldehyde solution. One of the samples of each bongo 40 tow was used to estimate mesozooplankton biomass, while the other was used to study the ichthyoplankton. Once in the laboratory, the totality of wedge sole eggs and larvae were sorted from the ichthyoplankton samples, identified and counted using a binocular microscope. The identification of *D. cuneata* eggs and larvae was based on the descriptions of Lagardère (1980) and Lagardère and Aboussouan (1981), respectively. Zooplankton biomass was estimated as sedimented plankton volume. Ichthyoplankton and zooplankton data were standardised to 100 m^3 of filtered water (number of eggs or larvae/100 m^3 and ml/100 m^3, respectively).

CTD (Seabird 19) casts were performed at each of the 30 stations down to about 5 m above the bottom. In addition, discrete water samples for nutrient (30 ml) and total chlorophyll (500 ml) were taken. In the laboratory, nutrients were analysed with a TRAAC 800 autoanalyser. Total chlorophyll was measured with a Turner Design Model 10 fluorometer using standard fluorometric methods (Parson *et al.*, 1984).

Densities of wedge sole eggs and larvae and zooplankton volumes, as well as values of temperature and salinity (5 m depth), bottom temperature, chlorophyll *a* and nitrate, were averaged for all the sampling stations on a monthly basis in order to analyse temporal trends.

TABLE 1. – Dates of surveys. Wind direction (°) and wind speed (km/h) of the prevalent winds and of the stronger bursts during these dates.

		Prevalent winds			Stronger burst	
Survey	Date	Wind direction	Wind speed	Mean wind speed	Wind direction	Wind speed
Mar-02	22-24 March 2002	0-360	8	4-14	40	14
Apr-02	2-5 April 2002	270-314	15.3	7-22	240-270	22
May-02	7-10 May 2002	270-314	16.7	7-29	280	29
Jun-02	11-14 June 2002	90-134	32.8	7-50	120	50
Jul-02	2-5 July 2003	270-314	12.5	7-18	180-290	18
Aug-02	7-10 August 2002	225-270	11.6	7-14	280	22
Sep-02	11-14 September 2002	180-224 / 270-314	9.6 / 10.8	4-18 / 7-14	180	18
Oct-02	9-12 October 2002	270-314	15.3	7-22	310	22
Nov-02	6-9 November 2002	0-45	4.5	0-18	40	18
Dec-02	3-5 December 2002	0-45	4.6	0-14	300-40	14
Jan-03	15-18 January 2003	0-45	3.2	0-11	100	18
Feb-03	17-20 February 2003	270-314	13.6	11-18	290	22
Mar-03	9-13 March 2003	90-134	32	14-58	130	58

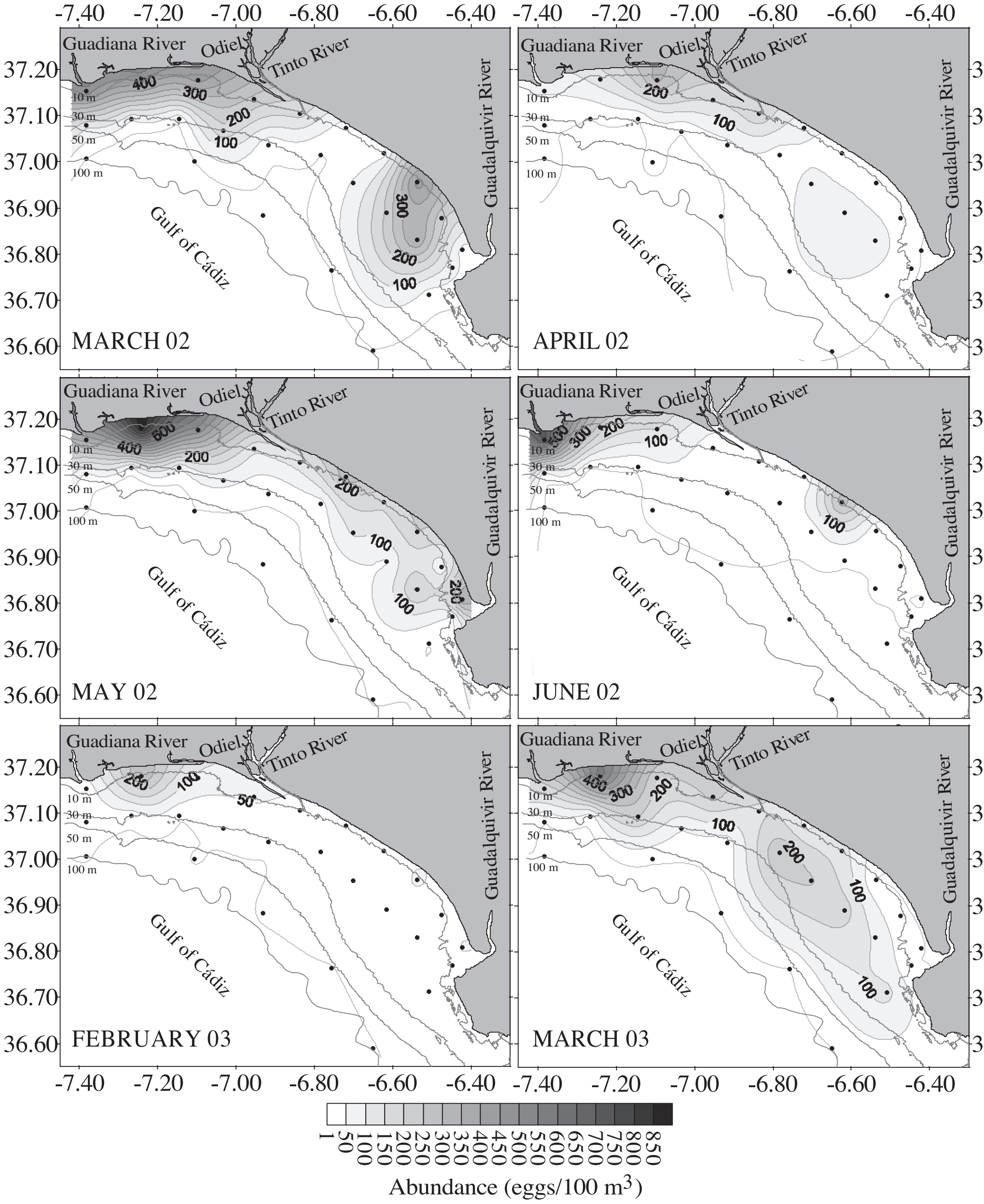

FIG. 2. – Horizontal distribution of the abundance of wedge sole eggs (number/100 m^3) during the main reproduction months.

