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Reproductive disturbances of Marine Species and Contaminant Related Issues

EGG PRODUCTION HAKE BIOMASS IN ICES DIVISIONS VIIIa,b IN 1995 IN COMPARISON WITH 1983.

L. Motos, P. Alvarez, H. Murua and P. Lucio
Fisheries Resources
AZTI[1]

The assessment of the European hake population faces several difficulties. There are problems to get reliable estimates of the stock size and namely the spawning component of the stock size. The estimate of fecundity in combination with estimates of egg production at sea may allow for getting figures of the spawning stock biomass which would increase the information about the state of the stock and would be useful to improve the management of this population.

The egg production records from the ICES triennial surveys, which covers a major part of the spawning areas and periods of hake, can be used as abundance indices of the spawning population. When accompanied with unbiased fecundity estimations, absolute estimates of the population spawning biomass can be potentially attained.

This paper presents estimates of daily egg production for egg cruises carried out along ICES divisions VIIIa,b in 1995. The values of daily egg production for the entire area at peak spawning is quantified together with daily fecundity values to give estimates of spawning biomass. The results attained for the 1995 spawning season is compared to the results on egg production obtained from a set of data collected at a similar period in 1983. A severe decline of the hake spawning stock is recorded from 1983 to 1995. Finally, a discussion on the applicability of ichthyoplankton methods to the assessment of the mature population of hake is presented.

Keywords: hake, spawning biomass, DEPM, indeterminate fecundity, batch fecundity, spawning fraction.

[1] AZTI, Food and Fish Technological Institute
Avda. Satrústegui 8, 20008 San Sebastián, Basque Country
SPAIN
(tel: +34 43 214124, fax: +3443212162)
e-mail: lorenzo@rp.azti.es; paula@rp.azti.es; hilario@rp.azti.es; paulino@rp.azti.es

INTRODUCTION

The European hake population supports a major commercial fishery in Atlantic European waters. It is specially important for the Spanish and French fishing fleets. The assessment of the hake population faces several difficulties. Uncertainties in age determination make it difficult the use of catch-at-age analytical models. Besides this, there are problems to get reliable estimates of the stock size and namely the spawning component of the stock size (Anon., 1996). The estimate of fecundity in combination with estimates of egg production at sea may allow for getting figures of the spawning stock biomass (Saville, 1964; Hunter and Lo, 1993) which would increase the information about the state of the stock and would be useful to improve the management of this population.

The ICES triennial egg surveys, although primarily focused to mackerel and horse mackerel, provide a unique opportunity to collect information on the abundance and distribution of any fish population having a spawning area within the spatio-temporal sampling limits of the survey. For the European hake, the survey covers a major part of the spawning areas and periods. Hake has an extensive spawning area, this being along the shelf-edge and outer shelf region from off the Iberian Peninsula and Biscay to northern Scotland and southern Norway. Spawning starts in the south in winter and finishes at the northern end of the distribution at around July-August. Spawning seems to start on the shelf edge and progress towards the shelf as the season advances.

The egg production records from the ICES triennial surveys can be used as abundance indices of the spawnin; population. When accompanied with unbiased fecundity estimations, absolute estimates of th population spawning biomass can be potentially attained. Several works have studied the fecundity of the European hake. This species is a batch spawner (Sarano, 1985; Perez & Pereiro, 1985; Murua et al., 1996) of indeterminate fecundity (Murua et al., op.cit.). Consequently, the quantification of the annual reproductive output of the population should be estimated from the number of eggs laid in each spawning act (batch fecundity) and the number of spawning taking place along the season (spawning frequency and duration of the individual spawning season).

This paper presents estimates of daily egg production for egg cruises carried out along ICES divisions VIIIa,b in 1995. The values of daily egg production for the entire area at peak spawning is quantified together with daily fecundity values to give estimates of spawning biomass. The results attained for the 1995 spawning season is compared to the results on egg production obtained from a set of data collected at a similar period in 1983. Finally, a discussion on the applicability of ichthyoplankton methods to the assessment of the mature population of hake is presented.

