

SALMON RESEARCH TRUST
OF IRELAND.



IRISH FISHERIES INVESTIGATIONS

SERIES B (Marine)

No. 27

(1984)

**INVESTIGATIONS IN BANTRY BAY FOLLOWING
THE BETELGEUSE OIL TANKER DISASTER**

by

R. J. R. Grainger, C. B. Duggan, D. Minchin and D. O'Sullivan.

DUBLIN:
PUBLISHED BY THE STATIONERY OFFICE.

TO BE PURCHASED FROM THE
GOVERNMENT PUBLICATIONS SALE OFFICE, SUN ALLIANCE HOUSE,
MOLESWORTH STREET, DUBLIN 2.

Price: £1.85

Investigations in Bantry Bay following the *Betelgeuse* oil tanker disaster

by

R. J. R. GRAINGER, C. DUGGAN, D. MINCHIN and D. O'SULLIVAN

Department of Fisheries and Forestry, Fisheries Research Centre, Abbotstown, Castleknock, Dublin 15, IRELAND.

Received 18th November, 1981.

ABSTRACT

About 30,000 tons of Arabian light crude oil plus some bunker oil was lost from the tanker *Betelgeuse* in Bantry Bay following an explosion and fire in January 1979. Most of the oil was burnt, and in the intense heat more was polymerised into an asphalt-like material which coated the shoreline or sank, disrupting fishing activity. Oil leaked intermittently from the wreck for over a year during the salvage operation, and some of this was treated very effectively by spraying concentrated dispersant from an aircraft. Evidence of residual circulation suggested that the northern side of the inner Bay would have been most threatened by the dispersed oil. Several species of fish spawned in the Bay in the months following the disaster and larvae and post-larvae were not seriously affected. Fishing activity was disrupted but, apart from periwinkles *Littorina littorea* (L.), no commercial stocks were observed to suffer mortality as a result of the spillage. There was some very minor contamination of scallops *Pecten maximus* (L.) but this did not prevent scallop spatfalls in 1979 or 1980.

INTRODUCTION

On 8 January 1979 the tanker *Betelgeuse* exploded while discharging its cargo of crude oil at a jetty 400m off Whiddy Island, Bantry Bay, killing 50 people and causing oil pollution which continued intermittently during the salvage operation for over a year. The purpose of this report is to describe the scientific investigations carried out by the Department of Fisheries & Forestry following the disaster, and with reference to "baseline" surveys and to studies conducted in response to previous spillages, to assess the effects of the *Betelgeuse* oil spillage on the environment and fisheries of Bantry Bay.

In 1968 Gulf Oil Terminals (Ireland) Ltd. opened an oil terminal on Whiddy Island. Since the terminal became operational there have been numerous very small spillages of oil, and three major ones including the *Betelgeuse*. In October 1974 a valve left open at night on board the tanker *Universe Leader* allowed 2,597 tons of Kuwait crude to escape. In January 1975 the tanker *Afran Zodiac* was damaged while unberthing and steamed out of the Bay while 480 tons of Bunker C heavy fuel oil escaped.

There have been several biological surveys in the Bay with a view to setting a "baseline" and others to assess the effects of oil pollution. The fauna and flora of the littoral zone on the rocky shores of Bantry Bay was extensively surveyed prior to the major spillages (Crapp, 1973; Guiry, 1973; Thompson, 1979). Following the first two major spillages, Baker et al. (1981) re-surveyed the forty transects studied by Crapp (1973). They noted a number of changes but in most cases these were not obviously attributable to visible oil pollution and seemed more likely to result from the very different meteorological conditions which preceded each of the two surveys. However, some damage to seaweeds was recorded (Cullinane et al., 1975). In addition, some studies of the sub-littoral have been made, aspects of which could be used for monitoring in the future (Willis, 1975; Edwards, 1980).

A number of scallop *Pecten maximus* (L.) dredging and diving surveys have been conducted within Bantry Bay (Baird and Gibson, 1956; Gibson, 1956; Minchin (unpublished)). Since 1977 scallop spatfall has been monitored at Whiddy Point East by the Fisheries Research Centre.

THE BETELGEUSE SPILLAGE AND CLEAN-UP OPERATION

At the time of the *Betelgeuse* explosion about 39,000 tons of Arabian light crude remained on board, some 74,000 tons of Arabian heavy crude having been discharged earlier. Following the explosion a fire raged for almost 24 hours and the intense heat caused much of the oil to polymerise into an asphalt-like residue some of which coated about 400m of rocky shoreline near the jetty to a thickness of 30cm. This oil residue was denser than water. Sunken patches were seen in the vicinity of the wreck by divers and fishermen reported it contaminating bottom trawls and scallop dredges up to 28 km away. After the fire, oil leaked from the wreck at an estimated 5 tons/hour for about six days until some of the leaks were plugged. Leakage then continued at an estimated 2 tons/hour until the 10,000 tons remaining on board had been pumped ashore. Thus some 30,000 tons was either burnt or spilt. Estimates of the quantity which escaped unburnt during the first week vary between 2,000 (Cross et al. 1979) and 10,000 tons, of which a possible 500 tons reached the shore. In addition small quantities of crude as well as some bunker oil were released intermittently during the salvage operation which was in progress for about 18 months.

Until 10 January, oil was stranded only on the north shore of Whiddy Island and on the shores of Whiddy and Bantry Harbours (Fig. 1). Over the next two days it spread more widely around the inner Bay and then with easterly winds on 13 January oil in patches was stranded down the northern shore as far as Berehaven (Fig. 2). Most of the polymerised oil on the north shore of Whiddy Island was collected manually using pick axes and forks. Some of the unburnt oil stranded elsewhere was collected using straw, and on Whiddy Island using gully suckers. A boom placed across the mouth of Glengarriff Harbour prevented oil from entering this high amenity area.

Small amounts of oil were collected at sea in the vicinity of the wreck using a skimmer in conjunction with a towed Troill boom. Spraying of dispersant (BP 1100 WD) was kept to a minimum and much emphasis was put on applying it as effectively as possible. After an isolated case of incorrect application of dispersant by a tug, spraying was suspended by the Department of Fisheries and Forestry on 10 January and there was very little spraying by tugs and naval vessels after this. Following a demonstration of the effectiveness of spraying concentrated dispersant (BP 1100 WD) from a low-flying aircraft applying only 28 l/hectare (about one third of the quantity per unit area sprayed from ships), aerial spraying was used almost exclusively thereafter, and then only on the more substantial slicks of fresh oil.

Because of the danger from explosive gases it was not possible to recover all the remaining oil from the wreck during the salvage, and about 120 tons of light crude had to be released into the sea. Prior to the release about 5,000 l of dispersant in seawater (1 part dispersant to 20 parts water) were added to the oil. The resultant oil slick was successfully dispersed by agitation from ships and wind.

Between late March and late April 1980 dredging took place around the wreck as part of the salvage operation. About 20,000m³ of sediment was pumped to a site 70m west of the wreck. At the request of the Department of Fisheries and Forestry the salvors commissioned a sedimentological survey to monitor the distribution of the dredge spoil. Results indicated that the operation had only a minimal and temporary effect on the natural environment and that the area affected was, at most, within 1km of the outfall. These conclusions were supported by observations from the Fisheries Research Centre on 30 April 1980 who found no discoloration in the water and no deposits of dredge spoil on the bottom in the vicinity of dive station 20 (Fig. 20).

In November and December 1980 about 10 scallop-dredging boats were employed by the insurers for 20 days clearing sunken oil from an area between the jetty and Whiddy Island and about 30 tons was removed. It is likely, however, that much sunken oil still remains in the area which is on an scallop *Pecten maximus* bed.

After the Betelgeuse spillage, Myers et al. (1979, 1980) who have been regularly monitoring the littoral zone at five sites in Bantry Bay since 1978, surveyed a number of additional transects which had been established by Crapp (1973). No biotic changes were noted though particular attention had been given to species which are sensitive to oiling (Crapp, 1973). Myers et. al. (1979) concluded that the effects of the spillage up to six months afterwards had been slight, except for a section of the north shore of Whiddy Island where burning oil came ashore and devastated life in the littoral zone which included periwinkles *Littorina littorea* (L.).

Fishing was disrupted by the pollution and clean-up process. Floating oil prevented fishing in some areas and sunken oil fouled scallop dredges and, to a lesser extent, trawls. Exploitation of shellfish, particularly periwinkles, scallops and clams *Venerupis decussata* (L.) was most seriously affected and some catches of *Nephrops norvegicus* (L.) were rejected by buyers.

FISHERIES-RELATED INVESTIGATIONS

The Department of Fisheries & Forestry carried out hydrographic and zooplankton surveys, diving surveys, taste-panel tests for scallop tainting and chemical analysis for hydrocarbon contamination of scallops.

HYDROGRAPHIC AND ZOOPLANKTON SURVEYS

The larval stages of fish and shellfish are the most sensitive to oil (Kunhold, 1972) and dispersant (Wilson, 1972) toxicity. For this reason zooplankton surveys were conducted to determine the distributions of eggs and larvae of species which were spawning in Bantry Bay. Hydrographic surveys were made to determine the circulatory patterns and to assess the areas which would be most affected by dispersed oil.

Freshwater run-off enters Bantry Bay mainly from the eastern and northern shores; according to catchment area and rainfall distribution data (Anon. 1977), 64% of the total run-off into the Bay is discharged between Bantry town and Seal Harbour, 25% between Seal Harbour and Fair Head (just west of Bere Island) with only the remaining 11% entering from the southern shore between Bantry and Sheep's Head (Fig. 1). This distribution of run-off taken in conjunction with the hydrographic data from the surveys can indicate circulatory patterns.

Five hydrographic/zooplankton surveys have been conducted. On the first, temperatures were measured using reversing thermometers on NIO bottles which were used to take water samples for salinity analysis by titration. On the remainder of the surveys a Salinity/Temperature Bridge (NIO Type MC5) was used to determine temperature and salinity profiles. Zooplankton samples were taken using a high-speed Dutch-modified Gulf III sampler with 275 μm aperture mesh. This was towed in double oblique fashion to within 7m of the sea bed from a vessel travelling at 5 knots. The warp was payed out and hauled in at about 40m/minute. The volume of water filtered was recovered by a precalibrated flowmeter mounted in the nose cone. The plankton samples were preserved in 5% formalin in sea water. Fish eggs, larvae and juveniles and *Nephrops* larvae were extracted, identified and measured and expressed as numbers per square metre of sea surface by reference to the volume sampled and the water depth.

The plankton samples from several surveys contained fish eggs which belonged to a group of species which it is not possible to distinguish between unless the eggs are very well developed. These eggs were probably whiting *Merlangius merlangus* (L.), flounder *Platichthys flesus* (L.) or pouting *Trisopterus luscus* (L.) and are hereafter referred to as "whiting-type".

The results of each survey are described below.

12-14 January 1979:

The limited sea temperature data of this survey show a decline with increasing remoteness from the open sea (Fig. 3) as would be expected in winter. Also, temperatures appear higher on the southern side than on the northern side, suggesting a more oceanic influence on the southern side. Profiles of temperature and salinity across the Bay suggest a circulatory pattern of residual (net) flow in a northeastward direction on the southern side of the Bay and a seaward direction on the northern side, at least in the inner Bay (Fig. 2). This suggests that the north side of the Bay would have been most threatened by the oil once dispersed.

No dead or moribund zooplankters were observed in a cursory examination of the live material and no decayed specimens were noted in the preserved material. All the fish eggs taken in the plankton sample, except for four (3 sprat *Sprattus sprattus* (L.) and 1 rockling), were whiting-type eggs. Figure 4 shows the distribution of these eggs (expressed as numbers below one square meter of sea surface) which were probably being spawned off the north shore of Whiddy Island and drifting towards the mouth of the Bay along the northern shore, supporting the circulatory pattern suggested above (Fig. 2). Incubation times for these eggs at the temperatures prevailing would be about ten days (Russell, 1976), so it would seem that by the time the larvae emerged from the relatively resilient egg stage they would have been well away from Whiddy Island, and possibly lost from the Bay, where concentrations of oil and dispersant would probably have been much lower. The only fish larvae taken were two sprat and two herring and in addition one adult goby, *Aphia minuta* (Risso), was captured.

Thus the oil spillage did not prevent fish, probably whiting, from spawning. Dense marks of fish in mid-water were recorded on the echosounder north of Whiddy over three days (12-14 January) and these according to fishermen were probably sprat.

22 February 1979:

Temperature and salinity data suggested a circulatory pattern in the inner half of the Bay similar to that in January (Fig. 2), but in the outer half the outflow seemed to be down the centre of the Bay as exemplified by the surface salinity distribution (Fig. 5).

Whiting-type eggs were again present in February (Fig. 6). Intense spawning was taking place off Glengariff Harbour and these eggs were drifting westwards along the north shore. Spawning was probably also taking place southwest of Whiddy Island. However, in the outer Bay sprat eggs (Fig. 7) also showed maximal numbers off Glengariff and along the northern shore of the inner Bay with some evidence of a "tongue" down the centre of the outer Bay. Rockling eggs were most abundant in the western inner Bay and in the outer Bay in a band from Shot Head southwestwards. The distributions of fish eggs seemed to conform generally to the proposed pattern of residual circulation. The only fish larvae taken were sprat ranging in length between 4mm and 7mm; a single specimen was captured at each of eight stations. The whiting-type eggs which were present in January may have been swept from the Bay before they hatched. Thus the continued slow leakage of oil and occasional use of dispersant since the first survey did not stop the spawning of whiting or prevent sprat and rockling from commencing spawning.

22 May 1979:

The temperature and salinity distributions suggested a clockwise residual current with the warmer and less saline water from the inner Bay flowing out along the south shore (Fig. 8). This was in complete contrast to the circulation pattern seen in January, and to some extent to that in February also, when the gyre flowed in the opposite direction.

