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# Sampling by the Continuous Plankton Recorder survey

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**Abstract** – The Continuous Plankton Recorder (CPR) survey provides a unique multi-decadal data set on the abundance of plankton in the North Sea and North Atlantic. To show the scope of the data that have been collected, maps of the tows made and details of the species identified since 1948 are documented. It is hoped that this information will promote wider use of this data set.

CONTENTS



## 1. INTRODUCTION

The Continuous Plankton Recorder (CPR) is a high-speed plankton sampler designed to be towed from commercially operated 'ships of opportunity' over long distances. The original CPR was designed and first deployed by Alister Hardy during the *Discovery* Expedition to the Antarctic in 1925-27 to study patchiness of plankton in different areas (HARDY, 1926). During the 1930s, monthly deployments of CPRs on several routes in the North Sea were used to monitor the seasonal and annual changes in the plankton and to correlate these changes with hydrographic and meteorological data and the fluctuations in fisheries (HARDY, 1935, 1939). This can be considered as the start of the CPR survey and, except for a break during the Second World War, CPRs have continued to be deployed up to the present day in both the North Sea and North Atlantic. CPRs have been towed for over 3,800,000 miles resulting in the acquisition of over 160,000 samples (Fig.1).

Although the survey started in the 1930s, changes in methodology over the early years have made it difficult to use some of that data for direct comparison with that collected in later years.

Since zooplankton sampling has remained unchanged since 1948, and phytoplankton sampling since 1958, this account describes the survey after 1948. Data collected by the CPR survey have been used to describe the seasonal and long term changes in phytoplankton and zooplankton populations (COLEBROOK, 1979, 1984) and as the basis for many current theories concerning the ultimate and proximal causes of patterns in plankton abundance (AEBISCHER, COULSON and COLEBROOK, 1990; DICKSON, KELLY, COLEBROOK, WOOSTER and CUSHING, 1988; TAYLOR, COLEBROOK, STEPHENS and BAKER, 1992). The CPR survey is presently operated by an independent organisation, The Sir Alister Hardy Foundation for Ocean Science, and the data collected by the survey are now more readily available for use by the general scientific community. In view of this new initiative, there is a need for a general description of what information has been collected and where sampling has been conducted, in order that the data set can be used more widely and effectively.

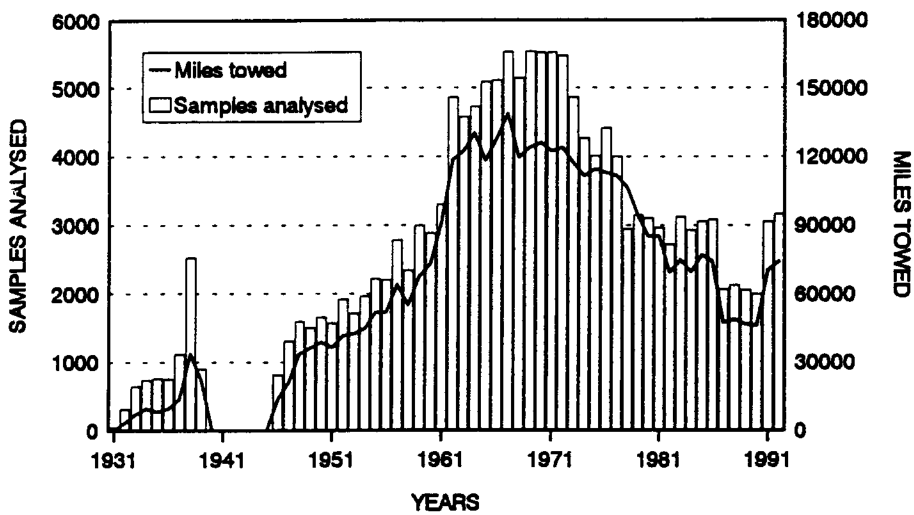


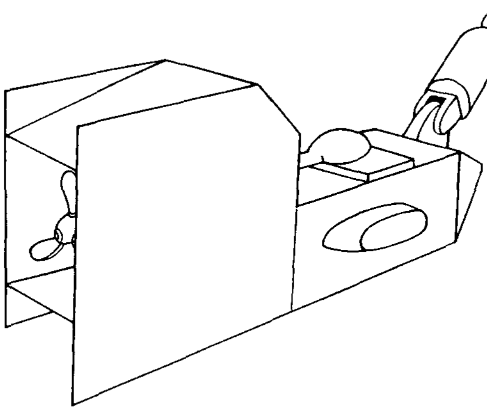

Fig.1. Miles of CPR towing and the number of CPR samples analysed per year from 1931 to 1992.

## 2. OVERVIEW OF THE CPR SURVEY

CPRs are towed in the surface mixed layer (HAYS and WARNER, 1993). Water enters the CPR through a 1.27cm square entrance aperture and travels down a tunnel which expands to cross-sectional dimensions of 5cm x 10cm where it passes through a silk filtering mesh (mesh size 270μm) before exiting via a rectangular exit aperture (dimensions 10cm x 3cm) at the back of the CPR (Fig.2). The movement of the CPR through the water turns an external propeller which, via a drive-shaft and gear-box, moves the silk across the tunnel at a rate of approximately 10cm per 10 nautical miles of tow. As it leaves the tunnel, the filtering silk is covered by a second band of silk (the 'covering' silk) so that the plankton is sandwiched between these two silk layers. The silk and associated plankton is then reeled into a storage chamber containing formaldehyde.

On return to the laboratory, the silks are processed in a set manner (COLEBROOK, 1960). First the silk band is unrolled and from the position that the recorder was deployed and recovered (and assuming a constant tow speed) marks are written on the silk corresponding to 10 nautical miles of tow. The green coloration of each 10-mile section is then assessed by reference to standard colour charts and the silk is then cut into sections (or 'blocks') corresponding to 10 nautical miles of tow. For the shorter (<100 nautical miles) tows (e.g. across the English Channel and Irish Sea) all the blocks are then analysed for the presence of plankton (detailed below). For the longer tows, however, only alternate 10-mile sections of silk are analysed. All blocks, including those not analysed, are then stored in borax-buffered 4% formaldehyde.

(a)



(b)

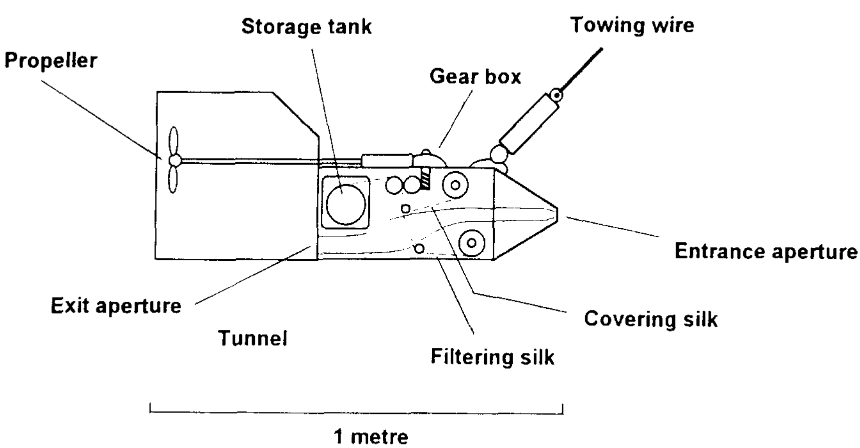



FIG.2. (a) A three-dimensional view of the Continuous Plankton Recorder, and (b) A schematic showing the position of the filtering system.

## 3. METHODS OF ANALYSIS

More detailed accounts of the methods of analysis are given by RAE (1952) and COLEBROOK (1960). The plankton analysis procedure begins with the silk 'sandwich' (filtering plus covering silk) being opened on a specially constructed microscope stage so that the contents of the 'sandwich' are facing upwards. The analysis procedure is then split into 3 stages: (i) phytoplankton, (ii) zooplankton 'traverse', and (iii) zooplankton 'eye count'.

### *3.1 Phytoplankton*

The following method of analysis has remained unchanged since 1958 (COLEBROOK, 1960). The silk is viewed under x450 magnification (field of view 295µm diameter) and a traverse of the filtering silk is made in which 20 fields of view, centred on one mesh of the silk, are examined (representing a sub-sample of approximately 1/8000 of the silk). The phytoplankton in each field is identified, though not necessarily to species level (see section 4, Plankton Identified), and the number of fields of view (maximum 20 out of 20) in which each entity is seen is then recorded.

### *3.2 Zooplankton traverse*

The following method of analysis has remained unchanged since 1948. The silk is viewed under x48 magnification (field of view 2.05mm diameter) and a traverse of both the filtering and covering silks is made during which approximately 1/40th of the silk is viewed. All the zooplankton organisms (of which a specified part of the organism, depending on species, is seen) are counted and identified (see counting system, below).