MATERIAL AND METHODS

The ICES triennial egg survey covers the full range of spawning periods and areas of the target species, i.e. mackerel and horse mackerel. A review of the coverage and techniques used in the surveys is given in Anon (1994). The cruises/periods used in the present work are listed in table

1 and figures 1 & 2. They covered the area to the south of 48° in the period March to June in 1983 and February to June in 1995. The basic sampling unit used in these surveys was a ½ x ½ rectangle with the sample taken at its centre. Sampling gear used by participants in these surveys was a national variant of the Gulf III type high speed sampler (Gehringer, 1952) furnished with a 250 µm mesh net.. Samplers were towed at a speed of 5 knots in a double oblique tow from surface to sampling depth. Maximum sampling depth was 200m or to within 2m of the bottom where the bottom depth was less than 200m. In the presence of a thermocline greater than 2°C in 10m depth, sampling was confined to 20m below the thermocline.

Additionally, two specific hake egg and larval cruises were carried out in February and March 1995 (Table 1). The cruises followed a central systematic sampling scheme. Stations were located at the centre of 10*30 nm² rectangles along transects perpendicular to the 200 m depth contours (Figure 1). At each station, a plankton haul was made using a 60 cm BONGO net furnished with nets of 333 y 505 µm mesh, respectively. The tows were oblique from the surface to 200 m depth, or 5 m above the bottom whichever shallower, and back to the surface at a pay off and retrieving speed of 20 m/min. The vessel speed was set at approx. 2.5 knots. GO flowmeters were used in every tow to measure the distance run during the tow. The plankton material collected in the 333 µm net was processed.

Immediately after sampling, plankton was preserved in 5% buffered formaldehyde solution. For the specific objectives of this paper, we worked or re-worked if necessary the samples collected to the south of 48°N in the cruises listed in table 1. Hake eggs were sorted out from the samples and classified by development stage (Coombs & Mitchell, 1982). Hake eggs were identified using the SAT procedure (Porebski, 1975). This procedure takes profit of the hydrofugue nature of hake eggs and has proven workable when applied to both field collected and artificially fertilized material (Coombs, 1994: Marrale *et al.*, in press).

Table 1. Research Vessels, dates and areas within which samples were studied for hake egg abundance.

Cruise	Survey dates	Bay of Biscay	Period	Gear	# samples
Cirolana 4/83	18 Mar - 09 Apr	19 - 23 Mar	Mar	GULF III	56
Scotia 5/83	27 Apr - 17 May	08 - 12 May	May	GULF III	11
Tridens 5/83	04 - 31 May	04 - 31 May	May	GULF III	66
Scotia 6/83	06 - 28 Jun	18 - 22 Jun	Jun	GULF III	35
Tridens 6/83	01- 15 Jun	01 - 07 Jun	June	GULF III	35
Lebal 2/95	15 Feb - 24 Feb	15 Feb - 24 Feb	February	BONGO-60	40
Lebal 3/95	22 Mar - 01 Apr	22 Mar - 01 Apr	March	BONGO-60	62
Walter Herwig III 4/95	26 Mar - 12 Apr	2 Apr -9 Apr	April	GULF III	40
Cirolana 4a/95	22 Apr - 17 May	15 May - 17 May	May	GULF III	17
Scotia 5/95	23 Apr - 12 May	1 May -7 May	May	GULF III	28
Tridens 5/95	18 May - 31 May	22 May - 31 May	May	GULF III	58
Tridens 6/95	13 Jun - 26 Jun	13 Jun - 21 June	June	GULF III	60

The material used in the fecundity studies was collected by sampling on board commercial boats in 1994 and in 1995 (Murua et al., 1996).