The abundance of fish eggs was not as high as in the February survey but fish larvae were more abundant. Most of the eggs were whiting-type and these were found throughout the Bay (Fig. 9). Sprat and *Callionymus* (dragonet) eggs, the next most abundant species, were also widespread (Fig. 10). Several species of fish larvae were found in the plankton but sprat numbers were strongly dominant (Fig. 11 and Table 1). The distribution of sprat larvae (Fig. 11) shows a dramatic gradient of abundance, decreasing from the mouth to the inner Bay. The extremely high numbers at the mouth may mean that many of the larvae in the Bay originated outside. The plankton samples also contained many decapod larvae, predominantly *Nephrops* and *Pagurus* species. *Nephrops norvegicus* larvae were most abundant on the southern side (Fig. 12).

The fact that the distributions of eggs and larvae did not obviously relate to the proposed circulatory system as they did in the previous surveys suggests that the current reversal indicated by the temperature and salinity data may have been a short-lived and temporary phenomenon.

10 August 1979:

By August sea surface temperatures had risen sharply and the water had become stratified; in the inner and central Bay this was most marked on the southern side and in the outer Bay in the middle. The stratification may mean that circulation was occurring on a vertical plane along the Bay, with an inflow of cool water at depth and an outflow of warmer water near the surface. There was little salinity variation at the surface across the Bay (Fig. 13) though there was a gradient throughout the length of the Bay.

Few fish eggs were taken on this survey, the majority being rockling which were nearly all found in the outer Bay. Details of the eggs taken are shown in Table 2. There were also fewer fish larvae (Table 3) than in May. The dominant species in August were gobies, *Aphia minuta* (Rosso) and *Crystallogobius linearis* (Duben), rather than sprat. The distribution of gobies (< 5mm) (Fig. 14) shows the greatest abundance on the northern side of the inner Bay.

8-9 April 1980:

At the surface salinities tended to be lower, and temperatures higher, on the northern side than on the southern side (Fig. 15) while near-bottom temperatures and salinities varied little throughout the Bay. Temperatures had not yet become very marked. This may mean that residual circulation on a horizontal plane was significant and that flow in an anti-clockwise direction as in January 1979 (Fig. 2) was occurring.

Fish eggs, in particular sprat, dragonet (*Callionymus spp.*) and whiting-type were very abundant during this survey and the distribution of these are shown in Figures 16-18. Sprat eggs were most abundant on the northern side of the outer Bay and least abundant on the southern side which may have been subject to inflow from outside. Whiting-type eggs appeared most densely on the southern side of the inner Bay and numbers decreased towards the mouth. *Callionymus* eggs spawned in the Bay (Fig. 18) may have been drifting out along the northern side while some along the southern side may have originated outside the Bay, possibly in Dunmanus Bay.

Of the fish larvae sprat were by far the most common and, like the sprat eggs, were most abundant on the northern side of the Bay (Fig. 19). Eggs and larvae of at least 17 other species of fish were found in small numbers. Details of their occurrence are given in Tables 4 and 5.

DIVING INVESTIGATIONS

Diving surveys by the FRC diving unit using standard SCUBA equipment were made at 17 stations between 27 February and 2 March 1979 and at 12 stations between 30 April and 2 May 1980 in areas where scallops *Pecten maximus* were thought to exist based on observations from previous surveys. The purpose of the diving surveys was to look for sunken oil, to note any abnormal animal behaviour or mortality, to record the presence or absence of selected species of the macrobenthos and the relative abundance of scallops as well as to collect scallops for taste panel assessment. In addition, at dive station 6 (Fig. 20) near Whiddy point East (50°42'28" N; 9°28'40" W) scallop spat settlement was assessed by counting the number of spat collected per dive hour at depths of 7-10m during August in each year between 1977 and 1980.

No trace of oil was seen below the surface while diving at any of the stations suggesting that sunken oil was not widely distributed. Nor was any abnormal animal behaviour or mortality seen. No great change of the associated macrobenthos was noted at the dive stations examined in both 1979 and 1980 (stations 3, 4, 6, 25). Scallops and queen scallops *Chlamys opercularis* (L.) exhibited normal swimming activity. Although clean shells of recently-dead scallops were noted at station 17 near the terminal, this was not evidence of abnormal mortality; crabs and starfish were active in the area and may have been responsible. Dead shells are common on scallop grounds and were seen previously while diving in Bantry Bay. Many of the shells of O-group scallops had been crushed and cracked in a typical manner (Minchin, unpublished). The number of scallops and queen scallops collected per hour at each dive station is given in Table 6.

Scallop spat settled in 1979 and 1980 at dive station 6 in similar abundance to previous years (Table 7) though the numbers collected per diving hour cannot be directly compared among years because the time of settlement varies and so may predation on the spat. The age structure of the population as a whole showed each age group to be represented indicating a settlement each year back to 1968. This included the 1979 year-class which was represented in the 1980 samples.

TASTE PANEL TESTS

Scallops collected on 18 February, 1 and 2 March 1979 from dive stations 1-9, 11 and 12 (Fig. 20) were shelled and cleaned on arrival in the laboratory. They were then cooked in boiling water for 8 minutes and served to taste panels as shown in Table 8. None of the panel members found any of the scallops to be tainted. However, some members considered some samples to be of poor quality, and in each of these cases the muscle was thought to be perfect but the gonad to be poor. However, no significant difference ($P < 0.22$) was found between the control and the sample from station 3 which had the highest proportion regarded as objectionable using the Exact Test of contingency (Bailey, 1973).

A second taste panel test was conducted using scallops collected by divers on 3 May 1980 at dive stations 2, 3 and 17 (Fig. 20) and a control sample was taken from Berehaven. The results are given in Table 8. The only sample to show significant difference from the control was that from station 17 ($P < 0.02$) which indicates that the scallops near the terminal were tainted.

A third taste panel test (Table 8) was conducted on samples collected on 11 December 1980 by dredge from Berehaven (control) and from the area then being cleared of sunken oil adjacent to dive station 17 (Fig. 20). A significantly higher proportion of the scallops from near the terminal were recorded as tasting objectionable ($P < 0.02$) than were the control scallops. Thus scallops in the vicinity of the sunken oil were still tainted almost two years after the spillage.

CHEMICAL ANALYSIS

As the results of the first taste panel test suggested that the gonad was more contaminated than the muscle, chemical analysis was restricted to the gonad. The gonads have a high lipid content which may form a good base for incorporating hydrocarbons.

The analytical procedure involved extraction and purification of the liquid fraction from the gonads of cooked scallops according to Bligh and Dyer (1959) and Ehrhardt (1972). The samples, including *Betelgeuse* oil and an scallop control, from the Kenmare River were analysed for aliphatic hydrocarbons using Gas Liquid Chromatography in the range 80°-300°C under a programmed run. The 2m column was packed with 2½% silicone OV/17.

A positive trace of oil was detected in scallop gonads collected on 1 and 2 March 1979 at dive stations 3 and 14 (Fig. 21). In all other samples (dive stations 2, 4, 6, 7, 11, 17,) any concentration of oil was too low to detect. The analysis was qualitative rather than quantitative as the concentrations found were close to the limits of detection of the method.

A second chemical analysis of scallops collected on 30 April 1980 at dive stations 2, 3, and 16 was conducted on control scallops and *Betelgeuse* cargo oil using a slightly different method. The non-polar material was extracted from freshly-thawed uncooked scallop gonad. After cleaning in a silica/alumina column, the isolated aliphatic fraction was analysed by GLC as before. No oil contamination was detected (Fig. 22 and 23).

CONCLUSIONS

About 30,000 tons of Arabian light crude plus some bunker oil was lost from the tanker in Bantry Bay; most of it was burned and some was polymerised by the intense heat into an asphalt-like material which coated the north Whiddy shoreline or sank and created a nuisance for fishermen throughout the Bay. Substantial quantities of sunken oil were still present on an scallop bed between the jetty and Whiddy Island over two years later. Of the unburnt oil, some came ashore and was collected, some was dispersed at sea and small quantities were collected at sea.

Intermittent leakages of oil continued for 18 months during the salvage operation and these slicks were mostly treated in a novel way by spraying concentrated dispersant (BP 1100 WD) from an aircraft with an application rate of only about one third that of ships. Throughout, application of dispersants was kept to a minimum and they were only used when they were being fully effective.

Good baseline data were available for the littoral zone and Myers et al. (1979, 1980) were able to state that the species in this zone had been only slightly affected, except on the north shore of Whiddy where burning oil came ashore. Though fishing activity was disrupted, the adult stocks of commercial species themselves, with the exception of periwinkles in at least one area, were not seriously affected.

The five hydrographic and zooplankton surveys undertaken following the explosion provided evidence of residual currents in the Bay and in all surveys except that of May 1979 circulation on the horizontal plane in the inner Bay was probably towards the head of the Bay on the southern side and seawards on the northern side (Fig. 2). This suggests that the northern side would be most threatened from dispersed oil (floating oil being mainly subject to wind-drift). These surveys also showed which species were spawning in the Bay and so potentially threatened at the larval stage. The oil and dispersant pollution did not prevent sprat, dabs, rockling and dragonets and fish which were probably whiting from spawning in the Bay, sometimes just north of Whiddy Island. Often the distribution of these eggs supported the proposed residual circulation suggested by the hydrographic studies (e.g. Fig. 4 and 7). However, many of these eggs were probably swept from the Bay before they were due to hatch to release the more sensitive larvae. At least 23 species of fish larvae were collected. No dead larvae were observed in the fresh samples nor were decayed larvae found in the preserved samples. Thus it seems unlikely that the oil/dispersant pollution seriously affected the survival of fish larvae and postlarvae.

The diving surveys showed that sunken oil was probably confined to an area between the jetty and the shoreline. At none of the dive stations on scallop beds was abnormal behaviour or mortality observed in scallops or other animals in either 1979 or 1980. Also scallop spat settlement was observed in both these years.

Taste panel tests and chemical analysis did suggest that there was some minor contamination of scallops close to the terminal and also at one point on the northern shore, possibly as a result of residual drift in that direction. Scallops close to the terminal were still tainted in December 1980.

ACKNOWLEDGEMENTS

We would like to thank our colleagues John Brown, diving co-ordinator, Tom Dunne and Nigel Bond, divers; Alan McIntyre and Mark Kilroy who held Fisheries student bursaries, and John O'Keeffe and Mick O'Driscoll who sent in material for examination. We would also like to thank Patrick Gallagher, boatman, Michael Max of the Irish Geological Survey and Capt. Lane who assisted in the collection of materials.

We are also most grateful to the National board for Science and Technology for making the R.V. *Lough Beltra* available for the survey immediately after the disaster at very short notice, the master and crew of the R.V. *Lough Beltra*, skipper (R. Power) and crew of MFV *Stelimir* and the skipper (D. Leonard) and crew of MFV *Brendette* for their co-operation during the hydrographic and plankton surveys and Brian Walshe who sorted and identified many of the plankton samples.

REFERENCES

- Anon. (1977) *Summary of hydrometric records, Southern Water Resource Region, An Foras Forbartha*, Dublin.
- Bailey, N. T. J., (1973). *Statistical Methods in Biology*. London, E.U.P.
- Baird, R. H. and Gibson, F.A. (1956). Underwater observations on scallop (*Pecten maximus* L.) beds. *J. Mar. Biol. Ass. U.K.* 35 : 555-562.
- Baker, J.M., Hainsworth, S., Hiscock, K., Levell, D., Bishop, G., Willis, M., Collinson, R., Kingsburty, R., and O'Sullivan, A.J., (1981). The rocky shore of Bantry Bay: a re-survey. *Ir. Fish. Invest. B*, 23, 27pp.
- Bligh, E.G. and Dyer, W.J. (1959). A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37:911-917.
- Crapp, G.B. (1973). The distribution and abundance of animals and plants on the rocky shores of Bantry Bay. *Ir. Fish. Invest. B*, 9, 35pp.
- Cross, T. F., Southgate, T. and Myers, A. A. (1979). The initial pollution of shores in Bantry Bay, Ireland, by oil from the tanker *Betelgeuse*. *Mar. Poll. Bull.* 10 : 104-107.
- Cullinane, J.P., McCarthy, P. and Fletcher, A. (1975). The effect of oil pollution in Bantry Bay. *Mar. Poll.* 6:173-176.
- Edwards, A. (1980). Ecological studies of the kelp *Laminaria hyperbores*, and its associated fauna in southwest Ireland. *Ophelia* 19: 47-60.
- Ehrhardt, M. (1971). Petroleum hydrocarbons in oysters from Galveston Bay. *Pollution.* 3: 257-271.
- Gibson, F.A. (1956). Escallops (*Pecten maximus* L.) in Irish waters. *Sci. Proc. Roy. Dub. Soc.* 27(8): 253-270.
- Guiry, M.D. (1973). The marine algal flora of Bantry Bay, Co. Cork. *Ir. Fish. Invest. B*, 10, 22pp.
- Kunhold, W.W. (1972). The influence of crude oils on fish fry. *Marine Pollution and Sea Life*. Ed. M. Ruivo, London, Fishing News (Books).
- Minchin, D. (unpublished). The behaviour of young scallops (*Pecten maximus* (L.)-Pectinidae). Second Scallop Workshop, Brest, France, 8-13 May, 1978.
- Myers, A.A., Cross, T.F. and Southgate, T. (1979). *Bantry Bay Ecological Survey. Second Annual Report*, University College, Cork.
- Myers, A.A., Southgate, T. and Cross, T.F. (1980). Distinguishing the effects of oil pollution from natural cyclical phenomena on the biota of Bantry Bay, Ireland. *Mar. Poll. Bull.* 11: 203-207.
- Russell, F.S. (1976). *The eggs and planktonic stages of British marine fishes*. London, Academic Press. 524pp.
- Thompson, G.B. (1979). Distribution and population dynamics of the limpet *Patella aspera* in Bantry Bay. *J. exp. mar. Biol. Ecol.* 40: 115-135.
- Willis, M.E. (1975) Studies on the biology of the sea urchin, *Paracentrotus lividus* in Bantry Bay, southwest Ireland. M.Sc. thesis, University College Cork.
- Wilson, K.W. (1972). Toxicity of oil spill dispersants to embryos and larvae of some marine fishes. *Marine pollution and Sea Life*. Ed. M Ruivo, London, Fishing News (Books).