### *3.3 Zooplankton eye count*

The following method of analysis has remained unchanged since 1948. All the larger (generally >2mm) zooplankton organisms on the filtering and covering silks are removed, counted and identified (see counting system, below).

### *3.4 Counting system*

For zooplankton 'traverse' and 'eye count', exact counts of the individuals of the different species are not made. Rather, a category counting system is employed to reduce the time taken for the analysis procedure (details are given in RAE, 1952). The range of counts falling into the different categories are listed in Table 1. The 'accepted mid-points' of each category were determined by making exact counts of the numbers in each category. It can be seen that the 'accepted midpoint' does not equal the arithmetic midpoint of each category. This is simply because the abundance values are not uniformly distributed, but instead low abundances predominate, i.e. the frequency distribution for abundance values is skewed to the left.

## 4. PLANKTON IDENTIFIED

Not all the organisms seen are identified to species simply because a balance has had to be struck between obtaining as much information as possible, while keeping the time and cost spent on analysing each sample within reasonable limits. The entities identified by the CPR survey are listed in Tables 2 to 4. It can be seen that in some cases organisms are identified to species, genera or even higher groups, while in other cases several species or genera are grouped together into one diagnostic grouping (e.g. *Para-Pseudocalanus* includes all *Paracalanus* and *Pseudocalanus* species and all harpacticoid copepods are grouped as Harpacticoida).

TABLE 1. Details of the category counting system employed by the CPR survey.

| Number of individuals counted | Recorded value | Accepted value |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 2 | 2 |
| 3 | 3 | 3 |
| 4-11 | 4 | 6 |
| 12-25 | 5 | 17 |
| 26-50 | 6 | 35 |
| 51-125 | 7 | 75 |
| 126-250 | 8 | 160 |
| 251-500 | 9 | 310 |
| 501-1000 | 10 | 640 |
| 1001-2000 | 11 | 1300 |
| 2001-4000 | 12 | 2690 |

TABLE 2. Phytoplankton identified

| | | |
|---|---|---|
| *Actiniscus pentasterias* | *Ceratium falcatiforme* | *Cladopyxis* spp. |
| *Actinoptychus* spp. | *Ceratium falcatum* | *Climacodium frauenfeldianum* |
| *Amphidoma caudata* | *Ceratium furca* | Coccolithaceae |
| *Amphiprora hyperborea* | *Ceratium fusus* | *Corethron criophilum* |
| *Amphisolenia* spp. | *Ceratium geniculatum* | *Corythodinium* spp. |
| *Asterionella bleakeleyi* | *Ceratium gibberum* | *Coscinodiscus concinnus* |
| *Asterionella glacialis* | *Ceratium hexacanthum* | *Coscinodiscus* spp. |
| *Asterionella kariana* | *Ceratium horridum* | *Coscinodiscus wailesii* |
| *Asteromphalus* spp. | *Ceratium inflatum* | *Cylindrotheca closterium* |
| *Aulacodiscus argus* | *Ceratium karstenii* | *Dactyliosolen antarcticus* |
| *Bacillaria paxillifer* | *Ceratium kofoidii* | *Dactyliosolen mediterraneus* |
| *Bacteriastrum* spp. | *Ceratium lamellicorne* | *Detonula confervacea* |
| *Bacteriosira fragilis* | *Ceratium lineatum* | Dinoflagellate cysts |
| *Bellerochea malleus* | *Ceratium longipes* | *Dinophysis* spp. |
| *Biddulphia alternans* | *Ceratium longirostrum* | *Diploneis* spp. |
| *Biddulphia biddulphiana* | *Ceratium lunula* | *Diplopelta symmetrica* |
| *Blepharocysta paulsenii* | *Ceratium macroceros* | *Dissodinium pseudolunula* |
| *Campylosira cymbelliformis* | *Ceratium massiliense* | *Ditylum brightwellii* |
| *Centrodinium* spp. | *Ceratium minutum* | *Eucampia groenlandica* |
| *Cerataulina pelagica* | *Ceratium pavillardii* | *Eucampia zodiacus* |
| *Ceratium arcticum* | *Ceratium penatgonum* | *Exuviaella* spp. |
| *Ceratium arietinum* | *Ceratium petersii* | *Fragilaria* spp. |
| *Ceratium azoricum* | *Ceratium platycorne* | *Goniodoma polyedricum* |
| *Ceratium belone* | *Ceratium praelongum* | *Gonyaulax* spp. |
| *Ceratium breve* | *Ceratium pulchellum* | *Gossleriella tropica* |
| *Ceratium bucephalum* | *Ceratium ranipes* | *Guinardia flaccida* |
| *Ceratium buceros* | *Ceratium setaceum* | *Gymnodinium* spp. |
| *Ceratium candelabrum* | *Ceratium teres* | *Gyrodinium* spp. |
| *Ceratium carriense* | *Ceratium trichoceros* | *Gyrosigma* spp. |
| *Ceratium compressum* | *Ceratium tripos* | *Halosphaera* spp. |
| *Ceratium concilians* | *Ceratium vultur* | *Hemiaulus* spp. |
| *Ceratium contortum* | *Ceratocorys* spp. | *Hemidiscus cuneiformis* |
| *Ceratium declinatum* | *Chaetoceros (Hyalochaete)* spp. | *Histioneis* spp. |
| *Ceratium extensum* | *Chaetoceros (Phaeoceros)* spp. | *Katodinium* spp. |

.../cont

| | | |
|---|---|---|
| *Lauderia borealis* | *Pachysphaera* spp. | *Rhisozolenia calcar-avis* |
| *Leptocylindricus danicus* | *Paralia sulcata* | *Rhizosolenia cylindrus* |
| *Melosira arctica* | *Phaeocystis pouchetii* | *Rhizosolenia delicatula* |
| *Melosira lineata* | Phytoplankton colour | *Rhizosolenia fragilissima* |
| *Melosira varians* | *Planktoniella sol* | *Rhizosolenia hebetata semispina* |
| *Navicula planamembranacea* | *Podolampas* spp. | *Rhizosolenia imbricata shrubsolei* |
| *Navicula* spp. | *Podosira stelliger* | *Rhizosolenia robusta* |
| *Nitzschia delicatissima* | *Polykrikos schwartzii* cysts | *Rhizosolenia setigera* |
| *Nitzschia longissima* | *Pronoctiluca pelagica* | *Rhizosolenia stolterfothii* |
| *Nitzschia seriata* | *Prorocentrum* spp. | *Rhizosolenia styliformis* |
| *Nitzschia sigma rigida* | *Protoceratium reticulatum* | *Schroederella delicatula* |
| *Nitzschia* spp. | *Protoperidinium* spp. | *Scrippsiella* spp. |
| *Noctiluca scintillans* | *Pterosperma* spp. | Silicoflagellida |
| *Odontella aurita* | *Ptychodiscus noctiluca* | *Skeletonema costatum* |
| *Odontella granulata* | *Pyrocystis* spp. | *Stauroneis membranacea* |
| *Odontella mobiliensis* | *Pyrophacus* spp. | *Stephanopyxis* spp. |
| *Odontella obtusa* | *Rhaphoneis amphiceros* | *Streptotheca tamesis* |
| *Odontella regia* | *Rhizosolenia acuminata* | *Surirella* spp. |
| *Odontella rhombus* | *Rhizosolenia alata alata* | *Thalassionema nitzschioides* |
| *Odontella sinensis* | *Rhizosolenia alata curvirostris* | *Thalassiosira* spp. |
| *Ornithocercus* spp. | *Rhizosolenia alata indica* | *Thalassiothrix longissima* |
| *Oscillatoria* spp. | *Rhizosolenia alata inermis* | *Triceratium favus* |
| *Oxytoxum* spp. | *Rhizosolenia bergonii* | |

TABLE 3. Traverse zooplankton identified

| | | |
|---|---|---|
| *Acartia danae* | *Diaixis pygmoea* | *Microcalanus* spp. |
| *Acartia longiremis* | Echinoderm larvae | *Monstrilla longiremis* |
| *Acartia negligens* | Euphausiacea calyptopis | *Oithona* spp. |
| *Acartia* spp. | Euphausiacea eggs | *Oncaea* spp. |
| *Acrocalanus* spp. | Euphausiacea nauplii | *Para-Pseudocalanus* spp. |
| *Calanus* I-IV | *Euterpina acutifrons* | *Parapontella brevicornis* |
| *Calanus* Total Traverse | *Evadne* spp. | *Penilia* spp. |
| *Calocalanus* spp. | *Farranula gracilis* | *Podon* spp. |
| *Candacia* I-IV | *Farranula* spp. | *Pontellina plumata* |
| *Centropages furcatus* | Foraminifera | *Pseudocalanus elongatus* Adult |
| *Centropages hamatus* | 'Fusopsis' | Radiolaria |
| *Centropages typicus* | *Halithalestris croni* | Rotifer eggs |
| Chaetognatha Traverse | Harpacticoida Total | *Saphirella tropica* |
| Cirripede larvae | *Isias clavipes* | *Scolecithricella* spp. |
| Cladocera Total | Lamellibranchia larvae | 'Spindelei' |
| *Clausocalanus* spp. | Larvacea | *Temora longicornis* |
| *Clione* shells | *Limacina retroversa* | *Temora stylifera* |
| *Clytemnestra* spp. | *Lubbockia* spp. | *Temora turbinata* |
| Copepod eggs | *Lucicutia* spp. | Tintinnidae |
| Copepod nauplii | *Macrosetella gracilis* | *Tortanus discaudatus* |
| *Corycaeus* spp. | *Mecynocera clausi* | Total Copepods |
| *Ctenocalanus vanus* | *Metridia* I-IV | *Urocorycaeus* spp. |
| Cyphonautes larvae | *Metridia* Total Traverse | *Zoothamnium pelagicum* |
| *Diaixis hibernica* | | |

