



Spring plankton surveys in the Blackwater Estuary: 1993-1997

C. J. Fox, S. P. Milligan and A. J. Holmes

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1. Introduction

The Blackwater Estuary lies on the Essex coast and runs inland from Clacton-on-Sea to Maldon (Figure 1). Each spring the estuary provides the spawning site for a population of herring (*Clupea harengus*). Eggs are laid on gravel banks between February and April and hatch after two to three weeks. The principal recognised spawning area is the Eagle Bank (Dempsey and Bamber, 1983) although anecdotal evidence also points to limited spawning at Stone, opposite Osea Island (Wood, 1981; Figure 1). The estuary provides a semi-contained, natural system in which larvae may stay for up to two months (Henderson *et al.*, 1984). During the spring of 1993 to 1997 regular weekly plankton sampling was undertaken in the estuary with the aim of investigating the conditions affecting growth and survival of herring larvae in this region. This report presents a summary of the samples collected as well as providing background information relating to the area and the herring stock.

2. The Thames estuary herring fishery and its management

Thames estuary herring belong to a small localised stock, sometimes called Blackwater herring. They are members of a spring-spawning (between late February and April) coastal race as opposed to the larger offshore stocks in the North Sea which spawn in the autumn. Adult herring in the Thames estuary are primarily composed of a mixture of Blackwater fish and those from the Downs stock. The Downs stock spawns in the Southern Bight of the North Sea and in the eastern English Channel in November and December (Cushing, 1992). The inshore migration of Blackwater herring starts in early November with fish concentrating within 10 miles of the coast in preparation for spawning the following spring.

Blackwater herring are assessed annually by means of Virtual Population Analysis (VPA) supported by a

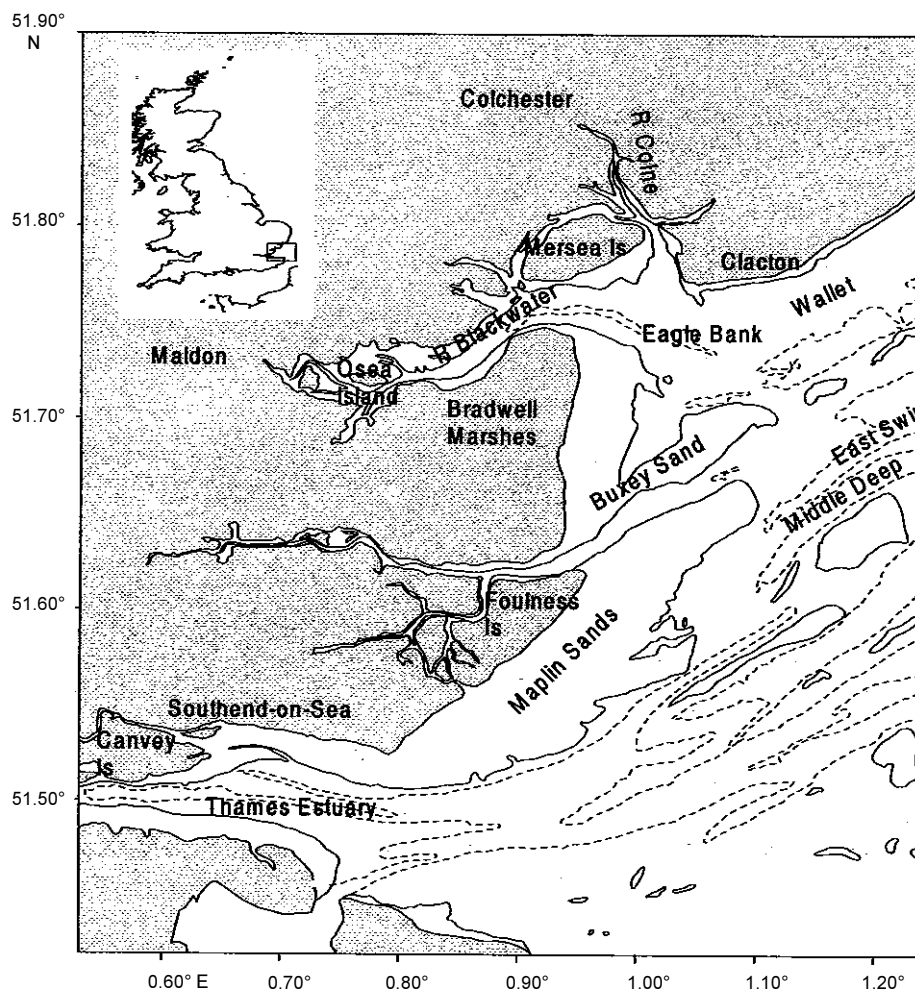


Figure 1. The Thames Estuary

fishery independent young fish survey in the autumn (undertaken by CEFAS for MAFF). Spring spawning Blackwater fish are separated from autumn spawners on the basis of otolith structure and state of maturity. Autumn spawning Downs fish are treated as part of the North Sea stock for assessment and management purposes. The results of this analysis are used to advise MAFF headquarters in London on the current state of the stock and its prospects for the future. This enables MAFF to set a provisional Total Allowable Catch (TAC) for the period October-April. The TAC is reviewed in January using new data from the young fish survey carried out during November. If appropriate, a revised TAC is set for the remainder of the season. This TAC applies to a specific area of the Thames (west of longitude 01° 20' E), established in 1989, in which only drift netting for herring by licensed vessels is permitted. The catch is composed mostly of Blackwater spring spawning herring with a small component of autumn spawning herring. The assumed proportions from the two populations are re-assessed annually based upon otolith data. Once the TAC is exhausted, the fishery is closed. Drift netting over the Eagle Bank is not permitted between 1 February and 1 June. Blackwater herring may also be caught outside the drift net box by mid-water trawlers but are counted against the southern North Sea/Eastern Channel TAC set by the EU Council of Ministers. The aim of TAC management is to maintain the spawning stock biomass (SSB) of Blackwater herring above 500 tonnes which is considered the safe biological limit. This has recently been revised down to 410 tonnes based upon a precautionary approach and current knowledge of the stock and recruit relationship for this stock.

Historical trends in catch and effort for the Blackwater stock are shown in Figure 2. In the 1960s the stock was dramatically reduced by pair trawling over the spawning grounds with the result that by 1977 the SSB had fallen to a historical low. Similar trends were observed in the North Sea stocks leading to the closure of the North Sea herring fishery in 1977. Since then stocks have partially recovered resulting in a lifting of the total ban in 1980. During the 1960s recruitment (at age 1) fluctuated between total failure and 12.1×10^6 individuals. During the 1970s, recruitment was more stable at around 3×10^6 individuals but during the 1980s fluctuated between 2×10^6 and 8×10^6 individuals. Since 1992, a series of poor recruitments have occurred despite the SSB being at reasonably high levels (Figure 3). After the historical low of 1977, the SSB gradually increased, reaching 963 tonnes in 1992. However, it has subsequently been in decline as a result of the series of poor recruitments in recent years. The abundant 1991 recruitment, hatched in 1990, represented 16% of the total stock biomass at the start of the 1996/97 season. This assessment confirmed that all the year-classes since 1990 have been poor.

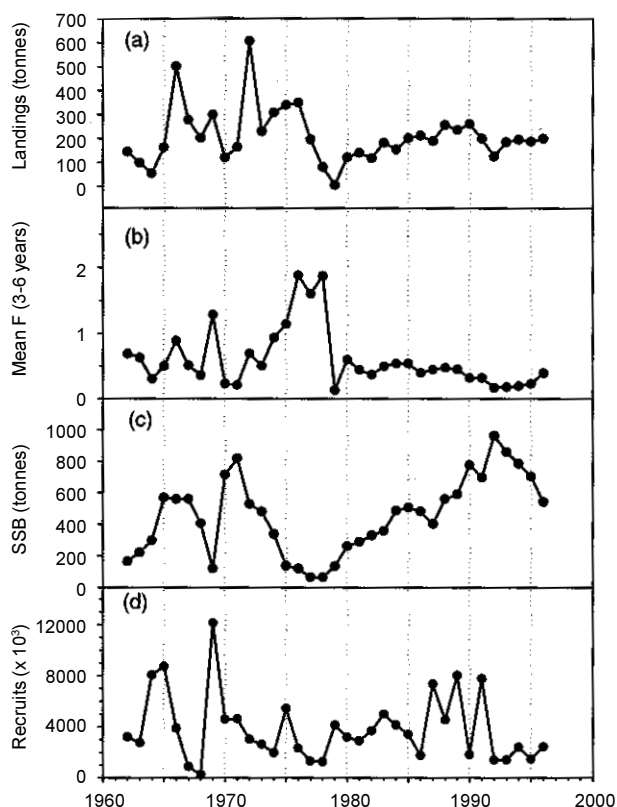


Figure 2. The history of the Blackwater herring stock as derived from Virtual Population Analysis (VPA). (a) Landings, (b) fishing mortality, (c) spawning stock biomass, (d) recruitment (age 1)

3. Hydrography

The majority of the Blackwater estuary is less than 10 m charted depth and is bounded by extensive mud-flats (Figure 1). Its hydrography has been well described by Talbot (1967) and is classified as vertically homogenous. The ratio of fresh-water inflow to tidal flow has been estimated in the order of 1:4000. During summer, evaporation may exceed freshwater inflow producing an overall residual inflow at the estuary mouth. Evaporation over the mud-flats leads to warmer, more saline water being advected out of the estuary on ebb tides (Fox *et al.*, 1999). Water flow in the estuary is considerably affected by the extensive mud-flats in the system leading to complex hydrographic flows. The Eagle Bank, which lies in the estuary mouth, consists of rough gravel and may be exposed during low spring tides. Water temperatures rise from about 7°C in January to over 20°C by July.

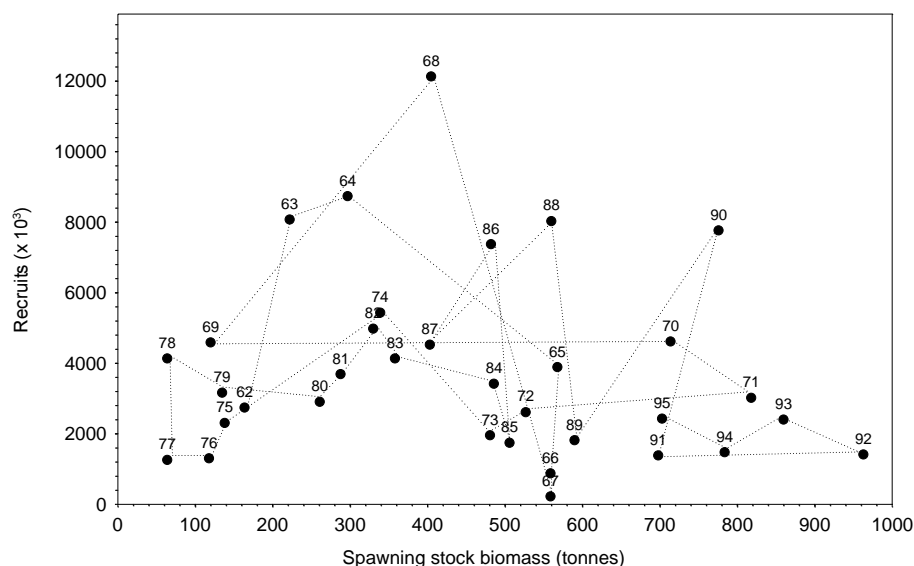


Figure 3. Time trace of the recruitment/spawning stock biomass relationship for Blackwater herring (recruits at age 1 plotted against SSB for previous year, points marked with year of SSB record)

4. Sampling scheme

Sampling in this area is complicated by the strong tidal influence. Twenty-one standard stations were located as shown in Figure 4. Single samples at these points were taken to be representative of the water in the designated boxes at the time of sampling. In 1993 the stations were sampled approximately weekly at various states of the tide. From 1994 onwards, sampling was arranged so that stations at the top of the river were sampled at low water. Since the whole sampling plan took about 8 hours

to complete, the seaward stations were sampled at high tide. The aim was to try and ensure that herring larvae were not missed in the shallow creeks at the river head and that larvae to seaward were not re-sampled. Because of the shallowness of the water it was not possible to sample above Station R at low water. Because of weather constraints the full grid, especially exposed stations, was not worked every week. In 1997 a slightly larger vessel was used to undertake the survey enabling the sampling area to be extended to the east of the Eagle Bank.

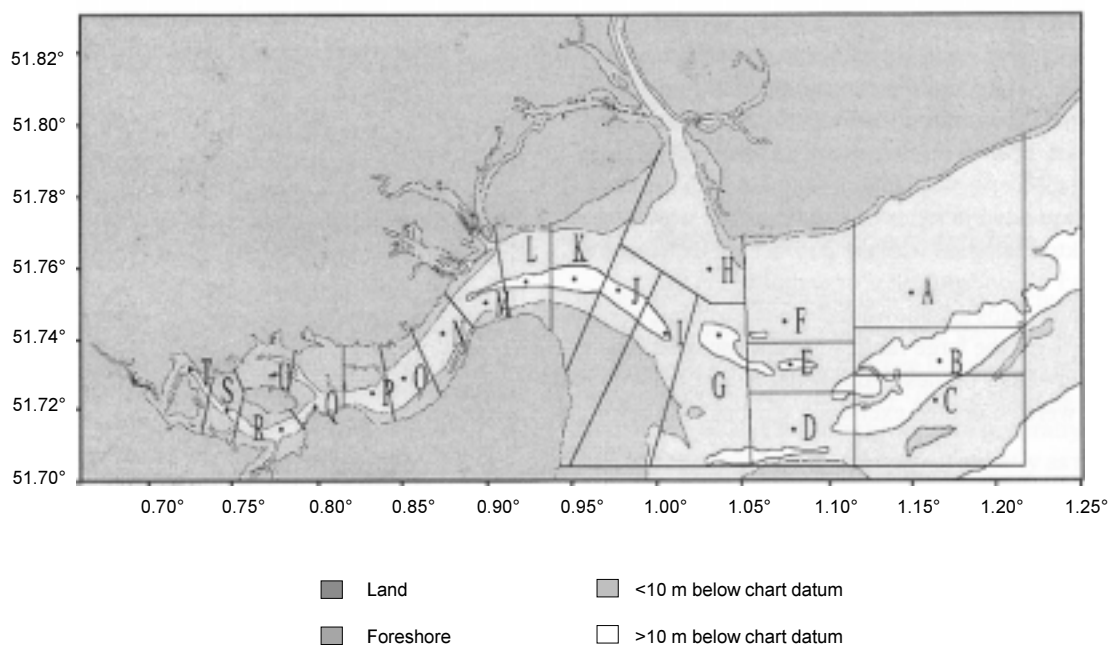


Figure 4. The bathymetry of the study area and location of the sampling stations

At each station a Lowestoft Gulf VII sampler (Nash *et al.*, 1998) was deployed at 3 knots for 5 minutes from a commercial fishing vessel (*FV GILL CK 152*, *FV OCEANUS CK 123*). The sampler was towed off the starboard derrick out of the wake of the ship. The sampler was equipped with a coarse main net (270 μm mesh) for sampling macro-zooplankton (fish eggs and larvae, ctenophores, chaetognaths etc.) and an auxiliary pup-net (80 μm mesh) for sampling meso-zooplankton (copepods, invertebrate larvae, etc.) and an FSI (Falmouth Scientific Instruments, Falmouth, USA) internally logging CTD. Each sampler carried an internal flow-meter (Valeport) mounted in the nose-cone and an external flow-meter. On recovery the nets were washed down and the samples fixed. In 1993, main-net samples were preserved in buffered alcohol but from 1994 this was changed to 4% formaldehyde in distilled water buffered with 2.5% sodium acetate trihydrate (Tucker and Chester, 1984). 'Pup-net' samples were always fixed in buffered formaldehyde.

Samples were returned to the laboratory for analysis. All herring larvae were counted out of the main-net samples and the standard lengths of up to 100 larvae per station measured using ColorMorph visual morphometric software (Perceptive Instruments, Halstead, England) linked to an Olympus SZH10 stereo-microscope. Calibration was checked daily against a slide graticule (Graticules Ltd, Tonbridge, England). Other organisms in the main-net samples were picked out and identified. Aliquots were withdrawn from the pup-net samples and organisms identified and measured using the ColorMorph system. Sub-sampling was stopped when 100-200 organisms had been measured from a station.

5. Data handling

All the data are stored on an ACCESS database (Microsoft Corp.) and are available on request. Calibration factors for the conversion of organism counts to concentrations were calculated from the flow-meter counts based on flume tank calibrations (Nash *et al.*, 1998). Macro-zooplankton sampled with the main net are expressed in terms of numbers m^{-3} , whilst meso-zooplankton sampled with the pup-net are expressed as numbers l^{-1} . Concentrations of organisms in the distribution maps are shown using a logarithmic scale in order to cover the large range of abundances recorded. The mean values of meso-zooplankton sampled with the pup-net were computed excluding stations with zero counts.

6. Herring larval abundance

Figures 5 to 8 show the abundances of herring larvae m^{-3} . In 1993, a few larvae were caught on 4 March but the major hatching was detected on 23 March. Areas of high concentration were centred around Osea Island. Concentrations declined slightly the following week

with low concentrations being found at the seaward end of the estuary. Another hatch was detected on 7 April. Larvae continued to be caught, mainly in the river, until 18 May when catches were so low that sampling was stopped. One problem with interpreting these distributions is that the sampling was carried out at different states of the tide. In 1994, the sampling pattern was standardised so that the up-river stations were sampled at low water. The outer stations were thus sampled around about high water since the whole sampling took 6 to 8 hours. In 1994, significant numbers of larvae were not detected until 29 March. Larvae continued to be found within the river in diminishing numbers until a second peak occurred on 19 April (Figure 6). They continued to be caught until the 10 May when sampling was suspended. In 1996 limited hatching was detected on 9 April (Figure 7) with major hatches occurring on 23 and 30 April. In 1997, (Figure 8) major hatching was detected on 25 March, in the same area of the river as in 1996, with concentrations decreasing gradually through to 12 May.

7. Other macro-zooplankton

In 1993 only selected main-net samples were fully analysed. The datasets from 1994 to 1997 are thus more complete and plotted in this report. Apart from herring larvae the other major macro-zooplankton organisms which occurred in the estuary were ctenophores, mysids, chaetognaths, amphipods and isopods (Tables 1 to 8). Other organisms sampled occasionally included larval and juvenile gobies, swimming decapods (*Natantia* spp.), eggs of sole (*Solea solea*), polychaete larvae, amphipods, juvenile sprat (*Sprattus sprattus*), pagurid and brachyuran larvae and isopods.

8. Ctenophore abundance

Ctenophores are a small phylum of marine animals commonly known as sea-gooseberries. In the Blackwater they are almost exclusively of the species *Pleurobrachia pileus*. They are carnivorous, entrapping prey with paired branched tentacles. They consume mainly copepods but may also occasionally take fish larvae (Fraser, 1970; Reeve, 1978; Purcell, 1985). Ctenophore concentrations for 1994 are plotted in Figure 9. Concentrations were initially low but increased rapidly in early April. Concentrations were highest at the estuary mouth at this time (Figure 9). Ctenophore abundance within the estuary then increased until, by 10 May, the highest concentrations were recorded near Osea Island. The maximum observed concentration was 73.4 m^{-3} on 19 April (Table 6). In 1996, the maximum concentration (18.4 m^{-3}) was observed on 3 April at the estuary mouth. Concentrations of 0.1 to 17.9 m^{-3} were observed through to 30 May (Table 7). Up to April 14 1997, lower concentrations were observed than in previous years. However, ctenophore abundance then increased rapidly reaching 27.9 m^{-3} by 19 May. In general, the

concentration of *Pleurobrachia pileus* appeared to increase from the river to the sea. At many stations the concentration of ctenophores exceeded that of herring larvae but data on biomass remains to be analysed. Because of their high concentration, ctenophores may compete with herring larvae for food in the estuary ecosystem.

9. Mysid abundance

Members of the order mysidacea are small shrimp-like crustaceans often known as opossum shrimps. They are primarily filter feeders taking algae and micro-zooplankton such as bacteria and ciliates. They are common members of the macro-zooplankton in the Blackwater and were recorded in all years of the survey. In early 1994, the highest concentrations were recorded around Osea Island. After mid-April this pattern changed with concentrations increasing at the estuary mouth although mysids were less common in the river itself (Figure 12). The maximum observed mysid concentration was 22.3 m^{-3} (Table 6). In 1996, lower concentrations were observed with a maximum of 7.38 m^{-3} on 23 April (Figure 13). Mysid concentrations in 1997 were much higher than in the previous years, with peak numbers of 71.03 m^{-3} occurring at the estuary mouth on 12 May (Figure 14). Overall, the general pattern of mysid distribution was of low concentrations in the river itself increasing toward the seaward end.

10. Chaetognaths

Chaetognaths (arrow-worms) are another important component of the zooplankton. They are voracious predators of copepods and fish larvae but rarely consume planktonic fish eggs since they detect their prey by vibrations caused by movement (Feigenbaum and Maris, 1984). Generally the abundance of chaetognaths increased moving toward the estuary mouth. In 1994, concentrations fluctuated throughout the season with a maximum of 7.7 m^{-3} recorded on 14 March (Figure 15). In 1996 a similar pattern was observed but in 1997 concentrations were higher in the estuary mouth reaching a maximum of 18.23 m^{-3} on 19 May (Figure 17). Chaetognaths may act both as direct predators upon and as competitors for food with the herring larvae in the estuary.