Distribution maps of the biological and physical parameters mentioned above were drawn for each survey during the main reproductive months by the kriging interpolation method under default settings in Surfer software.

The correlation between the biological and physical parameters (zooplankton biomass, chlorophyll, nitrate, temperature, salinity and depth) and the wedge sole egg and larval densities was explored through a pairwise Spearman rank correlation analysis.

Hourly values for wind vector and daily records of rainfall were obtained from meteorological stations in Cádiz. Guadalquivir discharge data (Alcalá del Río dam discharges) were provided by the Confederación Hidrográfica del Guadalquivir. This dam, located at Alcalá del Río, nearly 100 km from the river mouth, controls the flows of the river waters, which are intensively used for agriculture.

Dates for the different surveys and direction and intensity of the winds predominating during the sampling days are included in Table 1.

RESULTS

Wedge sole eggs and larvae

During the wedge sole reproductive season, eggs were more abundant at the most coastal stations, usually at depths shallower than 20 m and in the western sector, between the mouths of the Rivers Guadiana and Tinto-Odiel (Fig. 2). Highest larval abundance was mainly located in the central and eastern sectors, between the mouths of the Rivers Tinto-Odiel and Guadalquivir, at stations shallower than 30 m depth (Fig. 3). Eggs and larvae were hardly ever found at stations deeper than 50 m depth. Because of this, the mean abundance in the entire sampling area was relatively low, while abundance at the positive stations during the spawning peak months was of the order of 200-500 eggs/100 m^3 (maximum of 878 eggs/100 m^3) and 100-300 larvae/100 m^3 (maximum of 544 larvae/100 m^3). During 2002, wedge sole eggs were mainly collected from March to June, being very scarce or absent

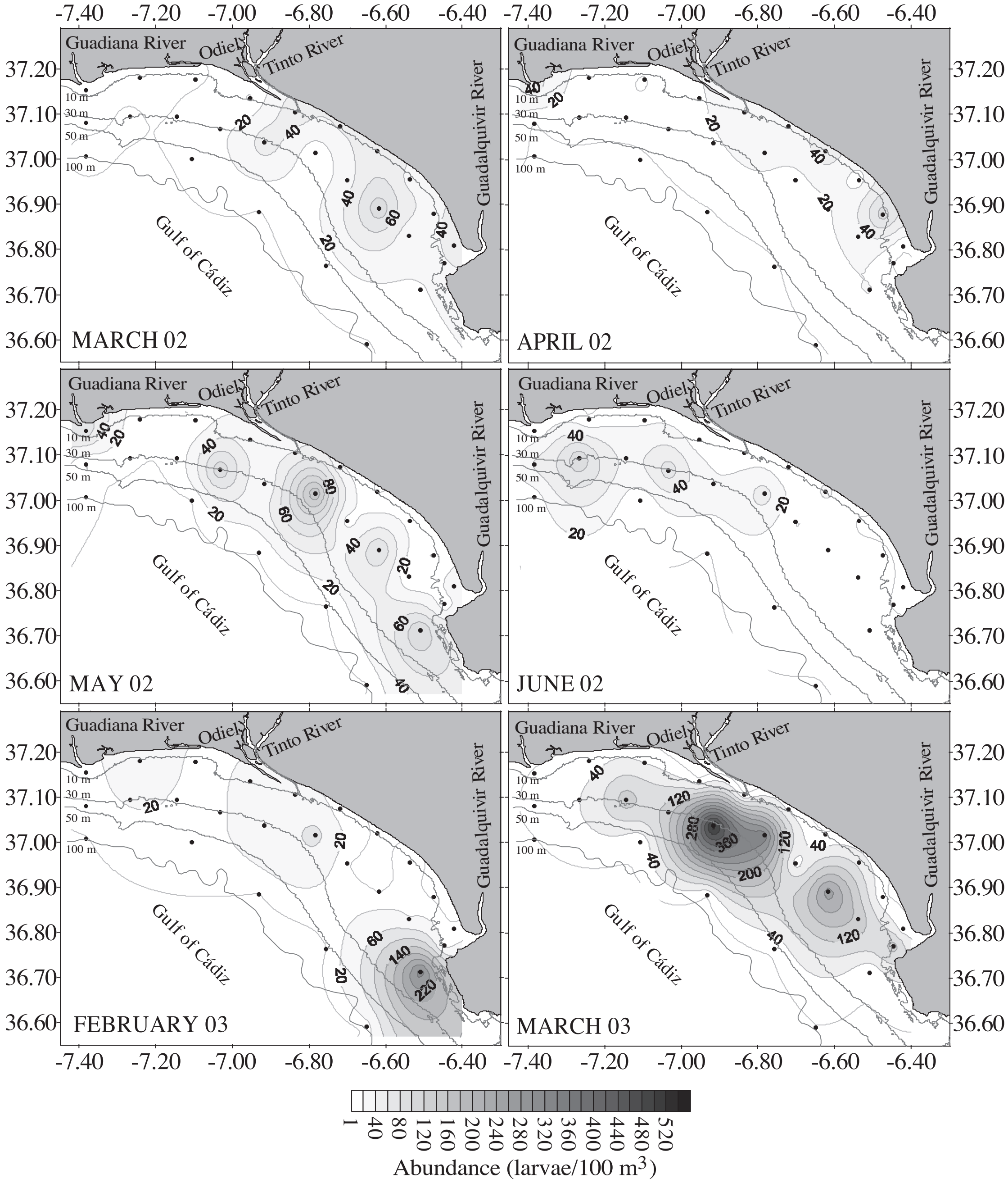

FIG. 3. – Horizontal distribution of the abundance of wedge sole larvae (number/100 m^3) during the main reproduction months.