Egg production calculations are similar to those used for mackerel or horse mackerel egg production calculation (Anon., 1994). Stage I egg abundances in the hauls were transformed to densities in numbers per square meter. Densities were transformed to daily egg production per surface unit rates using the equations given by Coombs & Mitchell (1982) for temperature specific hake egg development rates. Daily egg production per square meter was raised to the area each station represent to give the total daily egg production per rectangle. Total daily egg production for a cruise/period was calculated as the sum of individual daily egg production per rectangle. No values of variance were given associated to the total daily egg production figures. The reason for this is that we do not have replicate values of daily egg production within any rectangle, which would have allowed us to give an estimate of the variance associated to the total daily egg production estimate following standard procedures (Anon., 1994).

Fecundity figures were extracted from the values given by Murua et al. (1996). The study was carried out in February (1994 & 1995) and March, April, May and June (1994). Spawning biomass estimates were calculated as the ratio between the daily rate of egg production found at sea and the daily rate of fecundity of the population. No estimates of variance are provided either.

RESULTS

Figures 1 & 2 shows the distribution of stage I eggs (numbers per square meter) in the periods studied in 1983 and 1995, respectively.

Table 2 show the figures of sampling and positive areas and daily egg production for all the cruise/periods worked out in this study.

Table 2: Figures of sampling and positive areas and daily egg production for all the cruise/periods worked out in this study.

		1995			**1983**	
Period	DEP **# eggs. d^{-1}**	Area **km^2**	Positive area **km^2**	DEP **# eggs. d^{-1}**	Area **km^2**	Positive area **km^2**
February	2.91E+10	35 671	14 920			
March	7.03E+10	52 495	19 396	2.88E+11	143 671	47 285
April	1.70E+10	65 746	12 706			
May	1.11E+07	123 912	10 608	3.82E+10	143 567	8 431
Jun.	2.72E+07	127 027	4 236	2.59E+09	124 200	2 176

Peak egg production and maximum positive area were reached in March in both years 1983 and 1995.

Table 3 shows the figures of daily fecundity given by Murua et al (1996) for the European hake.

Table 3: Hypothetical level of daily fecundity at peak spawning for the hake stock based on the findings of Murua et al. (1996). F is batch fecundity (number of eggs laid per batch per female), R is sex ratio in percentage of females in the spawning stock. Spawning fraction values (S) are given according to the prevalence of nuclear migration stage, hydrated stage and (*) a value (0.12) corresponding to a duration of 12 hours of the nuclear migration stage and to half the index given by the prevalence of hydrated stage females. The sex ratio it is assumed to be a present value of 50%.

			nuclear migration stage		hydrated egg stage		*	
	F	R	S	Daily F	S	Daily F	S	Daily F
Period	eggs g^{-1}	%	%	eggs g^{-1}	%	eggs g^{-1}	%	eggs g^{-1}
Peak spawning	165	50	5	4.125	24	19.8	12	9.9

The figures of daily fecundity at the population level range from 4 to 20 eggs g^{-1} of stock, depending on the spawning fraction level.

Table 4 shows the biomass calculations fo[illegible]e spawning biomass of the hake population inhabiting the sampling area during peak spa[illegible]ing (March).

Assuming a similar level of daily fecundity in both years, the spawning biomass of hake inhabiting the sampling area in March 1995 was about 7 000 tons. This biomass level is much lower than the level of about 29 000 tons recorded in March 1983.

Table 4: Tentative calculations of spawning biomass for the European hake stock inhabiting the sampling area during peak spawning. Values for 1983 and 1995 assuming a similar fecundity rate in both years.