11. Meso-zooplankton

Relatively few studies have simultaneously estimated the abundance of fish larvae and their prey. The use of fine mesh nets necessary to quantitatively sample such items as copepod nauplii has not been common (Heath, 1992; McLaren and Avendano, 1995). In the present

investigation, meso-zooplankton were sampled using $80 \mu\text{m}$ mesh nets, which are sufficient to retain all except the youngest naupliar stages of *Acartia* (Nichols and Thompson, 1991). Selected pup-net stations spread across the study area were analysed from the 1993, 1994, 1996 and 1997 samples. In 1993 samples from sites E, J, M and P were analysed (Figure 4). In 1994, sites E and G were also analysed (although they were not sampled every week). In 1997, site A was also analysed. The estuarine meso-zooplankton was usually dominated by copepods and their nauplii (Tables 9 to 16). Other common organisms included polychaete larvae, cirripede nauplii and bryozoan, gastropod and bivalve larvae. Copepods were the only meso-zooplanktonic organisms identified to genus.

12. Copepods

Copepods and their nauplii are usually the preferred prey items for larval clupeoids (Blaxter and Hunter, 1982; Fox *et al.*, 1999). Because of this these organisms have received special attention in field studies. Figures 18-21 show that in March, average numbers of nauplii were usually less than 5 l^{-1} . Standing stocks tended to increase with time, until by mid-May concentrations were between $5\text{-}10 \text{ l}^{-1}$. In 1994 however, standing stocks of nauplii began at a higher level of around 7 l^{-1} and remained around this value throughout the season.

Copepod nauplii were not identified to species but adults and copepodite stages were. Since in all years *Acartia* dominated the copepods of the estuary, most nauplii were probably those of this species. The second most abundant copepods were harpacticoids which were not identified to species. Other calanoid copepods, *Temora*, *Pseudocalanus* and *Centropages*, contributed a relatively small proportion of copepod standing stocks. Remaining copepods sampled in low numbers included cyclopoids and *Calanus*. Overall, average copepod standing stocks (adults and copepodites) in March tended to be less than 2 l^{-1} with only a slight increase by mid-April and May.

13. Other meso-zooplankton

Other dominant meso-plankton species included the larvae of polychaetes, bryozoans, gastropods and bivalves. In most years, average numbers of polychaete larvae tended to be around 2 l^{-1} throughout the season. Bryozoan larvae concentrations were generally less than 1 l^{-1} in February-March increasing slightly as the season progressed. Gastropod larvae followed a similar trend, but reached a peak of 6 l^{-1} in mid-May in 1997. The exceptionally large value of miscellaneous items (35.3 l^{-1}) recorded on 30 May 1996 (Figure 20) was driven by a large concentration of lamellibranch larvae (Table 15).