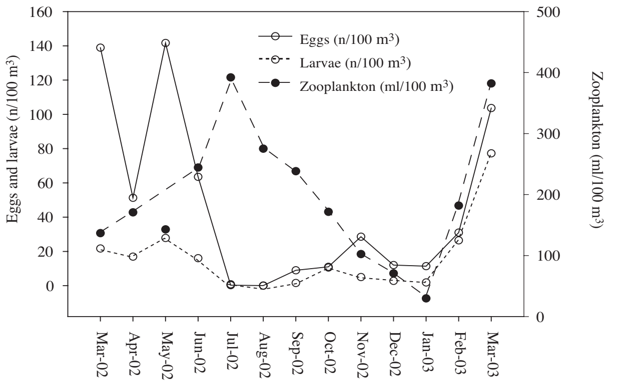

FIG. 4. – Temporal evolution of the mean monthly abundance of wedge sole eggs and larvae (number/100 m^3) and zooplankton (mL/100 m^3) during the period March 02-March 03.

during the summer months, July and August. From September onwards, eggs and larvae were in the plankton but in low densities, increasing in February and March (Fig. 4). The greatest mean eggs densities occurred at the end of winter (March 2002 and March 2003, with monthly mean densities of 139 and 104 eggs/100 m^3, respectively) and in mid-spring (May 2002, with a mean density of 142 egss/100 m^3). The highest larval density was recorded in March 2003, with a mean density of 77 larvae/100 m^3, followed by May 2002, with a mean density of 28 larvae/100 m^3 (Fig. 4). The reproduction period of the wedge sole in the area, based on

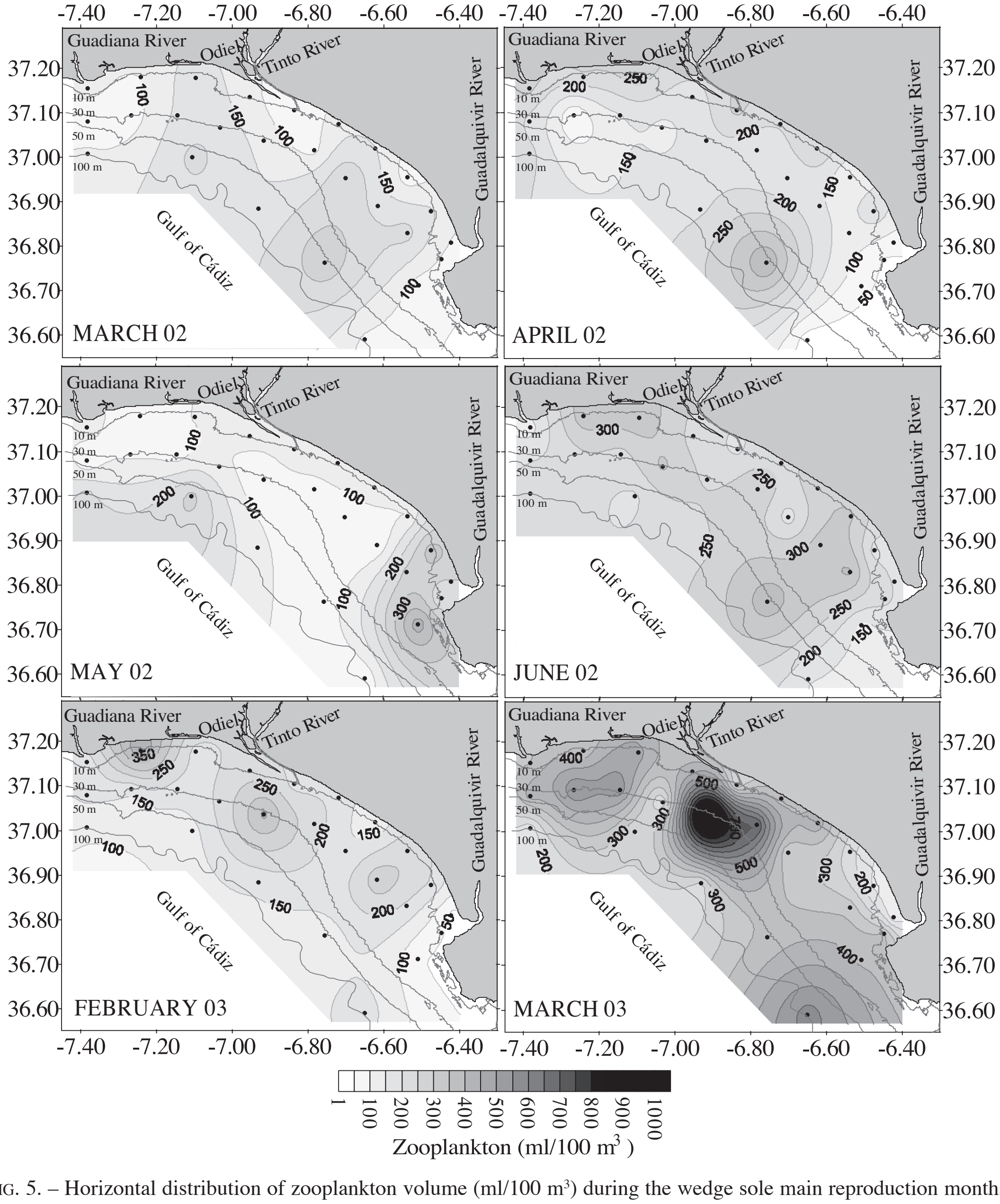

FIG. 5. – Horizontal distribution of zooplankton volume (ml/100 m^3) during the wedge sole main reproduction months.

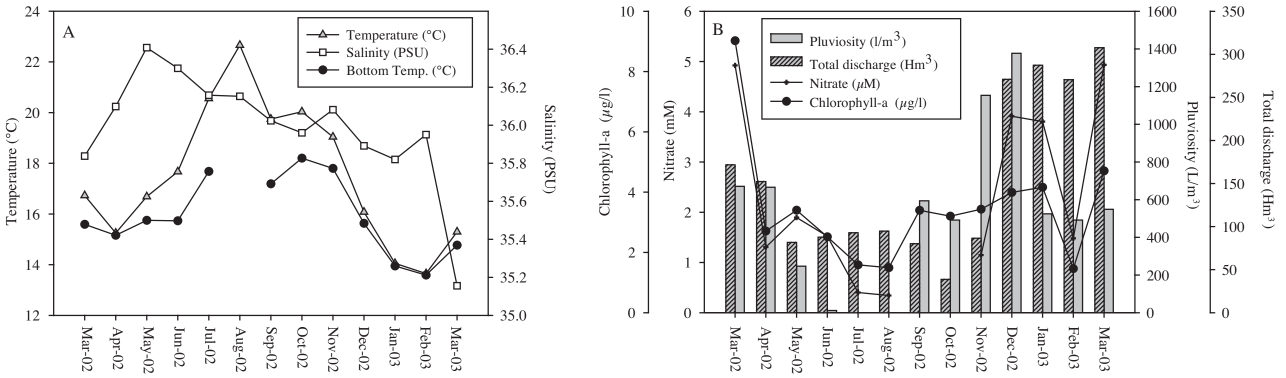

FIG. 6. – Temporal evolution of the mean monthly values of (A) sea surface temperature (ºC), surface salinity (PSU), bottom temperature (ºC), (B) chlorophyll *a* (μg/l), nitrate (μM), pluviosity (l/m^3) and River Guadalquivir discharge (Hm^3) during the period March 02-March 03.