	1995			1983		
PARAMETER	VALUE	VARIANCE	CV	VALUE	VARIANCE	CV
Total daily egg production	7.03E+10			2.88E+11		
Daily Fecundity	9.9			9.9		
Sex Ratio (1:1)	0.5			0.5		
Batch Fecundity	*165*			*165*		
Spawning Fraction	0.12			0.12		
BIOMASS (tons)	**7 099**			**29 091**		

DISCUSSION

This work shows the application of ichthyoplankton-based stock assessment methods to the hake stock. In spite of the restriction of the results to only a part of the distribution area of the stock, it is our view that the results obtained show that these techniques are potentially applicable to this stock. Our work was delimited to a reduced part of the whole spawning area, so that all the figures should be taken as abundance indices for the fraction of the stock inhabiting that sampling area, i.e. the Bay of Biscay with a northern limit in 48°N and a southern limit in the Basque Coast, during the month of March both in 1983 and in 1995. As a main conclusion, it can be detected a fourfold decrease in the abundance of adult hake inhabiting the bay of Biscay at peak spawning from 1983 (29 000 tons) to 1995 (7 100 tons). Wether this reflect a true decrease in biomass or not is a matter of consideration for the relevant experts.

Several difficulties have to be overcome to attain reliable estimates of hake spawning biomass using ichthyioplankton methods. The main topics to be known are listed in Table 5. We have developed an internal research programme aimed to reach a sufficient knowledge on these topics.

The geographical distribution of spawning of the European hake population (which is divided for assessment purposes into the Northern and Southern stocks) is relatively well known. However, most of the knowledge on spawning distribution come from fisheries related studies on adult hake maturation. We found that there have been no surveys specifically directed to depict the broad scale distribution of hake eggs and larvae. Having in mind this fact, we have carried out several actions aimed to collect more information on the distribution of hake eggs. On the one hand, we carried out an artificial fertilisation experiment in order to resolve the uncertainty around the reliable identification of hake eggs. On the other hand, we have re-worked a set of plankton samples coming from cruises carried out within the ICES triennial egg surveys (1983 and 1995) and, we have carried out a series of two consecutive surveys in the bay of Biscay specifically devoted to the collection of hake eggs during the theoretical peak spawning period in this region. From the results we have achieved, the occurrence of hake eggs match well the spawning cycles based on adult hake maturation studies given in the literature. This means that the ICES triennial surveys match in a rather satisfactory way the spawning areas and periods of the Northern stock of the European Hake, so that most of the seasonal egg production curve can be depicted in these surveys. Regarding the southern stock, it seems that significant spawning rates can start as early as January in the Iberian coast. If the objective was to embrace the whole hake egg production curve in this area, an earlier start of the survey should be necessary.

The vertical distribution of hake eggs have been studied by Coombs and Mitchell (1982). Hake eggs are distributed in the upper 150 m of the water column, with maximum numbers between 50 and 150 m water depth. A more recent vertical distribution study carried out in February March 1995 in the Bay of Biscay, showed a similar pattern of vertical distribution during February and a more shallower distribution at the end of March (Motos et al., in press). The sampling methodology used in the ICES triennial cruises fully covers this depth range.

Table 5: Basic data requirements for the application of ichthyoplankton methods to the assessment of the European hake stocks.

DATA REQUIREMENTS	STATE OF KNOWLEDGE
Egg production	
Spawning areas and periods	✔
Vertical distribution of eggs	✔
Egg identification	some uncertainty
Temperature specific development rates	✔
Daily spawning time	(?)
Egg abundance and spatial structure	in progress
Fecundity	
Batch Fecundity	✔
Spawning frequency	approx.
Daily spawning cycle	approx.
Duration of gonadal stages (hydration, nuclear migration, POFs...)	(?)
Spawner Distribution (vertical and horizontal)	(?)
Maturity ogive	approx.

Regarding the uncertainties around the identification of hake eggs, the SAT methodology has proven practical to reach a correct identification of hake eggs (Coombs, 1994; Marrale et al., 1996). There still remains some uncertainty in old, formaldehyde preserved material, but trained technicians are able to accurately identify fresh preserved hake eggs in plankton samples.

Equation for the temperature specific development rates were given by Coombs and Mitchell (1982). These equations allow us to transform egg densities to daily egg production.