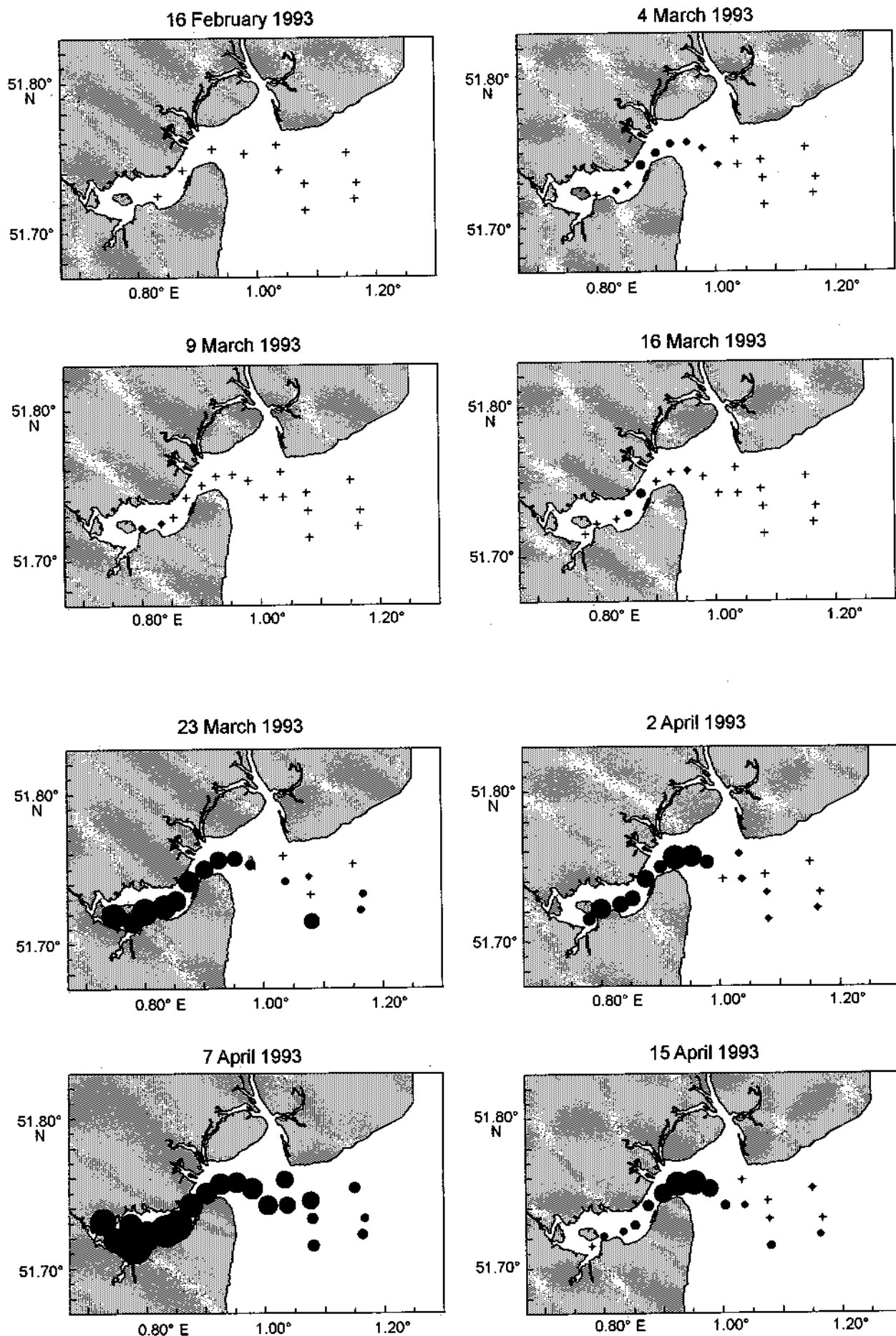


Figure 5. Herring larval concentrations during 1993

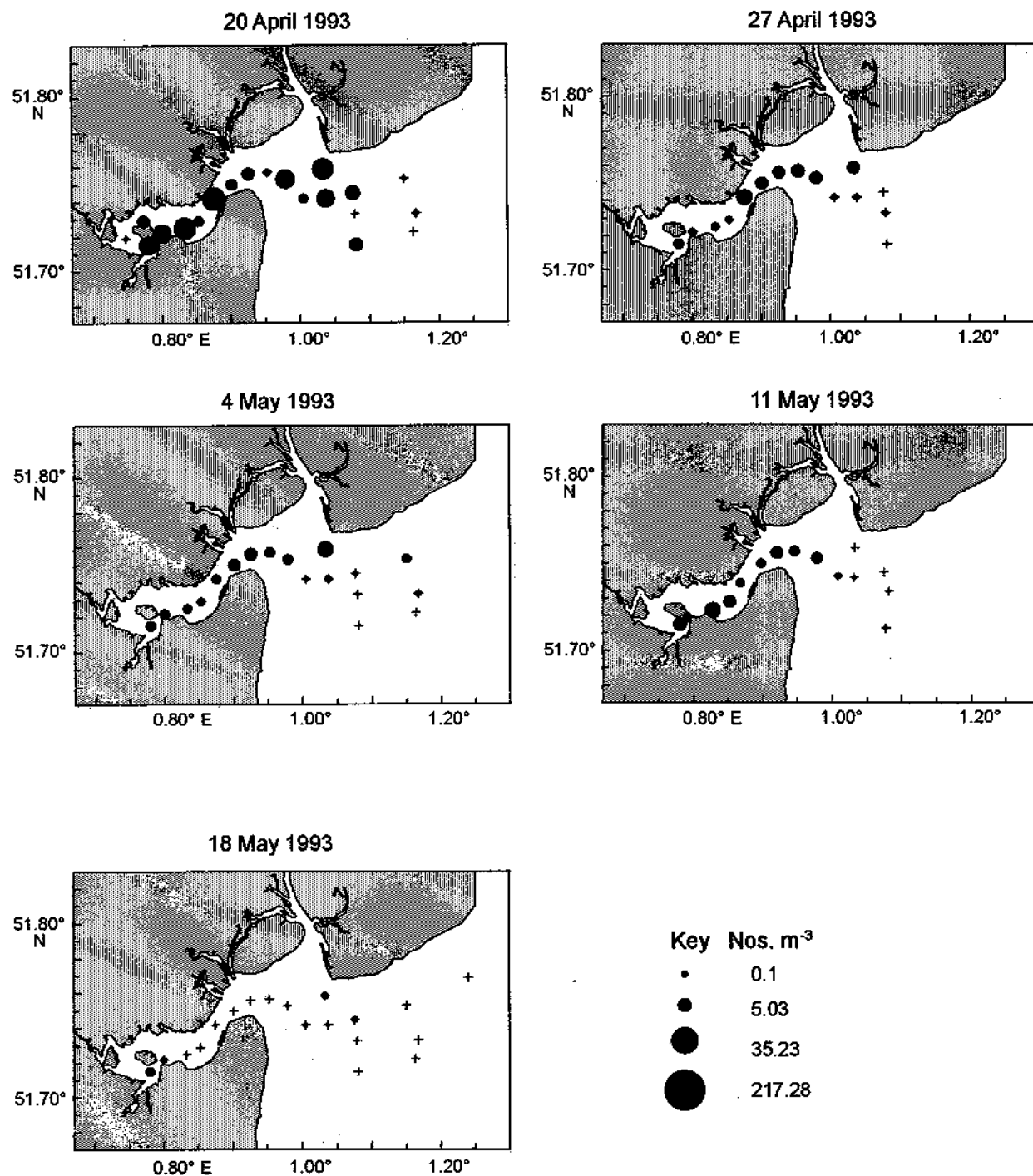


Figure 5 continued. Herring larval concentrations during 1993

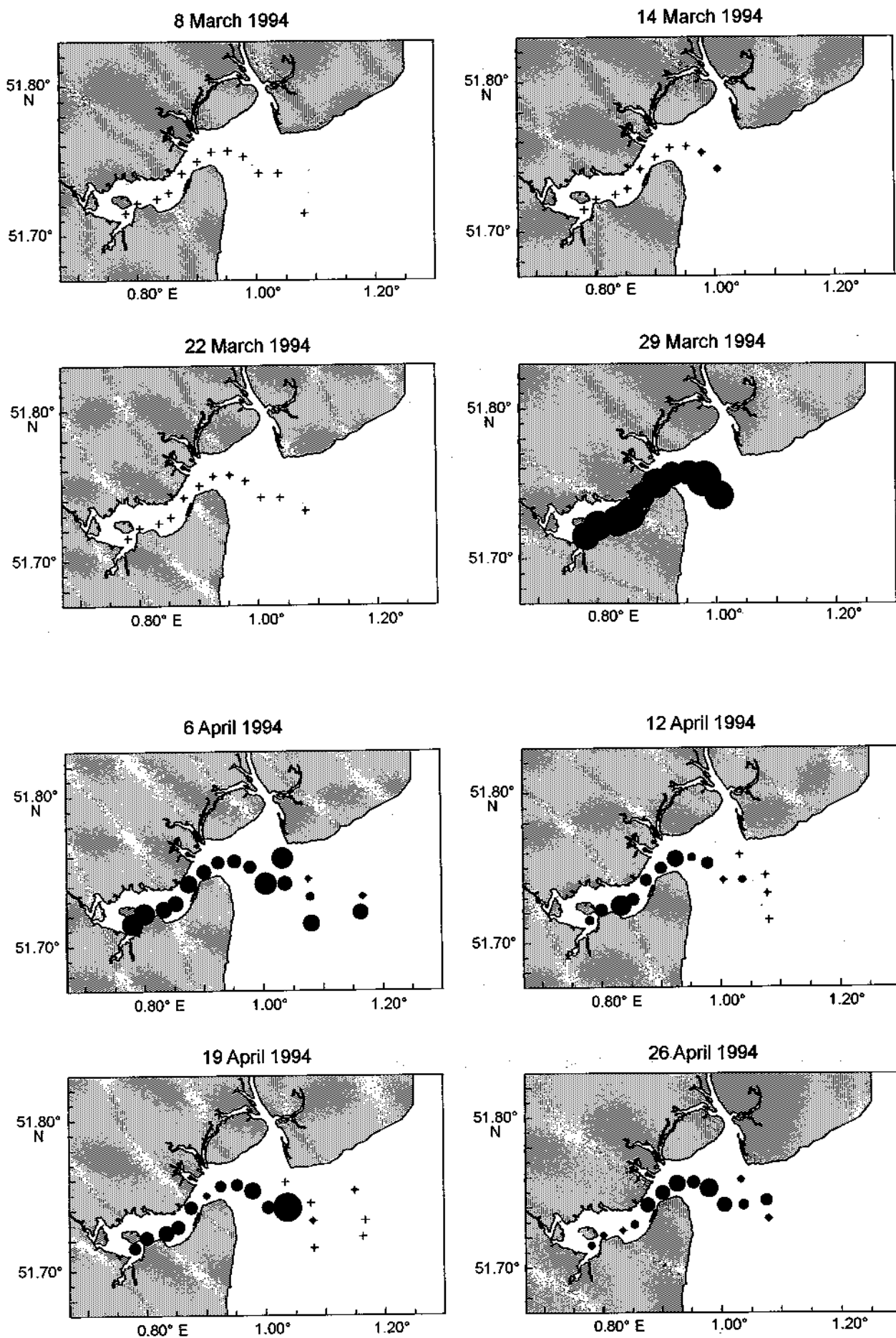


Figure 6. Herring larval concentrations during 1994

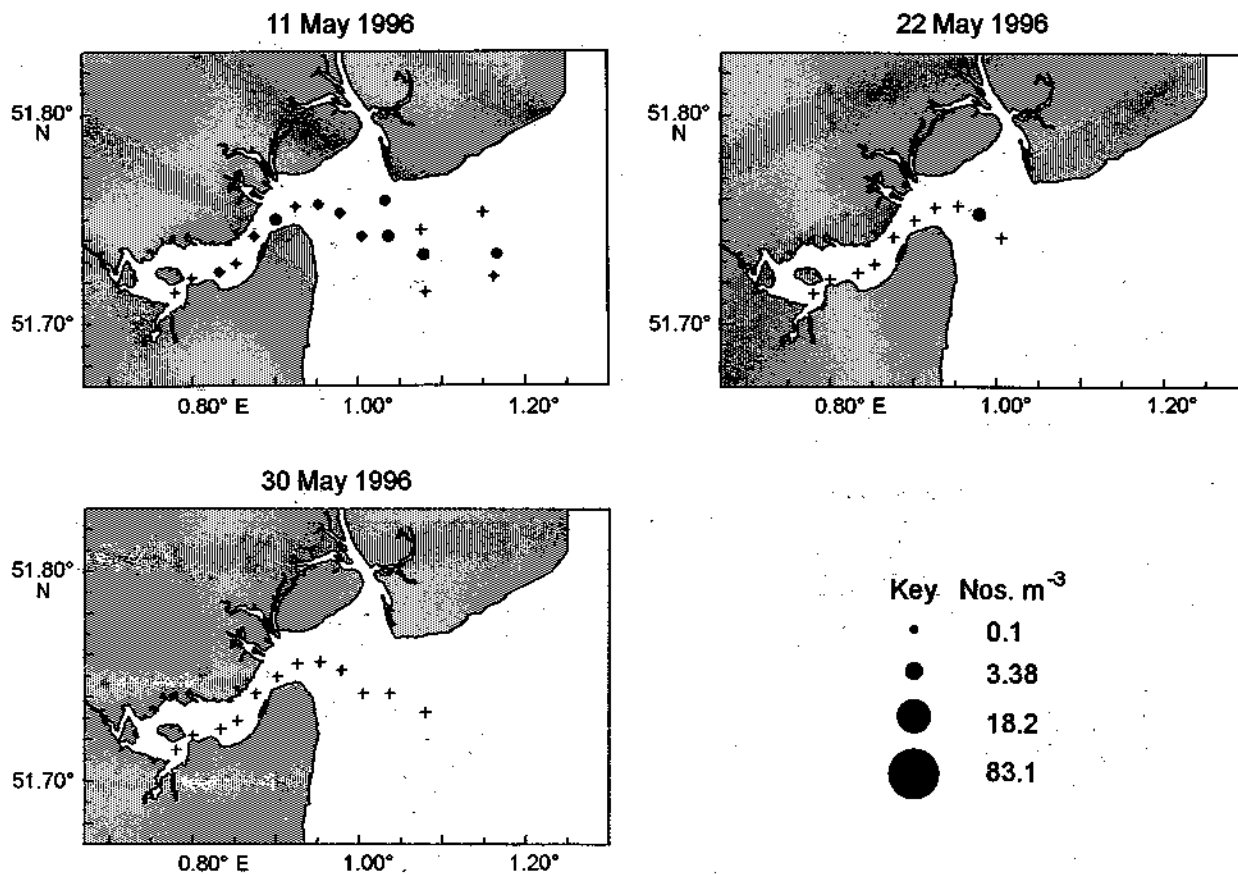


Figure 7 continued. Herring larval concentrations during 1996

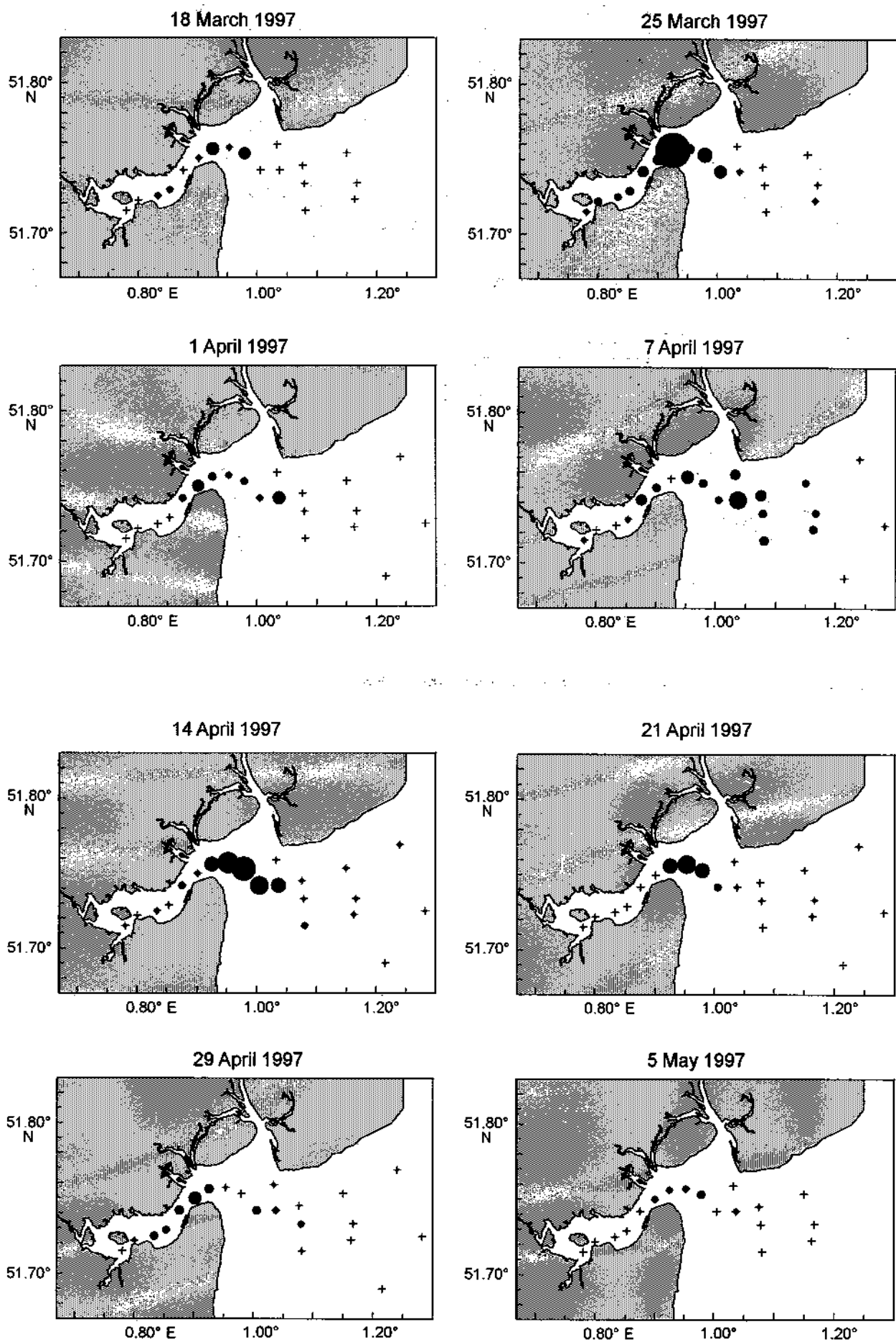


Figure 8. Herring larval concentrations during 1997

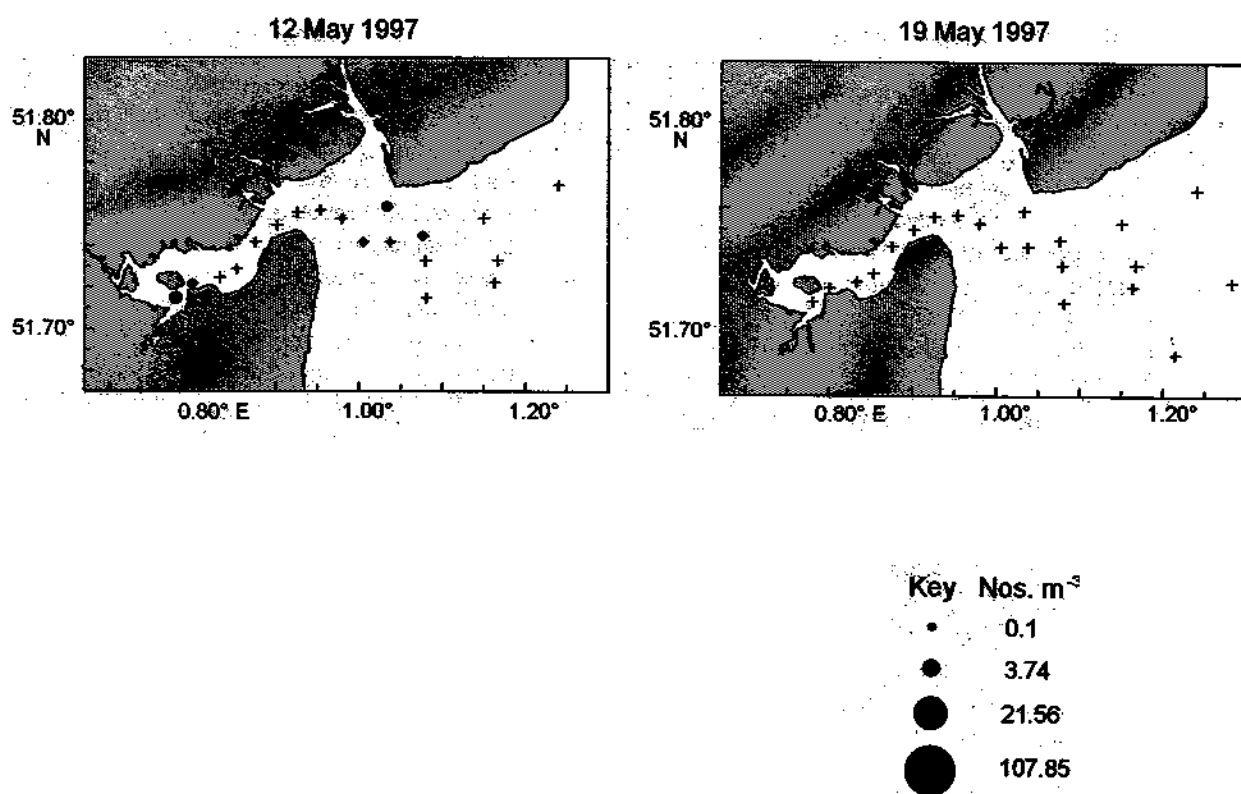


Figure 8 continued. Herring larval concentrations during 1997

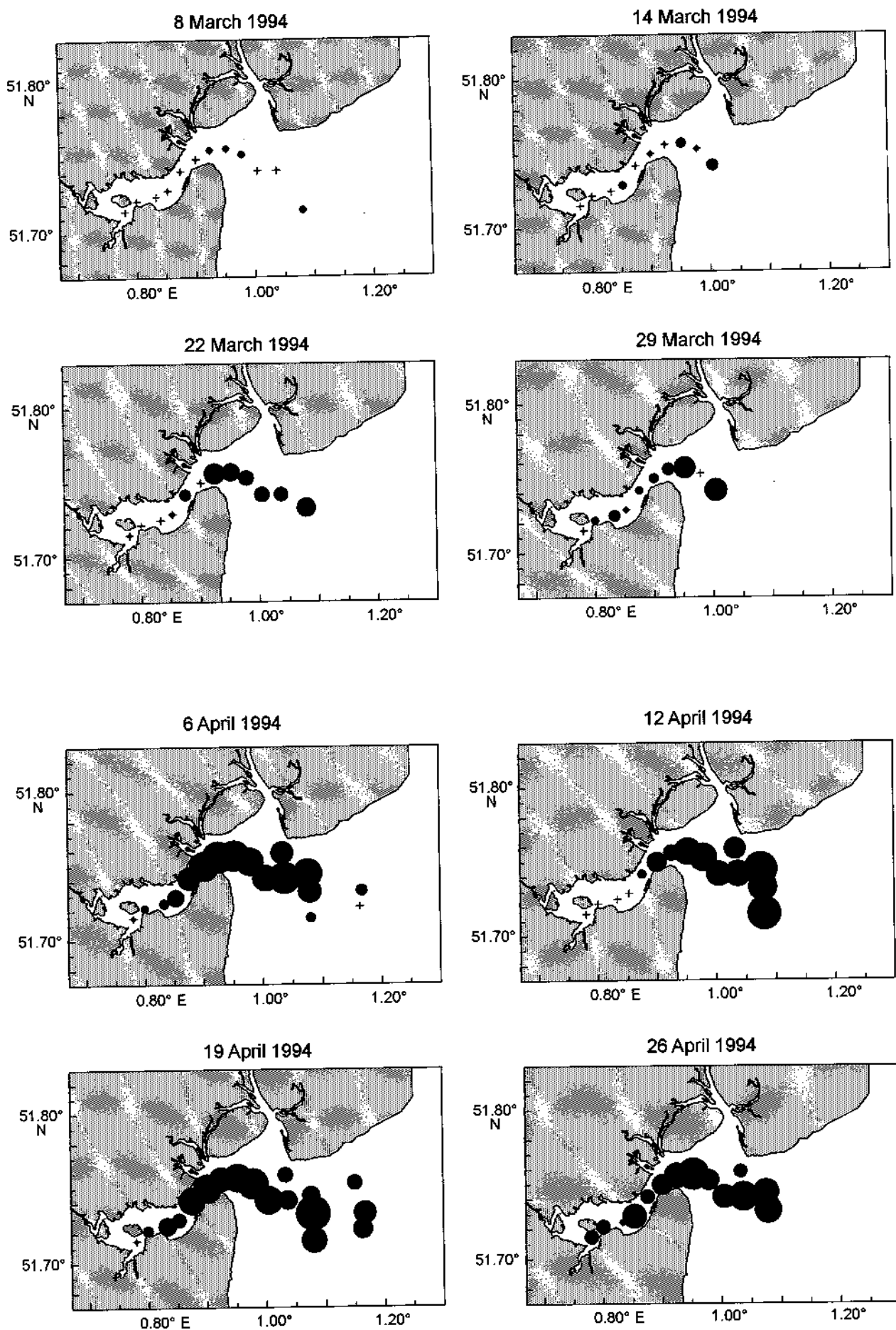