TABLE 4. Eyecount zooplankton identified

*Aetideus armatus*
*Amallothrix* spp.
*Anomalocera patersoni*
*Atlanta* spp.
*Augaptilus* spp.
*Branchiostoma lanceolatum*
*Calanoides carinatus*
*Calanus fin. finmarchicus*
*Calanus fin. glacialis*
*Calanus helgolandicus*
*Calanus hyperboreus*
*Calanus tenuicornis*
*Calanus* V-VI Total
Caligoida
*Candacia armata*
*Candacia bipinnata*
*Candacia curta*
*Candacia ethiopica*
*Candacia longimana*
*Candacia norvegica*
*Candacia pachydactyla*
*Candacia* spp.
*Candacia tenuimana*
*Candacia varicans*
Caprellidea
*Carinaria* spp.
*Cavolinia* spp.
*Centropages bradyi*
*Centropages chierchiae*
*Centropages* spp.
*Centropages violaceus*
*Cephalobrachia* spp.
Cephalopoda larvae
Chaetognatha Eyecount
*Chiridius armatus*
*Clio* spp.
*Clione limacina*
Coelenterata tissue
Copepod eggs
*Copilia* spp.
*Creseis* spp.
Cumacea
*Cuvierina* spp.
Decapoda larvae
*Diacria* spp.
Doliolidae
Echinoderm post-larvae
*Euaetideus giesbrechti*
*Eucalanus attenuatus*
*Eucalanus crassus*
*Eucalanus elongatus*
*Eucalanus monachus*
*Eucalanus mucronatus*
*Eucalanus pileatus*
*Eucalanus* spp.
*Euchaeta acuta*
*Euchaeta glacialis*
*Euchaeta gracilis*
*Euchaeta hebes*
*Euchaeta marina*
*Euchaeta media*
*Euchaeta norvegica*
*Euchaeta pubera*
*Euchaeta spinosa*
*Euchaeta* spp.
*Euchaeta tonsa*
*Euchirella amoena*
*Euchirella brevis*
*Euchirella curticauda*
*Euchirella maxima*
*Euchirella messinensis*
*Euchirella pulchra*
*Euchirella rostrata*
*Euchirella* spp.
Euphausiacea Adult
Euphausiacea Juvenile
Euphausiacea Total
*Firoloida* spp.
Fish eggs
Fish larvae
*Gaetanus minor*
*Gaidius* spp.
*Gaidius tenuispinus*
Gammaridea
Gymnosomata
*Haloptilus acutifrons*
*Haloptilus longicornis*
*Haloptilus spiniceps*
*Heterorphabdus abyssalis*
*Heterorhabdus clausi*
*Heterorhabdus novegicus*
*Heterorhabdus papilliger*
*Heterorhabdus spinifer*
*Heterorhabdus* spp.
*Heterostylites longicornis*
Hyperiidea
Isopoda
*Labidocera acutifrons*
*Labidocera aestiva*
*Labidocera* spp.
*Labidocera wollastoni*
Lepas nauplii
*Lophothrix* spp.
*Metridia longa*
*Metridia lucens*
*Miracia efferata*
Mysidacea
*Nannocalanus minor*
Nematoda
*Neocalanus gracilis*
*Neocalanus robustior*
*Notobranchaea* spp.
*Oculosetella gracilis*
Ostracoda
*Oxygyrus* spp.
*Paedoclione doliiformis*
*Paracandacia bispinosa*
*Paracandacia simplex*
*Paracandacia* spp.
Parasites
*Peraclis* spp.
*Phaenna spinifera*
*Pleuromamma abdominalis*
*Pleuromamma borealis*
*Pleuromamma gracilis*
*Pleuromamma piseki*
*Pleuromamma robusta*
*Pleuromamma* spp.
*Pleuromamma xiphias*
*Pneumoderma* spp.
*Pneumodermopsis canephora*
*Pneumodermopsis ciliata*
*Pneumodermopsis paucidens*
*Pneumodermopsis* spp.
Polychaeta larvae
*Pseudochirella* spp.
*Pterotrachea* spp.
Pycnogonida
*Rhincalanus cornutus*
*Rhincalanus nasutus*
Salpidae
*Sapphirina* spp.
*Scaphocalanus echinatus*
*Scaphocalanus* spp.
*Scolecithrix bradyi*
*Scolecithrix danae*
*Scottocalanus persecans*
*Scottocalanus securifrons*
Sergestidae
Siphonophora
Stomatopoda
Thaliacea
*Tomopteris* spp.
*Undeuchaeta major*
*Undeuchaeta plumosa*
*Undeuchaeta* spp.
*Undinopsis bradyi*
*Undinopsis* spp.
*Undinula vulgaris*
*Xanthocalanus* spp.

## 5. SAMPLING ROUTES

Since the CPRs are deployed from ships of opportunity, sampling is limited to areas traversed by commercial shipping routes. Although the survey can exercise no active control over the actual route a sampling ship follows, it can select ships that follow a regular standard route, and can request deployment and recovery of the CPR at almost any location along that route. The survey aims to tow a CPR at approximately one month intervals along each of the selected routes. The ship's crew records the position and time (Greenwich Mean Time) that the CPR is deployed and retrieved, plus the position and time of any changes in ship course. From this information the sampling track is calculated and, by assuming a constant ship speed, the location (latitude and longitude) of the mid-point of each plankton sample is determined.

The individual tows made along the selected sampling routes since 1948 are detailed in Figs 3-14. It can be seen that the number of routes has changed within the time-series, rising to a peak in the 1970s before declining to a minimum in the late 1980s. These changes reflect the support for the survey and hence the varying ability to open new routes or the necessity to close existing routes.

## 6. AVAILABILITY OF CPR DATA

The CPR data set is stored on IBM PC as ASCII text files, and can be interrogated using programs developed by CPR staff. The data set is currently being transferred to a Relational Data Base Management System (ORACLE) which facilitates easy extraction of specific information (e.g. data for any recorded entity, in any geographical area, over any time period, etc.). A sub-set of these data has been compiled which gives details of the yearly sampling on each CPR route, and is available on request. The data can be readily disseminated on hard copy, floppy disk or e.mail depending on the user's requirements. Requests for access to the CPR data base should be addressed to The Director, The Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK; e-mail SAHFOS@wpo.nerc.ac.uk.