Information on the daily spawning cycle of the European hake is scarce. From the data we gathered we were not able to reach to any conclusion on this topic.

Hake egg sampling is regarded to as a difficult task. Low densities of hake eggs are generally found in the field (peak values use to range from 100 to 200 eggs/m² and around 10 larvae/m²). This is sometimes blamed to particular temporal and spatial (both vertical and horizontal) distribution patterns, i.e. they occur too deep. However, our studies have proven that hake eggs are tractable provided that a volume of sea water big enough is filtered by the net during the plankton haul. Table 6 shows the volumes of water needed to sample a known density of any component of the plankton, provided that its distribution is uniform through the water volume sampled. For an abundance of 1 egg per square meter, one need to sample 200 m^3 to get 1 egg in average. As the maximum egg abundances that we have found are between 100 to 200 individuals per m^3, we need a minimum of 1-2 m^3 to collect 1 egg at these densities. Of course, samples should be much more abundant than 1 egg to be able to provide reliable estimates of egg abundance. In conclusion, in the case of hake eggs should be a target species for a particular survey, 50 m^3 of sea water can be a lower threshold for the volume to be filtered in a standard plankton tow.

Table 6: Water volumes to be filtered at different levels of plankton item abundance. Estimates are made for a standard haul down to 200 m water depth.

density egg/m^2	density egg/m^3	Filtered volume to collect 1 fish egg m^3
1	0.005	200
10	0.05	20
100	0.5	2
200	1	1
1,000	5	0.2
10,000	50	0.02

The estimation of the variance associated to the egg production estimate can be made following different approaches. One way is to have replicate sampling in several rectangles to be able to estimate the within rectangle variance which can be raised to the total estimation variance under the assumption of a common coefficient of variation for all rectangles sampled (Anon., 1994). Alternative ways would include the utilisation of spatial modelling techniques such as GAM models (Anon., 1994) or Geostatistics (spatial variance), and others.

Regarding to the requirements of data for fecundity estimates, preliminary results of hake fecundity studies are given by Murua et al. (1996). These authors concluded that hake is an indeterminate spawner. In this case, the Daily Egg Production Method (Parker, 1980) should be directly applied. The DEPM needs an estimate of the daily fecundity rate during peak spawning to derive an estimate of spawning biomass from the rate of daily egg production in the sea. Daily fecundity of female hake should be calculated from (concurrent) estimates of batch fecundity and spawning fraction. Batch fecundity estimation is a rather easy task, although more research is needed to improve the reliability of the estimates. On the contrary, spawning fraction is still not sufficiently known, although a range of probable values is given in that work (Murua et al, 1996). Field and laboratory studies should be devoted to estimate the duration of the spawning stages of female ovaries. An added difficulty on this is that the maintenance of hake adults in captivity is a hard task. Field studies are probably the only way to develop these investigations. Scientific fishing can provide mature hake samples with a sufficient temporal resolution as to provide a better understand of the daily spawning cycle of this species, including the synchronism of spawning.

An ideal DEPM exercise for the assessment of the spawning biomass of hake should envisage, in addition to the egg survey and concurrently to it, an extensive hake adult survey aimed to calculate the fecundity parameters of this species along the whole spawning area of the stock. The sample design should cover all the distribution habitat of this species at spawning to avoid any bias in the parameters. Clearly, more research is necessary on the spawning behaviour of hake at the individual and at the population level.

The fact that hake is an indeterminate spawner does not preclude the utilisation of the AEPM, provided that i) we are able to measure the egg production along the whole spawning periods and areas to yield a reliable seasonal egg production curve; ii) we are able to measure the potential fecundity of pre-spawning females and we can measure the rate of recruitment of pre-vitellogenic oocytes to the mature oocyte stock and the rate of atresia both during the spawning season and at the end of the spawning season.

In any case, the work to be carry out before a complete assessment exercise can be execute is considerable although attainable.