Figure 9. *Ctenophore (Pleurobrachia pileus) concentrations during 1994*

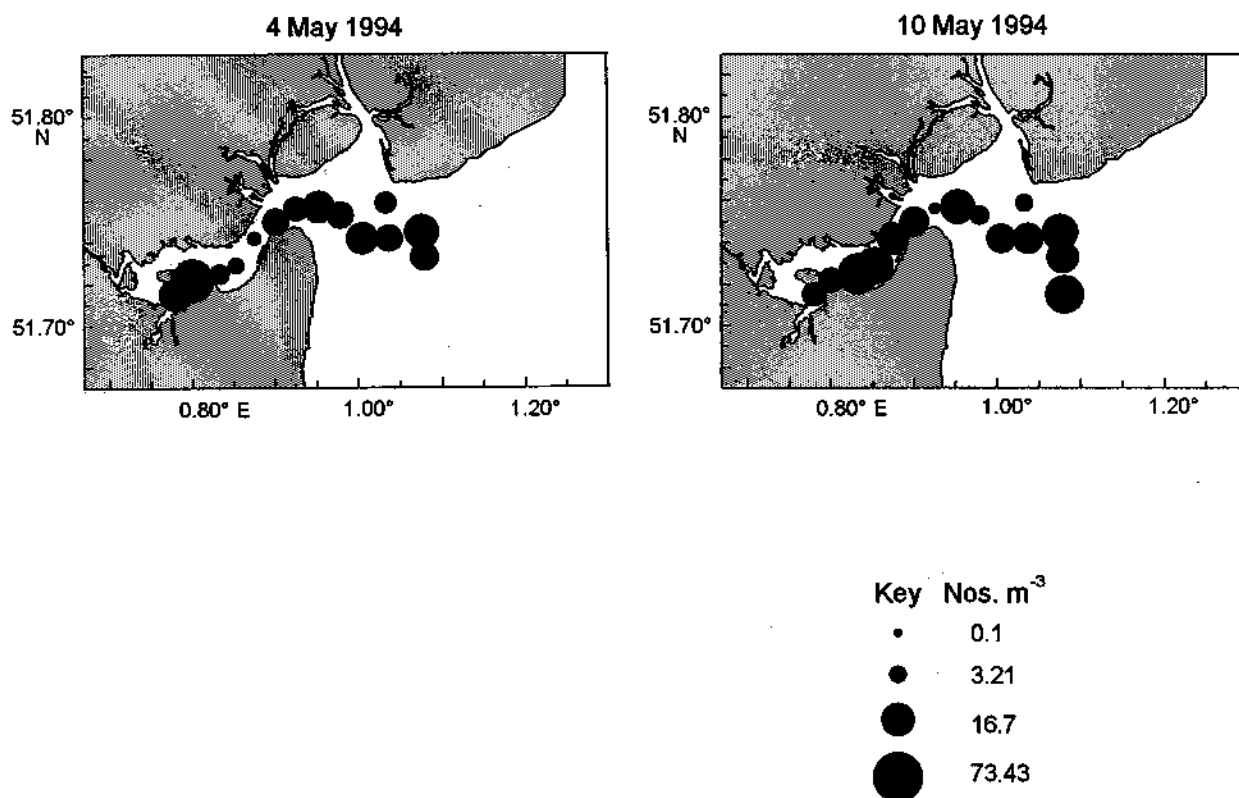


Figure 9 continued. *Ctenophore (Pleurobrachia pileus) concentrations during 1994*

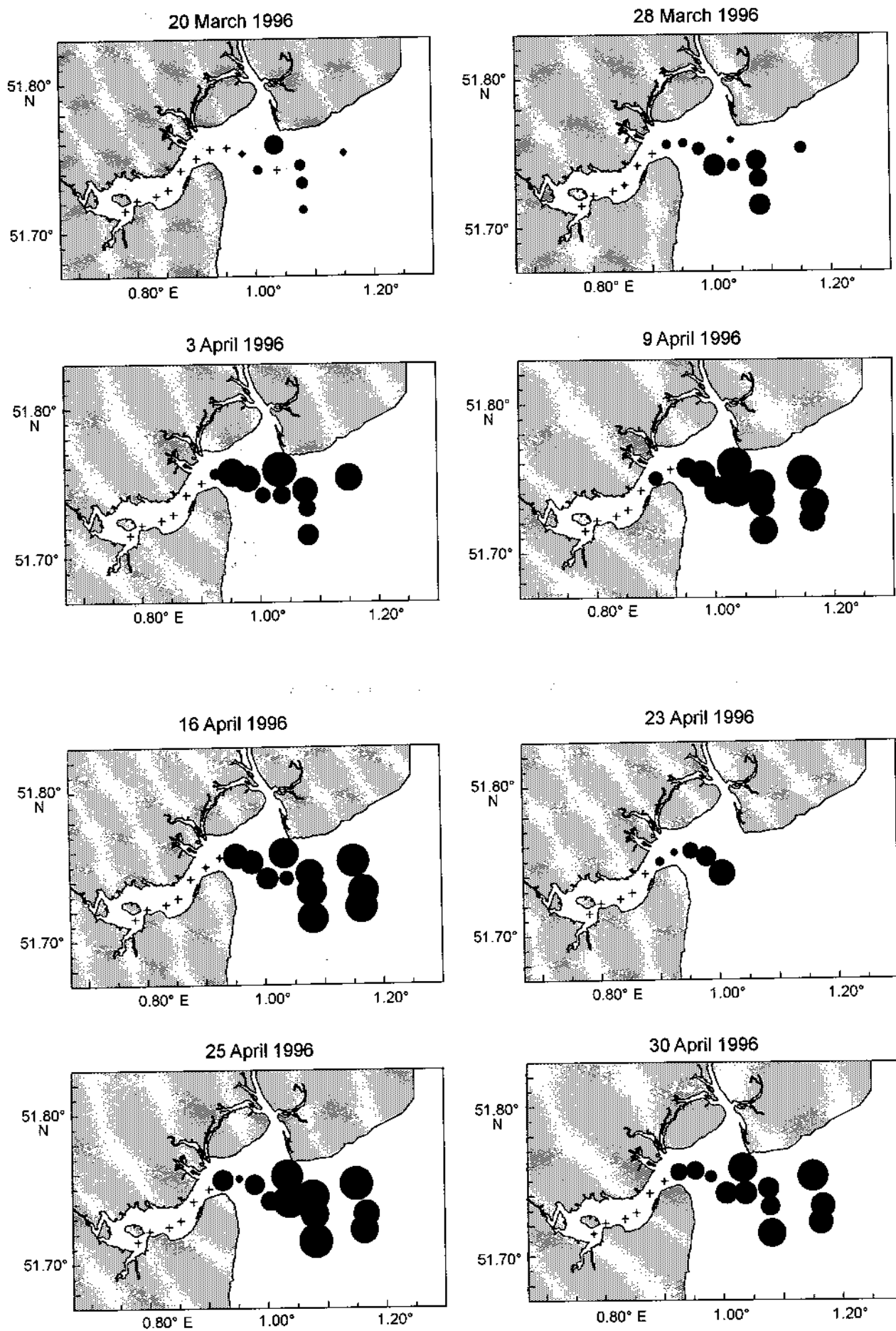


Figure 10. Ctenophore (*Pleurobrachia pileus*) concentrations during 1996

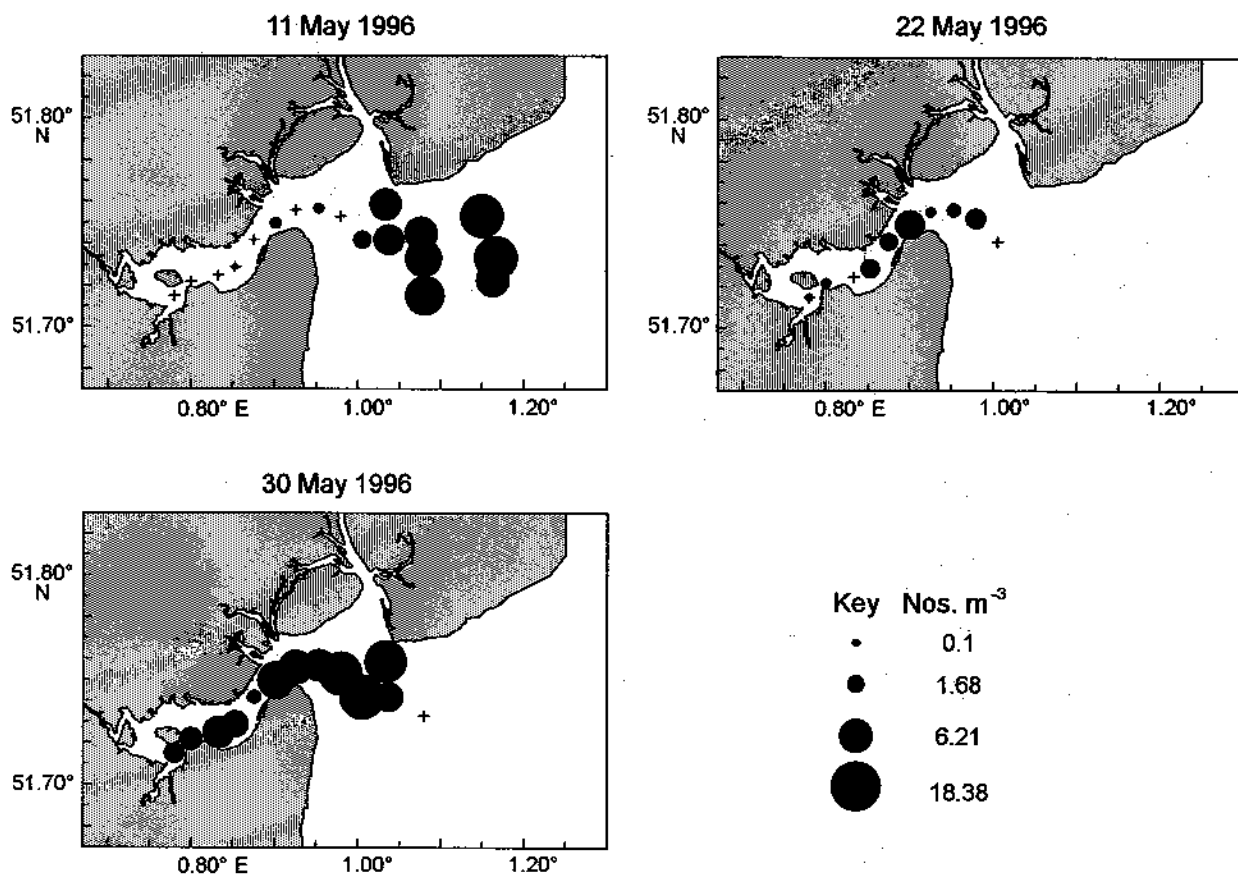


Figure 10 continued. *Ctenophore (Pleurobrachia pileus)* concentrations during 1996

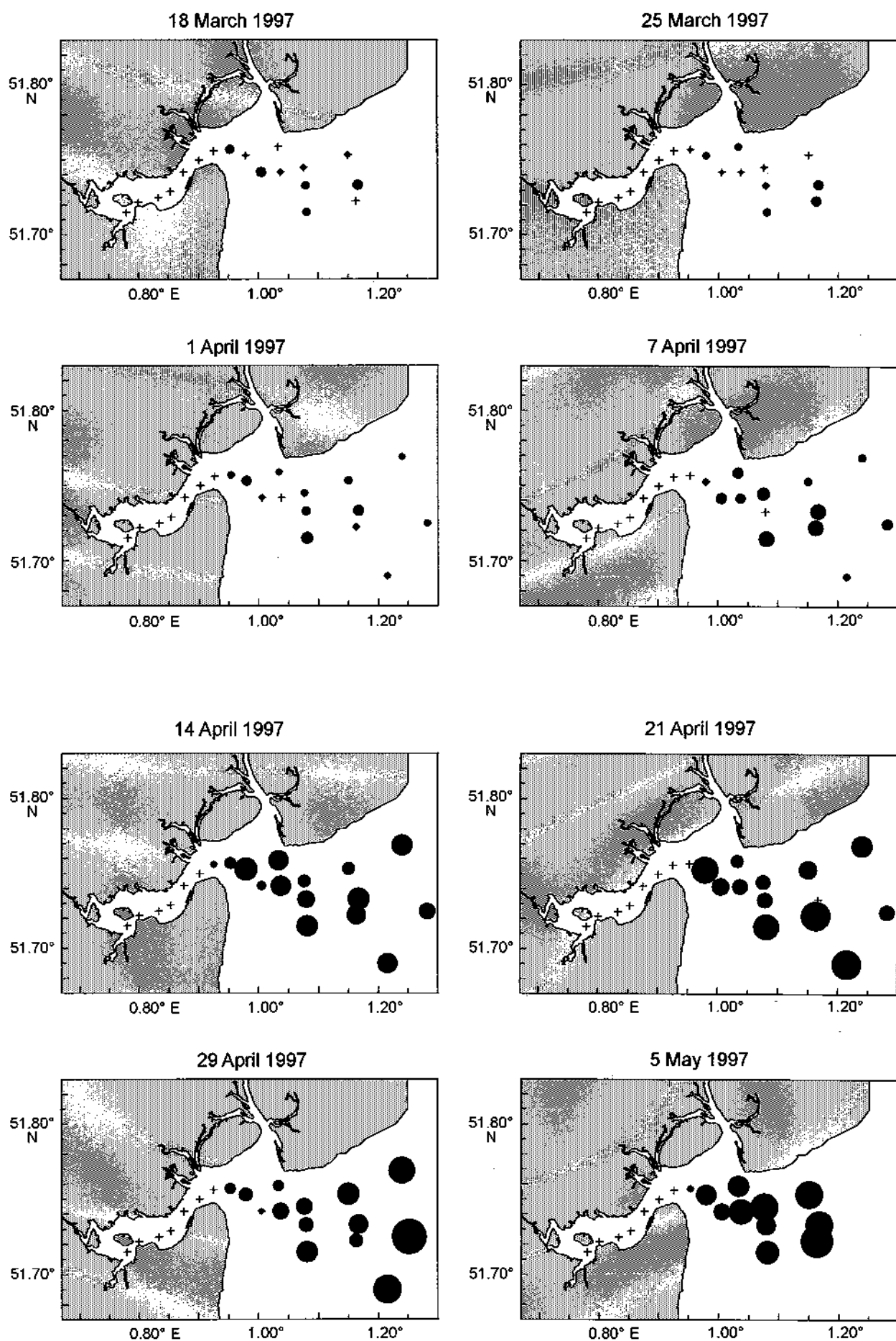


Figure 11. *Ctenophore (Pleurobrachia pileus)* concentrations during 1997

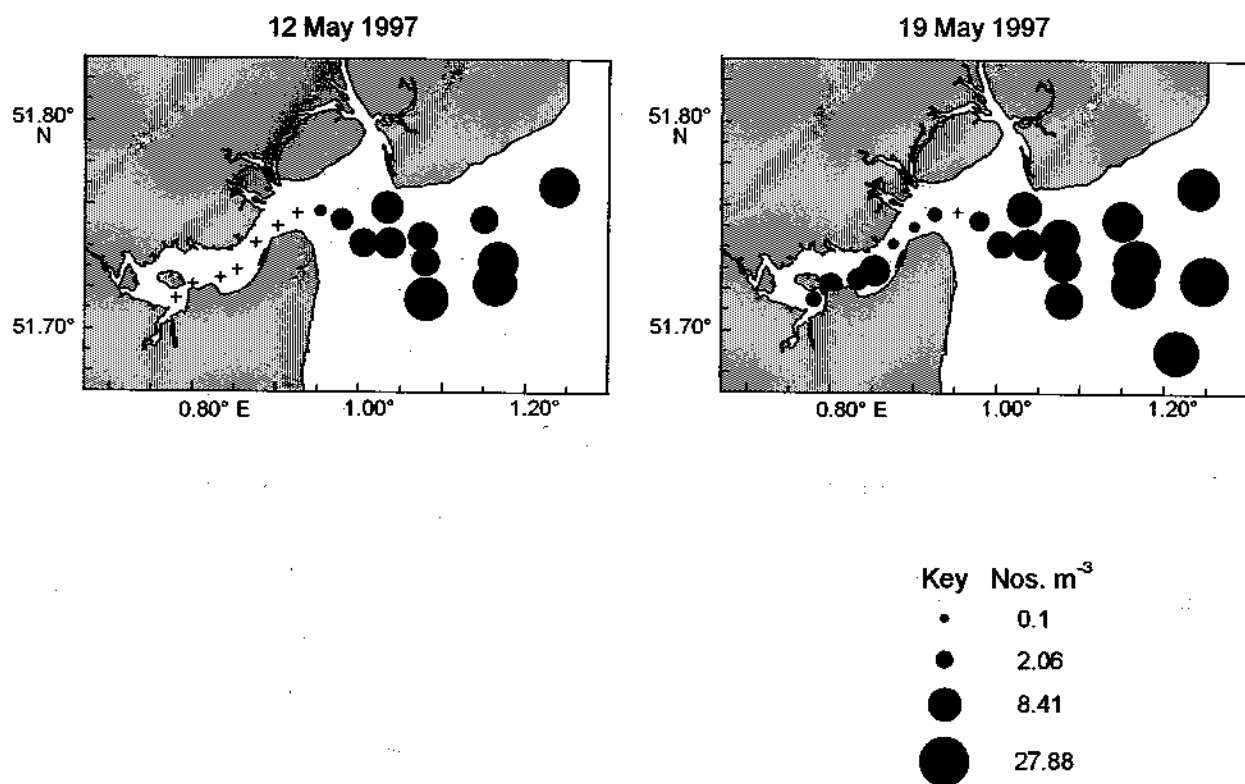


Figure 11 continued. Ctenophore (*Pleurobrachia pileus*) concentrations during 1997