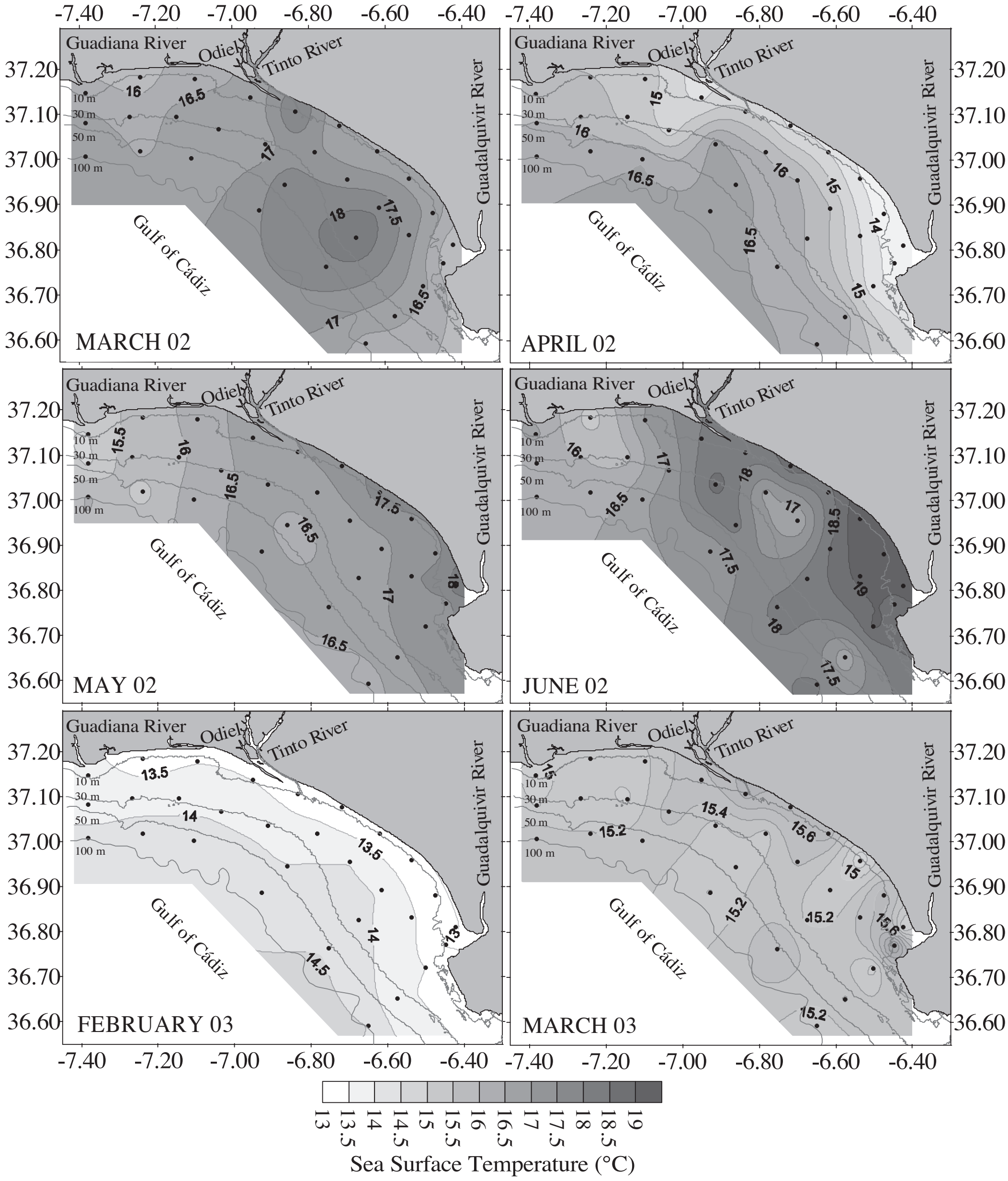

FIG. 7. – Distribution of surface temperature (ºC) at 5 m depth during the wedge sole main reproduction months.