Table 1: Numbers of fish larvae other than sprat taken on 22 May 1979.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
<i>Trisopterus</i> spp.		1	3	1							1	1	1	3	5	6		22
<i>Merlangius merlangus</i>													1		1			2
<i>Pollachius pollachius</i>							1											1
Rockling		1					1			1							1	4
Ammodytidae		1				1		1								5	1	9
<i>Callionymus</i> spp	2	6	1	5	1	1				1	1	1	3	3	3	5	3	36
Cottidae				1								1						2
<i>Liparis montagui</i>		1													1		1	3
Topknots		2	1													1		4
<i>Limanda limanda</i>	3	1	2	3	1						1	2	7	3	1	3		27
<i>Microstomus kitt</i>		1	1															2
<i>Platichthys flesus</i>	1												1	3	1	1		6
<i>Solea solea</i>														2				3
<i>Microchirus variegatus</i>			1															1
Total	6	14	9	10	2	2	1	2	0	2	2	5	13	12	10	20	12	122

Table 2: Numbers of fish eggs taken on 10 August 1979.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
<i>Sardina pilchardus</i>										1								1
Rockling	1		2	2			1			1			3	2	2	1	2	17
<i>Callionymus</i> spp										2						1		3
Topknots					1		1											2
<i>Limanda limanda</i>	2							1			1							4
Unidentified		1		2			2								1			6
Total	3	1	2	4	1	0	4	1	0	4	1	0	3	2	3	2	3	33

Table 3: Numbers of fish larvae other than gobies taken on 10 August 1979.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total		
<i>Sprattus sprattus</i>			7					1							2	9	8	18	45	
<i>Sardina pilchardus</i>																1			1	
Rockling							2												2	
Labridae			1	2	1		4	1	1										10	
<i>Trachinus vipera</i>									1										1	
<i>Callionymus</i> spp							1										1	1	3	
<i>Blennius gattorugine</i>												1							1	
<i>Liparis montagui</i>															1				1	
<i>Microstomus kitt</i>			1													1			2	
<i>Platichthys flesus</i>																	1		1	
Unidentified								1			1	2							4	
Total			9	2	1	1	6	3	1	1	0	1	3	0	0	3	11	10	19	71

Table 4: Numbers of fish eggs other than sprat, *Callionymus* and whiting-type taken on 8-9 April 1980.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total	
Rockling		1					2				1	1	1	2			2	10	
Topknots																	3	3	
<i>Lepidorhombus whiffiagonis</i>														1				1	
<i>Arnoglossus laterna</i>				1			1					1						3	
<i>Limanda limanda</i>		2			1	1	3			1		1						9	
<i>Microstomus kitt</i>		2																2	
Total		5	0	1	1	1	6	0	0	0	2	0	3	1	3	0	0	5	28

Table 5: Numbers of fish larvae other than sprat taken on 8-9 April 1980.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
<i>Clupea harengus</i>									1									1
<i>Trisopterus minutus</i>	3			3		1				1						1	1	10
<i>Merlangius merlangus</i>				1	1													2
Rockling	1				1													2
Ammodytidae	5		1	1								1						8
<i>Crystallogobius linearis</i>					1							1						2
<i>Callionymus spp.</i>	1					1				1			1					4
<i>Pholis gunnelus</i>						1				1			1					3
<i>Taurulus bubalis</i>						1		1						1			1	4
<i>Liparis montagui</i>				1													1	2
<i>Limanda limanda</i>				1	2													3
<i>Platichthys flesus</i>					2													2
<i>Diplecogaster bimaculata</i>					1													1
Unidentified	1																	
Total	11	0	1	7	8	4	0	1	1	3	0	2	2	1	0	1	2	44

Table 6: Information relating to dives and relative abundance of scallops present at each diving station during 28 February to 2 March 1979 (stations 1-17) and 30 April to 1 May 1980 (stations 18-29).

Station Number	Estimated visibility (m)	Min depth (m)	Max depth (m)	Reef present	Numbers of scallops/hr diving*	Numbers of queens/hr diving*
1	1	13	15	+	20	4
2	1½	14	14	+	37	0
3	1½	10	12	+	300	15
4	1½	12	12	-	120	8
5	2	15	15	+	45	0
6	2	8	13	-	64	0
7	1	10	14	+	60	0
8	1	10	10	+	54	0
9	2	6	14	+	37	0
10	2	6	12	+	0	0
11	1½	12	12	+	77	8
12	1½	14	14	-	40	0
13	1	8	8	-	0	20
14	1	12	12	-	34	8
15	1	15	16	+	16	0
16	1	16	16	+	0	0
17	1½	20	20	-	109	7
18	4	9	15	+	75	0
19	6	5	6	-	45	0
20	7	9	18	-	5	+
21	6	11	13	+	170	0
22	7	10	12	+	137	0
23	3	5	7	+	162	0
24	5	3	9	+	0	0
25	4	5	6	+	+	0
26	4	11	15	+	140	+
27	7	2	16	+	26	0
28	7	4	20	-	31	0
29	3	4	9	+	20	0

* + = present but sample not taken

Table 7: Escallop spat collected at diving station 6 each year during August since 1977, at a depth of 8-12m found byssally attached to pebbles, hydroids and Rhodophyceae.

Date	Collection time (minutes)	Number collected per hour diving	Shell height size range of scallops mm
20 August 1977	2	180	4-11
10 August 1978	40	417	4-11
28 August 1979	40	258	4-12
26 August 1980	72	112	3-17

Table 8: Results from three taste panel tests conducted on scallops which were collected on the dates shown.

28 February; 1-2 March 1979		Panel: 4 persons		
Dive station	Normal taste	Objectionable taste	Total	
1	5	0	5	
2	5	0	5	
3	3	2	5	
4	5	2	7	
5	7	0	7	
6	5	2	7	
7	5	2	7	
8	5	2	7	
9	4	0	4	
11	4	0	4	
12	3	1	4	
Total	51	11	62	

3 May 1980		Panel: 6 persons		
Dive station	Normal taste	Objectionable taste	Total	
control (Berehaven)	34	2	36	
2	10	2	12	
3	12	0	12	
17	8	4	12	
Totals	64	8	72	

11 December 1980		Panel: 6 persons		
Dive station	Normal taste	Objectionable taste	Total	
control (Berehaven)	33	2	35	
17	24	9	33	
Total	57	11	68	

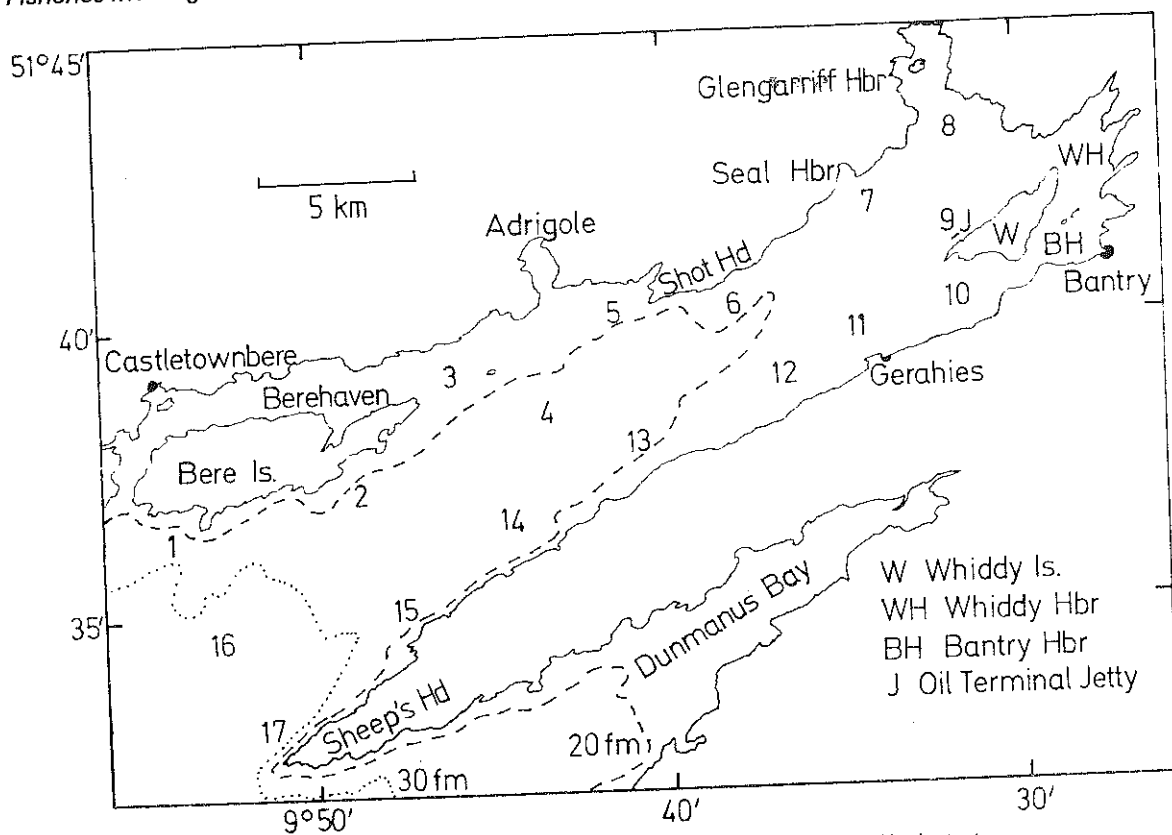


Figure 1: Positions of the 17 sampling stations, depth contours and places mentioned in the text.

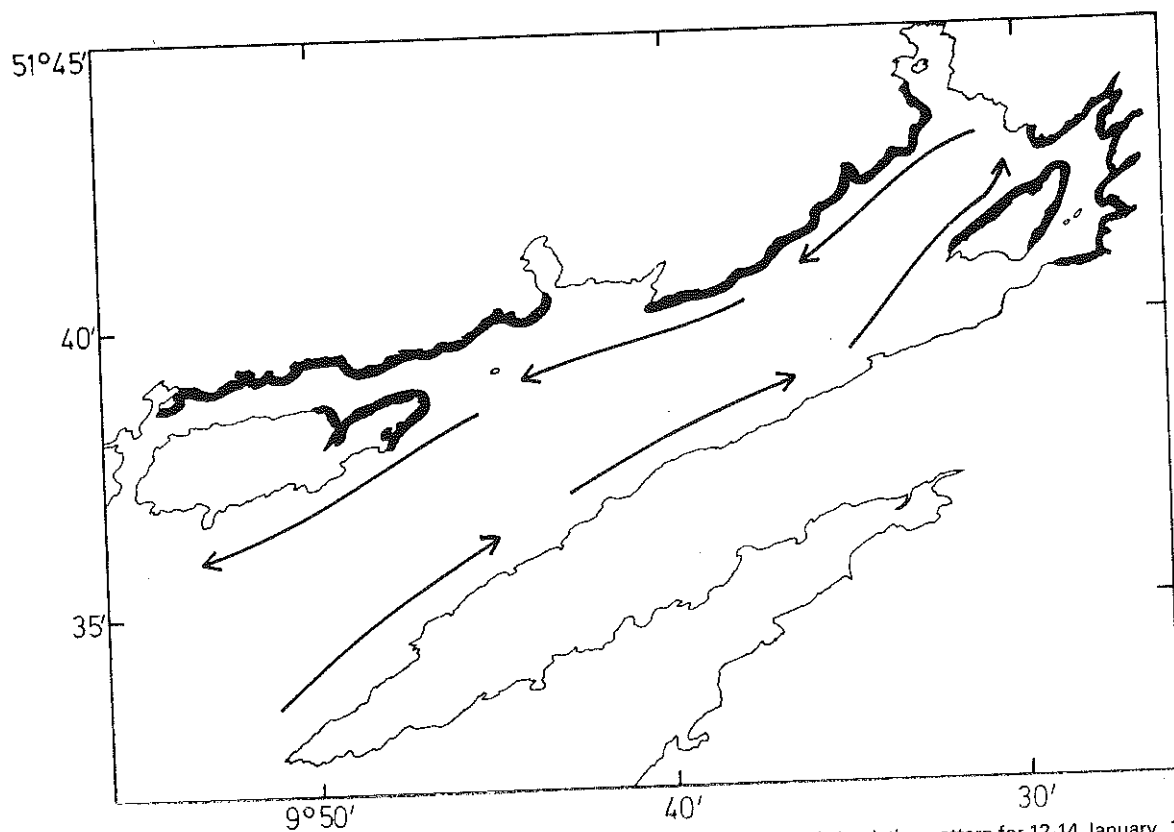


Figure 2: Shores on which oil was stranded (shaded) and the proposed residual circulation pattern for 12-14 January, 1979.