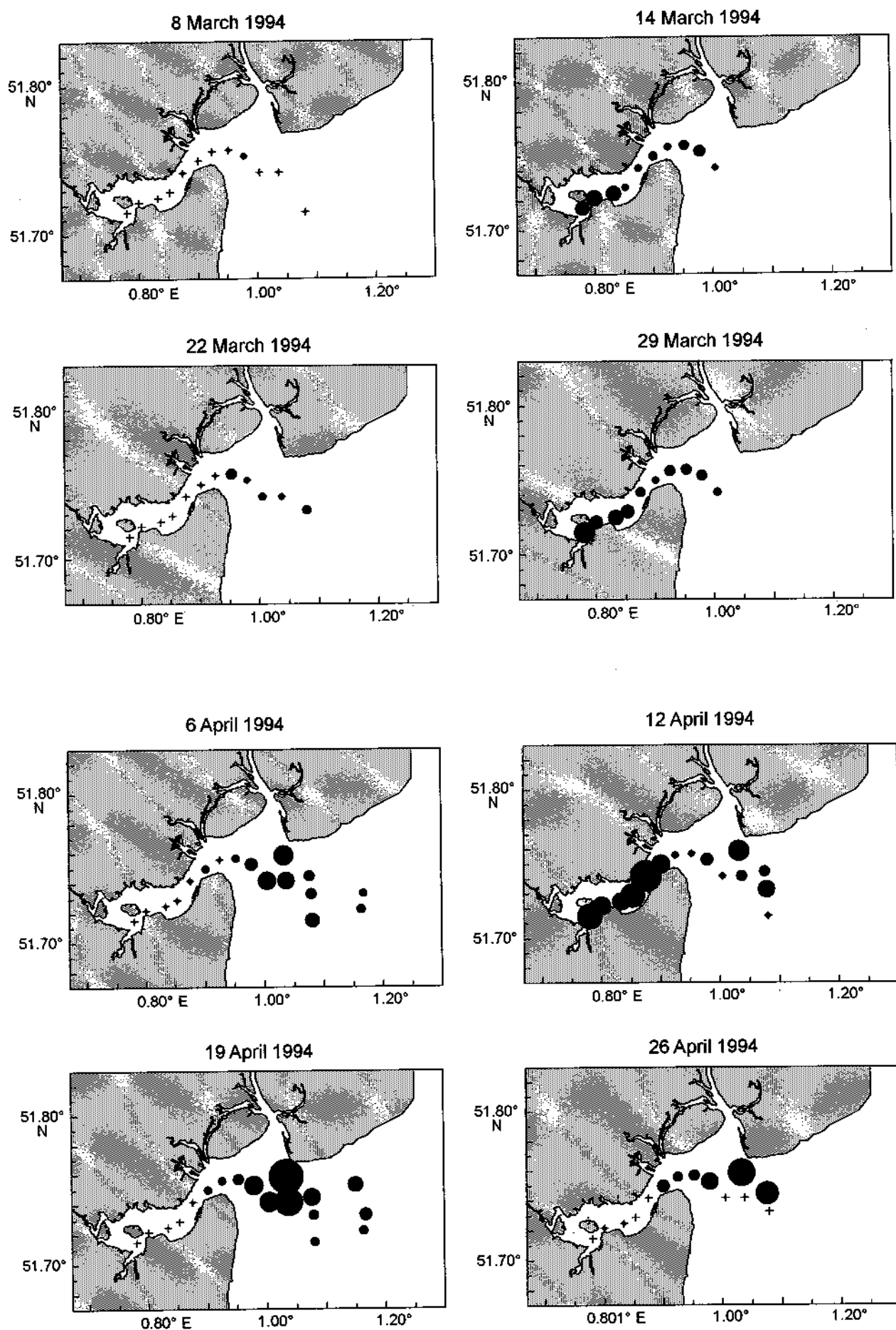


Figure 12. Mysid concentrations during 1994

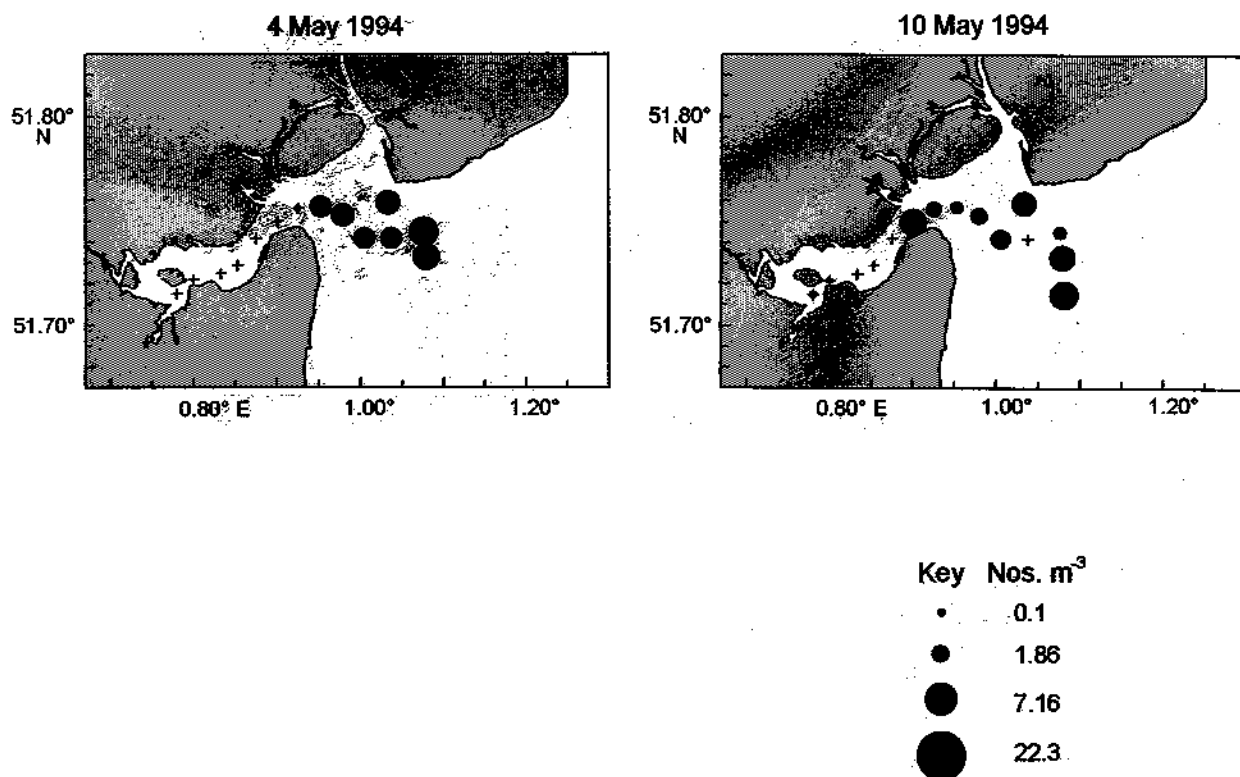


Figure 12 continued. Mysid concentrations during 1994

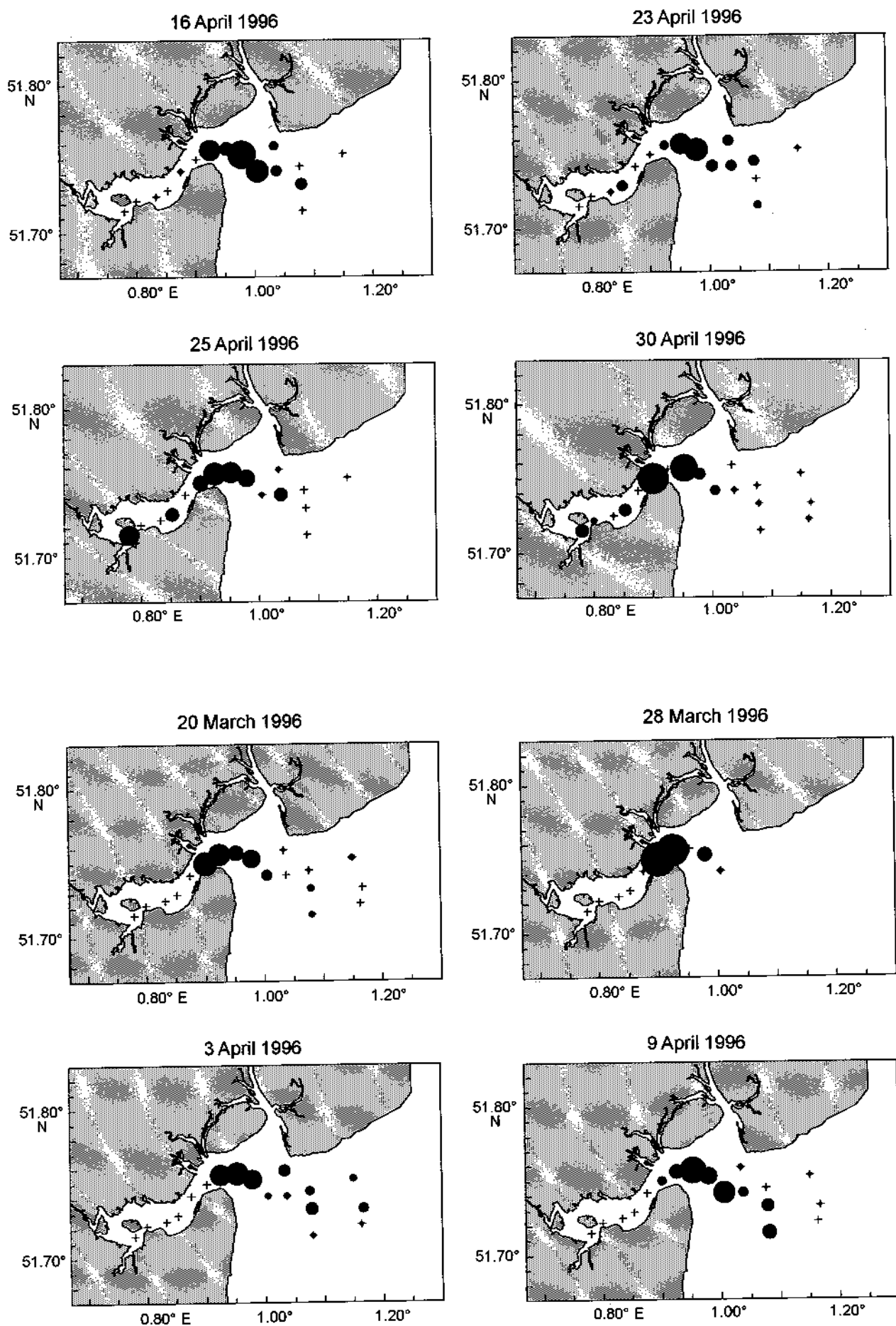


Figure 13. Mysid concentrations during 1996

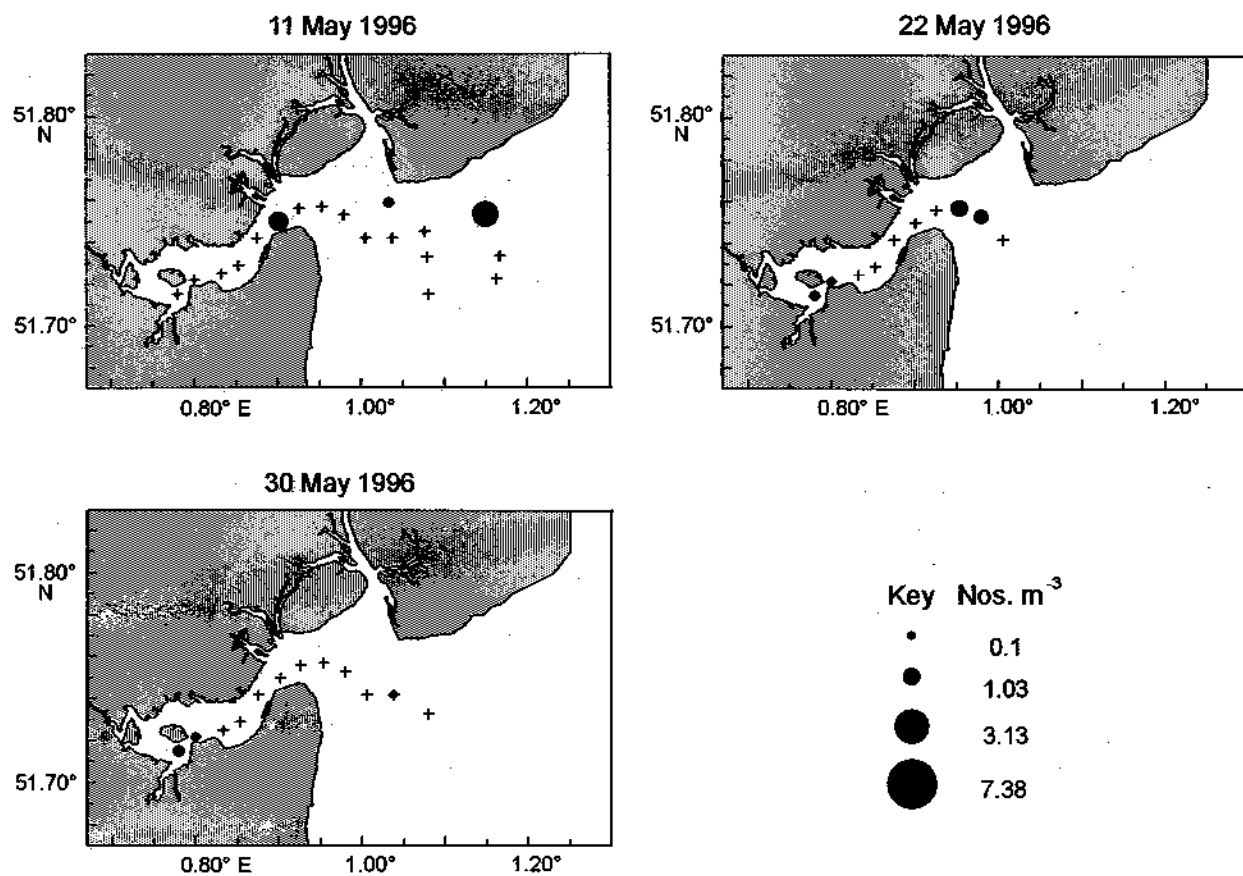


Figure 13 continued. Mysid concentrations during 1996

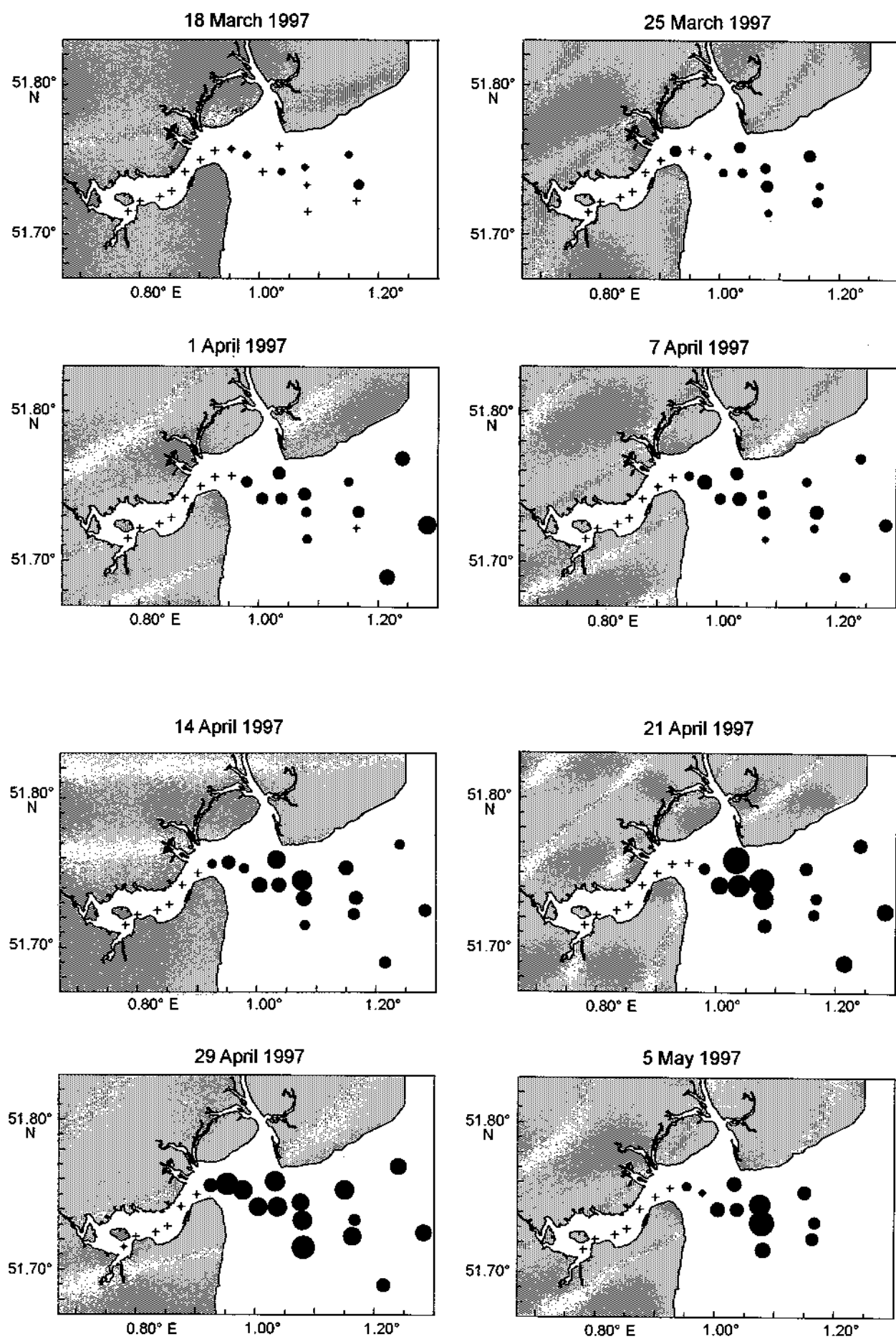


Figure 14. Mysid concentrations during 1997

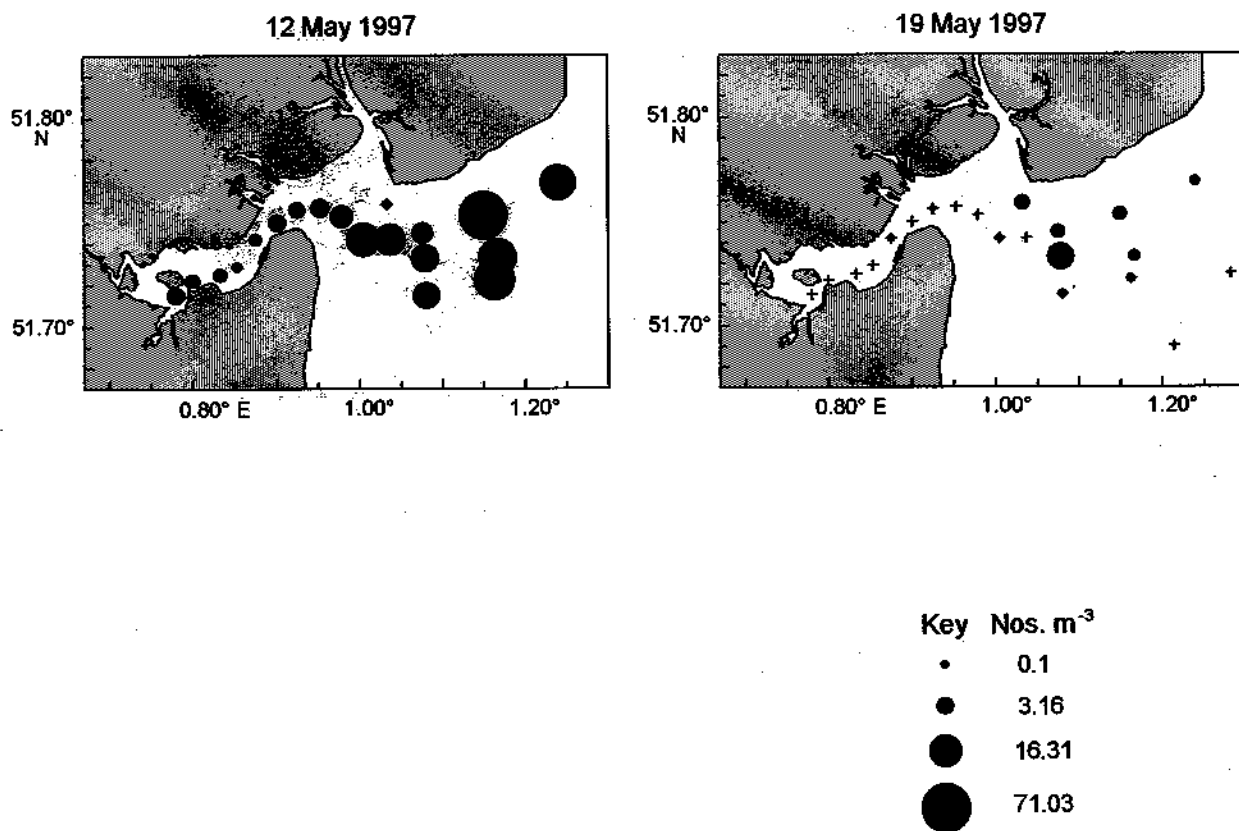


Figure 14 continued. Mysid concentrations during 1997

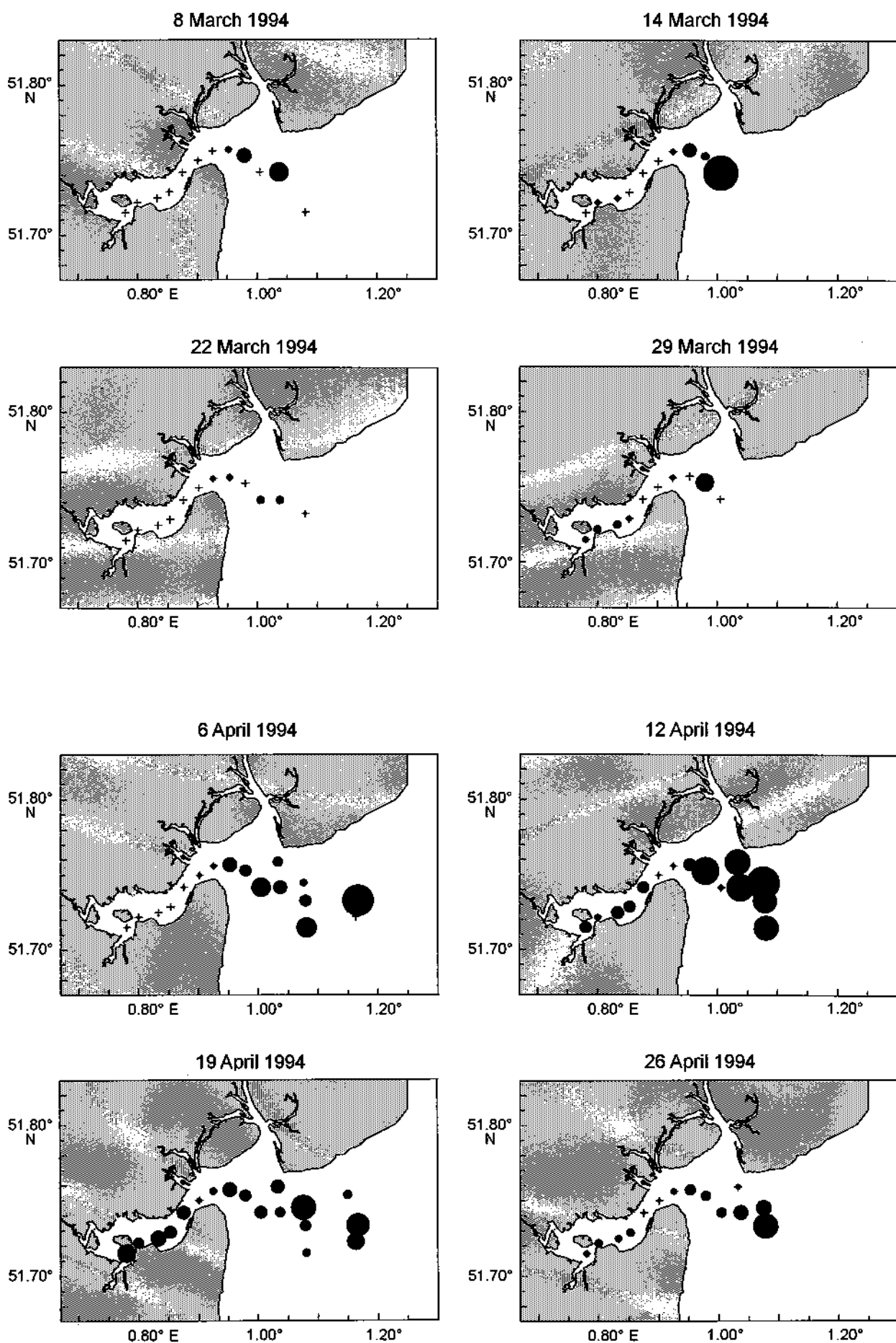


Figure 15. *Chaetognath* concentrations during 1994

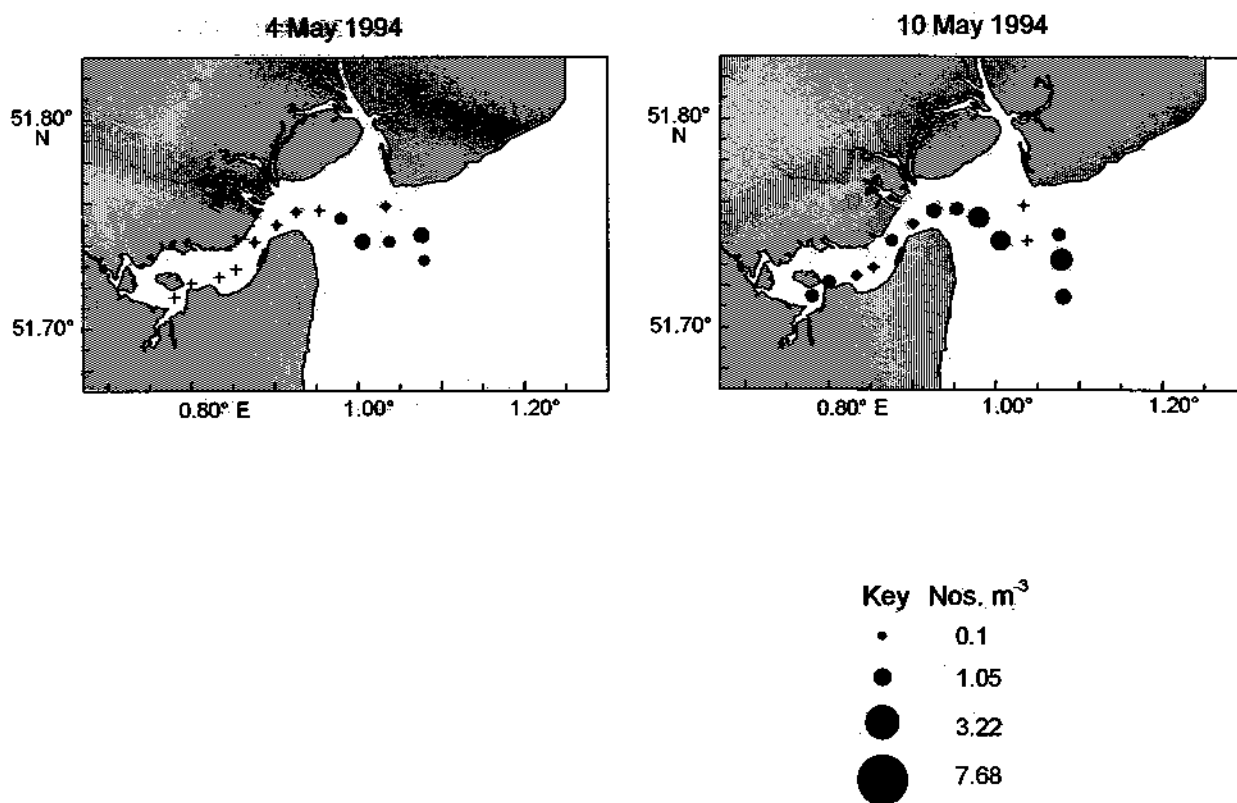


Figure 15 continued. Chaetognath concentrations during 1994

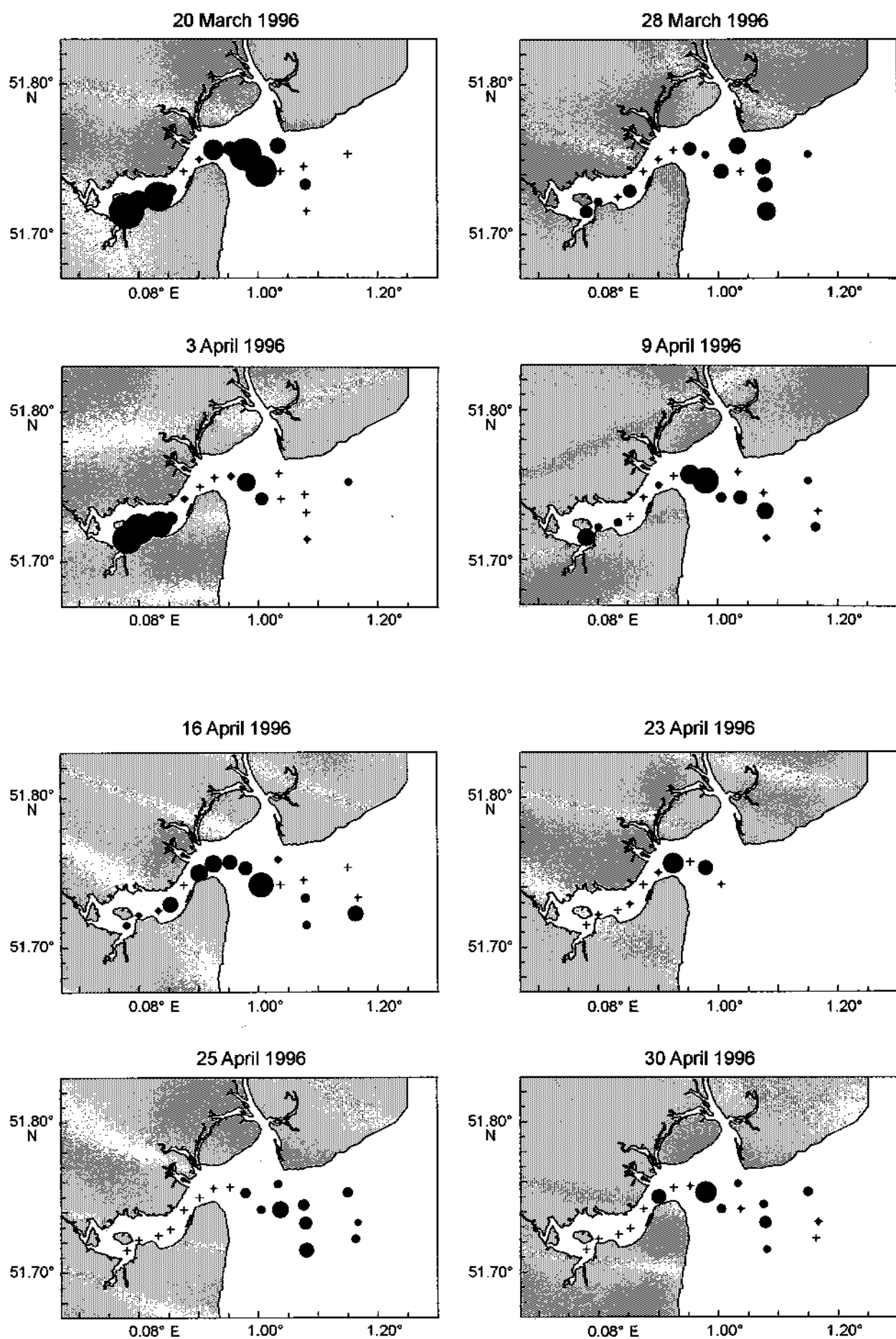


Figure 16. Chaetognath concentrations during 1996

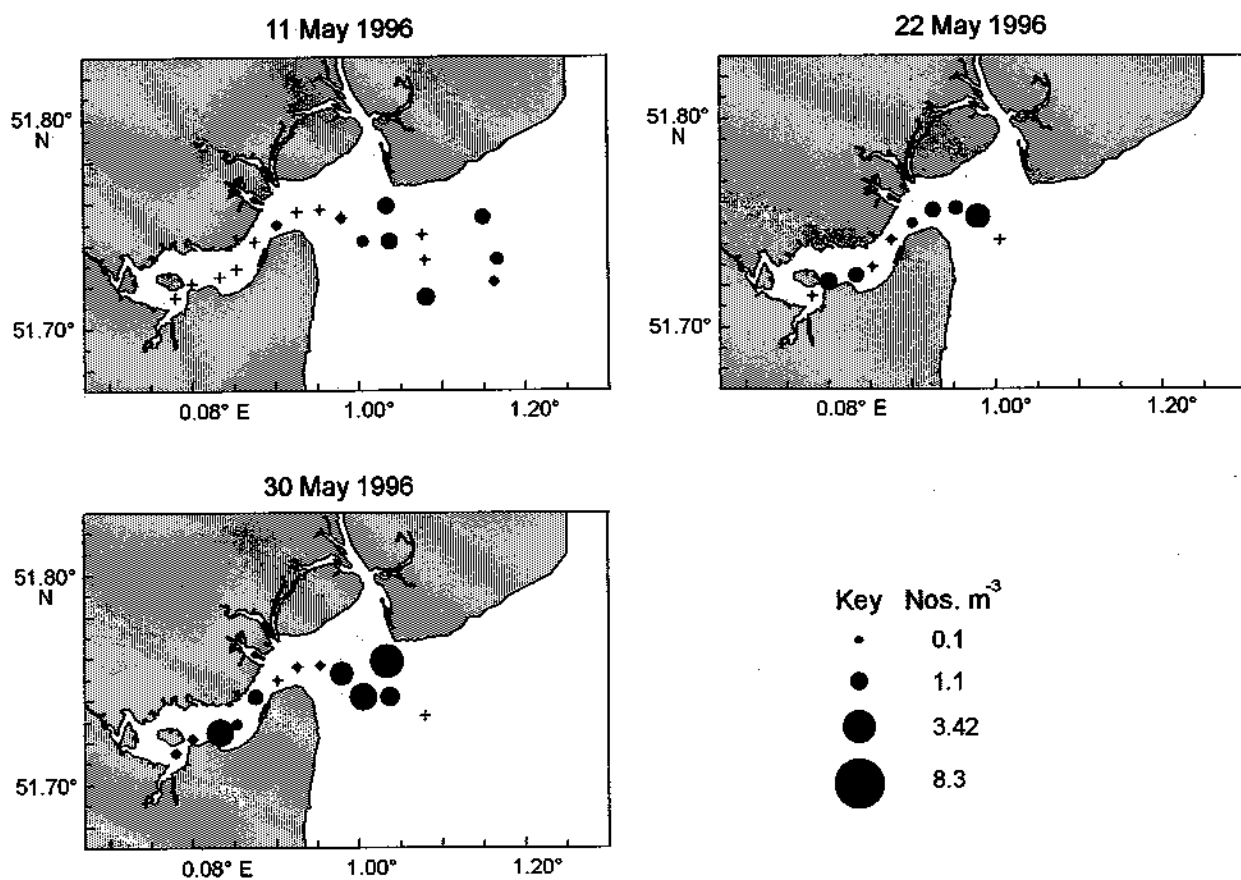


Figure 16 continued. Chaetognath concentrations during 1996

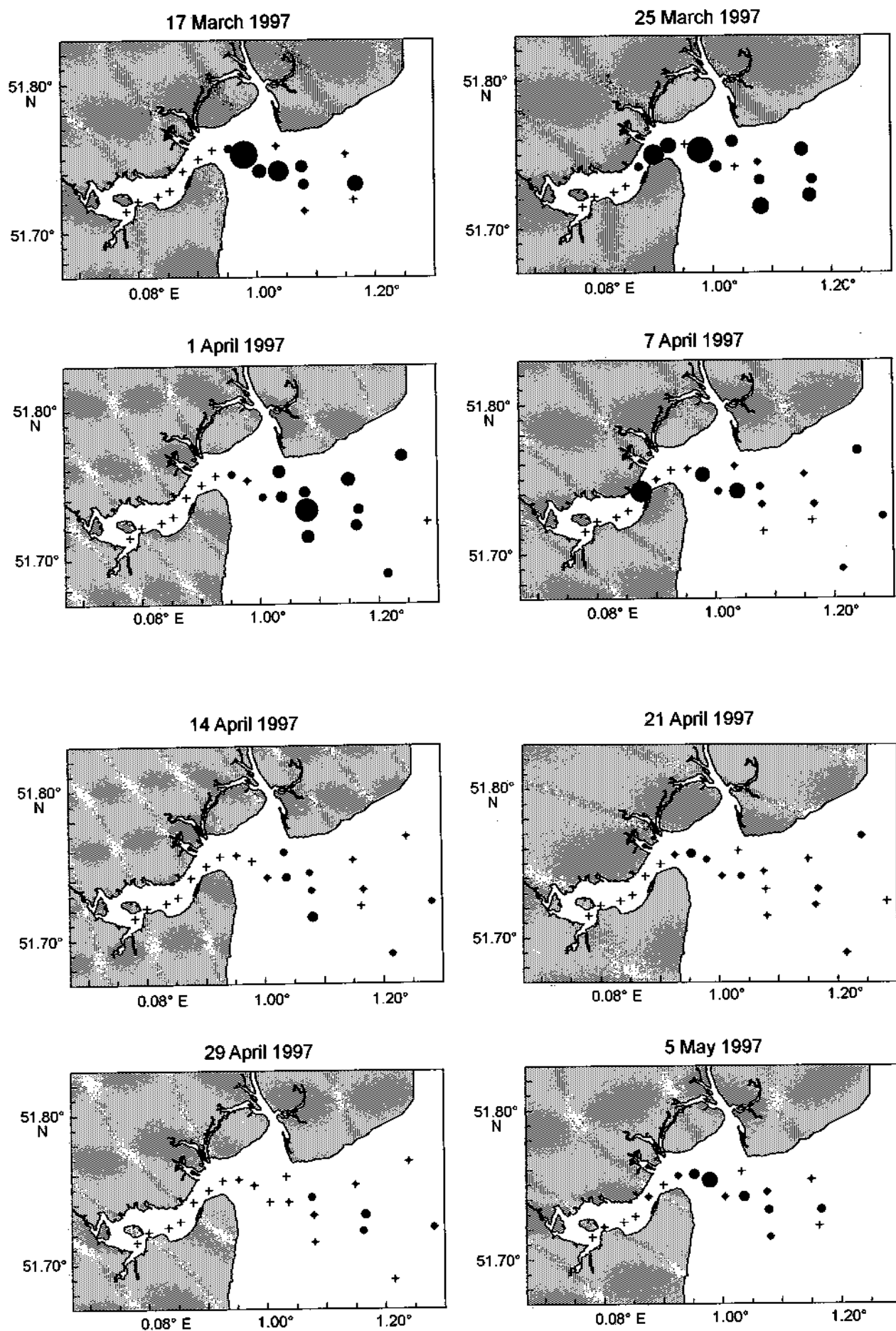


Figure 17. *Chaetognath* concentrations during 1997

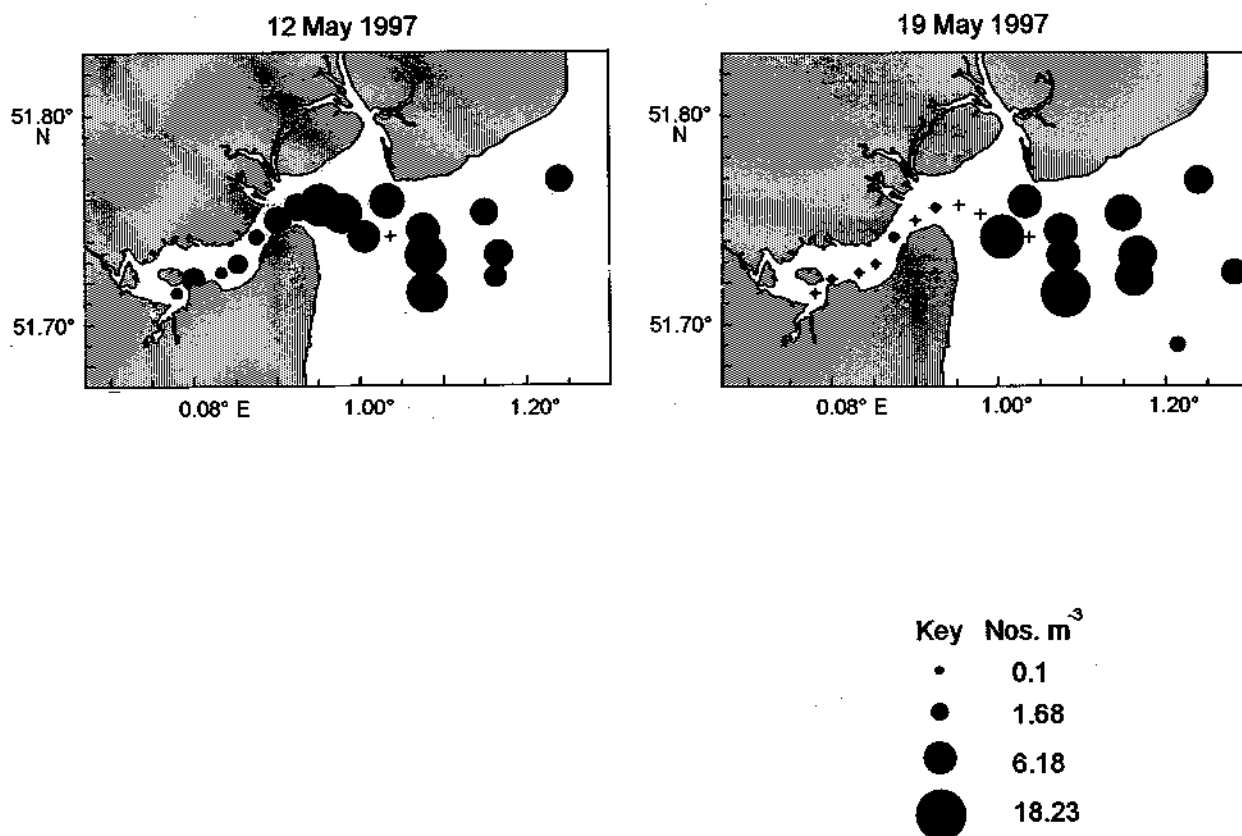


Figure 17 continued. Chaetognath concentrations during 1997

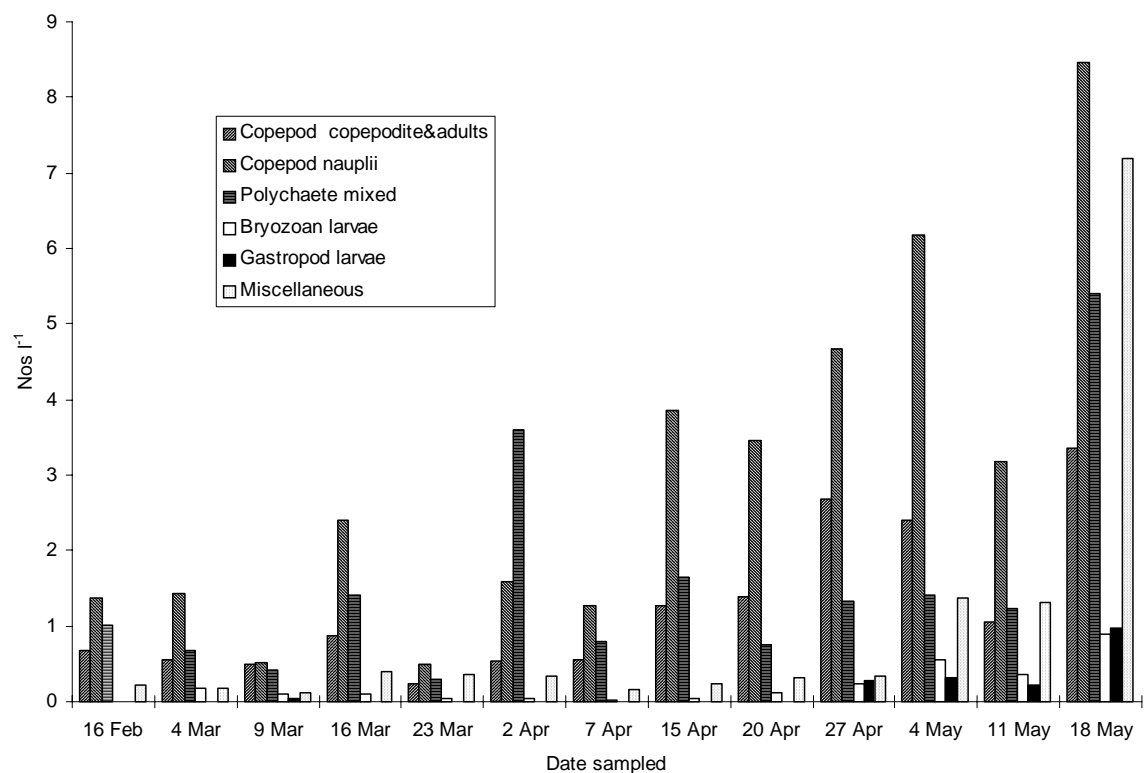


Figure 18. Mean concentrations of meso-zooplankton sampled in 1993

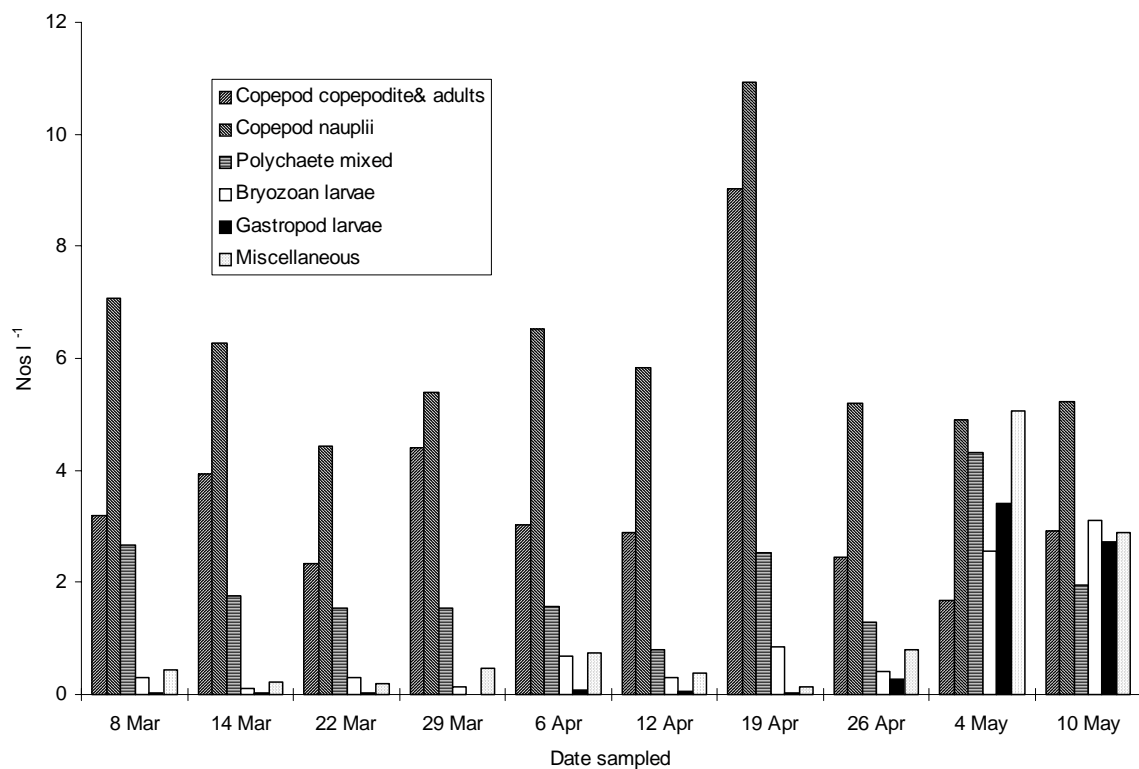


Figure 19. Mean concentrations of meso-zooplankton sampled in 1994

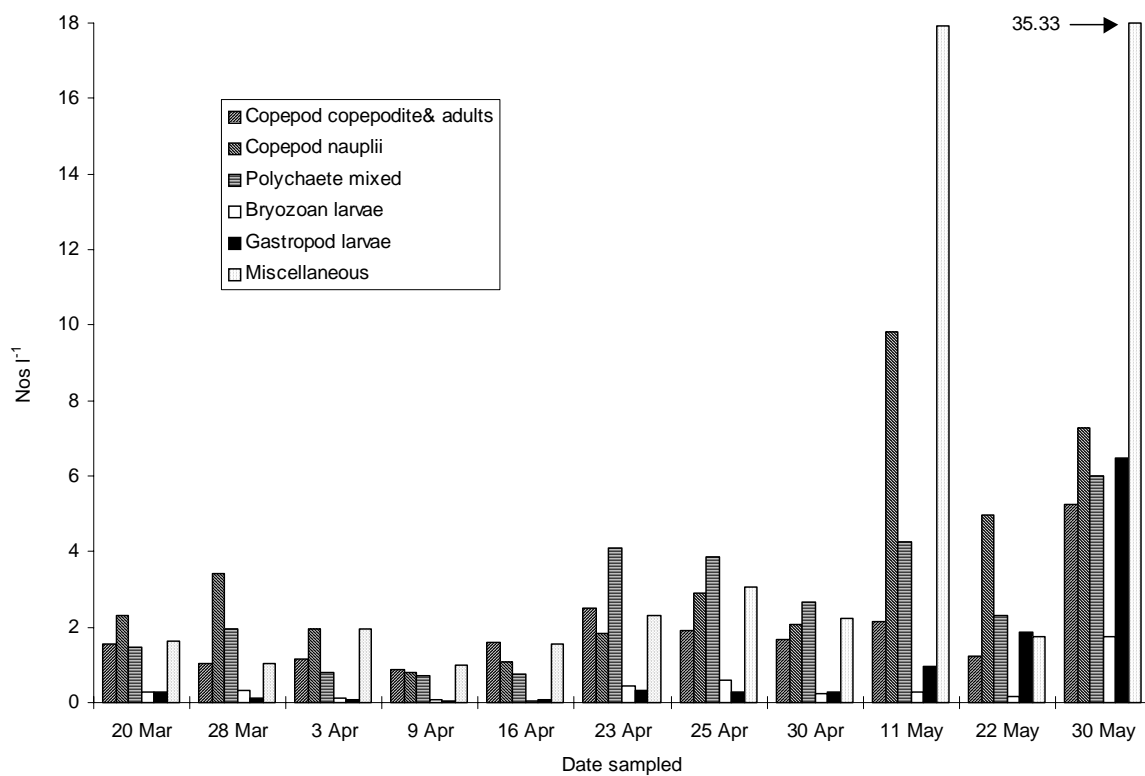


Figure 20. Mean concentrations of meso-zooplankton sampled in 1996

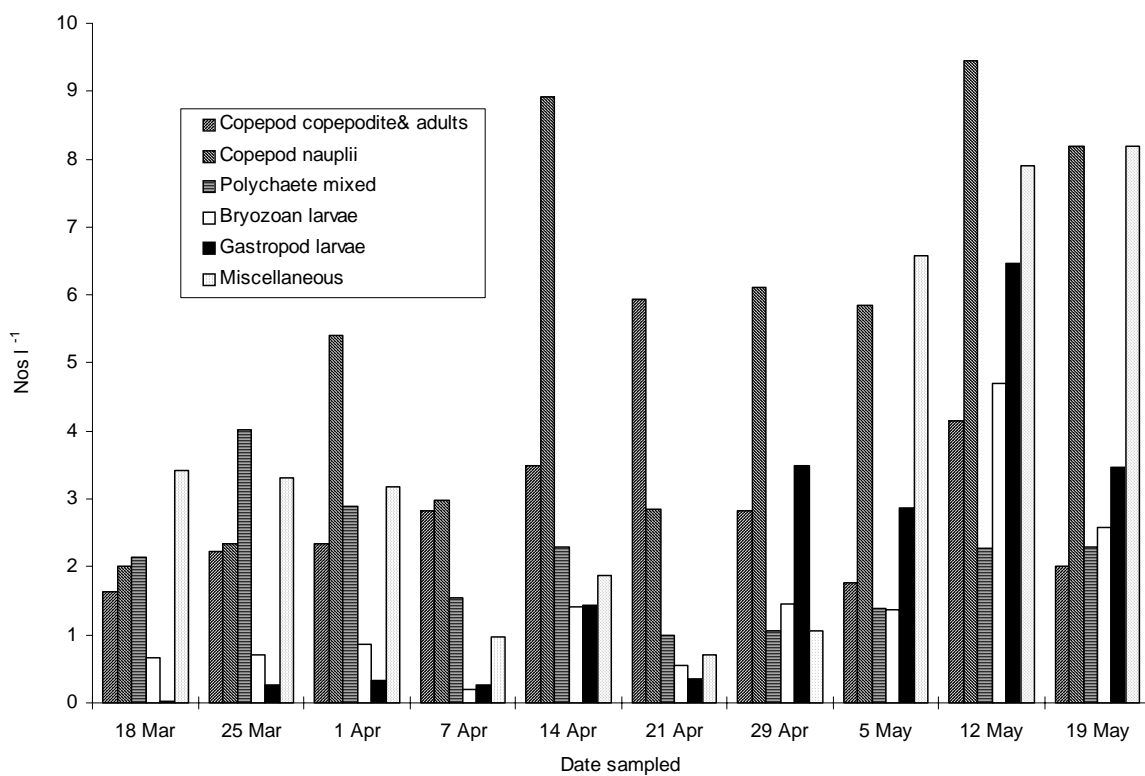


Figure 21. Mean concentrations of meso-zooplankton sampled in 1997

Table 1. Macro-zooplankton Main net sample statistics 1993 - % Positive stations

Species and development	16 Feb	4 Mar	9 Mar	16 Mar	23 Mar	2 Apr	7 Apr	15 Apr	20 Apr	27 Apr	4 May	11 May	18 May
Chaetognathae spp. mixed	100.0	100.0	75.0	100.0	100.0	75.0	100.0	100.0	75.0	100.0	100.0	75.0	75.0
<i>Clupea harengus</i> larvae	72.7	100.0	58.8	55.6	94.4	94.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mysidacea spp. mixed	72.7	75.0	100.0	75.0	75.0	100.0	100.0	75.0	100.0	75.0	100.0	100.0	100.0
Ctenophora spp. mixed	100.0	100.0	75.0	25.0	50.0	25.0	25.0	50.0	50.0	75.0	50.0	100.0	75.0
Cumacea spp. mixed	72.7	25.0	100.0	25.0	25.0	25.0	50.0	75.0	100.0	75.0	75.0	75.0	75.0
Amphipoda spp. mixed	63.6		50.0	50.0	75.0	50.0	100.0	50.0	75.0	75.0	50.0	50.0	25.0
Gobiidae spp. larvae								75.0	75.0	100.0	100.0	100.0	100.0
Natantia spp. mixed						25.0	25.0	50.0	75.0	75.0	75.0	100.0	75.0
Polychaete spp. mixed	18.2		25.0		50.0		25.0	25.0	50.0	25.0	100.0	75.0	100.0
Medusae spp. larvae	36.4			25.0	50.0	50.0	75.0	50.0	75.0	75.0			50.0
Unidentifiable spp. zoea						50.0	75.0	75.0	75.0	75.0	11.1	25.0	
Onos spp. eggs	45.5	25.0	25.0		25.0	25.0		25.0	50.0	50.0		75.0	25.0
Isopoda spp. mixed	9.1			25.0		25.0	50.0	25.0	25.0	25.0	25.0	50.0	
Brachyuran spp. larvae	27.3								50.0	25.0	25.0	25.0	75.0
Paguridae spp. larvae	54.5		25.0					50.0	25.0		25.0		25.0
Tomopteridae spp. mixed						25.0		50.0	50.0	50.0			
Liparis spp. larvae			25.0		25.0	50.0			25.0		25.0		
Lamellibranch spp. larvae								25.0	50.0	50.0			