## 7. ACKNOWLEDGEMENTS

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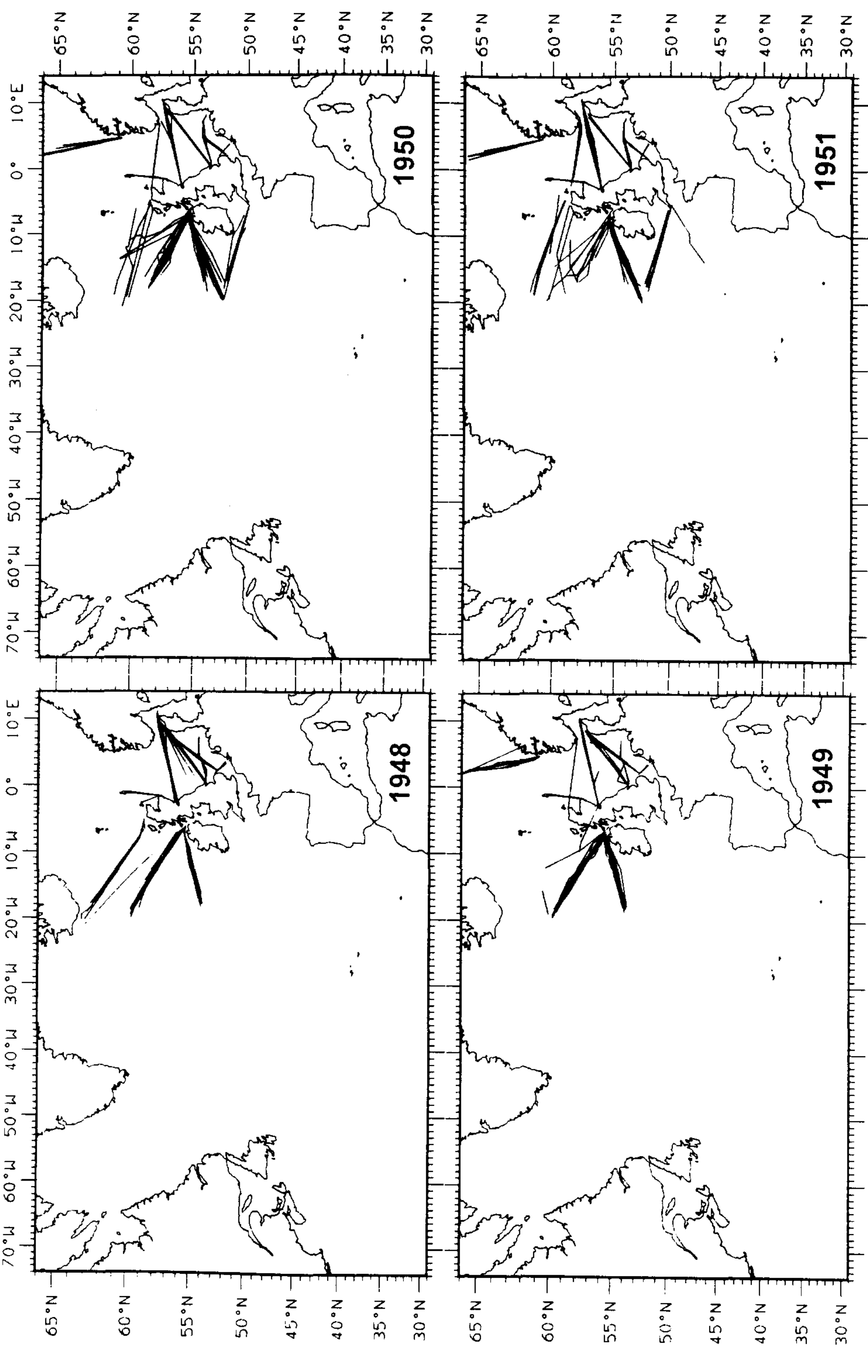


FIG.3. CPR tows, 1948-1951.

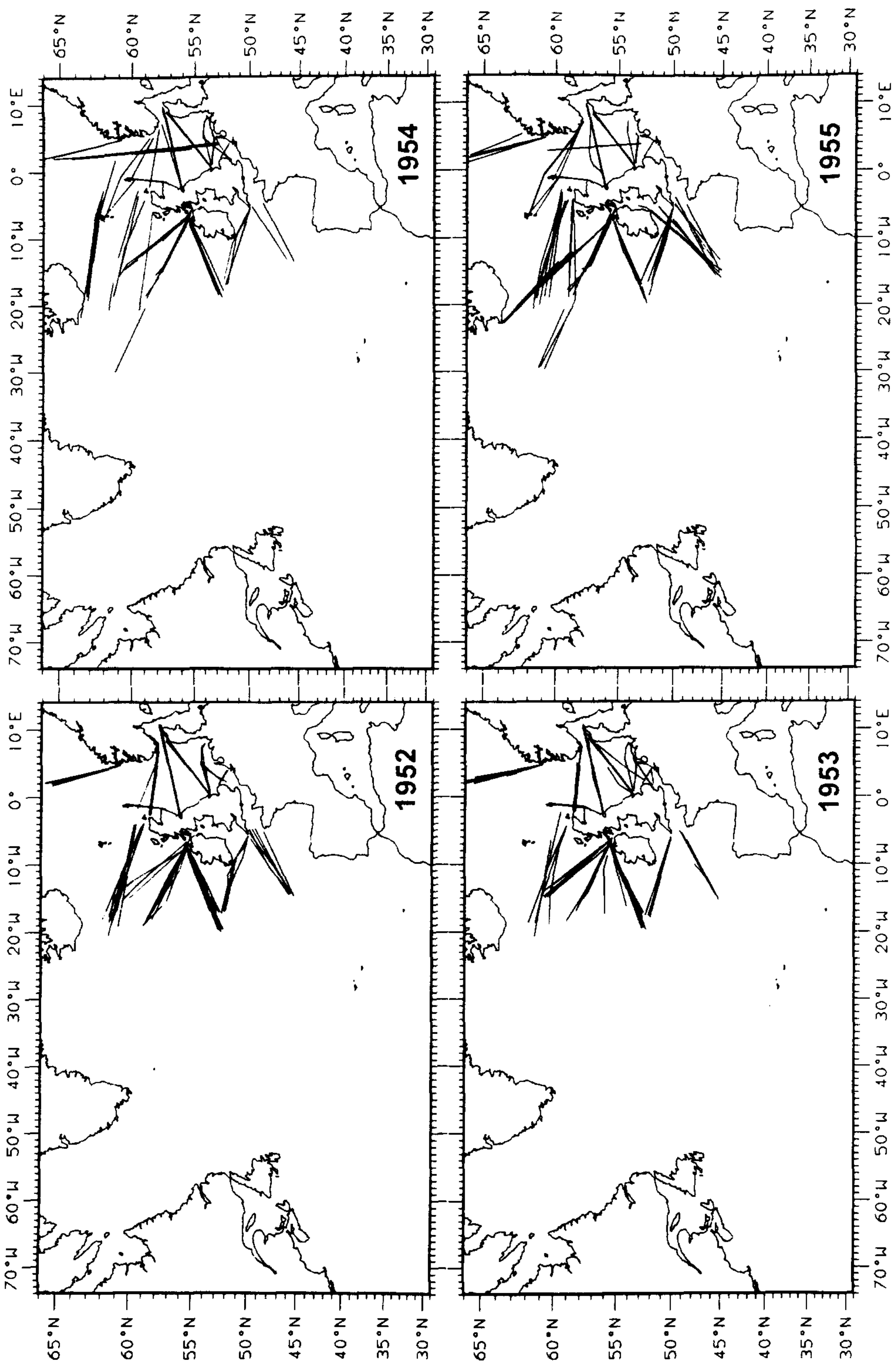


FIG.4. CPR tows, 1952-1955.

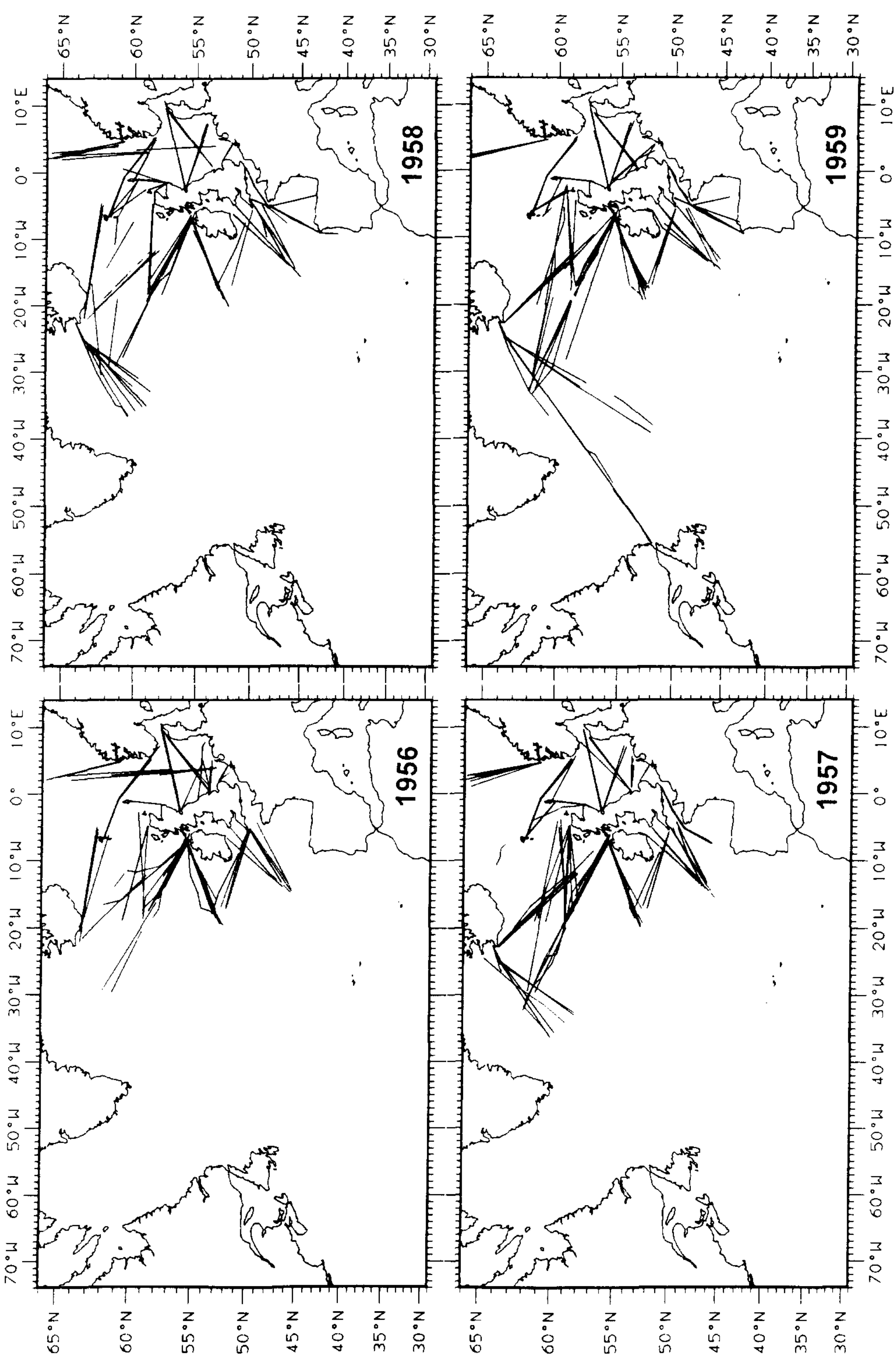


Fig.5. CPR tows, 1956-1959.