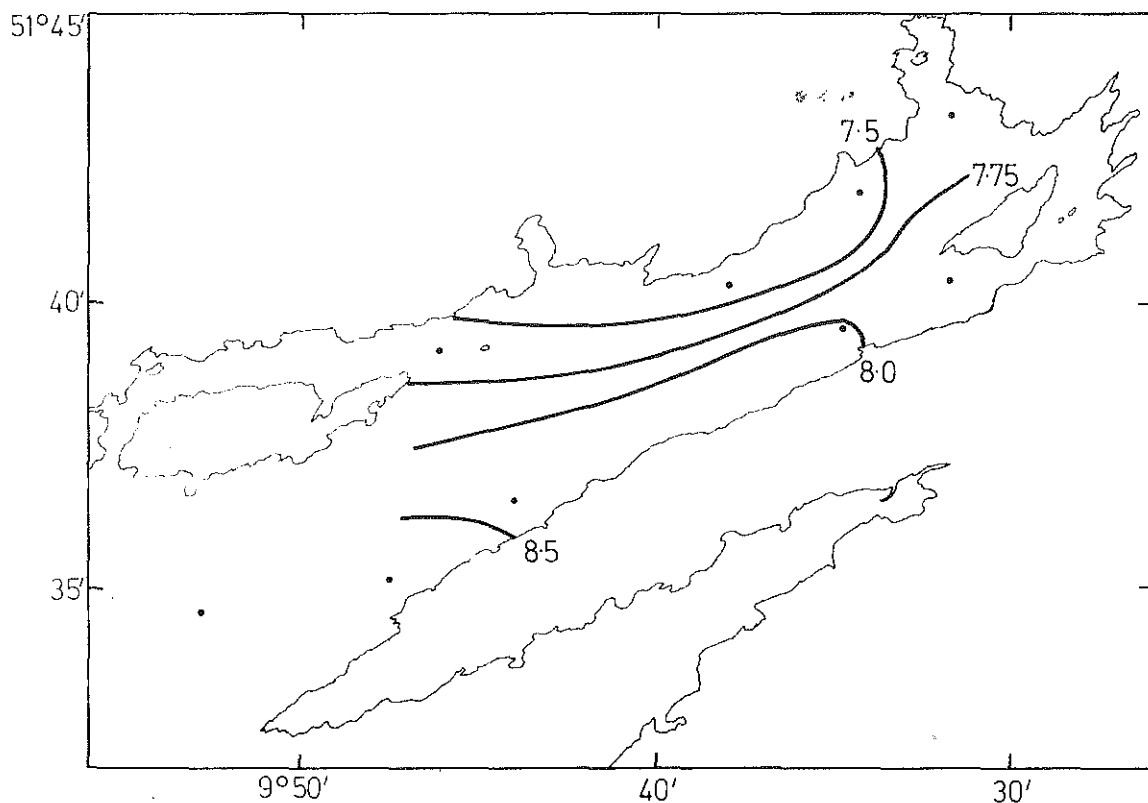


Figure 3: Surface temperature ($^{\circ}\text{C}$) 12-14 January, 1979. Dots denote stations at which temperature was recorded.

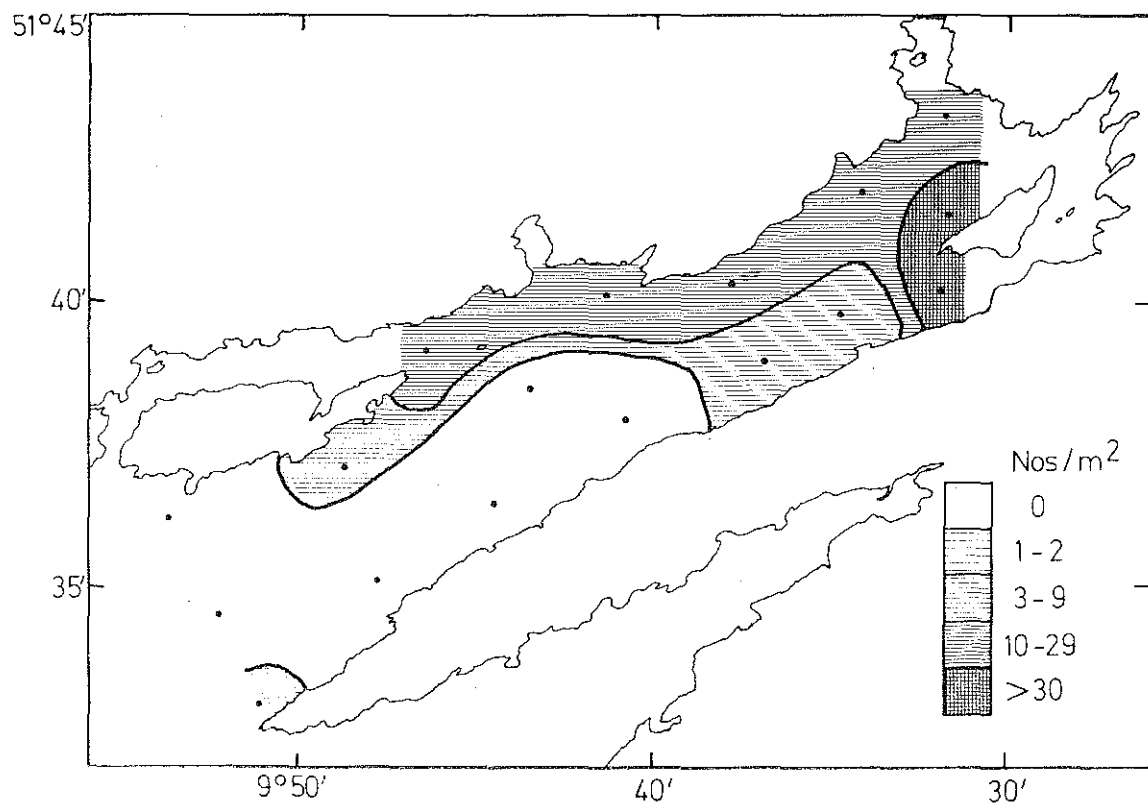


Figure 4: Distribution of fish eggs thought to be whiting (but possibly pouting, pollock or flounder), 12-14 January, 1979.

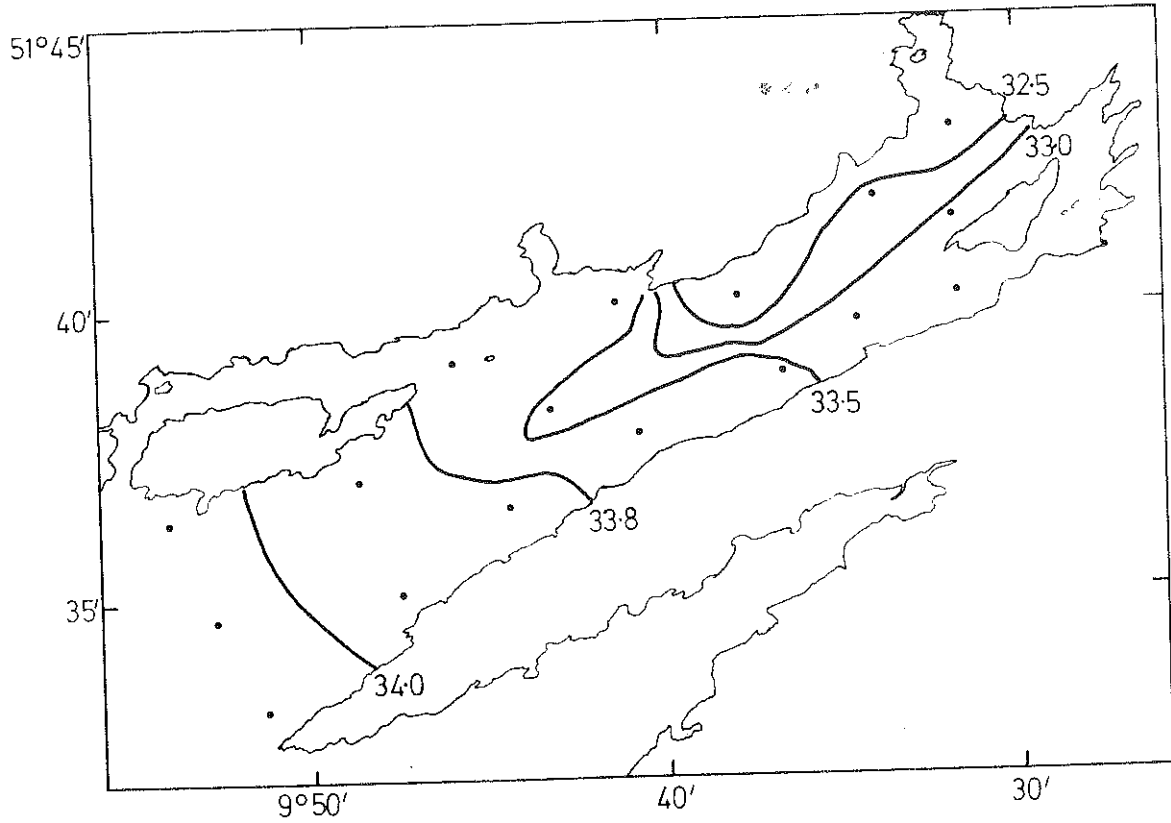


Figure 5: Surface salinity (‰) on 22 February, 1979.

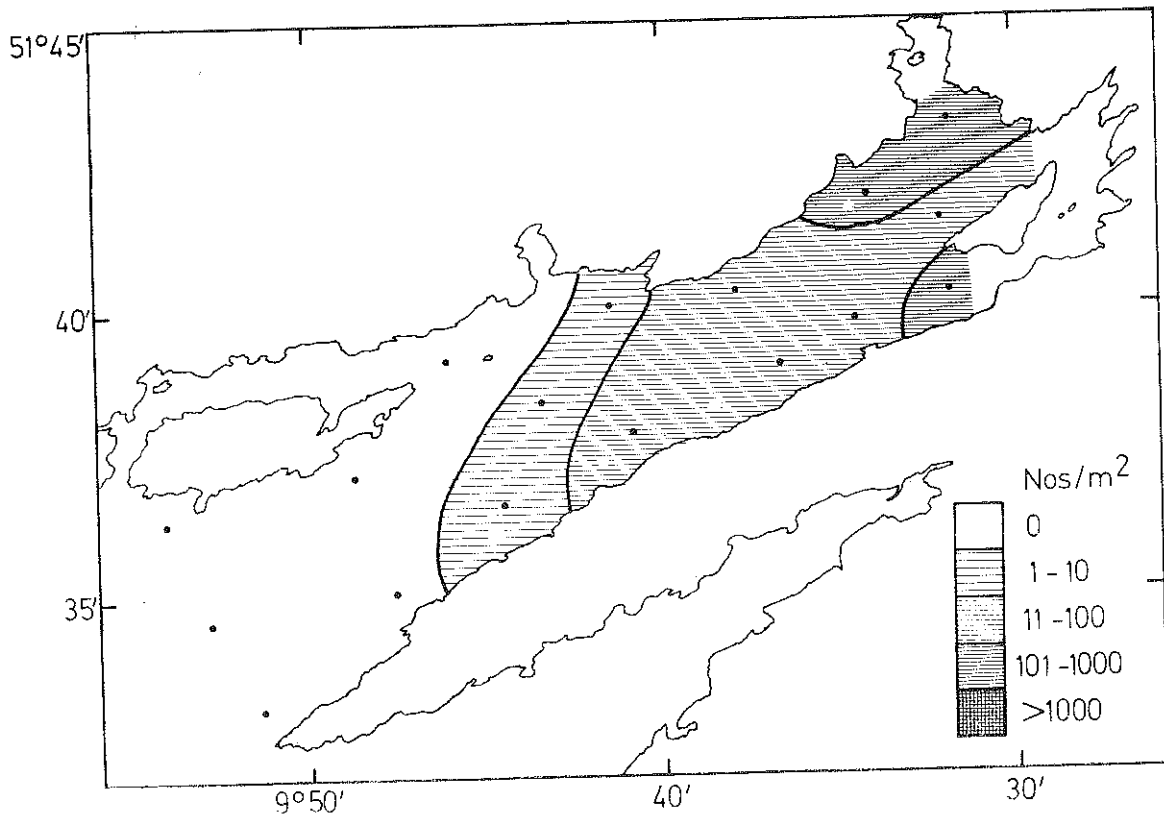


Figure 6: Distribution of fish eggs thought to be whiting (but possibly pouting, flounder or pollack) on 22 February, 1979.

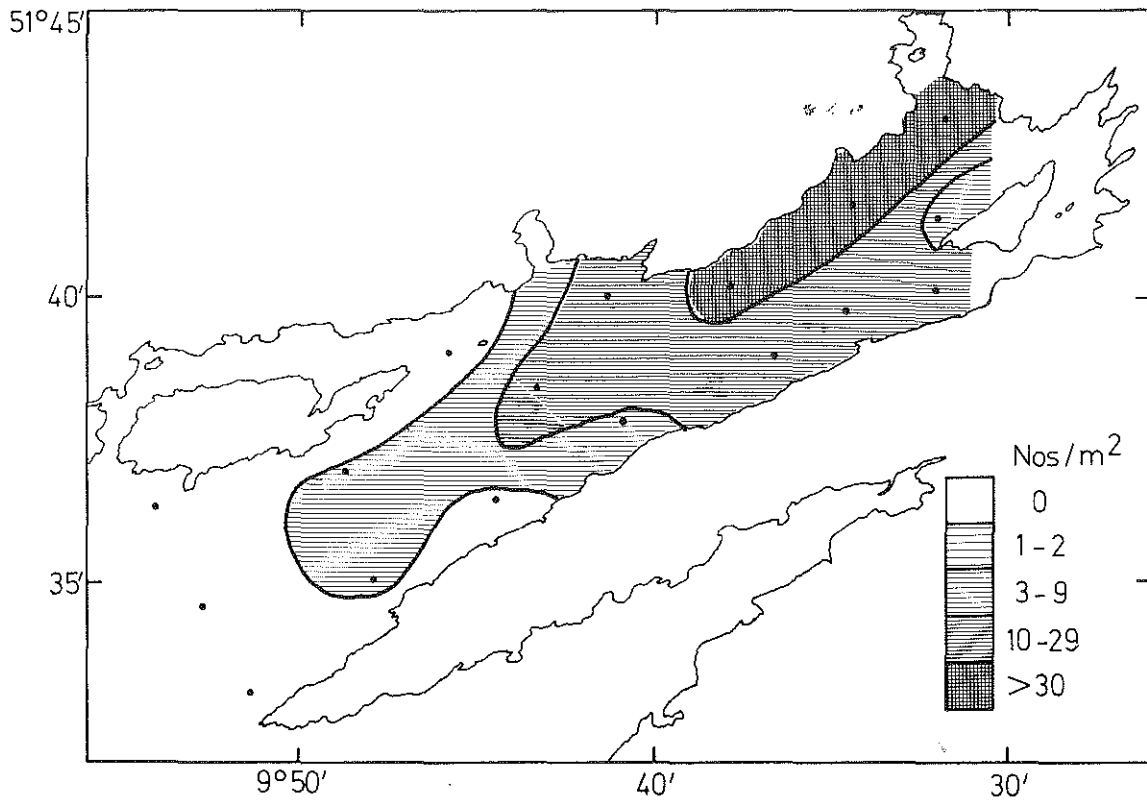


Figure 7: Distribution of sprat eggs on 22 February, 1979.