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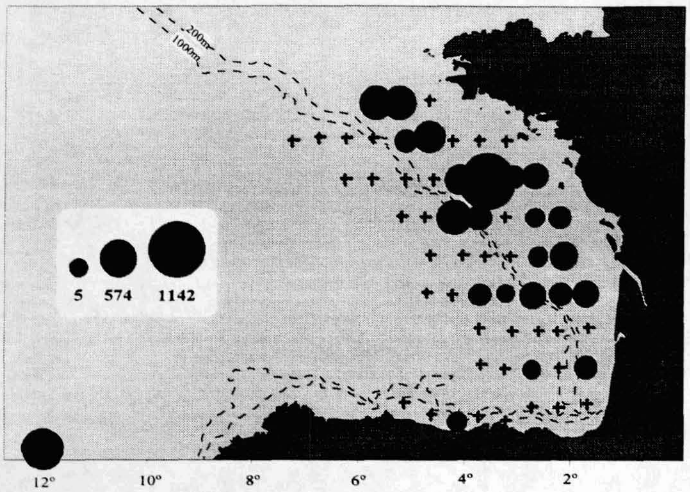
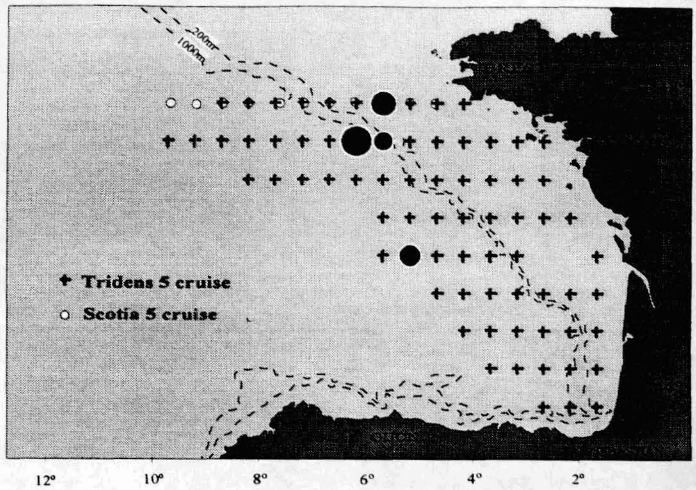
Merluccius merluccius
STAGE I EGGS 1983
(Nº/10 m^2)

MARCH



MAY



JUNE

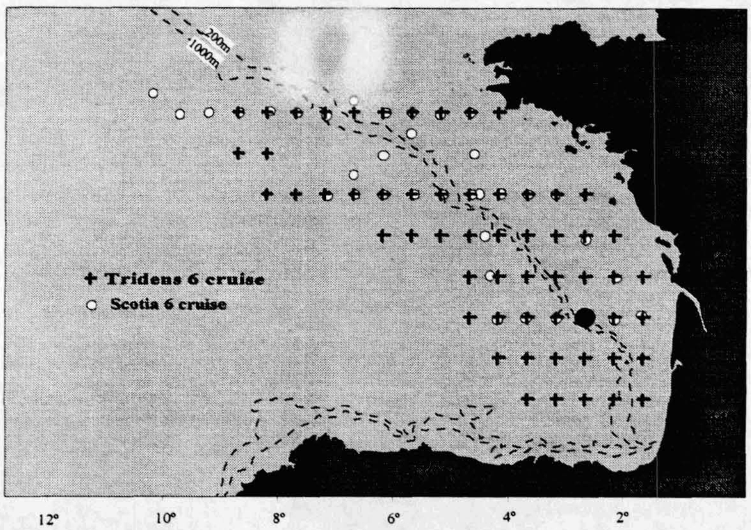


FIGURE 1

Merluccius merluccius
STAGE I EGGS 1995
(Nº/10 m^2)