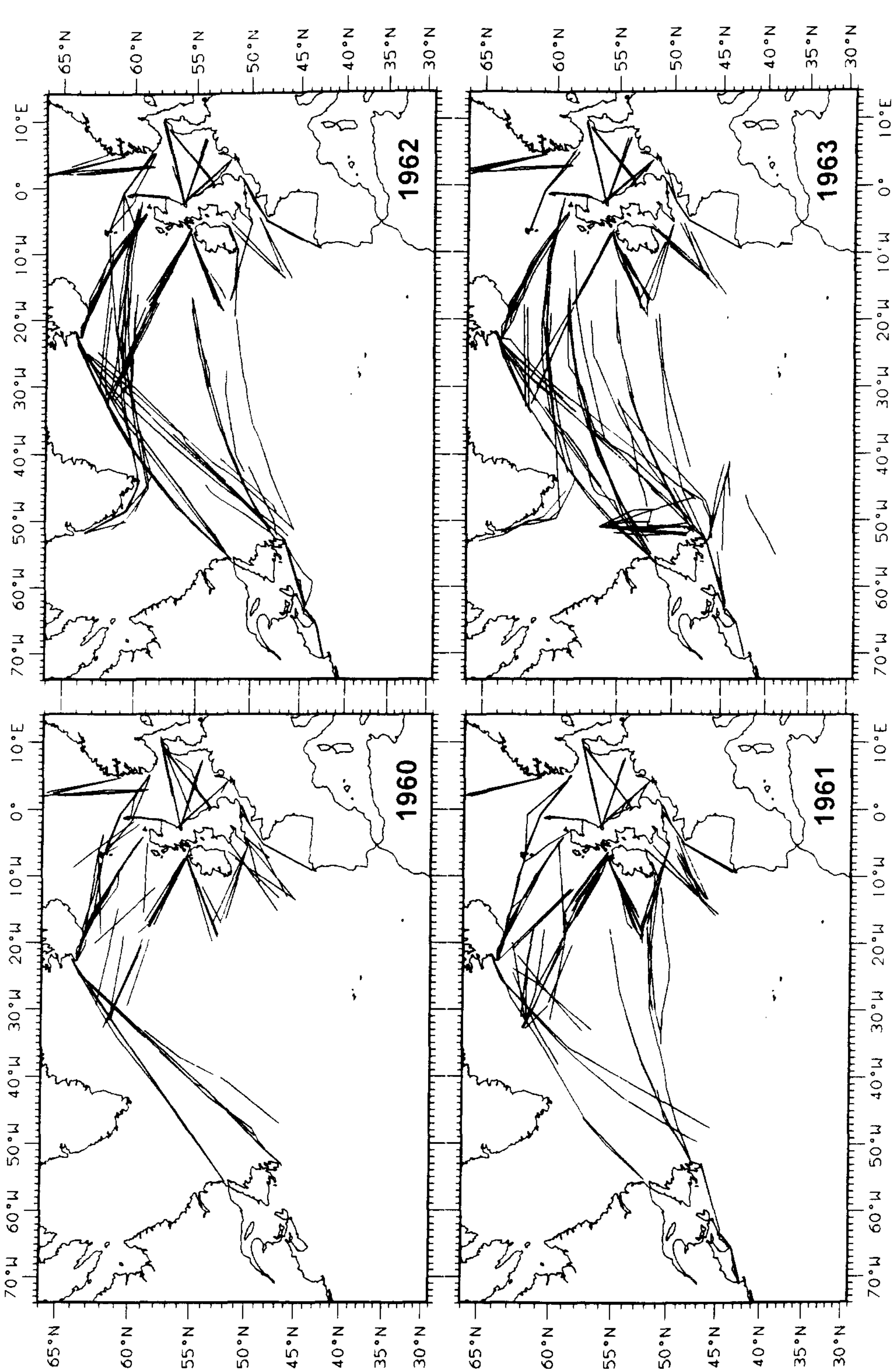


Fig.6. CPR tows, 1960-1963.

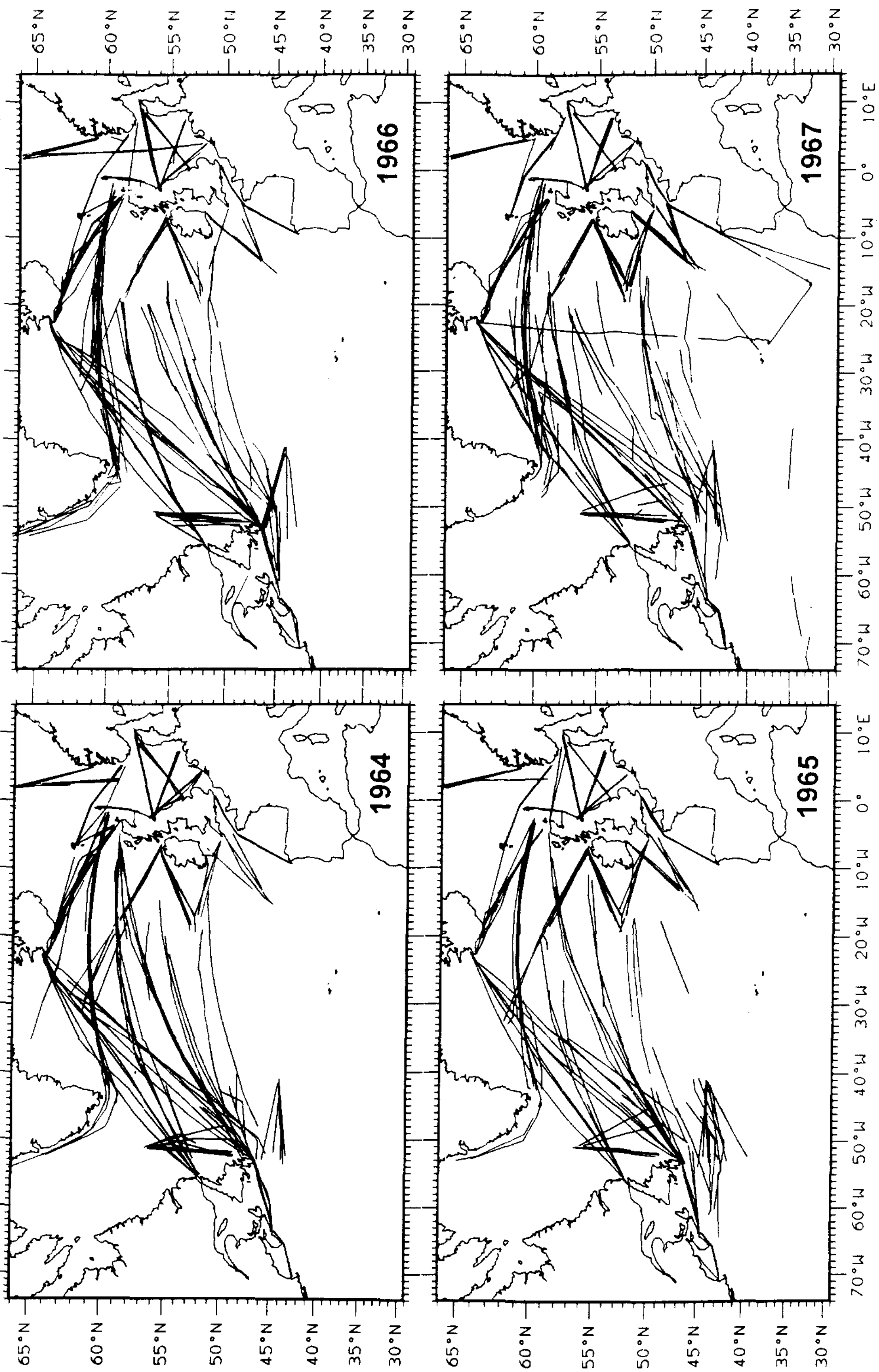


FIG.7. CPR tows, 1964-1967.