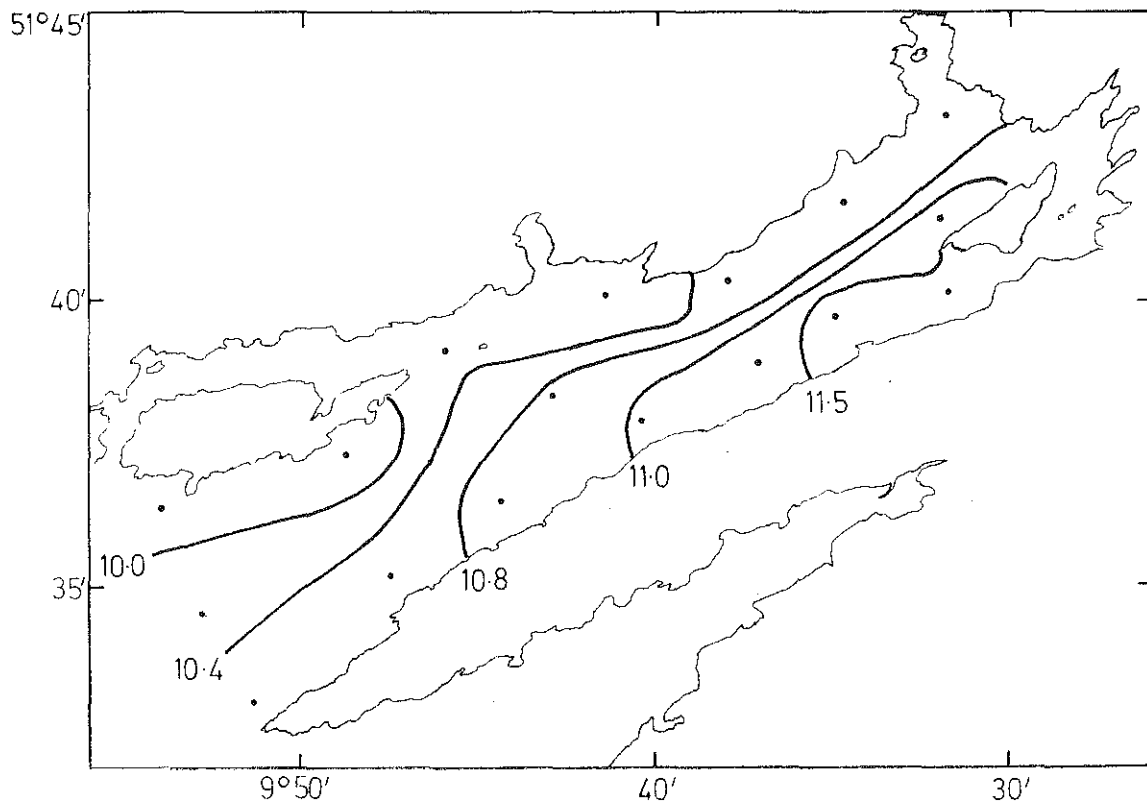


Figure 8: Surface temperature (°C) on 22 May, 1979.

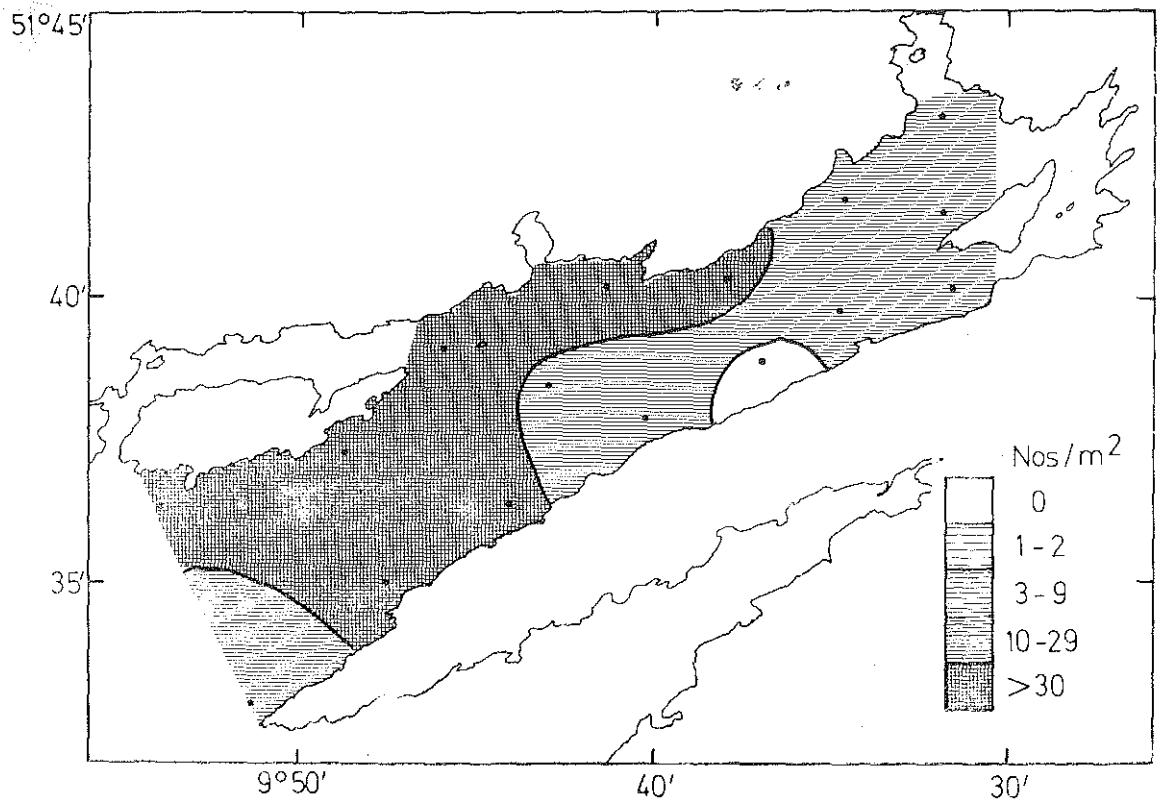


Figure 9: Distribution of eggs thought to be whiting (but possibly pouting, flounder or pollock) on 22 May 1979.

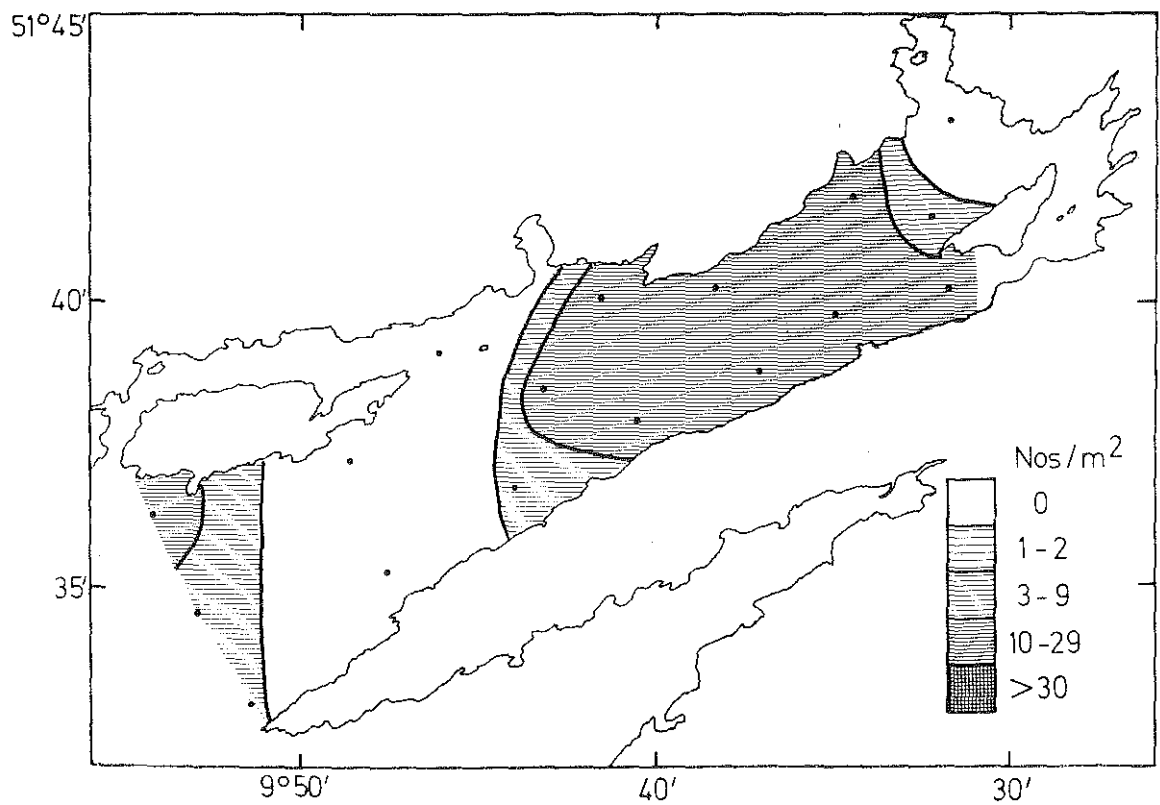


Figure 10: Distribution of sprat eggs on 22 May, 1979.

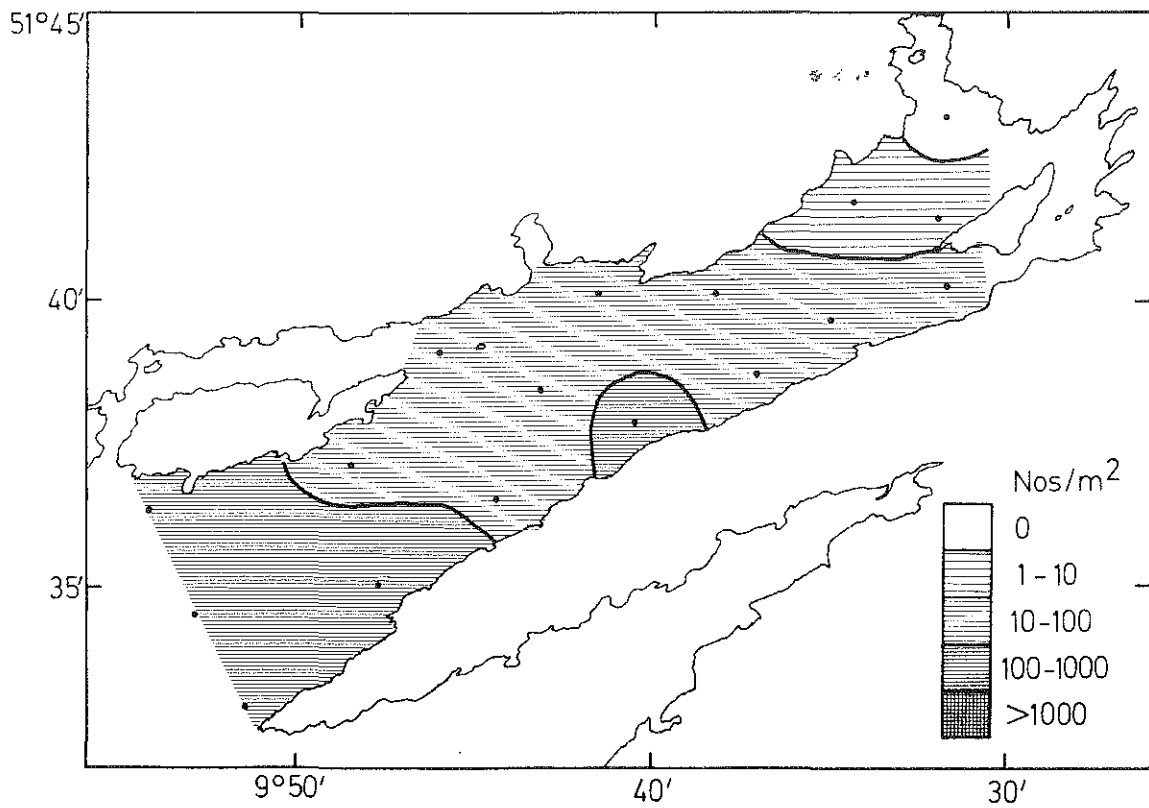


Figure 11: Distribution of sprat larvae and post-larvae on 22 May, 1979.