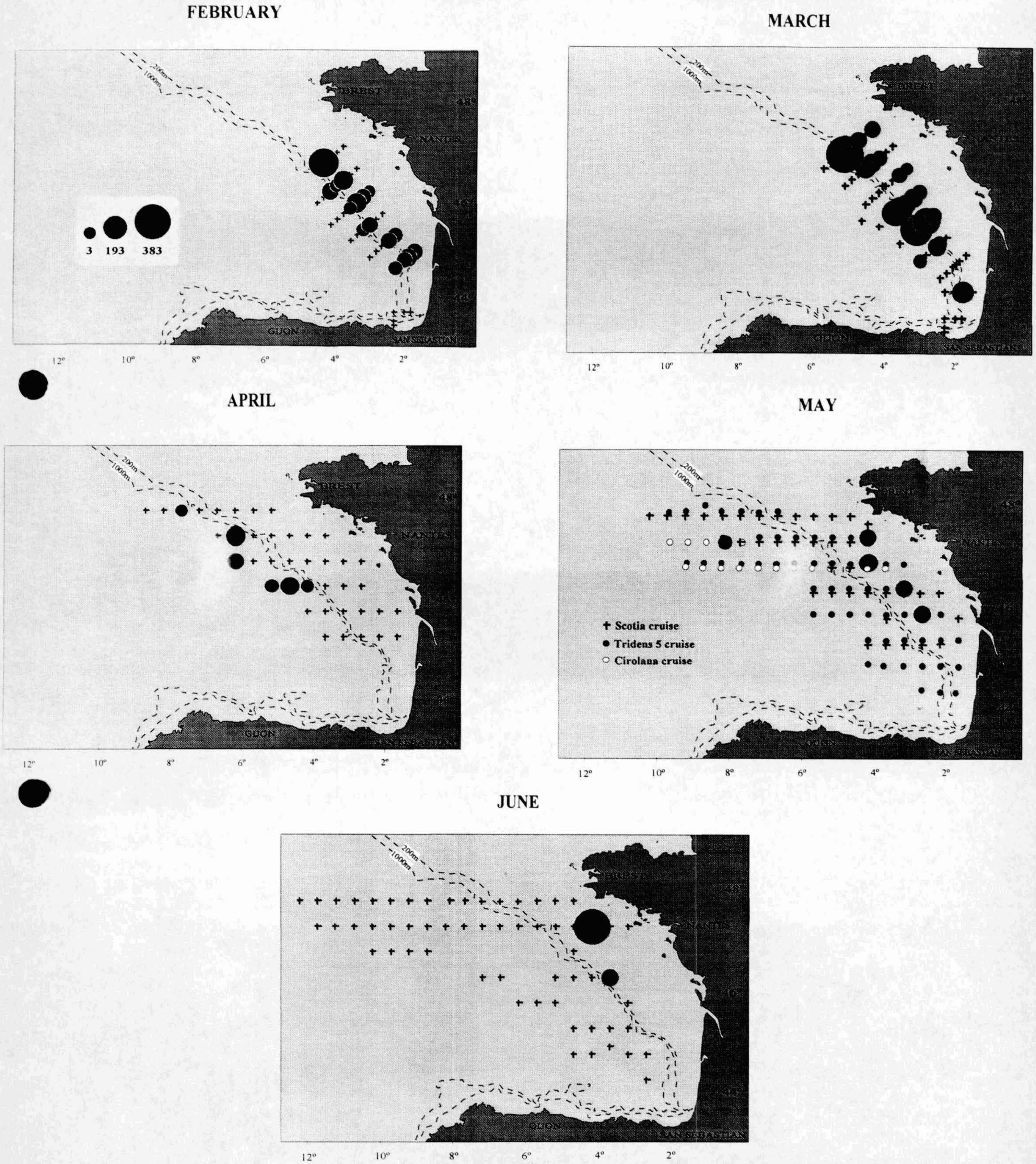


FIGURE 2