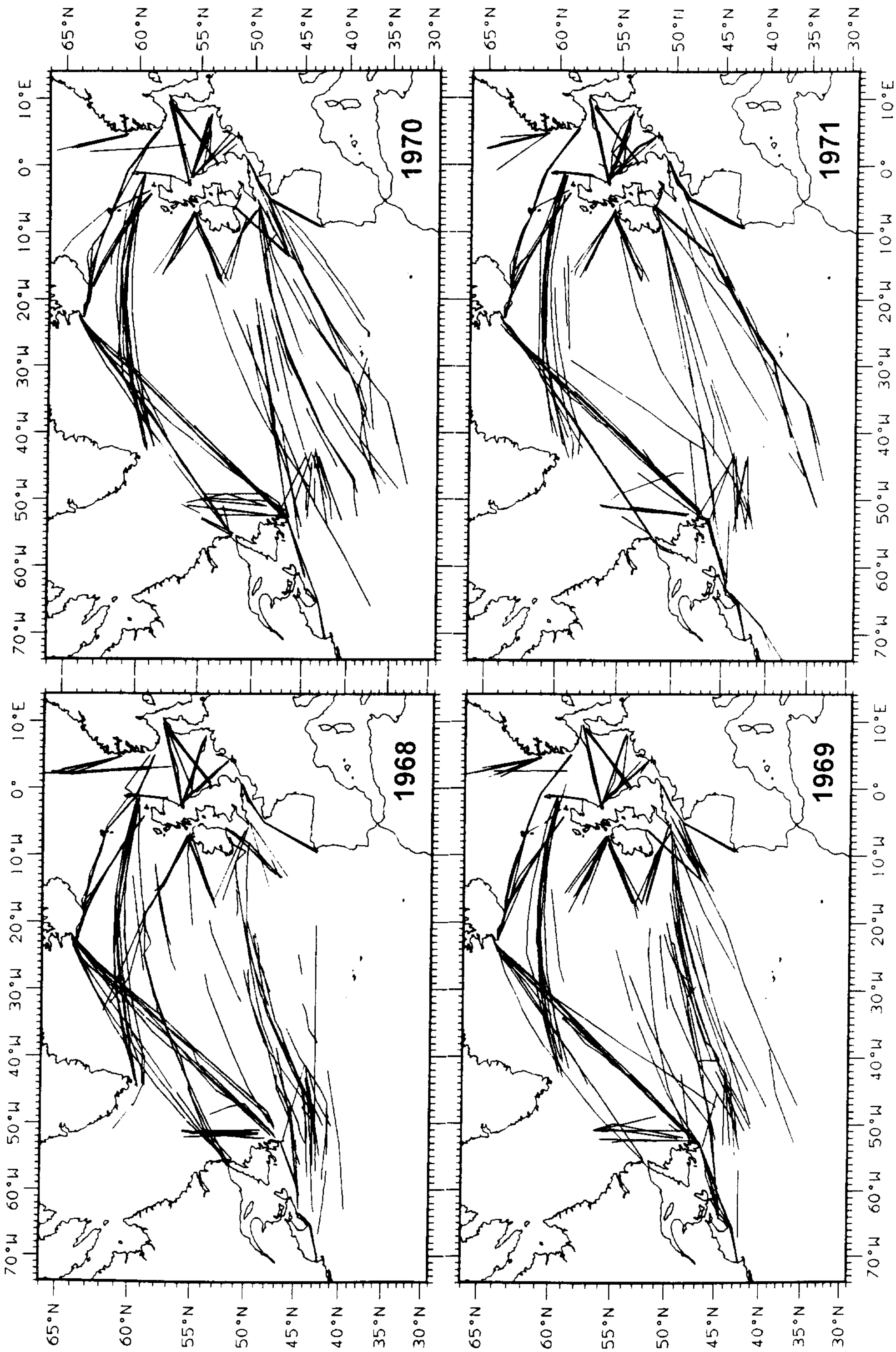


FIG.8. CPR tows, 1968-1971.

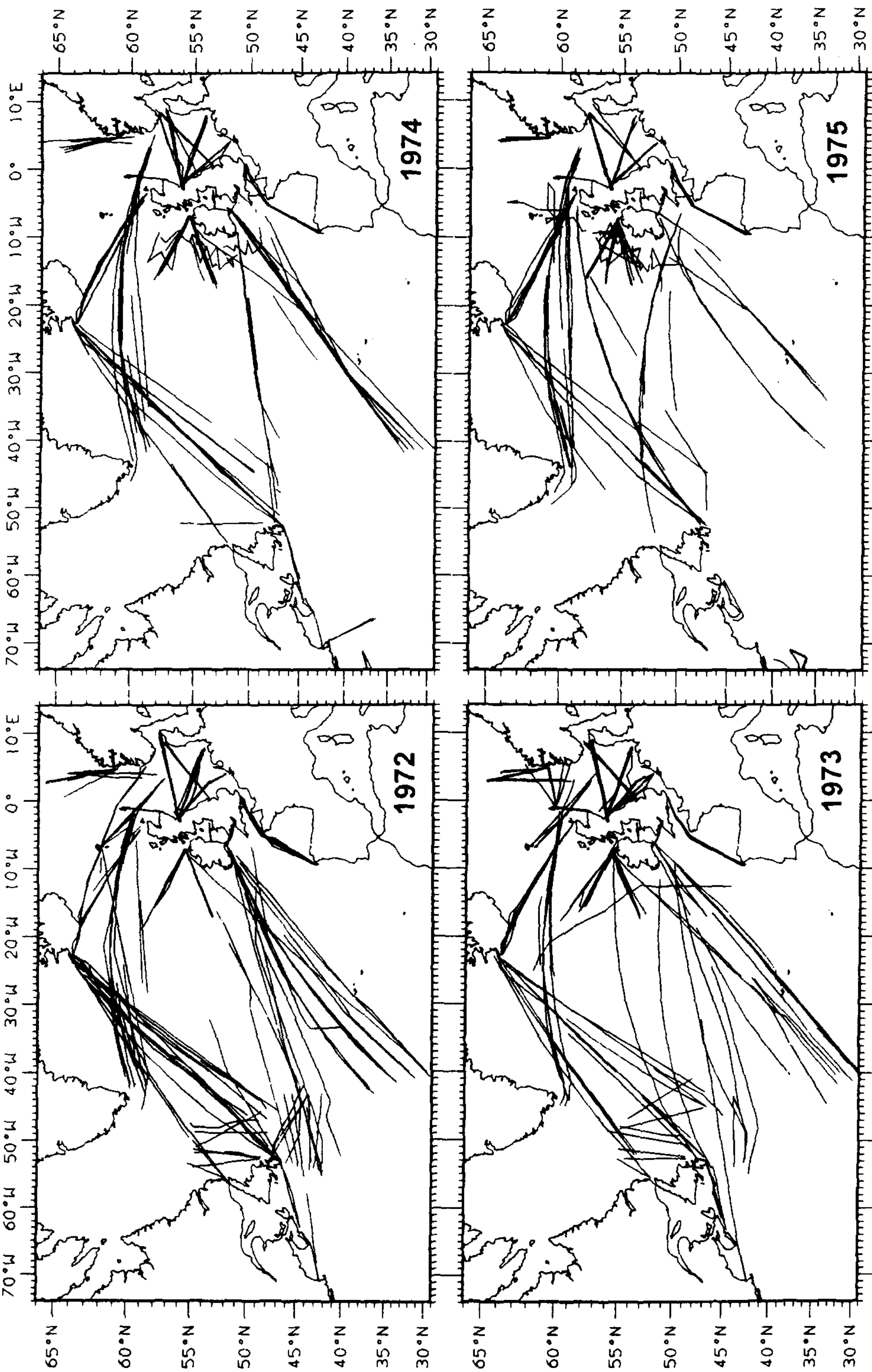


FIG.9. CPR tows, 1972-1975.