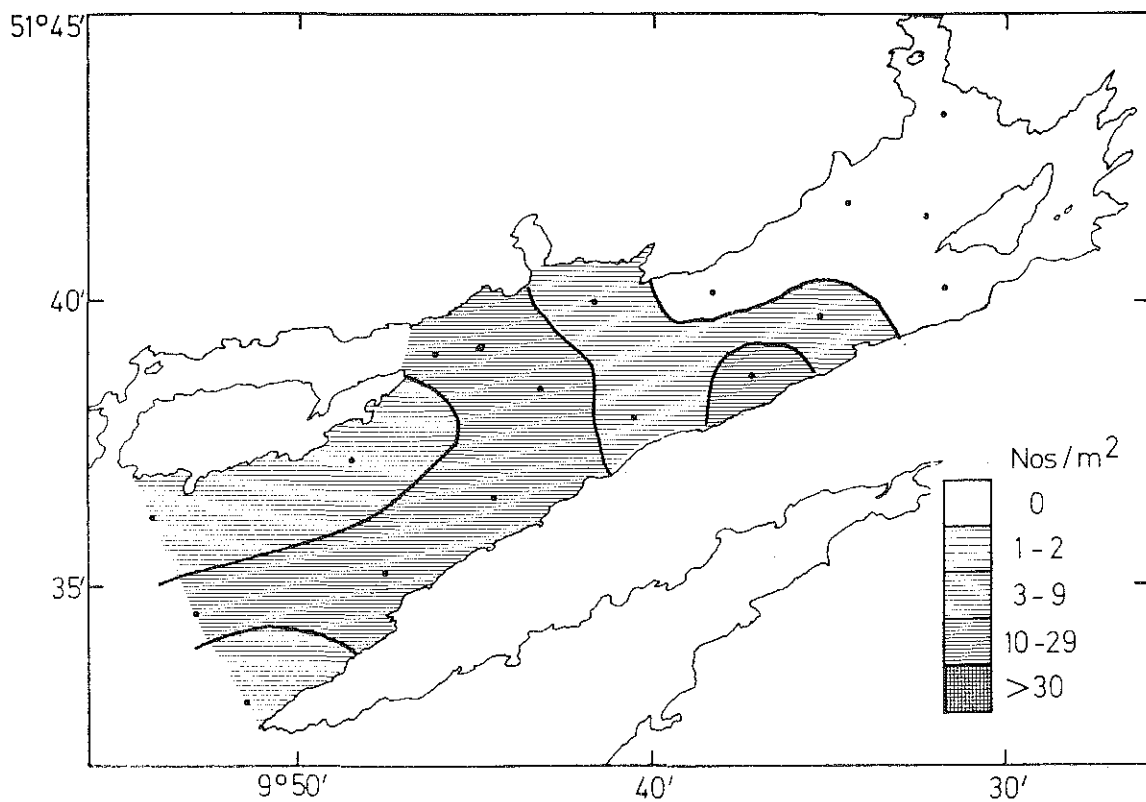


Figure 12: Distribution of *Nephrops* larvae of all stages on 22 May, 1979.

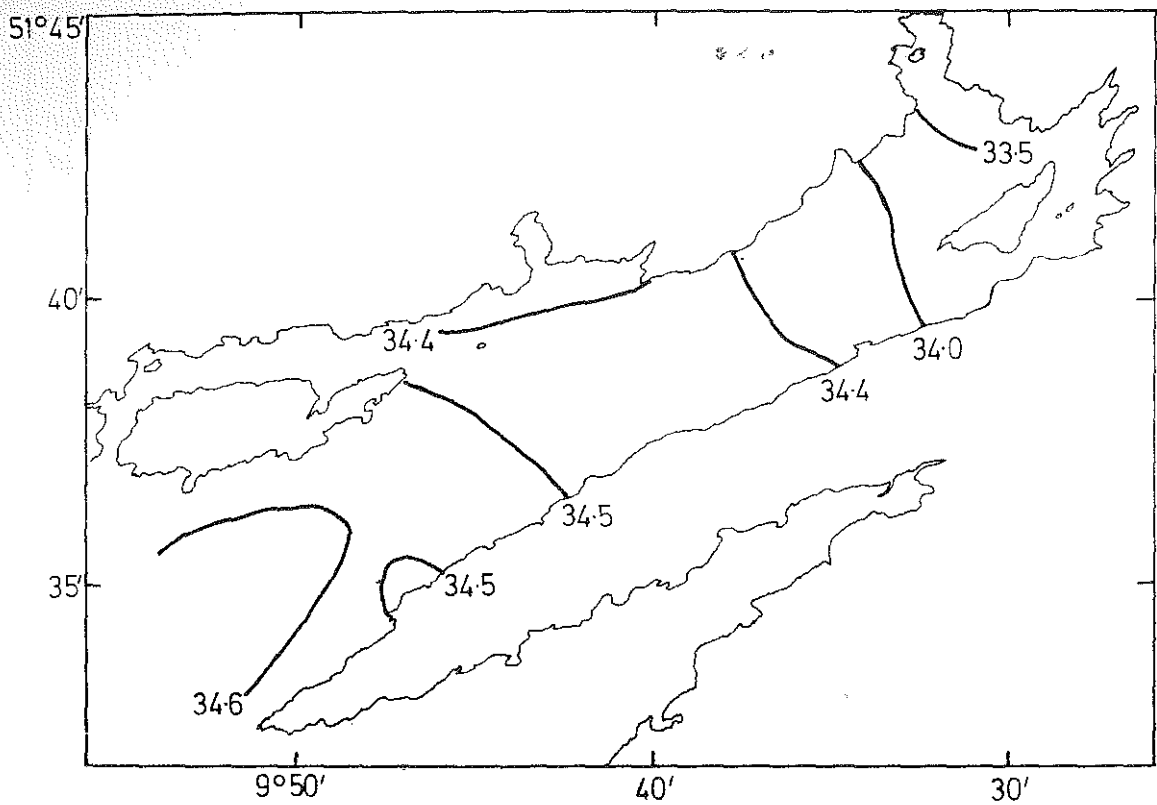


Figure 13: Surface salinity (‰) on 10 August, 1979.

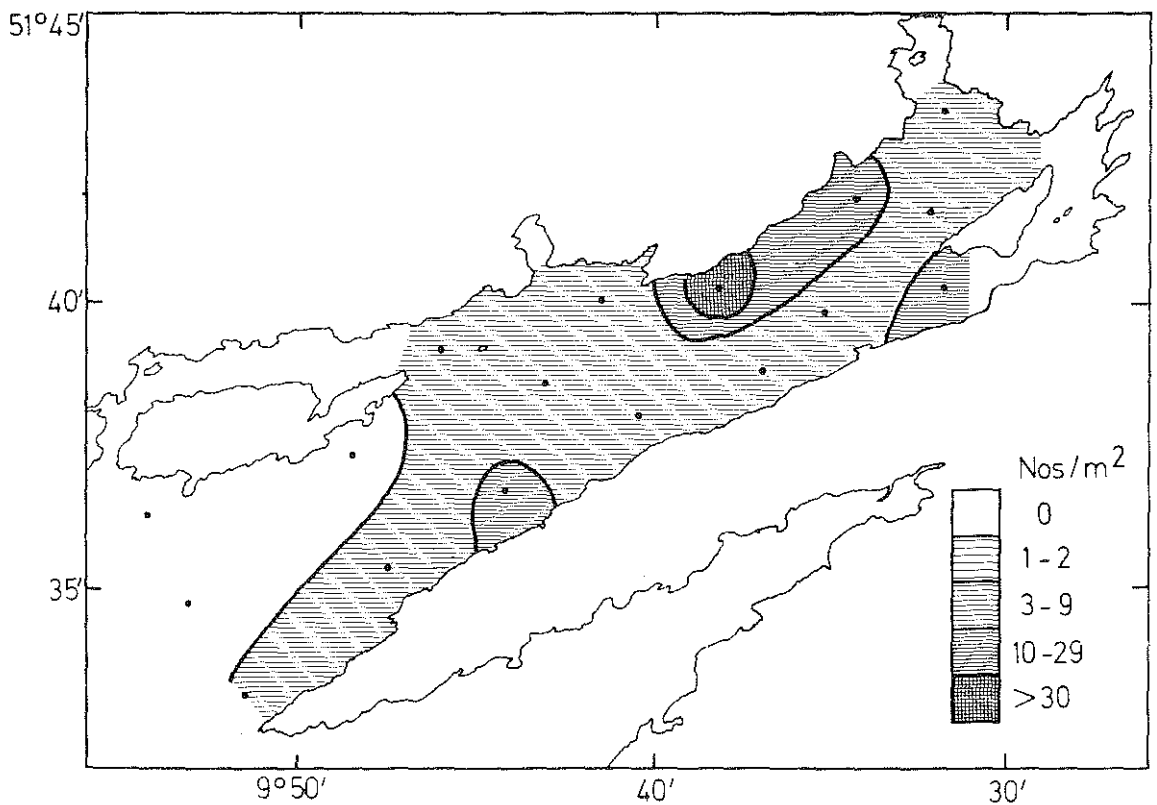


Figure 14: Distribution of pelagic gobies (*Aphia minuta* and *Crystallogobius linearis*) of 5mm or less on 10 August, 1979.

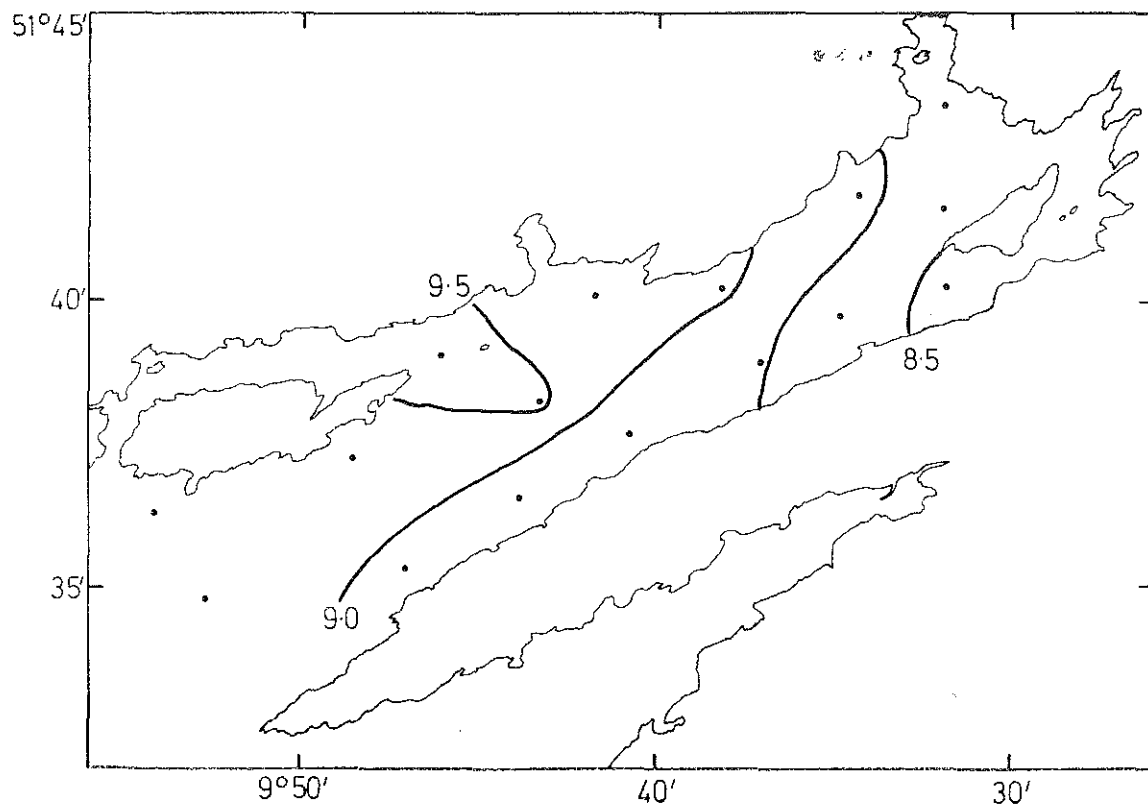


Figure 15: Surface temperature (°C) on 8-9 April, 1980.

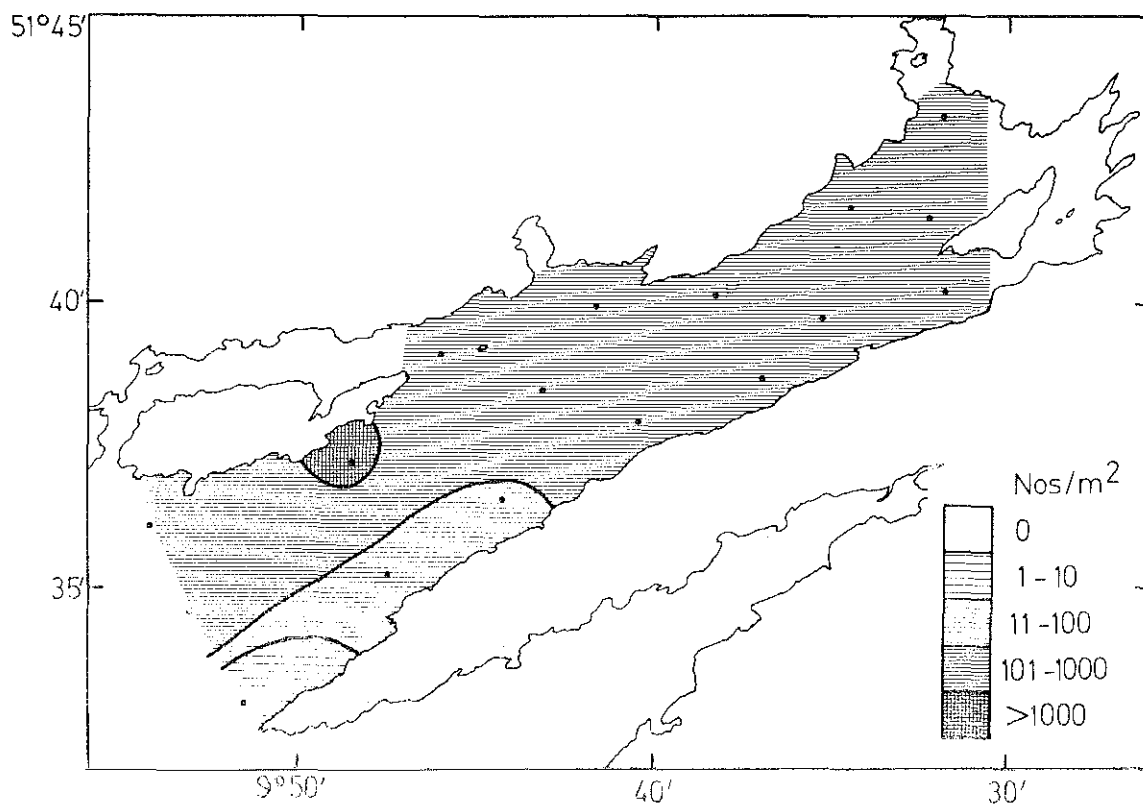


Figure 16: Distribution of sprat eggs on 8-9 April, 1980.