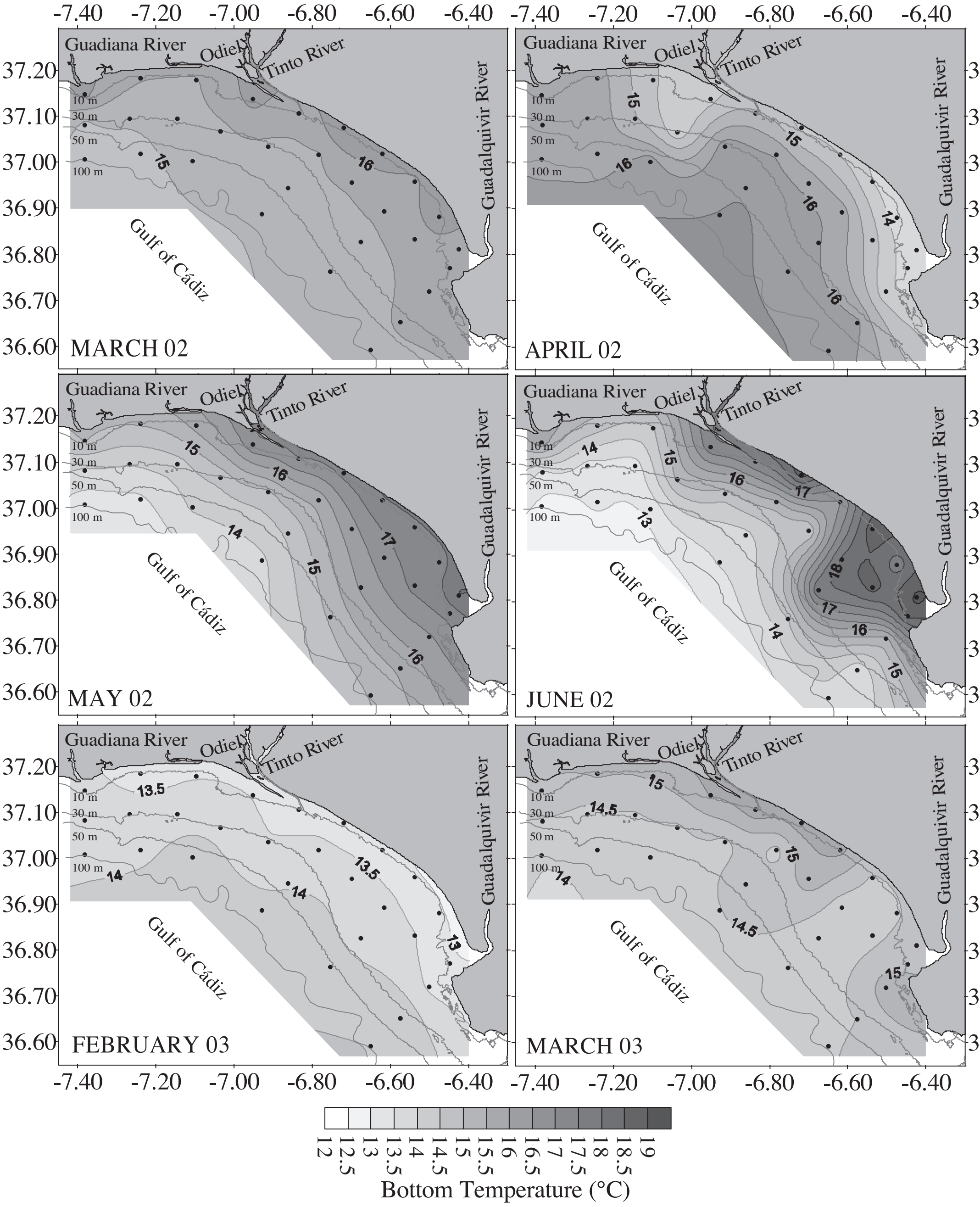

FIG. 8. – Distribution of bottom temperature (ºC) during the wedge sole main reproduction months.

total spawning abundance above 300 eggs/100 m^3, occurred from November to June, with a reproductive peak in March.

Zooplankton

Mean monthly zooplankton biomass levels ranged from mean volumes of 30 ml/100 m^3 in January 2003 to 392 ml/100 m^3 in July 2002 (Fig. 4). From March 2002, zooplankton biomass gradually increased (except for a small decrease in May) until it reached its highest level in July. After this maximum, a gradual diminution occurred, with the lowest values in January, followed by a new rise after this month, peaking again in March 2003.

Although horizontal distribution of zooplankton did not show a coherent pattern in time, the highest concentrations were mainly found in the central and eastern sectors of the study area during the analysed period (Fig. 5).

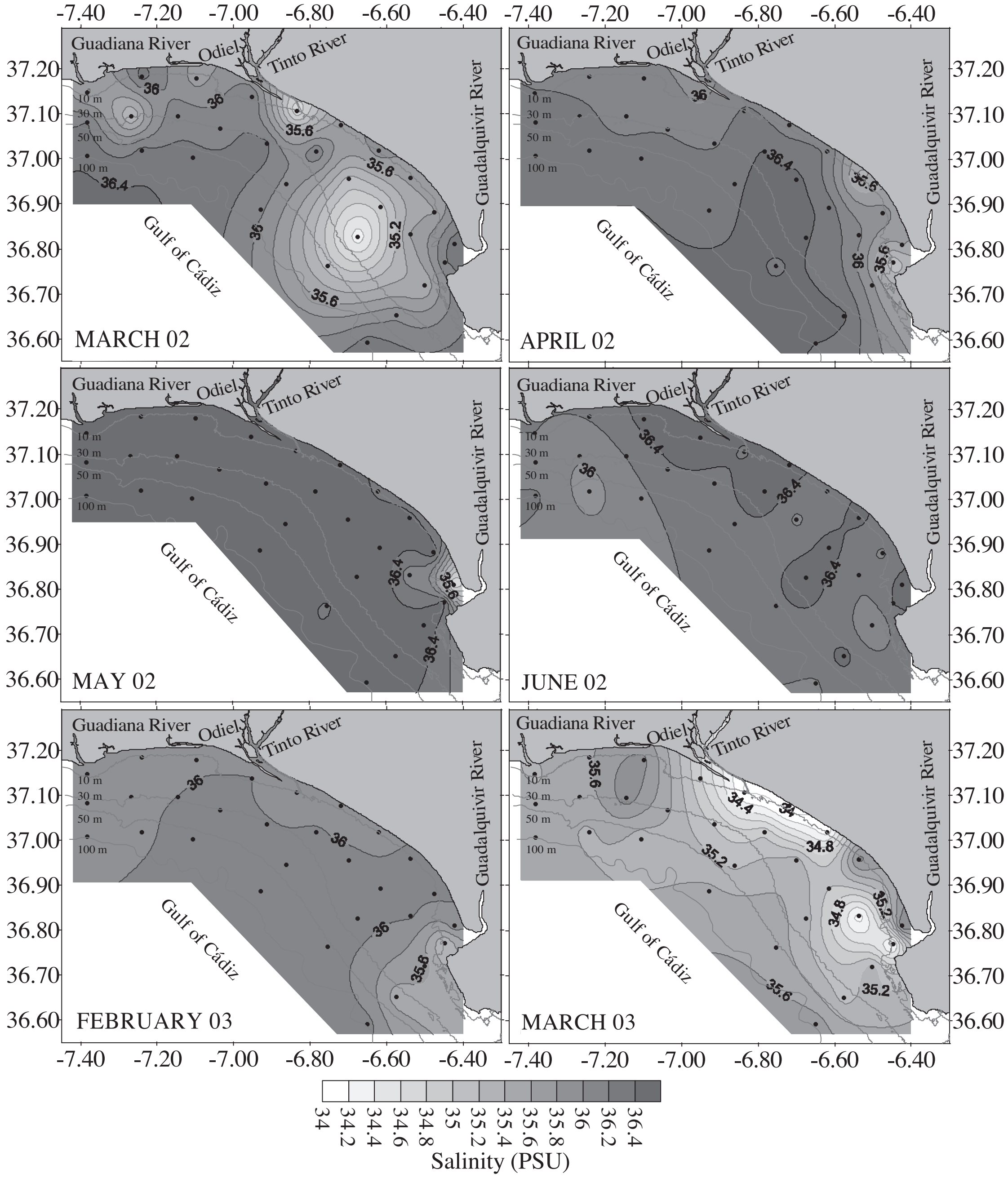

FIG. 9. – Distribution of surface salinity (PSU) at 5 m depth during the wedge sole main reproduction months.

Temperature

Mean monthly sea surface temperature (5 m depth) and mean monthly bottom temperature ranged from 13.6 to 22.6ºC and from 13.5 to 18.2ºC, respectively, following the same trend during the entire sampling period (Fig. 6A). Surface waters were warmer than 17ºC during the March 2002 survey, followed by a temperature decrease in April (Fig. 6A), when most of the area was occupied by waters below 16ºC (Fig. 7). From May onwards, waters warmed up again, reaching a maximum mean temperature near 23ºC in August (Fig. 6A). From July to October, mean temperatures were over 19.5ºC. After the maximum in August, water temperatures started to decrease (2-3ºC per month since November) until the lowest mean temperature (13ºC) was reached in February 2003, and they started warming up again (a temperature rise of almost 2ºC) in March 2003 (Fig. 6A).