Trigla spp. eggs					25.0		25.0					25.0	
Ammodytidae spp. larvae						50.0				25.0			
<i>Solea solea</i> eggs												50.0	25.0
Unidentified spp. yolk-sac	9.1				25.0							25.0	
Callionymidae spp. mixed										25.0			25.0
Gobiidae spp. adults							25.0	25.0					
Euphausiacea spp. mixed	9.1										25.0		
<i>Engraulis encrasicolus</i> eggs													25.0
Balanidae spp. larvae									25.0				
<i>Platichthys flesus</i> larvae													25.0
Porcellanidae spp. larvae													25.0
<i>Agonus cataphractus</i> larvae			25.0										
<i>Blennius pholis</i> larvae		25.0											
<i>Buglossidium luteum</i> larvae													25.0
<i>Trachinus vipera</i> larvae												25.0	
<i>Buglossidium luteum</i> eggs	9.1												
<i>Sprattus sprattus</i> eggs	9.1												
Unidentified spp. eggs	9.1												
Total number of stations sampled	11	4	4	4	4	4	4	4	4	4	4	4	4
Herring larvae stations analysed	11	16	17	18	18	18	21	18	21	15	18	15	19

Table 2. Macro-zooplankton Main net sample statistics 1994 - % Positive stations

Species and development	8 Mar	14 Mar	22 Mar	29 Mar	6 Apr	12 Apr	19 Apr	26 Apr	4 May	10 May
Ctenophora spp. mixed	75.0	90.0	100.0	90.0	100.0	93.3	100.0	100.0	100.0	100.0
<i>Clupea harengus</i> larvae	66.7	90.0	91.7	100.0	100.0	100.0	100.0	100.0	100.0	95.2
Chaetognathae spp. mixed	58.3	80.0	75.0	100.0	88.2	100.0	100.0	100.0	100.0	90.5
Mysidacea spp. mixed	75.0	100.0	75.0	100.0	100.0	100.0	88.9	78.6	85.7	81.0
Natantia spp. mixed	25.0	10.0	16.7	30.0	52.9	53.3	72.2	71.4	100.0	90.5
Polychaete spp. mixed	8.3	30.0	66.7	70.0	29.4	26.7	38.9	71.4	71.4	81.0
Cumacea spp. mixed		20.0		50.0	23.5	53.3	66.7	64.3	57.1	66.7
Amphipoda spp. mixed	33.3	40.0	25.0	50.0	29.4	33.3	44.4	42.9	42.9	52.4
Gobiidae spp. larvae		20.0				33.3	50.0	57.1	100.0	85.7
<i>Solea solea</i> eggs			8.3	50.0	64.7	53.3	11.1	57.1	42.9	47.6
Isopoda spp. mixed	25.0	70.0	33.3	40.0	17.6	6.7	16.7	14.3	50.0	23.8
Onos spp. eggs		10.0	75.0	30.0	41.2	20.0	33.3	21.4	42.9	14.3
Paguridae spp. larvae		10.0	33.3		41.2	46.7				4.8
<i>Platichthys flesus</i> larvae								28.6	7.1	66.7
Liparis spp. larvae	25.0	20.0	25.0		5.9	13.3	5.6		7.1	
Ammodytidae spp. larvae	16.7				11.8		16.7	35.7	7.1	4.8
Medusae spp. larvae				10.0	11.8			14.3	14.3	38.1
Sepiolidae spp. yolk-sac					41.2	13.3			7.1	
<i>Sprattus sprattus</i> eggs					17.6			14.3	7.1	9.5
Gnathia mixed								7.1		38.1
Euphausiacea spp. mixed						20.0	5.6	7.1		
Nematode mixed						13.3	16.7			
<i>Buglossidium luteum</i> eggs			16.7				5.6	7.1		
Gobiidae spp. adults					5.9	6.7	5.6			9.5
Paguridae spp. mixed					5.9				7.1	9.5
Caligas spp. mixed		10.0			5.9					
<i>Pholis gunnellus</i> larvae										14.3
<i>Limanda limanda</i> larvae	8.3				5.9					
<i>Pleuronectes platessa</i> larvae						6.7		7.1		
Brachyuran spp. larvae						13.3				
Unidentified spp. yolk-sac						6.7	5.6			
Spadella spp. mixed							11.1			
Syngnathidae spp. mixed		10.0								
<i>Belone belone</i> eggs										9.5
<i>Solea solea</i> larvae									7.1	
<i>Trisopterus luscus</i> larvae					5.9					
Corystidae spp. mixed										4.8
Total number of stations sampled	12	10	12	10	17	15	18	14	14	21