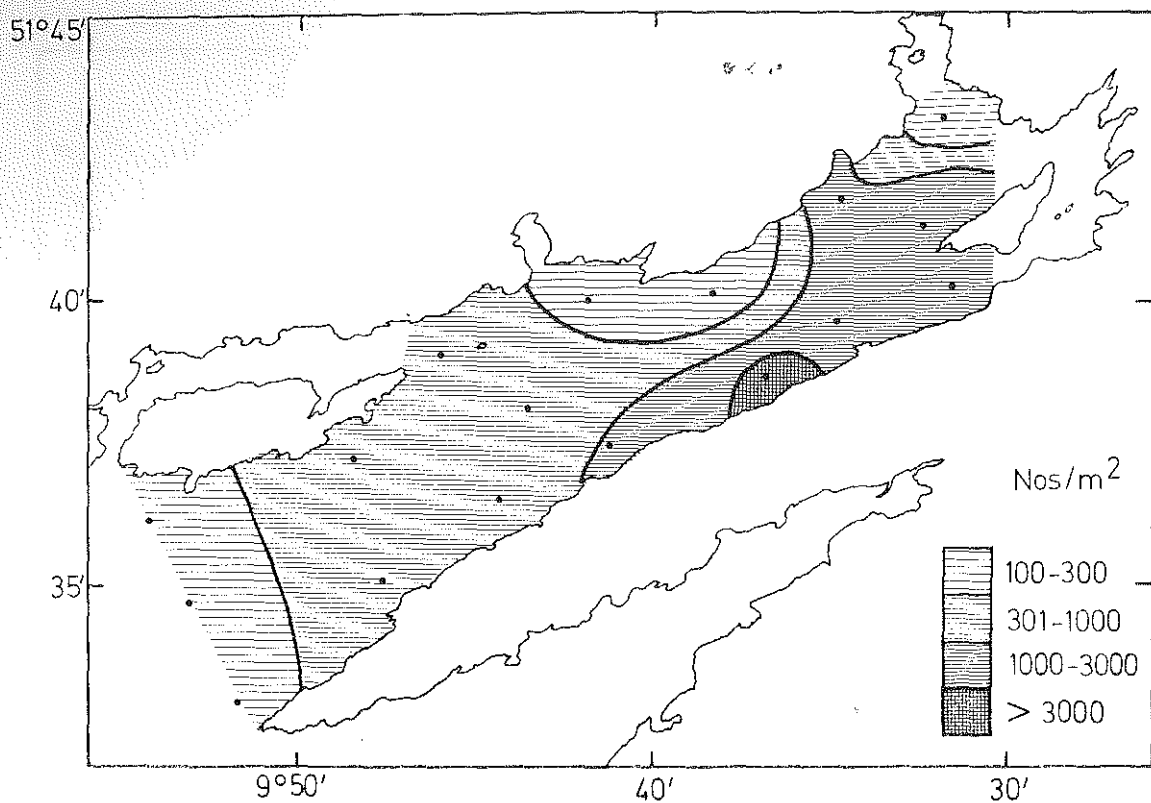


Figure 17: Distribution of eggs thought to be whiting (but possibly pouting, flounder or pollock) on 8-9 April, 1980.

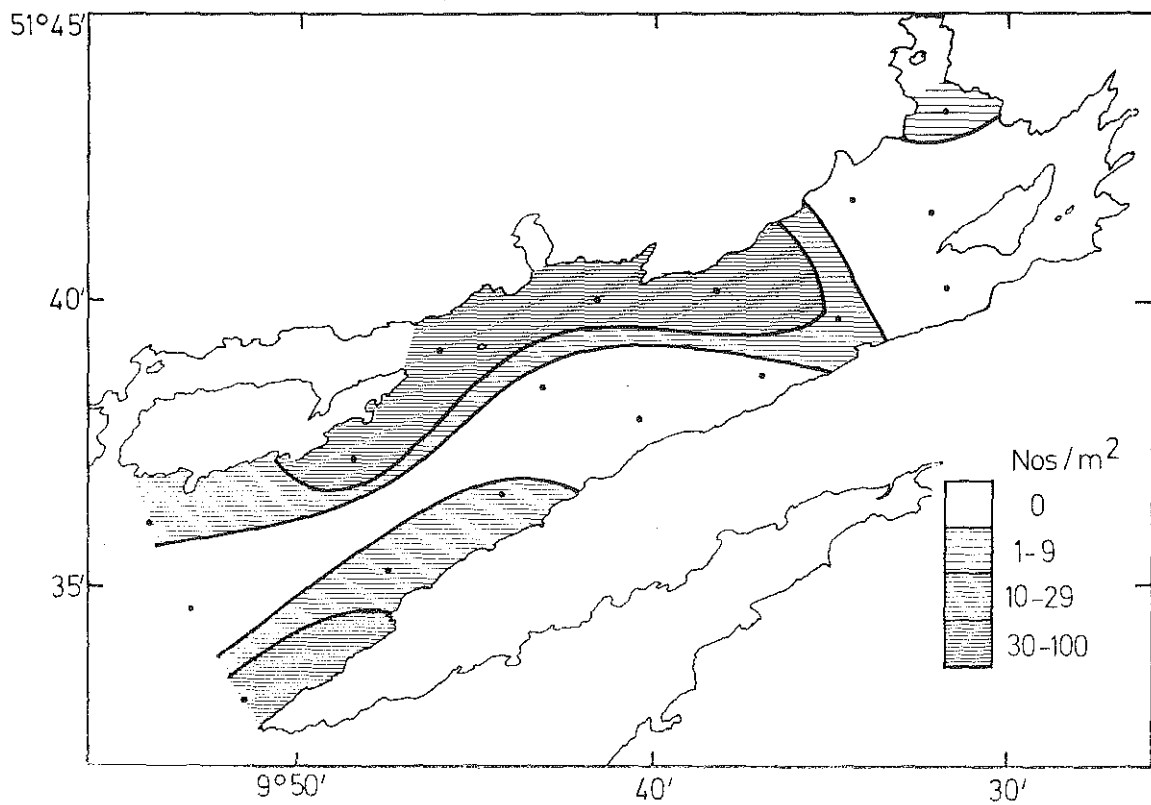


Figure 18: Distribution of dragonet (*Callionymus* spp.) eggs on 8-9 April, 1980.

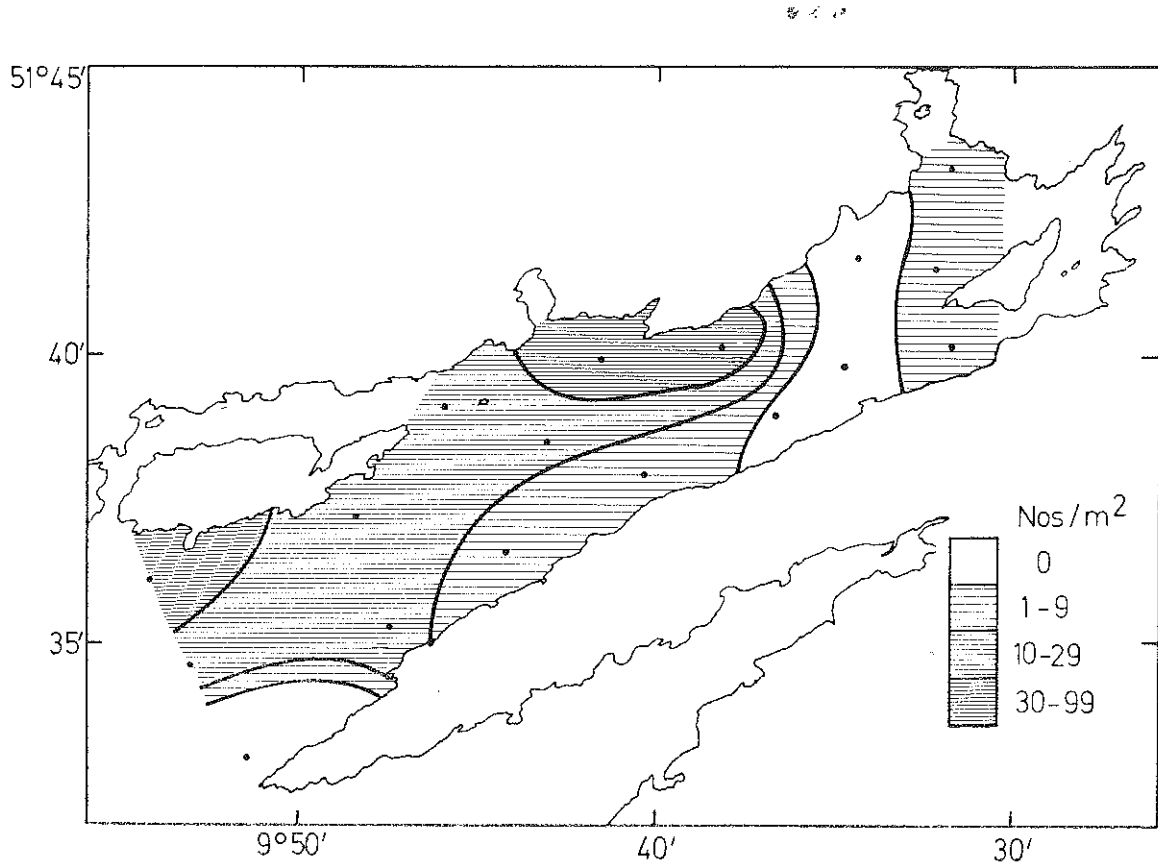


Figure 19: Distribution of sprat larvae and post larvae on 8-9 April, 1980.

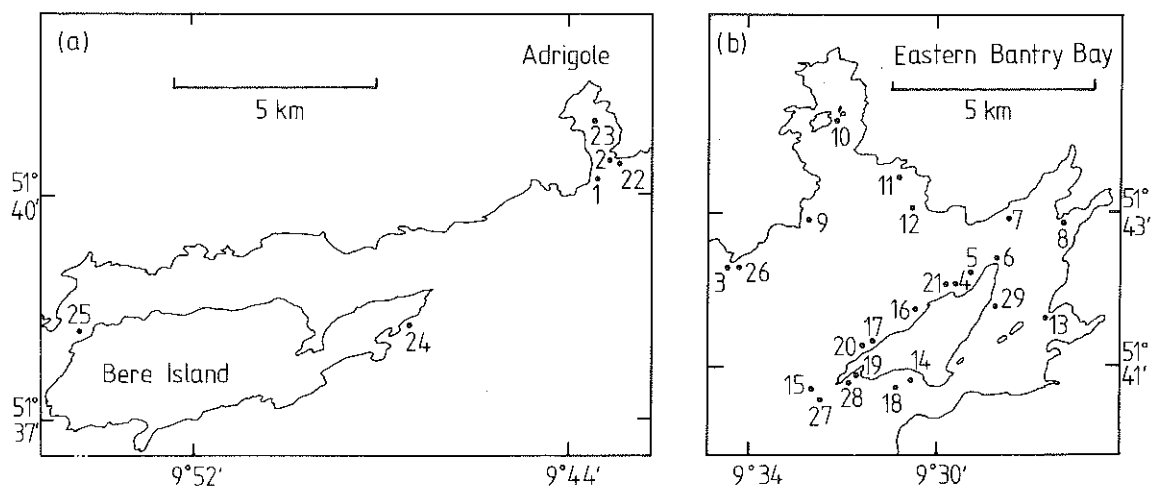


Figure 20: Stations at which diving surveys were made.