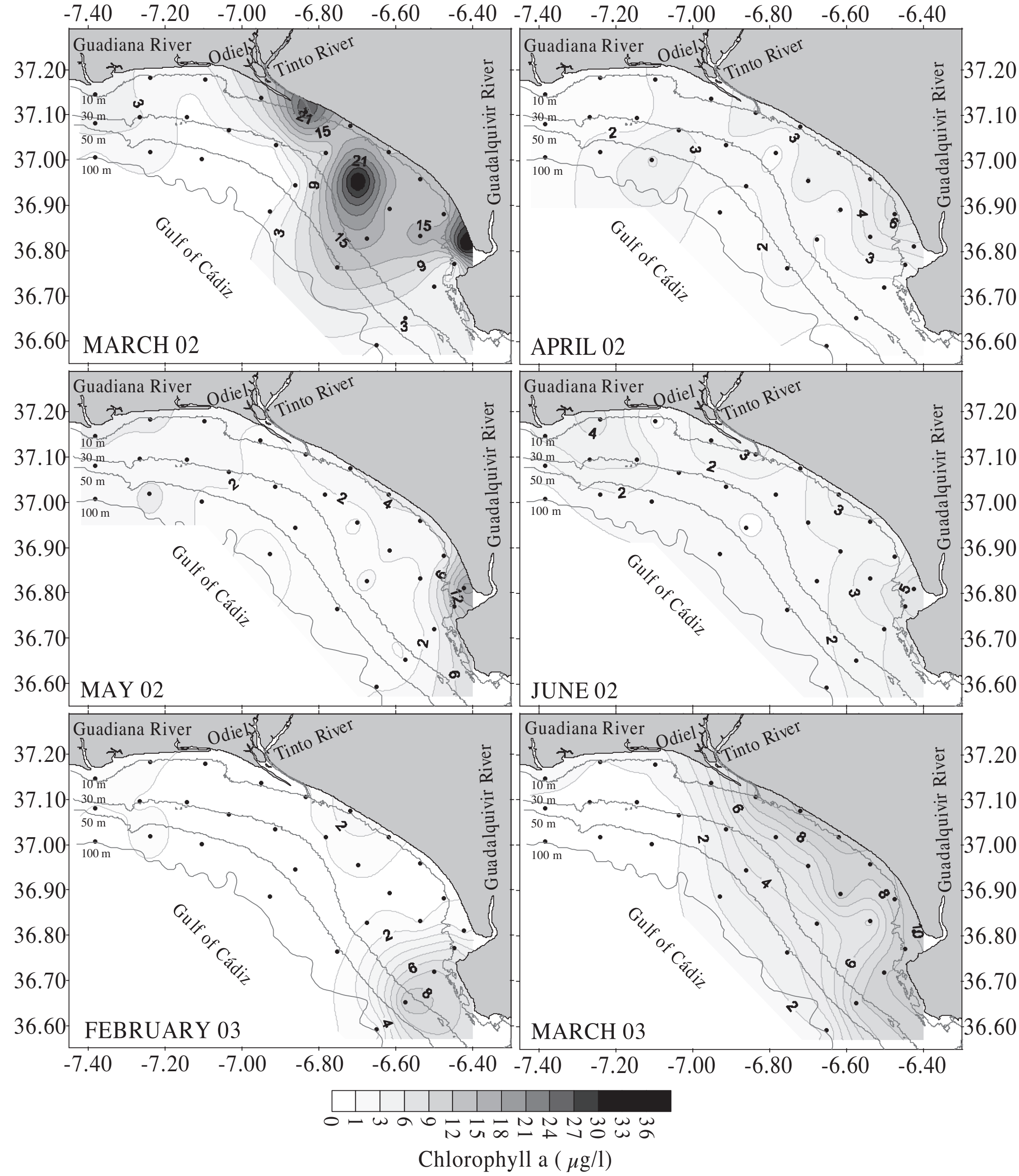

FIG. 10. – Chlorophyll *a* (μg/l) distribution during the wedge sole main reproduction months.

During the wedge sole reproductive season, mean monthly surface and bottom temperatures ranged between 13.6 and 17.8ºC (Fig. 6A). There were no changes between surface and bottom temperatures in April 2002 and March 2003, showing the typical winter mixing situation (Figs. 7 and 8). Surface and bottom waters in the westernmost section of the sampling area (between the mouths of the Rivers Guadiana and Tinto-Odiel) were colder than in the rest of the zone during this period. This pattern was especially evident in surface waters in March, April and May (Fig. 7), when the difference in the surface temperature between the westernmost and easternmost sector was 2-3ºC. In May and June, differences greater than 3ºC were found in the bottom temperatures of both zones (Fig. 8).

The highest densities of eggs and larvae were respectively found at surface temperature ranges of 15-17ºC and 13.5-15.2ºC in the westernmost sector. In the rest of the area, the surface temperature range for the presence of *D. cuneata* eggs and larvae was higher, between 15 and 18.5ºC. The high-