Table 3. Macro-zooplankton Main net sample statistics 1996 - % Positive stations

Species and development	20 Mar	28 Mar	3 Apr	9 Apr	16 Apr	23 Apr	25 Apr	30 Apr	11 May	22 May	30 May
Chaetognathae spp. mixed	100.0	100.0	93.8	88.9	88.9	70.0	76.5	58.3	77.8	100.0	100.0
Polychaete spp. mixed	68.8	50.0	68.8	94.4	72.2	90.0	94.1	75.0	100.0	100.0	100.0
<i>Clupea harengus</i> larvae	12.5	50.0	62.5	66.7	77.8	100.0	100.0	94.4	94.4	88.9	66.7
Medusae spp. mixed	62.5	93.8	68.8	94.4	77.8	90.0	76.5	70.8	88.9	100.0	83.3
Ctenophora spp. mixed	62.5	87.5	75.0	72.2	83.3	70.0	88.2	75.0	94.4	88.9	100.0
Mysidacea spp. mixed	93.8	87.5	87.5	100.0	77.8	70.0	76.5	54.2	77.8	88.9	66.7
Cumacea spp. mixed	62.5	56.3	75.0	100.0	72.2	70.0	76.5	70.8	77.8	55.6	58.3
Paguridae spp. larvae	43.8	75.0	87.5	77.8	72.2	60.0	64.7	37.5	66.7	66.7	50.0
Brachyuran spp. mixed	37.5	31.3	25.0	61.1	66.7	40.0	94.1	75.0	88.9	100.0	66.7
Amphipoda spp. mixed	62.5	56.3	37.5	77.8	61.1	60.0	64.7	54.2	11.1	22.2	41.7
Gobiidae spp. larvae	6.3					60.0	47.1	50.0	94.4	100.0	100.0
Isopoda spp. mixed	37.5	56.3	68.8	61.1	83.3	40.0	58.8	20.8			
Natantia spp. mixed	6.3			16.7	11.1	10.0	23.5	41.7	66.7	55.6	75.0
<i>Solea solea</i> eggs					27.8	70.0	76.5	54.2	11.8	33.3	25.0
Onos spp. eggs	6.3	6.3			11.1	10.0	5.9	8.3	44.4	33.3	25.0
Ammodytidae spp. larvae	37.5	31.3	12.5		11.1	20.0	11.8	4.2	11.1		
<i>Solea solea</i> larvae								12.5	33.3	11.1	58.3
<i>Platichthys flesus</i> larvae							5.9	25.0	11.1	44.4	16.7
Gnathia mixed			6.3	5.6	27.8	40.0					8.3
<i>Sprattus sprattus</i> eggs		6.3				10.0		29.2	11.1	22.2	
Nymphonidae spp. mixed	12.5			5.6	5.6		5.9	4.2			41.7
Caligas spp. copepodite & adult	68.8						5.9				
Clupeidae spp. larvae	62.5									11.1	
Liparis spp. larvae			6.3		11.1		5.9	4.2		11.1	
<i>Sprattus sprattus</i> larvae								4.2			33.3
Callionymidae spp. eggs											33.3
<i>Buglossidium luteum</i> larvae										22.2	8.3
<i>Sardina pilchardus</i> eggs											25.0
<i>Agonus cataphractus</i> larvae	6.3		6.3		11.1						
<i>Limanda limanda</i> larvae						10.0				11.1	
<i>Sprattus sprattus</i> juvenile	12.5		6.3								
Paguridae spp. mixed	12.5			5.6							
Unidentified spp. eggs	6.3			6.3							
<i>Sprattus sprattus</i> adult	12.5										
Euphausiidae spp. mixed										11.1	
<i>Liparis montagui</i> larvae										11.1	
Ascidian mixed									11.1		
<i>Scomber scombrus</i> eggs											8.3
Ammodytidae spp. eggs											8.3
<i>Anguilla anguilla</i> juvenile	6.3										
Gobiidae spp. adult	6.3										
Appendicularia spp. mixed							5.9				
<i>Gadus morhua</i> eggs					5.6						
Trigla spp. eggs									5.6		
Syngnathidae spp. mixed					5.6						
Onos spp. larvae									5.6		
<i>Trisopterus luscus</i> larvae											
<i>Myoxocephalus scorpius</i> larvae											
Total number of stations sampled	16	16	16	18	18	10	17	18	18	9	12

Table 4. Macro-zooplankton Main net sample statistics 1997 - % Positive stations

Species and development	18 Mar	25 Mar	1 Apr	7 Apr	14 Apr	21 Apr	29 Apr	5 May	12 May	19 May
<i>Clupea harengus</i> larvae	72.2	100.0	95.2	100.0	100.0	100.0	100.0	100.0	100.0	60.0
Chaetognathae spp. mixed	94.4	94.4	85.7	90.0	85.7	95.2	95.2	100.0	94.7	90.0
Cumacea spp. mixed	66.7	72.2	76.2	95.0	100.0	95.2	100.0	88.9	100.0	80.0
Polychaete spp. mixed	72.2	55.6	71.4	100.0	100.0	90.5	95.2	100.0	94.7	90.0
Ctenophora spp. mixed	88.9	83.3	95.2	75.0	76.2	66.7	85.7	100.0	94.7	100.0
Mysidacea spp. mixed	72.2	88.9	81.0	85.0	100.0	76.2	90.5	77.8	100.0	80.0
Brachyuran spp. larvae	50.0	38.9	42.9	95.0	100.0	95.2	100.0	100.0	100.0	80.0
Paguridae spp. mixed	88.9	61.1	71.4	85.0	85.7	76.2	90.5	88.9	68.4	60.0
Natantia spp. mixed		55.6	71.4	80.0	100.0	85.7	76.2	100.0	100.0	85.0
Amphipoda spp. mixed	55.6	55.6	57.1	70.0	90.5	76.2	90.5	94.4	94.7	60.0
<i>Solea solea</i> eggs	27.8	44.4	85.7	85.0	90.5	71.4	85.7	94.4	68.4	50.0
Gobiidae spp. larvae		5.6	42.9	50.0	66.7	61.9	85.7	94.4	89.5	55.0
<i>Clupea harengus</i> yolk-sac	72.2	44.4	57.1	90.0	71.4	61.9		5.6		
Onos spp. eggs	11.1	27.8	23.8	20.0	61.9	42.9	57.1	50.0	52.6	35.0
<i>Sprattus sprattus</i> eggs	11.1	44.4	47.6	35.0	57.1	42.9	38.1	44.4	36.8	20.0
Medusae spp. mixed	27.8	61.1	28.6	35.0	38.1	23.8	14.3	38.9	31.6	55.0
Ammodytidae spp. larvae			38.1	60.0	66.7	52.4	23.8	11.1	31.6	25.0
<i>Sprattus sprattus</i> larvae		16.7	47.6	20.0	33.3	14.3	47.6	27.8	36.8	30.0
Isopoda spp. mixed	38.9	33.3	9.5	25.0	23.8	9.5	19.0		21.1	5.0
Unidentified spp. eggs	5.6	5.6	19.0	25.0	19.0	19.0	23.8	38.9	10.5	5.0
<i>Solea solea</i> larvae			4.8		14.3	19.0	28.6	38.9	31.6	30.0
Gnathia mixed		5.6	9.5	25.0	23.8	4.8	14.3	27.8	5.3	15.0
Caligas spp. mixed	5.6	11.1		15.0	4.8	9.5		16.7		62.6
Nymphonidae spp. mixed				20.0	19.0	19.0	4.8	22.2	26.3	
<i>Dicentrarchus labrax</i> eggs				15.0	9.5		4.8	16.7	5.3	20.0
Callionymidae spp. eggs					4.8		9.5	27.8	10.5	15.0
<i>Buglossidium luteum</i> eggs		5.6		5.0	19.0		14.3	5.6	5.3	5.0
<i>Platichthys flesus</i> larvae									10.5	45.0
Ostracoda spp. mixed				5.0	4.8	4.8		5.6	5.3	20.0
Gobiidae spp. adult			4.8			4.8	14.3	5.6	10.5	
Trigla spp. eggs		5.6	4.8	5.0	4.8	4.8			10.5	
Euphausiidae spp. mixed	11.1	5.6	4.8							10.0
Liparis spp. larvae			4.8	10.0	4.8	4.8				5.0
Ascidian mixed								11.1		15.0
<i>Pleuronectes platessa</i> larvae		5.6					4.8	5.6		
<i>Agonus cataphractus</i> larvae		5.6	4.8							
<i>Engraulis encrasicolus</i> eggs									5.3	5.0
Onos spp. larvae									5.3	5.0
<i>Trisopterus luscus</i> larvae				5.0			4.8			
<i>Sprattus sprattus</i> juvenile					4.8					5.0
Cottidae spp. larvae						4.8	4.8			
Tomopteris spp. mixed			4.8		4.8					
<i>Pholis gunnellus</i> larvae		5.6								
Syngnathidae spp. mixed		5.6								
Unidentifiable spp. eggs				5.0						
<i>Anguilla anguilla</i> juvenile			4.8							
<i>Arnoglossus laterna</i> eggs						4.8				
Asteroidea spp. mixed					4.8					
Total number of stations sampled	18	18	21	20	21	21	21	18	19	20

Table 5. Macro-zooplankton Main net sample statistics 1993 - Maximum concentrations (Nos m⁻³)

Species and Development	16 Feb	4 Mar	9 Mar	16 Mar	23 Mar	2 Apr	7 Apr	15 Apr	20 Apr	27 Apr	4 May	11 May	18 May
<i>Clupea harengus</i> larvae	0.59	3.01	1.64	2.72	58.56	36.10	217.28	38.11	19.97	7.12	6.75	5.38	3.20
Mysidacea spp. mixed	0.65	0.98	1.82	0.68	0.30	0.74	7.61	8.03	13.99	6.99	3.37	3.95	5.00
Brachyuran spp. larvae	0.52								0.10	0.18	5.97	7.25	28.65
Gobiidae spp. larvae								0.74	1.85	1.01	1.96	10.90	12.57
Cumacea spp. mixed	1.20	0.10	6.88	0.07	0.86	0.28	0.23	0.31	2.13	1.63	0.99	2.87	1.31
Ctenophora spp. mixed	2.16	0.56	0.74	0.73	0.09	0.14	0.23	1.14	0.36	0.16	3.15	2.28	6.08
Chaetognathae spp. mixed	2.20	0.39	0.74	0.68	1.63	0.28	0.76	0.52	1.69	1.27	0.73	0.59	0.40
Natantia spp. mixed					0.04	0.05	0.05	0.48	1.52	1.05	1.37	2.37	4.35
Medusae spp. larvae	0.07			0.07	0.16	0.17	0.28	0.61	0.87	0.99			3.42
Amphipoda spp. mixed	0.19		1.07	0.17	0.27	0.40	0.37	0.16	0.13	0.18	0.28	0.53	0.61
Polychaete spp. mixed	0.04		0.43	0.17	0.12		0.19	0.08	0.04	0.06	0.23	0.76	0.74
Paguridae spp. larvae	0.44		0.21					0.07	0.21		0.09		0.66
Unidentifiable spp. zoea						0.09	0.14	0.36	0.55	0.27	0.17	0.04	
Porcellanidae spp. larvae													1.47
Isopoda spp. mixed	0.04			0.17		0.22	0.09	0.04	0.03	0.05	0.19	0.17	
Onos spp. eggs	0.04	0.05	0.07		0.14	0.05		0.04	0.25	0.07		0.10	0.14
Lamellibranch spp. larvae								0.04	0.42	0.22			
Tomopteridae spp. mixed					0.00	0.04		0.05	0.10	0.14			
Liparis spp. larvae			0.07		0.05	0.09			0.04		0.04		
Callionymidae spp. mixed										0.13			0.07
Unidentified spp. yolk-sac	0.02				0.09							0.08	
Trigla spp. eggs					0.05		0.07					0.04	
<i>Solea solea</i> eggs												0.04	0.10
Ammodytidae spp. larvae						0.06				0.05			
<i>Engraulis encrasicolus</i> eggs													0.10
Gobiidae spp. adult							0.06	0.04					
<i>Platichthys flesus</i> larvae													0.08
<i>Buglossidium luteum</i> larvae													0.08
Euphausiidae spp. mixed	0.03										0.04		
<i>Agonus cataphractus</i> larvae			0.07										
Balanidae spp. larvae									0.05				
<i>Blennius pholis</i> larvae		0.04											
<i>Trachinus vipera</i> larvae												0.04	
<i>Buglossidium luteum</i> eggs	0.03												
<i>Sprattus sprattus</i> eggs	0.02												
Unidentified spp. eggs	0.02												
Total number of stations sampled	11	4	4	4	4	4	4	4	4	4	4	4	4
Herring larvae stations analysed	11	16	17	18	18	18	21	18	21	15	18	15	19

Table 6. Macro-zooplankton Main net sample statistics 1994 - Maximum concentrations (Nos m⁻³)

Species and development	8 Mar	14 Mar	22 Mar	29 Mar	6 Apr	12 Apr	19 Apr	26 Apr	04 May	10 May
<i>Ctenophora</i> spp. mixed	1.34	2.93	11.34	15.71	48.82	64.06	73.43	50.65	45.94	37.15
<i>Clupea harengus</i> larvae	0.27	1.24	0.84	152.53	21.15	16.15	53.68	12.9	4.87	1.98
Mysidacea spp. mixed	0.7	3.31	1.51	5.77	5.19	16.53	22.3	10.27	5.56	4.78
Chaetognathae spp. mixed	2.32	7.68	0.63	2.06	5.81	6.49	3.17	3.48	0.94	1.51
Natantia spp. mixed	0.1	0.05	0.05	0.27	0.74	0.85	1.42	1.57	11	5.96
Gobiidae spp. larvae		0.08				0.11	0.54	0.67	4.33	9.39
<i>Solea solea</i> eggs			0.2	1.16	2.74	0.16	0.2	1.68	0.88	0.65
Cumacea spp. mixed		0.08		1.13	0.19	1.63	0.74	1.73	0.4	0.93
Amphipoda spp. mixed	0.2	0.27	0.1	0.25	0.19	0.2	0.2	0.33	0.19	1.58
Polychaete spp. mixed	0.13	0.09	0.19	0.13	0.22	0.21	0.15	1.02	0.47	0.79
Paguridae spp. larvae		0.26	0.09		1.31	1.54				
<i>Sprattus sprattus</i> larvae					2.47	0.15			0.14	0.15
Isopoda spp. mixed	0.21	0.16	0.08	0.09	0.8	0.11	0.14	0.14	0.28	0.23
Onos spp. eggs		0.07	0.23	0.07	0.23	0.08	0.23	0.22	0.47	0.27
Medusae spp. larvae				0.07	0.15			0.24	0.36	0.39
Paguridae spp. mixed					0.71				0.08	0.21
Gnathia mixed								0.07		0.9
Ammodytidae spp. larvae	0.07				0.11		0.23	0.25	0.15	0.07
<i>Platichthys flesus</i> larvae								0.08	0.1	0.68
Corystidae spp. mixed										0.79
Liparis spp. larvae	0.05	0.2	0.08		0.1	0.06	0.12		0.07	
<i>Sprattus sprattus</i> eggs					0.16			0.08	0.06	0.18
Euphausiidae spp. mixed						0.14	0.23	0.07		
<i>Buglossidium luteum</i> eggs			0.1				0.11	0.07		
Gobiidae spp. adults					0.06	0.05	0.07			0.08
Caligas spp. mixed		0.2			0.06					
Brachyuran spp. larvae						0.23				
Unidentified spp. yolk-sac							0.2			
Nematode mixed						0.08	0.1			
<i>Solea solea</i> larvae									0.15	
<i>Limanda limanda</i> larvae	0.05				0.08					
<i>Pleuronectes platessa</i> larvae						0.04		0.08		
<i>Pholis gunnellus</i> larvae										0.12
Spadella spp. mixed							0.1			
<i>Belone belone</i> eggs										0.09
Trisopterus luscus larvae					0.08					
Nematode adults							0.07			
Syngnathidae spp. mixed		0.07								
Sepiolidae spp. yolk-sac						0.05				
Total number of stations sampled	12	10	12	10	17	15	18	14	14	21

Table 7. Macro-zooplankton Main net sample statistics 1996 - Maximum concentrations (Nos m⁻³)

Species and development	20 Mar	28 Mar	3 Apr	9 Apr	16 Apr	23 Apr	25 Apr	30 Apr	11 May	22 May	30 May
Brachyuran spp. larvae	0.23	0.36	0.16	0.70	0.97	2.55	8.18	155.00	99.18	143.10	268.10
<i>Clupea harengus</i> larvae	0.08	1.17	0.90	11.85	2.94	83.05	37.63	19.75	2.14	2.92	0.65
Ctenophora spp. mixed	3.81	5.26	18.38	17.95	14.98	8.22	16.29	12.33	12.91	4.87	13.39
Cumacea spp. mixed	16.33	2.27	3.00	11.66	7.27	7.90	4.08	4.51	2.59	2.19	0.60
Chaetognathae spp. mixed	8.30	2.18	5.79	4.14	3.81	2.46	1.74	2.80	1.26	1.90	3.39
Mysidacea spp. mixed	4.38	2.98	2.85	5.62	3.27	7.38	2.86	4.08	2.00	1.01	0.60
Gobiidae spp. larvae	0.07					0.27	0.22	6.42	5.44	4.13	18.33
Polychaete spp. mixed	1.60	0.53	0.53	2.09	1.57	0.97	1.07	4.31	8.50	4.38	5.24
Natantia spp. mixed	0.12			0.08	0.06	0.11	0.39	1.34	1.71	1.60	20.95
Paguridae spp. mixed	3.03	2.30	1.00	1.42	1.63	2.39	1.16	1.95	3.45	5.89	1.67
Medusae spp. mixed	1.20	2.04	2.06	0.66	1.16	1.66	2.42	2.04	1.42	0.95	1.73
Amphipoda spp. mixed	1.67	0.68	0.63	3.15	2.09	1.51	0.83	0.74	0.44	0.12	0.24
<i>Solea solea</i> eggs					0.13	0.66	1.96	1.76	3.31	0.24	0.12
Isopoda spp. mixed	0.36	0.91	0.69	0.76	0.62	1.84	1.10	0.26			
Gnathia mixed			0.08	0.18	0.15	0.28					1.19
<i>Solea solea</i> larvae								0.17	0.36	0.12	0.71
Ammodytidae spp. larvae	0.22	0.13	0.15		0.15	0.24	0.10	0.10	0.26		
Onos spp. eggs	0.12	0.09			0.08	0.11	0.08	0.21	0.31	0.06	0.06
<i>Sprattus sprattus</i> eggs		0.07				0.11		0.43	0.10	0.18	
Nymphonidae spp. mixed	0.08			0.08	0.08		0.09	0.11			0.30
Platichthys flesus larvae							0.09	0.10	0.09	0.12	0.24
<i>Buglossidium luteum</i> larvae										0.24	0.24
Unidentified spp. eggs	0.07			0.09				0.13	0.16		
<i>Sprattus sprattus</i> larvae								0.08			0.30
Liparis spp. larvae			0.08		0.10		0.11	0.09			
<i>Agonus cataphractus</i> larvae	0.07		0.07		0.17						
<i>Limanda limanda</i> larvae						0.08				0.10	
Callionymidae spp. eggs											0.18
<i>Sprattus sprattus</i> juvenile	0.08		0.07								
Caligas spp. mixed	0.06						0.07				
<i>Scomber scombrus</i> eggs											0.12
Ascidian mixed									0.11		
Appendicularia spp. mixed							0.10				
Myoxocephalus scorpius larvae					0.08						
Syngnathidae spp. mixed					0.08						
<i>Sprattus sprattus</i> adults	0.08										
<i>Gadus morhua</i> eggs					0.08						
Gobiidae spp. adults	0.07										
Clupeidae spp. larvae	0.07										
<i>Anguilla anguilla</i> juvenile	0.07										
Onos spp. larvae									0.07		
Euphausiidae spp. mixed										0.06	
<i>Sardina pilchardus</i> eggs											0.06
Ammodytidae spp. eggs											0.06
<i>Liparis montagui</i> larvae										0.06	
<i>Trisopterus luscus</i> larvae											
Trigla spp. eggs											
Total number of stations sampled	16	16	16	18	18	10	17	18	18	9	12

Table 8. Macro-zooplankton Main net sample statistics 1997 - Maximum concentrations (Nos. m⁻³)

Species and development	18 Mar	25 Mar	1 Apr	7 Apr	14 Apr	21 Apr	29 Apr	5 May	12 May	19 May
Brachyuran spp. larvae	2.03	2.59	5.88	7.00	27.04	55.70	119.56	57.61	33.52	21.96
<i>Clupea harengus</i> larvae	22.74	107.85	4.74	19.99	21.35	9.71	4.11	1.72	2.13	0.39
Cumacea spp. mixed	5.66	2.95	6.14	23.18	85.99	15.58	18.87	3.31	21.81	5.06
Mysidacea spp. mixed	2.24	3.26	8.41	4.74	10.05	24.51	14.83	18.88	71.04	8.78
Ctenophora spp. mixed	1.57	1.62	2.10	3.32	7.59	14.96	27.61	21.04	18.52	27.88
Chaetognathae spp. mixed	9.48	7.56	5.98	4.89	1.20	1.02	1.09	2.52	11.38	18.23
Polychaete spp. mixed	0.23	0.31	0.17	1.11	1.07	2.07	15.81	2.85	23.45	1.30
Amphipoda spp. mixed	0.71	0.73	0.66	1.41	1.63	2.36	10.42	1.63	6.66	1.04
Natantia spp. mixed		1.73	0.23	0.75	1.47	1.04	7.22	2.94	4.79	5.82
Paguridae spp. mixed	3.63	1.73	3.49	0.85	0.62	4.03	3.99	2.08	2.80	1.27
Gobiidae spp. larvae		0.12	0.38	0.60	1.94	1.03	2.97	5.06	5.88	4.78
<i>Solea solea</i> eggs	0.16	0.86	0.69	1.18	2.55	1.50	3.84	2.86	0.48	1.71
Medusae spp. mixed	0.53	3.45	0.77	0.19	0.87	0.57	0.07	0.25	0.15	1.25
Ostracoda spp. mixed				1.34	0.03	0.09		0.14	3.45	0.46
<i>Sprattus sprattus</i> eggs	0.10	0.86	0.31	0.38	0.57	0.49	0.41	0.45	0.13	1.03
Onos spp. eggs	0.05	1.73	0.11	0.12	0.80	0.25	0.23	0.34	0.33	0.31
Isopoda spp. mixed	0.31	1.04	0.08	0.92	0.73	0.30	0.62		0.15	0.03
Gnathia mixed		0.13	0.08	0.17	0.27	0.06	0.23	1.31	0.27	1.52
<i>Sprattus sprattus</i> larvae		0.05	0.46	0.10	0.07	0.14	0.12	0.17	0.09	0.80
Ammodytidae spp. larvae			0.19	0.20	0.32	0.18	0.12	0.05	0.04	0.23
<i>Buglossidium luteum</i> eggs		0.06		0.03	0.59		0.12	0.06	0.05	0.03
Unidentified spp. eggs	0.10	0.11	0.09	0.19	0.10	0.11	0.04	0.08	0.06	0.03
<i>Solea solea</i> larvae			0.03		0.07	0.07	0.14	0.11	0.16	0.23
Callionymidae spp. eggs					0.06		0.12	0.16	0.09	0.11
<i>Dicentrarchus labrax</i> eggs				0.07	0.12		0.03	0.23	0.03	0.03
Caligas spp. mixed		0.10		0.06	0.12	0.20		0.03		
Nymphonidae spp. mixed				0.08	0.04	0.09	0.03	0.06	0.09	
Gnathia juvenile				0.14						0.20
<i>Platichthys flesus</i> larvae									0.07	0.25
Euphausiacea spp. mixed	0.08	0.03	0.04							0.15
Gobiidae spp. adult			0.04			0.03	0.04	0.04	0.09	
Trigla spp. eggs		0.07	0.03	0.03	0.04	0.03			0.03	
Ascidian mixed								0.11		0.12
Liparis spp. larvae			0.05	0.07	0.03	0.03				0.04
<i>Agonus cataphractus</i> larvae		0.12	0.05							
<i>Pleuronectes platessa</i> larvae		0.07					0.03	0.03		
Onos spp. larvae									0.03	0.08
<i>Engraulis encrasicolus</i> eggs										0.08
Cottidae spp. larvae						0.03	0.04			
Tomopteris spp. mixed			0.03		0.04					
Unidentifiable spp. eggs				0.07						
<i>Trisopterus luscus</i> larvae				0.03			0.03			
<i>Sprattus sprattus</i> juvenile					0.03					0.03
Syngnathidae spp. mixed		0.06								
Asteroidea spp. mixed					0.04					
<i>Pholis gunnellus</i> larvae		0.04								
<i>Anguilla anguilla</i> juvenile			0.03							
<i>Arnoglossus laterna</i> eggs						0.03				
Total number of stations sampled	18	18	21	20	21	21	21	18	19	20