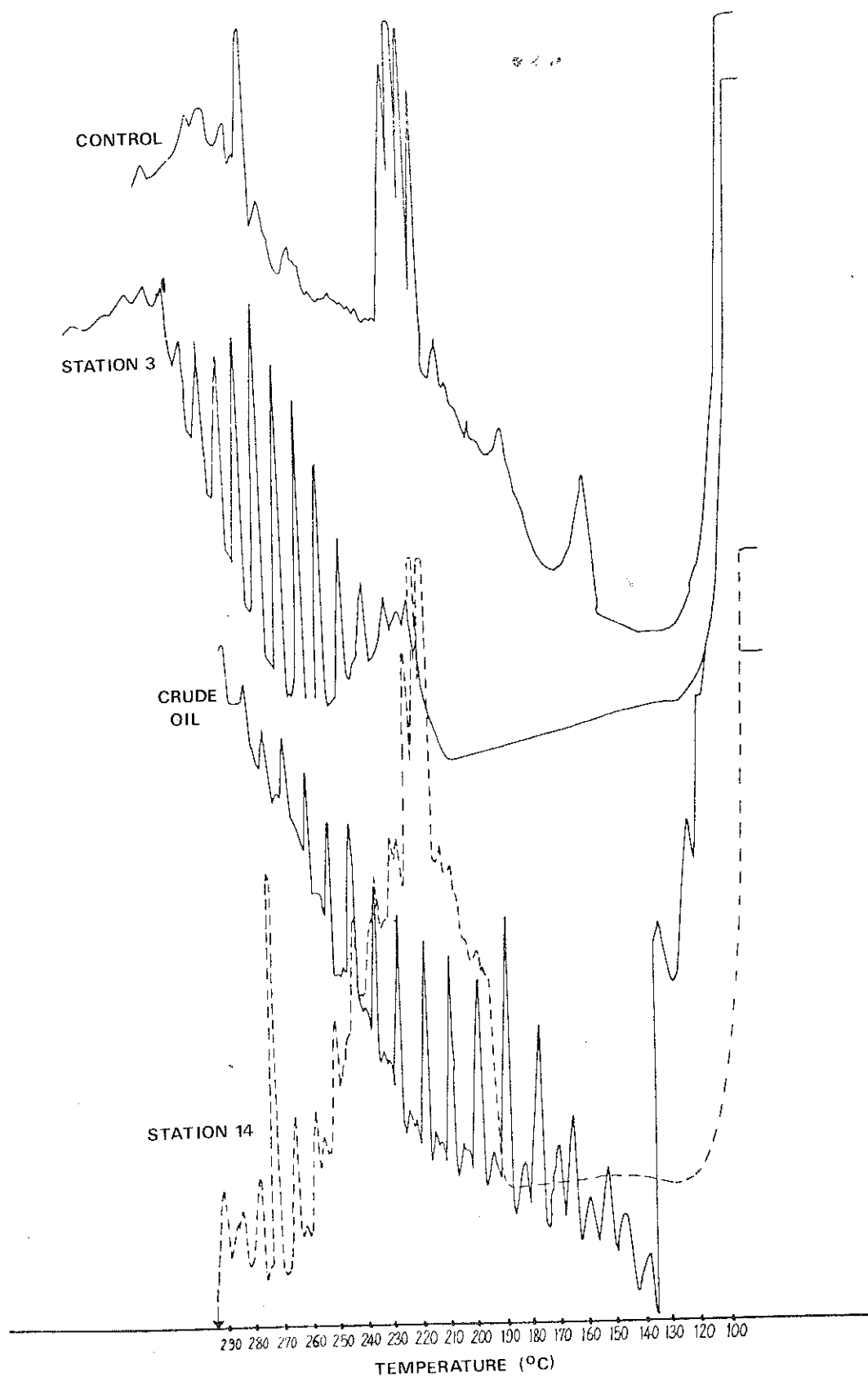


Figure 21: Gas-liquid chromatograms of *Betelgeuse* cargo oil and extracts from gonads of scallops collected on 1 and 2 March, 1979 at dive stations 3 and 14 and control scallops.

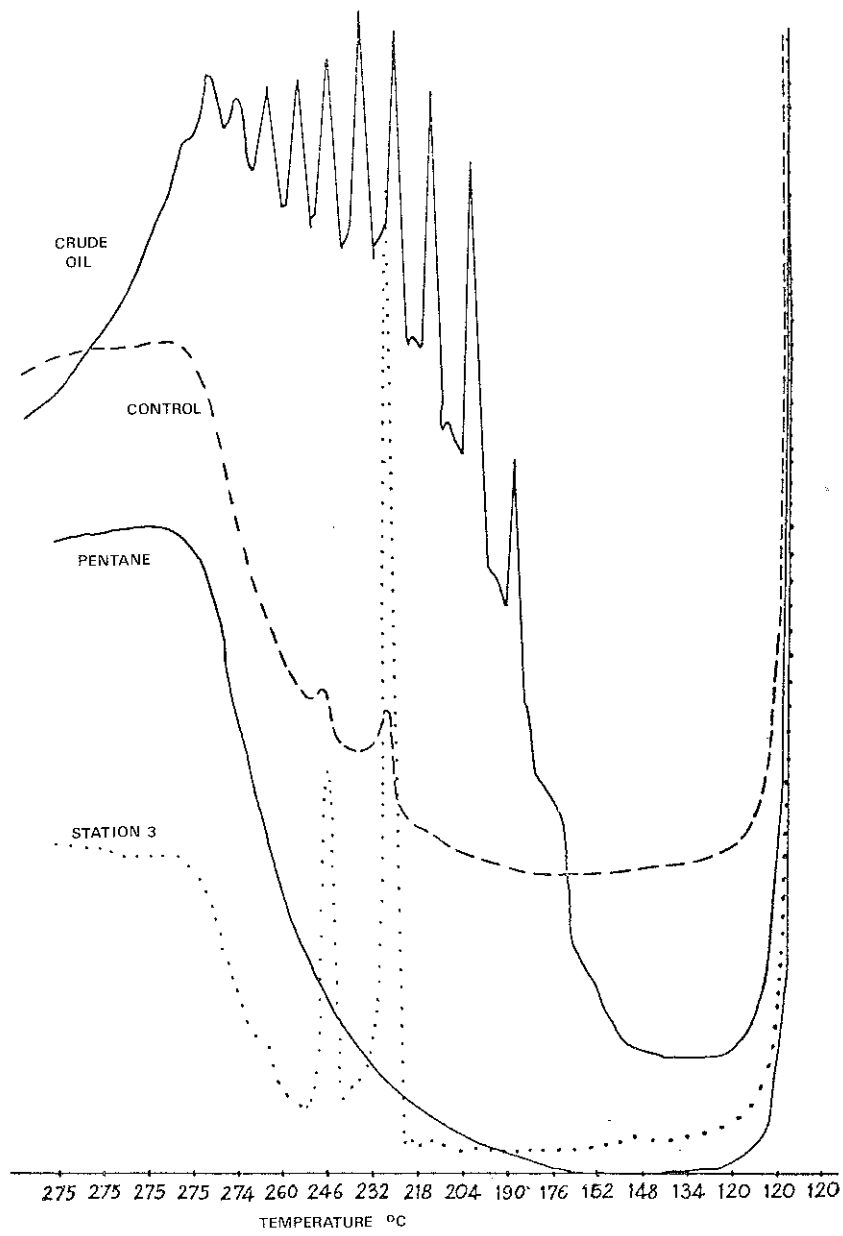


Figure 22: Gas-liquid chromatograms of *Betelgeuse* cargo oil, pentane blank and extracts from gonads of scallops collected on 30 April, 1980 at dive station 3 and control scallops.

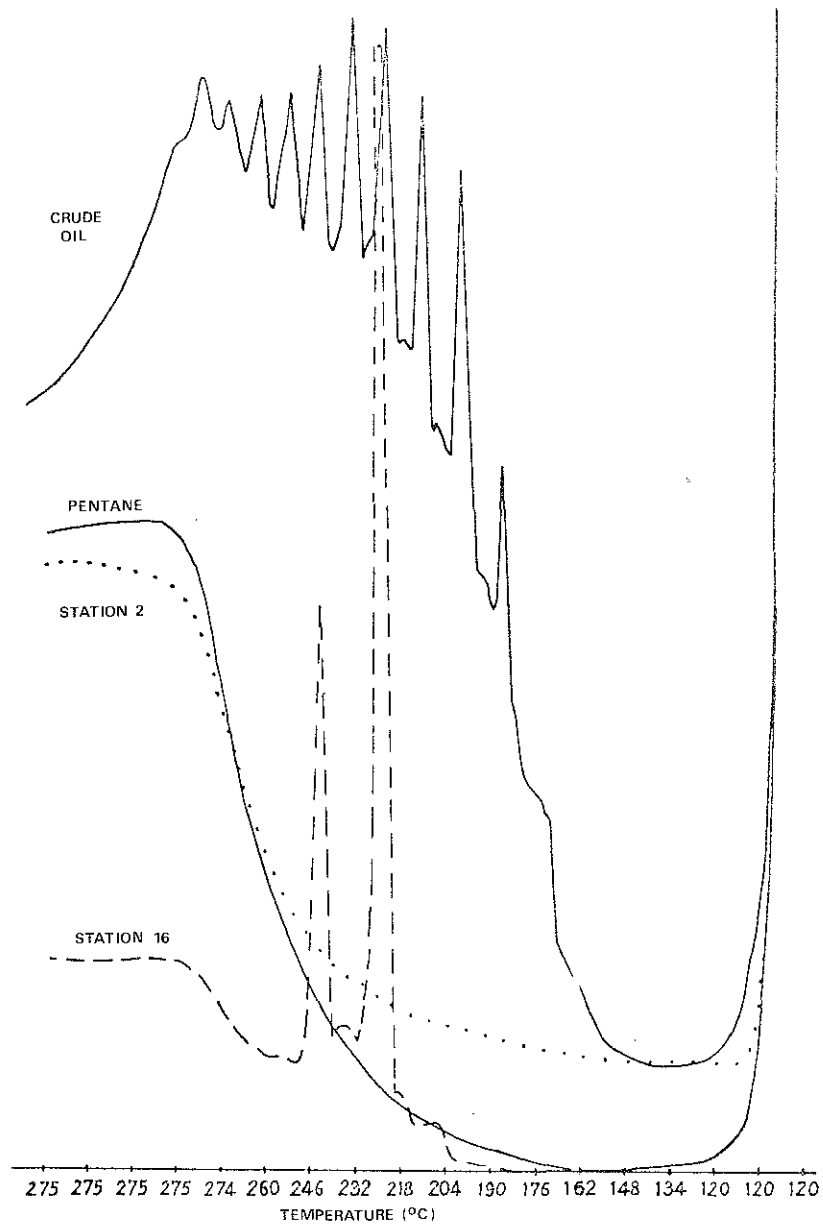


Figure 23: Gas-liquid chromatograms of *Betelgeuse* cargo oil, pentane blank and extracts of gonads of scallops collected on 30 April, 1980 at dive stations 2 and 16.

IRISH FISHERIES INVESTIGATIONS SERIES B (MARINE)

1967. 1. (1) Stocks of *Nephrops norvegicus* off the south coast of Ireland.
F. A. Gibson, Ph.D.
(2) Irish investigations on the lobster (*Homarus vulgaris* Edw.).
F. A. Gibson, Ph.D.
2. Irish sprats and sandeels.
John Molloy, B.Sc.
3. Notes on some Irish estuarine and inshore fishes.
J. Bracken, Ph.D., and M. Kennedy, Ph.D. (with records of the distribution of shads by Eileen Twomey, M.Sc.).
1968. 4. The whiting fishery off Counties Dublin and Louth on the east coast of Ireland.
1. The commercial catch.
J. P. Hillis.
1969. 5. (1) Pelagic eggs and young stages of fishes taken on the south coast of Ireland in 1967.
M. Kennedy and P. Fitzmaurice.
(2) Age, growth and maturity of Irish lobsters.
F. A. Gibson.
6. A review of the Dunmore East herring fishery, 1962-68.
John Molloy, B.Sc.
1971. 7. (1) The whiting fisheries off Counties Dublin and Louth on the east coast of Ireland.
2. Research vessel investigations.
(2) Occurrence of eggs of *Echiodon drummondii* Thompson on the coast of Co. Kerry.
M. Kennedy and T. Champ.
1973. 8. Pelagic eggs of fishes taken on the Irish coast.
M. Kennedy, P. Fitzmaurice and T. Champ.
9. The distribution and abundance of animals and plants on the rocky shores of Bantry Bay.
G. B. Crapp, Ph.D.
10. The marine algal flora of Bantry Bay, Co. Cork.
Michael D. Guiry, M.Sc.
1974. 11. Size distribution and food of Thornback Ray (*Raja clavata* L.) caught on rod and line on the Mayo coast.
P. Fitzmaurice.
12. A diving study on Dublin Bay prawns *Nephrops norvegicus* (L.) and their burrows off the east coast of Ireland.
J. P. Hillis.
13. Field observations on larvae of the Dublin Bay prawn *Nephrops norvegicus* (L.) in the western Irish Sea.
J. P. Hillis.
Laboratory experiments on pumping and filtration in *Mytilus edulis* L. using suspensions of colloidal graphites.
J. H. Wilson and R. Seed.
Reproduction in *Mytilus edulis* L. (Mollusca: Bivalva) in Carlingford Lough, Northern Ireland.
J. H. Wilson and R. Seed.
1975. 16. Captive rearing of larvae of *Nephrops norvegicus* (L.).
J. P. Hillis.
1977. 17. The growth of *Mytilus edulis* from Carlingford Lough.
1979. 18. Observations on a bloom of *Gyrodinium aureolum* Hulbert on the South Coast of Ireland. Summer 1976, associated with mortalities of littoral and sub-littoral organisms.
B. Ottway, M. Parker, D. McGrath, M. Crowley.
19. The exploitation of grey mullet *Chelon labrosus* (Risso) in the south east of Ireland.
E. Fahy.
20. The cockle *Cerastoderma edule* (L.) on the South Bull, Dublin Bay: population parameters and Fishery potential.
A. B. West, J. K. Partridge and A. Lovitt.
21. Laboratory investigations into the absorption of dissolved free amino acids by the gill of the mussel *Mytilus edulis* L.
A. J. Elliott.
1980. 22. Benthic ecology of Dublin Bay in relation to sludge dumping: Fauna.
A. J. M. Walker and E. I. S. Rees.
1981. 23. The rocky shore biology of Bantry Bay—a re-survey.
J. M. Baker, S. Hiscock, K. Hiscock, D. Levell, G. Bishop, M. Precious, R. Collinson, R. Kingsbury, A. J. O'Sullivan.
1982. 24. Distribution and ecology of oysters, *Ostrea edulis* (L.) in Kilkieran and Bertraghboy Bays, Connemara, Co. Galway.
M. D. Barry.
25. The scallop, *Pecten maximus* (L.) in Killary Harbour.
Dan Minchin and F. Mathers.
26. The littoral fauna of Dublin Bay.
J. G. Wilson.
1984. 27. Investigations in Bantry Bay following the Betelgeuse oil tanker disaster.
R. J. R. Grainger, C. B. Duggan, D. Minchin and D. O'Sullivan.
28. Seasonal changes in the intertidal fish and crustacean populations of Aughinish Island in the Shannon Estuary.
G. O'Sullivan.

Irish Fisheries Investigations Series A (Freshwater) deals with scientific research into all aspects of freshwater fisheries.