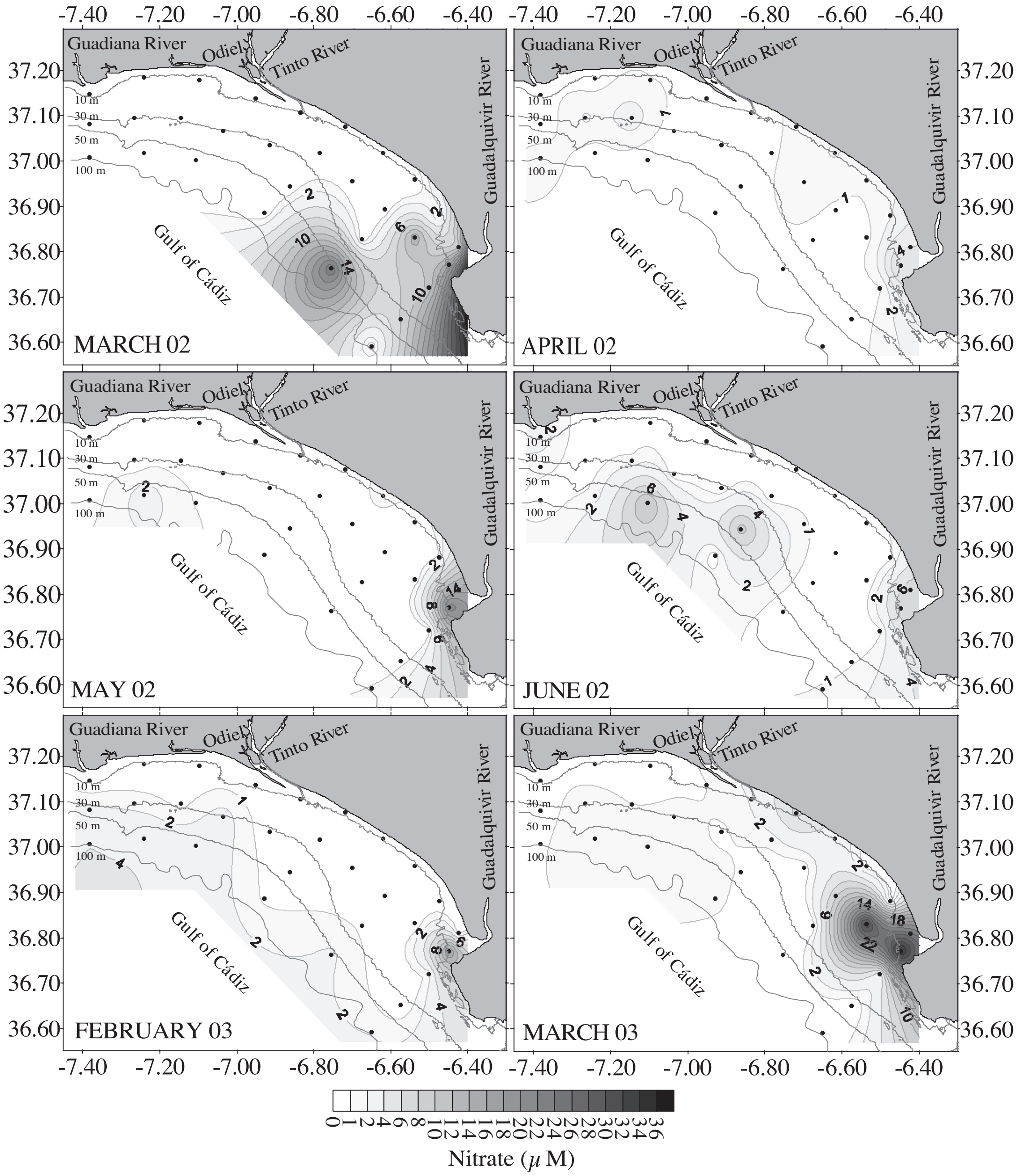

FIG. 11. – Nitrate (µM) distribution during the wedge sole main reproduction months.

est egg abundances occurred at bottom temperatures of 15-16ºC.

Salinity

The survey in March 2002 was preceded by a rainy period. The lowest value for the mean salinity for the entire sampling period recorded during this month (Fig. 6a) was the result of the presence of less saline waters highly localised at the mouths of the rivers (Fig. 9). The absence of rainfall and low river discharges led to high salinities during the spring and summer months (over 36.02 PSU from April to September). November and December were the rainiest period, followed by major river discharges from December 2002 to March 2003 (Fig. 6B). The Guadalquivir River discharges in March 2003 caused a decrease in the salinity (Fig. 6A), which mainly affected the waters very close to the Guadalquivir mouth (34.0 PSU at the station closest to the mouth of the river) (Fig. 9). A similar situation occurred in a very restricted and shallow area near the River Tinto-Odiel mouth (>34.0 PSU).

In spite of these local (in time and space) river influences, the salinity differences were very low and did not seem to affect the wedge sole egg and larval distribution. Furthermore, the great majority of eggs were found in the westernmost sector, where the salinity varied little during the reproductive period.

Nutrients and chlorophyll

Nitrate and chlorophyll followed the same tendencies during the sampling period (Fig. 6B). Both parameters peaked in March 2002 (9.02 μg/l and 4.92 μM, respectively) and March 2003 (4.70 μg/l and 4.93 μM, respectively). The nitrate peaks and phytoplankton blooms (especially intense in 2002) recorded in March were associated with the freshwater inputs from the River Guadalquivir and, to a lesser extent, from the Rivers Tinto-Odiel and Guadiana (Figs. 10 and 11), after a rainy period (Fig. 6B) in the waters surrounding these river mouths. Thus, the highest values occurred in the Guadalquivir mouth area, coinciding with low salinity levels (negative correlation coefficient of $r = -0.316$, $p<0.01$ between nitrate and salinity and $r= -0.372$, $p<0.01$ between chlorophyll and salinity). Although lower during the rest of the reproduction period, the highest chlorophyll (Fig. 10) and nitrate (Fig. 11) concentrations were related to this river outflow.

Wedge sole eggs and larvae versus environmental parameters

Egg abundance were positively correlated with zooplankton volume ($r= 0.126$, $p<0.01$) and chlorophyll concentration ($r= 0.289$, $p<0.01$) and negatively correlated with temperature ($r= -0.314$, $p<0.01$) and depth ($r= -0.351$, $p<0.01$). Larvae density was positively correlated with zooplankton and chlorophyll concentration ($r= 0.196$ and $r= 0.181$, $p<0.01$) and negatively correlated with temperature ($r= -0.340$, $p<0.01$), depth ($r= -0.154$, $p<0.01$) and salinity ($r= -0.129$, $p<0.05$).

DISCUSSION

The presence of eggs and larvae in the area revealed a long reproductive season, since the first spawning was detected in September-October and lasted until the beginning of summer. The main spawning peaks and the greatest larval abundances occurred between March and May, showing a late winter-early spring main spawning period. The long spawning period, as well as the egg and larval peaks of abundance, were fairly consistent with the protracted reproductive period and peaks proposed by Jiménez *et al.* (1998) in the Gulf of Cádiz, Vila *et al.* (2002) in Spanish and Portuguese zones of the Atlantic Iberian coast and García-Isarch *et al.* (2003) in the River Guadalquivir mouth. These studies located the onset of reproduction in autumn, and it lasted until the end of the spring. The months when reproduction occurred were characterised by colder waters and high levels of nutrient, phytoplankton and zooplankton concentrations. The reproduction period occurred at a surface temperature range between 13.6 and 17.6ºC, coinciding with temperature ranges of 13-20º reported for the spawning of this species in the Bay of Biscay (Lagardère, 1982) and of 14.5-18ºC in the Guadalquivir River mouth (García-Isarch *et al.*, 2003). Lagardère and Aboussouan (1981) determined a minimum bottom temperature for the reproduction of *D. cuneata* of 12-14ºC in the Bay of Biscay and 15.5ºC in the Western African coast. In our area of study, bottom temperatures at the stations where maximum spawning was recorded ranged from 15 to 16ºC. At these temperatures, the spawning occurs in the bottom waters and once the eggs have been fecundated, they reach the surface waters, where they continue their development (Lagardère, 1982). Temperature causes latitudinal differences in the location and extension of the wedge sole reproduction period (Jiménez *et al.*, 1998). This season begins earlier in southern regions, becoming later as latitude increases, indicating a latitudinal gradient in reproduction time along its distribution range.