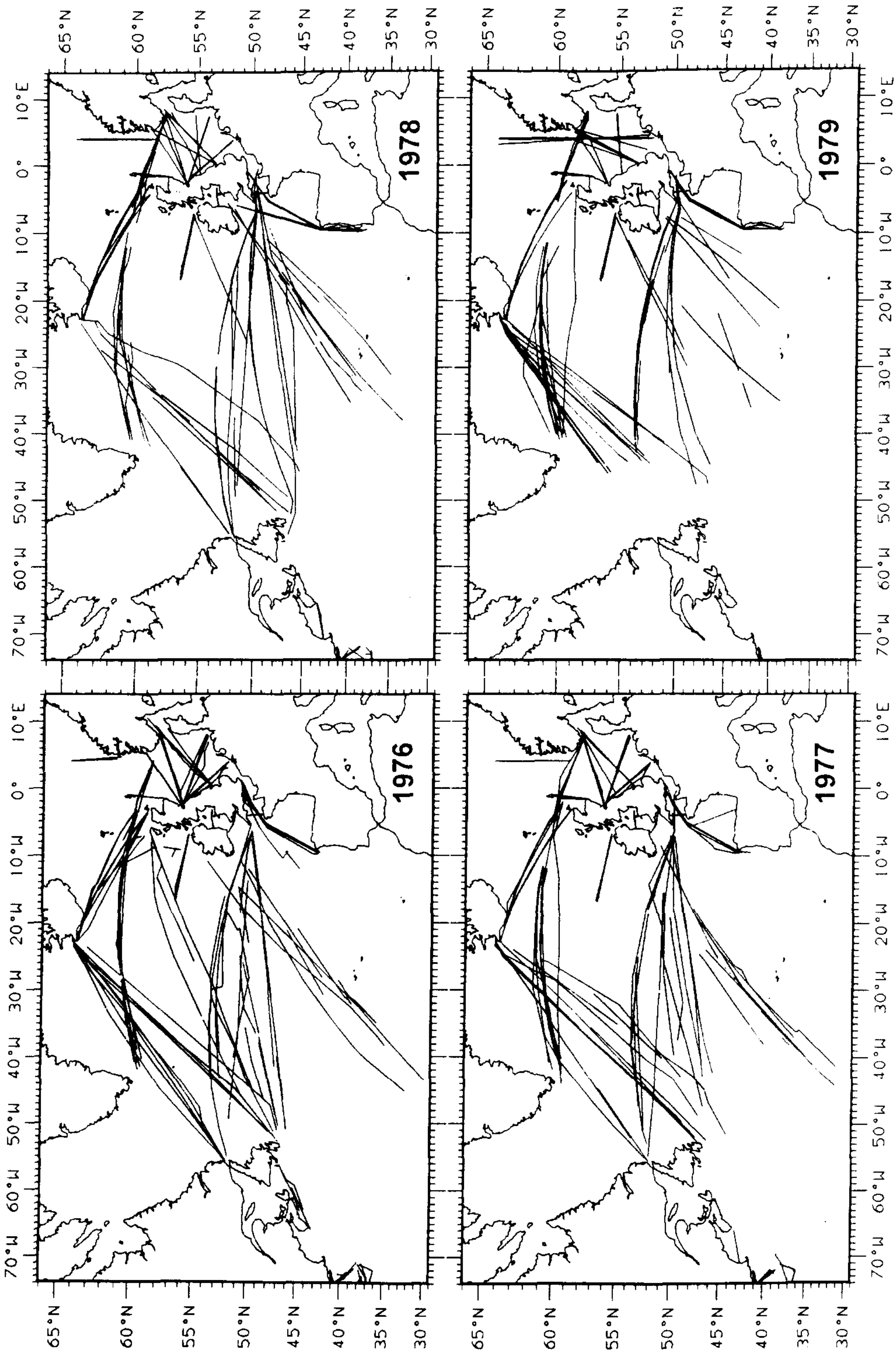


FIG.10. CPR tows, 1976-1979.

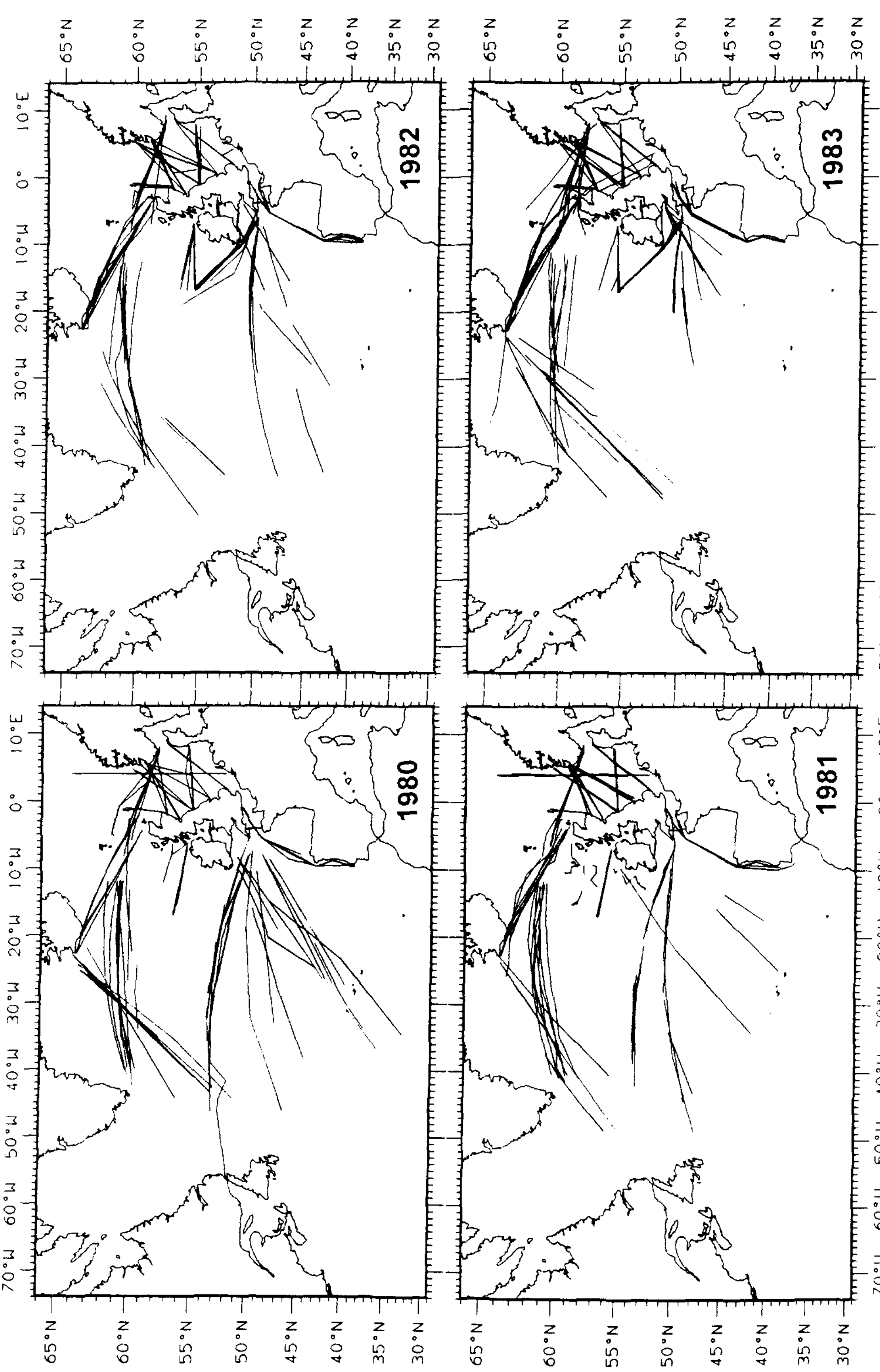


FIG. 11. CPR tows, 1980-1983.