Table 9. Meso-zooplankton pup net sample statistics 1993 - % positive stations

Species and development	16 Feb	4 Mar	9 Mar	16 Mar	23 Mar	2 Apr	7 Apr	15 Apr	20 Apr	27 Apr	4 May	11 May	18 May
Polychaete spp. mixed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Copepoda spp. nauplii	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Harpacticoida spp. copepodite & adult	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Acartia sp. copepodite & adult	66.7	100.0	75.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Balanus sp. nauplii	100.0	100.0	50.0	75.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	75.0	75.0
Bryozoan larvae	33.3	100.0	75.0	50.0	100.0	75.0	25.0	25.0	75.0	50.0	75.0	50.0	100.0
Temora longicornis copepodite & adult	100.0	50.0		25.0	25.0	25.0	75.0	100.0	75.0	75.0	50.0	25.0	50.0
Pseudocalanus elongatus copepodite & adult	100.0	100.0	50.0	50.0	100.0	50.0	75.0	50.0	25.0	25.0	25.0		
Gastropoda spp. larvae	33.3	25.0	25.0	25.0			25.0		25.0	50.0	25.0	75.0	75.0
Centropages sp. copepodite & adult		25.0					100.0	75.0	50.0		25.0	25.0	75.0
Unidentifiable spp. mixed	33.3	25.0	25.0			25.0			50.0	25.0	50.0	75.0	50.0
Cyclopoida spp. copepodite & adult	66.7	25.0	25.0	50.0	50.0				25.0			25.0	50.0
Lamellibranch spp. larvae	33.3	50.0					25.0	25.0	50.0	25.0	25.0	25.0	25.0
Balanus sp. cypris				25.0		25.0	25.0	25.0	25.0		50.0	25.0	25.0
Invertebrate spp. eggs	33.3	25.0		25.0									25.0
Copepoda spp. copepodite & adult		25.0					25.0	25.0		25.0			
Calanus sp. copepodite & adult	33.3	25.0		25.0									
Echinoderm spp. larvae											25.0	25.0	25.0
Brachyuran spp. larvae										25.0	25.0		
Oithona sp. copepodite & adult	33.3												
Appendicularia spp. mixed										25.0			
Cumacea spp. mixed												25.0	
Total number of stations sampled	4	4	4	4	4	4	4	4	4	4	4	4	4

Table 10. Meso-zooplankton pup net sample statistics 1994 - % Positive stations

Species and development	8 Mar	14 Mar	22 Mar	29 Mar	6 Apr	12 Apr	19 Apr	26 Apr	4 May	10 May
<i>Acartia</i> sp. copepodite & adult	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Polychaete spp. mixed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Copepoda spp. nauplii	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Harpacticoida spp. copepodite & adult	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Bryozoan larvae	80.0	50.0	83.3	75.0	100.0	100.0	100.0	100.0	100.0	87.5
<i>Balanus</i> sp. nauplii	100.0	100.0	100.0	50.0	33.3	66.7	50.0	83.3	100.0	100.0
<i>Temora longicornis</i> copepodite & adult	60.0	25.0	66.7	100.0	50.0	83.3	83.3	66.7	66.7	87.5
Gastropoda spp. larvae	20.0	25.0	33.3		66.7	33.3	33.3	83.3	100.0	100.0
Lamellibranch spp. larvae	20.0		16.7	25.0	50.0	50.0	16.7	100.0	100.0	87.5
<i>Centropages</i> sp. copepodite & adult	20.0	25.0	50.0	50.0	66.7	50.0	50.0	66.7	33.3	50.0
<i>Pseudocalanus elongatus</i> copepodite & adult	40.0	25.0	33.3	25.0	66.7	83.3	66.7	50.0	16.7	25.0
<i>Balanus</i> sp. cypris					16.7	50.0		33.3		37.5
Copepoda spp. copepodite & adult	20.0		33.3		50.0	16.7				12.5
Cyclopoida spp. copepodite & adult	20.0	25.0	16.7		16.7	16.7				12.5
<i>Calanus</i> sp. copepodite & adult					16.7	16.7				12.5
Echinoderm spp. mixed					16.7					
Total number of stations sampled	5	4	6	4	6	6	6	6	6	6

Table 11. Meso-zooplankton pup net sample statistics 1996 - % Positive stations

Species and development	20 Mar	28 Mar	3 Apr	9 Apr	16 Apr	23 Apr	25 Apr	30 Apr	11 May	22 May	30 May
<i>Acartia</i> sp. copepodite & adult	75.0	100.0	100.0	100.0	83.3	100.0	100.0	100.0	100.0	100.0	100.0
Copepoda spp. nauplii	100.0	100.0	100.0	100.0	83.3	100.0	100.0	100.0	100.0	100.0	100.0
Polychaete spp. mixed	75.0	100.0	100.0	100.0	83.3	100.0	100.0	100.0	100.0	100.0	100.0
<i>Balanus</i> sp. nauplii	100.0	100.0	80.0	80.0	66.7	66.7	100.0	100.0	100.0	100.0	100.0
Harpacticoida spp.											
copepodite & adult	100.0	80.0	100.0	80.0	33.3	66.7	100.0	100.0	80.0	100.0	20.0
Bryozoan larvae	100.0	80.0	60.0	60.0	50.0	33.3	80.0	80.0	100.0	66.7	60.0
Gastropoda spp. larvae	50.0	60.0	80.0	40.0	33.3	100.0	60.0	80.0	80.0	100.0	80.0
Lamellibranch spp. larvae	25.0	20.0	40.0	40.0	33.3	100.0	80.0	80.0	100.0	100.0	100.0
Invertebrate spp. eggs	50.0	80.0	20.0	60.0	33.3	33.3	40.0	40.0	40.0	66.7	80.0
<i>Temora longicornis</i>											
copepodite & adult	25.0	40.0	60.0	20.0	33.3	33.3	20.0	30.0	60.0	100.0	100.0
<i>Pseudocalanus elongatus</i>											
copepodite & adult	50.0	60.0	60.0		16.7				20.0	100.0	40.0
<i>Centropages</i> sp. copepodite											
& adult		20.0		20.0			20.0			66.7	80.0
Appendicularia spp. mixed									60.0	66.7	60.0
<i>Balanus</i> sp. cypris		20.0					20.0	20.0	40.0	33.3	20.0
Brachyuran spp. larvae		20.0	20.0					10.0	20.0	33.3	40.0
Copepoda spp. copepodite & adult		25.0		40.0		16.7		40.0			
Cyclopoida spp. copepodite & adult				40.0	40.0			20.0			
Unidentifiable spp.	25.0		20.0					40.0			
<i>Calanus</i> sp. copepodite											
& adult	25.0										20.0
Echinoderm spp. mixed									40.0		
Ascidian larvae									40.0		
<i>Centropages</i> sp. larvae										33.3	
Nematode mixed	25.0										
Caligas spp. larvae									20.0		
<i>Paracalanus brevicornis</i>											
copepodite & adult								20.0			
Ostracoda spp. mixed					16.7						
Total number of stations sampled	4	5	5	5	5	3	5	5	5	3	5

Table 12. Meso-zooplankton pup net sample statistics 1997 - % Positive stations

Species and development	18 Mar	25 Mar	1 Apr	7 Apr	14 Apr	21 Apr	29 Apr	5 May	12 May	19 May
Copepoda spp. nauplii	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
<i>Balanus</i> sp. nauplii	100.0	83.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Polychaete spp. mixed	100.0	83.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
<i>Acartia</i> sp. copepodite & adult	100.0	100.0	100.0	83.3	100.0	100.0	100.0	100.0	100.0	100.0
Harpacticoida spp. copepodite & adult	83.3	83.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Bryozoan larvae	100.0	83.3	83.3	66.7	83.3	83.3	100.0	100.0	100.0	66.7
Gastropoda spp. larvae	50.0	50.0	66.7	66.7	100.0	66.7	100.0	83.3	100.0	100.0
Lamellibranch spp. larvae	16.7	16.7	33.3	16.7	50.0	66.7	83.3	66.7	83.3	83.3
<i>Temora longicornis</i> copepodite & adult	66.7	33.3	50.0			50.0	66.7	16.7	66.7	50.0
<i>Centropages</i> sp. copepodite & adult			16.7	16.7	16.7	16.7	33.3	16.7	33.3	50.0
<i>Pseudocalanus elongatus</i> copepodite & adult	33.3	16.7	16.7				33.3			50.0
Invertebrate spp. eggs			33.3	16.7	16.7			16.7		33.3
Echinodermata spp. mixed								16.7	33.3	33.3
Harpacticoida spp. copepodite & adult	16.7	16.7		16.7	16.7		16.7			
<i>Balanus</i> sp. cypris						16.7		33.3	16.7	
<i>Centropages</i> sp. male					16.7	16.7	16.7			16.7
Appendicularia spp. mixed								16.7	16.7	16.7
Cyclopoida spp. copepodite & adult	16.7					16.7	16.7			
Isopoda spp. larvae							16.7			16.7
<i>Paracalanus brevicornis</i> copepodite & adult						33.3				
Cladocera spp. mixed						16.7				
Copepoda spp. copepodite & adult		16.7								
Euphausiacea spp. nauplii						16.7				
Oithona spp. copepodite & adult						16.7				
Unidentifiable spp. mixed	16.7									
Total number of stations sampled	6	6	6	6	6	6	6	6	6	6

Table 13. Meso-zooplankton pup net sample statistics 1993 - Mean concentrations l⁻¹

Species and development	16 Feb	4 Mar	9 Mar	16 Mar	23 Mar	2 Apr	7 Apr	15 Apr	20 Apr	27 Apr	4 May	11 May	18 May
Copepoda spp. nauplii	1.83	1.42	0.51	2.41	0.50	1.59	1.27	3.85	3.46	4.67	6.19	3.17	8.47
Polychaete spp. mixed	1.35	0.67	0.42	1.42	0.30	3.60	0.80	1.66	0.75	1.34	1.41	1.24	5.41
<i>Balanus</i> sp. nauplii	0.03	0.08	0.07	0.50	0.35	0.31	0.12	0.20	0.26	0.30	1.20	1.57	8.27
<i>Acartia</i> sp. copepodite & adult	0.30	0.18	0.33	0.37	0.07	0.35	0.18	0.77	0.93	2.23	2.04	0.60	2.48
Bryozoan larvae	0.02	0.19	0.14	0.21	0.05	0.06	0.09	0.18	0.16	0.49	0.74	0.70	0.90
Lamellibranch spp. larvae	0.04	0.17	0.15				0.16	0.13	0.03	0.09	0.10	0.04	2.79
Gastropoda spp. larvae	0.01	0.02	0.13	0.01			0.02		0.02	0.55	1.29	0.30	1.29
Harpacticoida spp. copepodite & adult	0.05	0.24	0.19	0.25	0.12	0.13	0.24	0.27	0.38	0.34	0.30	0.43	0.58
<i>Pseudocalanus elongatus</i> copepodite & adult	0.39	0.11	0.06	0.07	0.03	0.08	0.07	0.17	0.07	0.06	0.09		
Unidentifiable spp. mixed	0.75	0.01	0.03			0.05			0.07	0.02	0.07	0.05	0.10
Echinoderm spp. larvae											0.17	0.25	0.67
Cyclopoida spp. copepodite & adult	0.32	0.01	0.16	0.36	0.02				0.02			0.03	0.13
<i>Temora longicornis</i> copepodite & adult	0.03	0.01		0.04	0.02	0.05	0.05	0.10	0.05	0.12	0.07	0.03	0.19
<i>Balanus</i> sp. cypris				0.02		0.06	0.02	0.03	0.02		0.05	0.04	0.19
<i>Centropages</i> sp. copepodite & adult		0.03					0.03	0.06	0.05		0.06	0.04	0.11
Invertebrate spp. eggs	0.02	0.04		0.04									0.15
<i>Calanus</i> sp. copepodite & adult	0.04	0.01		0.13									
Brachyuran spp. larvae											0.17		
Copepoda spp. copepodite & adult			0.02					0.05	0.05		0.02		
Cumacea spp. mixed												0.04	
Appendicularia spp. mixed										0.02			
<i>Oithona</i> sp. copepodite & adult		0.01											
Total Number of stations sampled	4	4	4	4	4	4	4	4	4	4	4	4	4

Table 14. Meso-zooplankton pup net sample statistics 1994 - Mean concentrations l⁻¹

Species and development	8 Mar	14 Mar	22 Mar	29 Mar	6 Apr	12 Apr	19 Apr	26 Apr	4 May	10 May
Copepoda spp. nauplii	7.08	6.28	4.43	5.38	6.52	5.84	10.92	5.21	4.91	5.22
<i>Acartia</i> sp. copepodite & adult	2.39	3.31	2.00	3.51	2.21	1.55	7.30	1.41	0.87	0.92
Polychaete spp. mixed	2.66	1.75	1.54	1.55	1.56	0.79	2.54	1.28	4.32	1.95
Bryozoan larvae	0.37	0.24	0.35	0.17	0.68	0.32	0.87	0.40	2.56	3.12
Gastropoda spp. larvae	0.07	0.13	0.05		0.11	0.13	0.10	0.33	3.40	2.73
Lamellibranch spp. larvae	0.08		0.07	0.27	0.55	0.34	0.18	0.32	3.85	1.50
Harpacticoida spp. copepodite & adult	0.30	0.50	0.12	0.67	0.38	0.59	1.22	0.64	0.47	1.07
<i>Balanus</i> sp. nauplii	0.44	0.21	0.19	0.18	0.35	0.11	0.23	0.53	1.22	1.33
<i>Temora longicornis</i> copepodite & adult	0.30	0.10	0.21	0.15	0.39	0.58	0.44	0.35	0.39	0.24
<i>Pseudocalanus elongatus</i> copepodite & adult	0.67	0.05	0.09	0.04	0.13	0.24	0.14	0.13	0.10	0.16
<i>Centropages</i> sp. copepodite & adult	0.15	0.12	0.06	0.13	0.17	0.07	0.09	0.14	0.11	0.17
Copepoda spp. copepodite & adult	0.15		0.04		0.07	0.06				0.25
<i>Balanus</i> sp. cypris					0.04	0.28		0.08		0.05
Cyclopoida spp. copepodite & adult	0.04	0.18	0.02		0.05	0.07				0.06
<i>Calanus</i> sp. copepodite & adult					0.05	0.04				0.28
Echinoderm spp. mixed					0.21					
Total number of stations sampled	5	4	6	4	6	6	6	6	6	6

Table 15. Meso-zooplankton pup net sample statistics 1996 - Mean concentrations l⁻¹

Species and development	20 Mar	28 Mar	3 Apr	9 Apr	16 Apr	23 Apr	25 Apr	30 Apr	11 May	22 May	30 May
Copepoda spp. nauplii	2.32	3.42	1.94	0.80	1.06	1.84	2.92	2.06	9.80	4.97	7.29
Polychaete spp. mixed	1.47	1.94	0.79	0.70	0.74	4.09	3.86	2.66	4.23	2.32	6.02
Lamellibranch spp. larvae	0.29	0.17	0.08	0.04	0.29	0.12	1.07	0.75	1.94	0.55	23.49
<i>Balanus</i> sp. nauplii	0.72	0.69	1.68	0.79	1.03	1.81	1.73	1.23	1.17	0.60	7.35
Invertebrate spp. eggs	0.25	0.09	0.12	0.18	0.15	0.37	0.16	0.10	7.42	0.10	2.46
Gastropoda spp. larvae	0.28	0.11	0.08	0.05	0.10	0.33	0.26	0.27	0.97	1.88	6.47
<i>Acartia</i> sp. copepodite & adult	0.51	0.56	0.79	0.64	1.32	1.68	1.29	1.30	1.48	0.46	0.44
Appendicularia spp. mixed									6.83	0.35	1.39
Bryozoan larvae	0.29	0.31	0.12	0.06	0.05	0.44	0.61	0.25	0.29	0.14	1.75
Harpacticoida spp. copepodite & adult	0.54	0.16	0.16	0.11	0.17	0.64	0.31	0.20	0.19	0.23	1.45
<i>Temora longicornis</i> copepodite & adult	0.10	0.20	0.06	0.04	0.07	0.17	0.15	0.05	0.41	0.43	2.24
<i>Paracalanus elongatus</i> copepodite & adult	0.11	0.09	0.06		0.04				0.06	0.08	0.41
Brachyuran spp. larvae		0.05	0.02					0.11	0.09	0.08	0.49
<i>Centropages</i> sp. copepodite & adult		0.03		0.04			0.04			0.05	0.55
Copepoda spp. copepodite & adult	0.26		0.05				0.04				
<i>Balanus</i> sp. cypris		0.02					0.08	0.02	0.04	0.03	0.16
Nematode mixed	0.26										
<i>Calanus</i> sp. copepodite & adult	0.04										0.17
Echinoderm spp. mixed									0.19		
Unidentifiable spp.	0.10		0.05					0.04			
Cyclopoida spp. copepodite & adult			0.04	0.03			0.08				
Ascidian larvae									0.14		
<i>Paracalanus brevicornis</i> copepodite & adult									0.12		
Caligas spp. larvae									0.09		
Ostracoda spp. mixed					0.06						
<i>Centropages</i> sp. larvae										0.04	
Total number of stations sampled	4	5	5	5	5	3	5	5	5	3	5

Table 16. Meso-zooplankton pup net sample statistics 1997 - Mean concentrations l⁻¹

Species and development	18 Mar	25 Mar	1 Apr	7 Apr	14 Apr	21 Apr	29 Apr	5 May	12 May	19 May
Copepoda spp. nauplii	2.00	2.34	5.40	2.97	8.92	2.86	6.12	5.86	9.45	8.19
<i>Acartia</i> sp. copepodite & adult	1.58	1.83	2.03	3.55	3.21	6.25	2.15	1.51	3.24	0.90
<i>Balanus</i> sp. nauplii	3.38	3.79	3.09	0.91	1.66	0.38	0.67	1.21	2.90	3.86
Polychaete spp. mixed	2.15	4.81	2.88	1.54	2.30	0.98	1.06	1.39	2.28	2.28
Lamellibranch spp. larvae	0.08	0.94	0.14	0.16	0.32	0.44	0.45	7.76	5.75	4.37
Gastropoda spp. larvae	0.06	0.52	0.51	0.41	1.44	0.52	3.50	3.45	6.47	3.46
Bryozoan larvae	0.67	0.84	1.03	0.31	1.70	0.66	1.45	1.37	4.69	3.86
Harpacticoida spp. copepodite & adult	0.21	0.71	0.45	0.45	0.44	0.42	0.45	0.65	0.79	0.72
<i>Temora longicornis</i> copepodite & adult	0.08	0.34	0.20	0.32	0.16	0.23	0.18	0.29	0.61	0.64
<i>Centropages</i> sp. copepodite & adult			0.10	0.32	0.32	0.14	0.32	0.29	0.27	0.39
Echinoderm spp. mixed								0.17	0.31	1.39
Invertebrate spp. eggs			0.14	0.19	0.34			0.55		0.33
<i>Pseudocalanus elongatus</i> copepodite & adult	0.21	0.39	0.23		0.17		0.06		0.12	0.32
Appendicularia spp. mixed								0.14	0.50	0.54
Harpacticoida spp. copepodite & adult	0.19	0.09	0.19	0.07	0.16		0.27			
Copepoda spp. copepodite & adult		0.17					0.27			
<i>Balanus</i> sp. cypris						0.07		0.13	0.18	
Cyclopoida spp. copepodite & adult	0.18					0.03	0.05			
<i>Paracalanus brevicornis</i> copepodite						0.24				
Isopoda spp. larvae							0.05			0.18
Euphausiacea spp. nauplii						0.20				
Unidentifiable spp. mixed	0.14									
Cladocera spp. mixed						0.08				
Oithona spp. copepodite & adult						0.08				
Total number of stations sampled	6	6	6	6	6	6	6	6	6	6

14. Conclusions

The macro- and meso-zooplankton of the Blackwater Estuary have been described for the periods covering March to May 1993 to 1997. The dominant macrozooplankton were herring larvae, ctenophores, mysids, chaetognaths, amphipods, isopods and other *Natantia* spp. The distribution of the macrozooplankton followed identifiable seasonal and geographical trends. The meso-zooplankton were dominated by *Acartia* and harpacticoid copepods. Other common organisms were polychaete larvae, cirripede nauplii and bryozoan, gastropod and bivalve larvae.

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