Three zones can be distinguished in the study area during the reproduction period of the wedge sole:

- The shallow waters (less than 30 m in depth) located in the westernmost zone, between the mouths of the Rivers Guadiana and Tinto-Odiel. This sector is characterised by colder waters than the rest of the area and salinity values higher than 35.5 PSU, with a probable origin in the deep waters upwelled east of the sampled area (nearby Cape Santa María) (Ruiz *et al.*, 2006). Temperature and salinity did not show great variations during the wedge sole reproductive season. These shallow, temperate and stable waters are certainly preferred by *D. cuneata* for spawning (Lagardère, 1982). This area can be defined as a main wedge sole spawning ground, as the highest egg densities were located there.

- The inshore coastal waters (below 50 m depth), in the central and eastern zone of the sampling area, between the mouths of the Rivers Tinto-Odiel and Guadalquivir. This is a highly productive zone, under a much greater continental influence than the western zone. Waters are warmer than in the western section, and have a slightly more variable salinity, depending on the river discharges. Processes like the river discharges and tidal mixing (Ruiz *et al.*, 2006) enhance nutrient enrichment and consequently phytoplankton and zooplankton production. This means more food availability for larvae, which favours their growth and development. The highest larval densities were found in this area, mainly associated with the mouths of the Rivers Tinto-Odiel and Guadalquivir and at depths between 20 and 30 m. Within this zone, the Guadalquivir River mouth has been traditionally considered as the main nursery area for this species in the Gulf of Cádiz (Muñoz, 1972). García-Isarch *et al.* (2003) revealed the great importance of shallow waters (5-20 m deep) in the river mouth for the nursery and the recruitment of this species. In fact, the wedge sole life cycle is closely related to shallow coastal waters near large river mouths, with sandy-muddy bottoms (Lagardère, 1975, 1980; Lagardère and Aboussouan, 1981). The same bottoms occur in this area (Ramos *et al.*, 1996), which constitutes an optimum habitat for this species (Jiménez *et al.*, 1998). In fact, the most important fishing grounds for *D. cuneata* in the Gulf of Cádiz are located near the Guadalquivir River outflow (Jiménez *et al.*, 1998). This section functions as a main nursery habitat and a secondary spawning ground (less important than the western sector) for the wedge sole.

- The offshore zone (more than 50 m depth), characterised by the warmest, most saline and least productive waters. Early life stages of wedge sole were hardly ever found in this section (maximum values of 21 eggs/100 m^3 and 8 larvae/100 m^3 at stations above 50 m depth). This was probably because the habitat of the adults is mainly constricted to waters less than 30 m in depth (Jiménez *et al.*, 1998).

Consequently, the spawning habitat is mainly located in the westernmost and most coastal sector of the study area, and to a lesser extent in the coastal zone extending between the mouths of the Rivers Tinto-Odiel and Guadalquivir. This spawning habitat, characterised by shallow and colder waters, is mainly determined by the distribution of the adults and by the water temperature and bathymetry. The existence of two different spawning nuclei, occurring in two thermally different sectors, has also been reported in the Bay of Biscay by Lagardère (1982), who defined two eggs stocks: the “cold stock”, with slow development, and the “warm stock”, with fast development.

In contrast, nursery grounds are distributed in the shallow and highly productive waters between the mouths of the Rivers Tinto-Odiel and Guadalquivir. Thus, the main spawning and nursery habitats were clearly segregated in the study area. Two main factors, or the combination of both, may affect this spatial segregation. On one hand, we can consider larval transport from the spawning to the nursery areas. In this sense, the captured larvae were of small size, with total lengths (TLs) ranging between 1.3 mm (yolk-sac larvae) and 8.2 mm (symmetric planktotrophic larvae), and a mode around 2 mm. Thus, most of the larvae may have been very young individuals, probably recently hatched and all prior to metamorphosis. These sizes do not allow active larval movement from the spawning ground to the nursery area and the larvae may have been passively transported by the surface currents. In this area winds generate alongshore currents, which are eastward or westward depending on the direction from which the wind blows (westerlies or easterlies respectively) (Ruiz *et al.*, 2006). Thus, the westerly winds that predominate in the sampling area during the reproduction period (see Table 1) may advect larvae from the spawning grounds in the west to the nursery areas in the central and eastern sector. Actually, an exception to this situation was found in June, when larvae were mainly distributed in the westernmost sector, coinciding with an intense easterly wind event in Cádiz preceding the sampling days (Ruiz *et al.*, 2006). On the other hand, it may be considered that though eggs spawned in the central and eastern sectors are less abundant, the larvae hatch with greater chances of survival. It is likely that the combination of warm and rich waters in this area (Ruiz *et al.*, 2006) offers an adequate environment for larval development and survival. This environment under the Guadalquivir influence may provide good feeding conditions for fish larvae, allowing them to grow faster and thus experience a shorter larval stage and better survival (the “short-foodchain" hypothesis of Grimes and Kingsford, 1996). The coincidence in time and space of small larvae and phytoplankton leads us to infer a phytoplankton foraging conduct of early wedge sole larvae. Furthermore, the high level of phytoplankton influences other elements in the food web and is reflected in the abundance of zooplankton, whose highest concentrations are also in this area. These high concentrations of zooplankton also favour larval feeding, since Soleidae mainly feed on planktonic copepods during their planktonic larval phase (Izquierdo, 1985; Amara and Bodin, 1995).

In conclusion, the inshore area located between the mouths of the Rivers Guadalquivir and Guadiana River constitutes a very suitable habitat for the reproduction of *D. cuneata*, where conditions for both spawning (mainly in the coastal western sector) and subsequent larval development and survival (in the central and eastern sectors) are very appropriate. The existence of a defined recruitment area in the coastal zone surrounding the River Guadalquivir mouth (García-Isarch *et al.*, 2003; Sobrino *et al.*, 2005) may be linked to these favourable conditions for larval growth and survival.

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