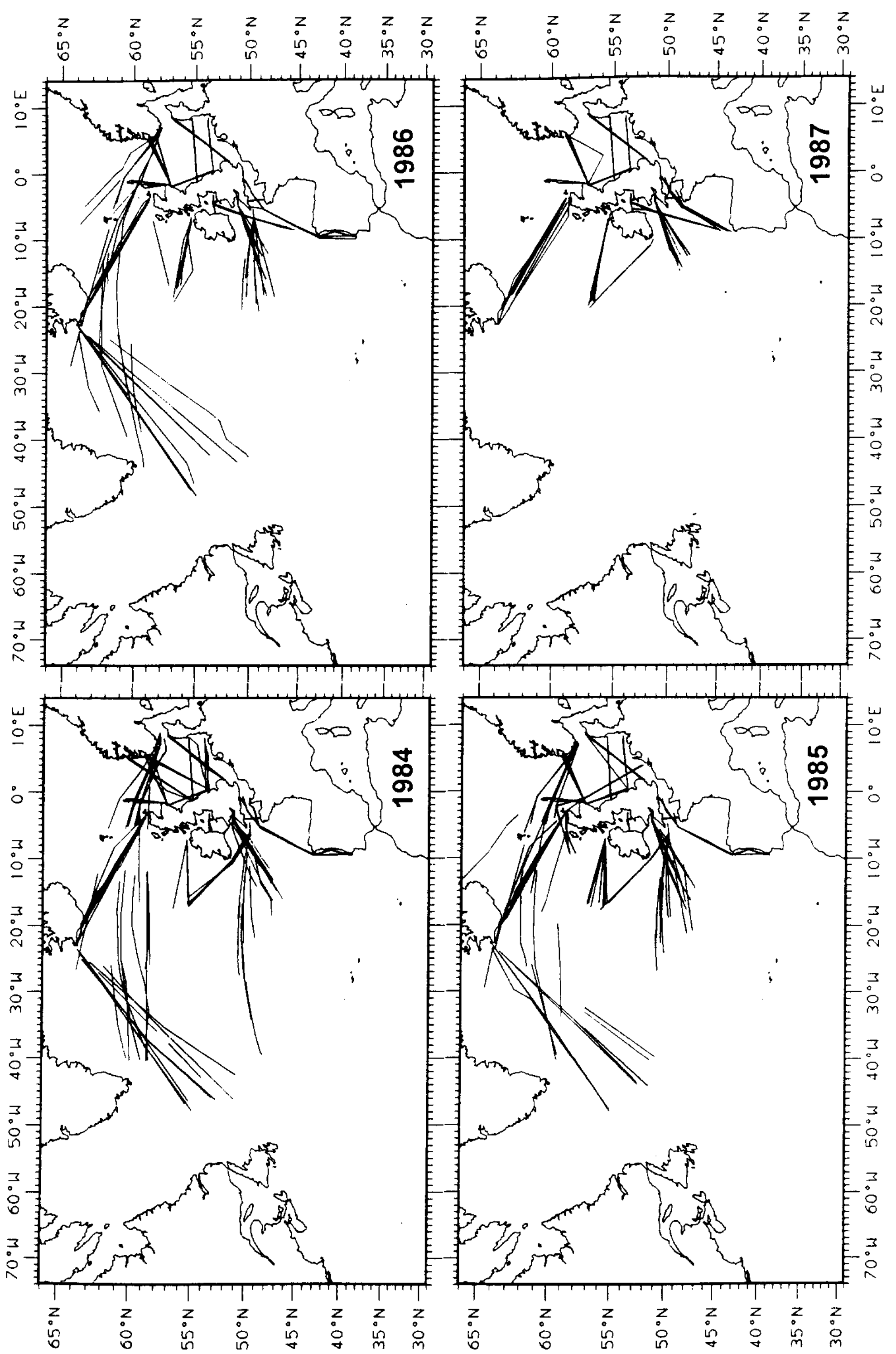


FIG.12. CPR tows, 1984-1987.

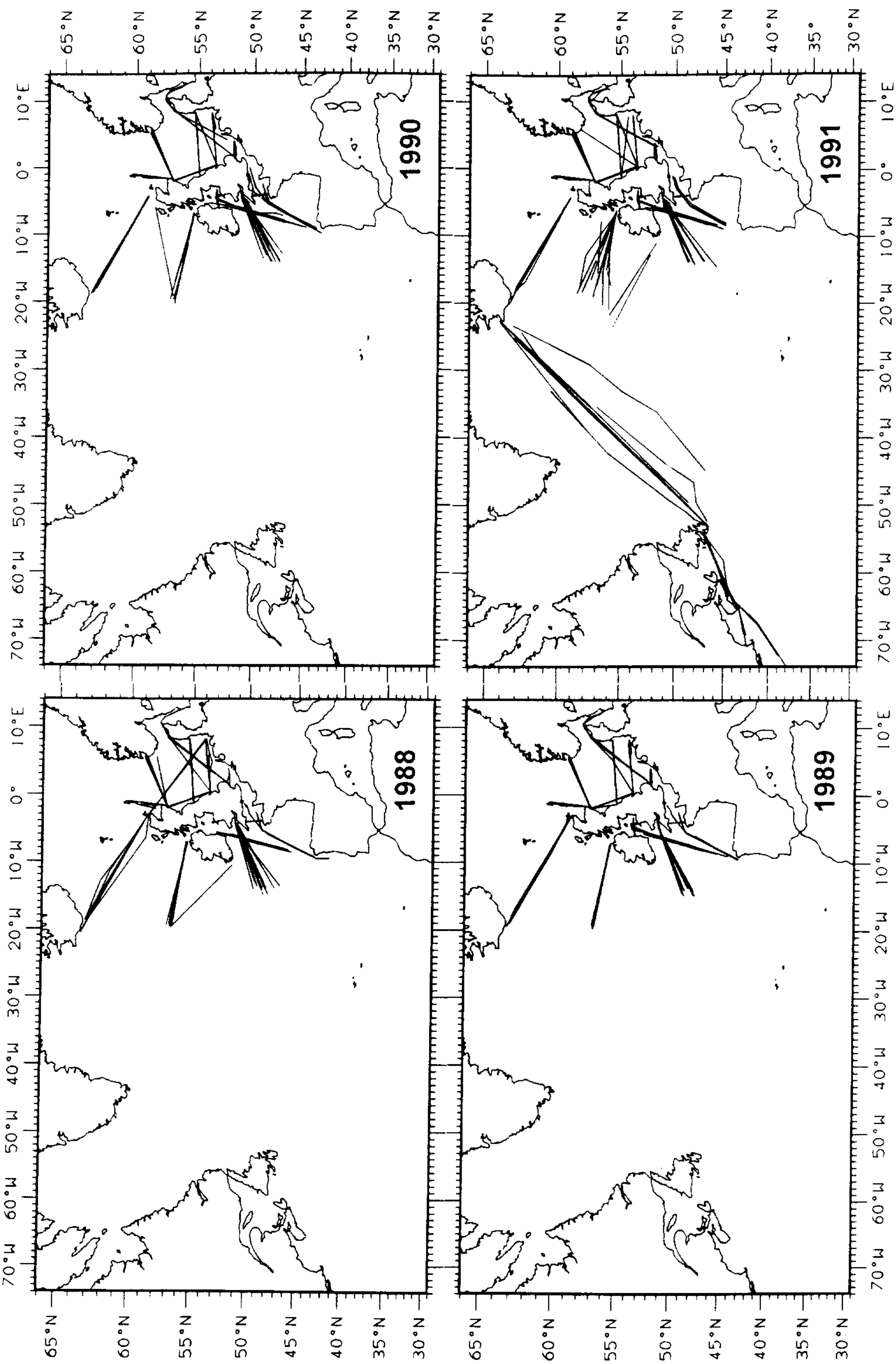


FIG.13. CPR tows, 1988-1991.

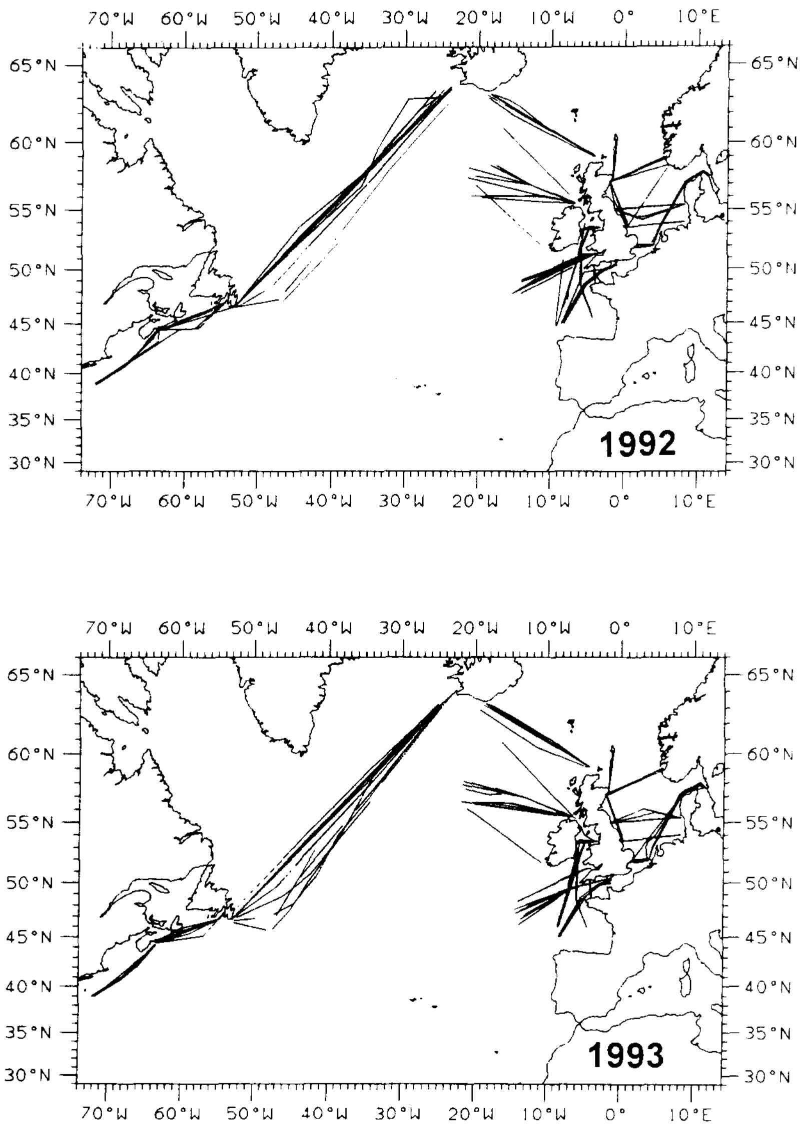


FIG.14. CPR tows in 1992 and 1993.