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Comparison of Spawning Characteristics of Cod (*Gadus morhua*) Stocks Throughout the North Atlantic

by

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ABSTRACT

A fundamental problem in studying fish populations is to identify the processes which govern their dynamics and the appropriate scales (in time and space) at which to investigate these processes. For example, annual recruitment to some fish stocks is influenced by temperature; such a relationship might arise in several ways, but it is difficult to distinguish which of the many possibile processes in fact operate and therefore what the appropriate measure of temperature should be.

One possible way to identify efficient processes is by description of the life history characteristics of the species concerned and comparison of those characteristics for different areas in which the species occurs. This is one of the purposes of a comparative study of cod and haddock life histories and population dynamics, being undertaken by scientists within ICES. I have been asked to prepare a paper for this symposium on behalf of that group in order to present some preliminary results and to stimulate further development of the initiative. The paper is partly based on information supplied through the ICES comparative study and it discusses some of the issues of methodology and sampling procedure which arise.

The paper will concentrate principally on the timing and location of cod spawning, and will briefly summarise the information available for most of the geographic range of the species. It will look in greater detail at the area around the British Isles and at the Scotian Shelf in order to investigate variablity in timing of spawning on a smaller scale. Finally I will try to draw some conclusions about the processes and scales which may be appropriate for further investigation.

COD SYMPOSIUM, SEPTEMBER 1991

INTRODUCTION

One of the characteristics of temperate fish species is their relatively short spawning period, whereas tropical species breed over a long period of the year (Fig 1). In a species such as cod, eggs are generally released over a period of a few weeks in spring and one may compare the timing of spawning and its duration (the mean and standard deviation of the egg production curves) between different stocks, or within the same stock in different years. Possibly the best example of the latter type of comparison is for the Arcto-Norwegian cod in the Vestfjord, where "spawning intensity" over an eight year period shows remarkable consistency from year to year (Fig 2).

These estimates of "spawning intensity" are derived from egg surveys, which is probably the most accurate, if costly, procedure, but there are alternative methods for estimating the spawning period. One of these, which has also been applied to Arcto-Norwegian cod for the period since 1929, is based on an index of the weight of roe. It shows that over the period 1930-1960

spawning tended to occur later by about 7-15 days and the delay was ascribed to a decline in the average age of spawning fish over that period (Pedersen 1984). For this stock there is no evidence that year to year variability in temperature affects the date of spawning, but this may be because the vertical temperature differences in the spawning area are bigger than the year to year differences and the fish can select a preferred temperature by vertical movement. Arcto-Norwegian cod spawn at a temperature of 4-6 C, at the thermocline between the cold coastal water and the warmer Atlantic water. The time of spawning at the main spawning site of the Arcto-Norwegian cod, at Lofoten, is about two weeks earlier than at the northernmost spawning field.

To what extent can the Arcto-Norwegian cod be used as a paradigm for other cod stocks? Is it generally true that the timing of cod spawning at a particular site is calendar fixed and does not respond to proximate environmental variability (e.g. annual temperature variation)? Is it generally true that the location of spawning is fixed either geographically or in relation to a hydrographic feature or discontinuity? Which factors govern the observed differences in timing between different spawning sites? These are the sorts of questions which the comparison of spawning characteristics between different cod stocks is designed to answer. The development of generally applicable models of the relationship between cod population dynamics and the physical environment (e.g. in the context of the Cod and Climate programme) depends partly on answers to questions of this kind.

Pepin and Myers (1991) recently proposed that variability of recruitment may be a function of the duration of the pelagic phase and that this could be tested among stocks of single species. This and similar hypotheses require information on the duration of the pelagic period of the life history. Since the pelagic period lasts from the time of spawning to the time of settlement, information on time of spawning will be useful in this regard and information on time of settlement will also be sought through the ICES checklist exercise.

A number of questions were posed above but this paper will concentrate principally on the timing and location of cod spawning, and will briefly summarise the information available for most of the geographic range of the species. It will look in greater detail at the area around the British Isles and at the Scotian Shelf in order to investigate variablity in timing of spawning on a smaller scale and the factors which may be responsible for observed differences in timing between different spawning sites.

MATERIAL, METHODS AND RESULTS

The checklists of spawning characteristics provide information on location and timing of cod spawning from many published and unpublished sources (Anon. 1990). The major spawning sites and dates of peak spawning are shown in Figs. 3 and 4. The most southerly stock in the NE Atlantic spawns in the English Channel (50 N) in January - February and the northernmost stock spawns around northern Norway (70 N) in April. The most southerly stock in the NW Atlantic spawns on Georges Bank (42 N) during the first three months of the year. Further information on the duration of spawning in different areas and the depth at which it occurs is given in Table 1. Spawning takes place at depths ranging from 15m to more than 800m, but as can be seen from the gaps in Table 1, there is no information on depth of spawning for most areas.

The quality and kind of information available on timing of spawning varies a great deal, even for supposedly well studied areas such as the North Sea. Fig. 3 shows a scatter of points in the North Sea, which presumably is intended to indicate widespread spawning. Since there has been no comprehensive series of eggs surveys in the North Sea it is difficult to judge the relative contribution of particular areas to the total, but Fig. 5 summarises available information on spawning for most of the areas around the British Isles (Graham 1923; Heesen and Rijnsdorp 1989; Brander in prep).

In the English Channel the level of spawning is low, but the fact that it is the most southerly stock in the NE Atlantic and one of the earliest to spawn gives it some interest (Fig. 6). Spawning starts in January at two locations close to the coast of France. Off the NE coast of England spawning begins in early February about 40 miles offshore and it remains mainly offshore (Fig. 7). Egg surveys of the Bristol Channel in 1990 show a clearly defined spawning in space and time (Fig. 8) and surveys in 1953, 1971 and 1972 and 1980 confirm that this is a regular area.

Moving across to the Scotian Shelf, a detailed picture of the location and timing of spawning was obtained from ichthyoplankton surveys carried out in 1979 - 1981 (Fig. 9). Spawning is widespread, but occurs mainly on the various offshore banks. The timing is earliest at the south-western end of the area and progressively later to the north-east (Fig. 10).

DISCUSSION

Several questions were posed in the Introduction, which might be answered by comparisons between cod stocks. Is the location of spawning fixed? Does it vary from year to year in response to environmental factors? Can we identify the factors responsible for variations in timing between areas? The material collected so far in the checklist exercise can go a small way towards answering these questions, but it quickly becomes apparent that the questions could be answered more fully if they were posed as part of the checklist exercise from the outset. Therefore the next stage should perhaps be to go round the contributors again with more specific information requirements.

Taking the question about causes of variation in timing between areas, there are three principal factors to consider: latitude, temperature and production timing. Latitude per se (and its relation to day length) is not a dominant factor since the latitudinal ranges are very different on the two side of the Atlantic, but within each area it may play a part. One contrary example seems to be the timing of spawning off Labrador, which is apparently earlier further north.

Spawning occurs over a fairly wide temperature range (perhaps 0 - 10 C, although it is much easier to tell the temperature at which eggs occur than the temperature at which spawning occurs; in areas with strong vertical or horizontal temperature gradients there may be considerable differences). Within the North Sea, cod spawn at a time when temperature is stable and the differences in timing of about one month between the south and the north do not correspond to a difference in temperature (Fig. 5).

It is difficult to define or measure production timing as it may affect cod spawning. In the North Sea the Continuous Plankton Recorder (CPR) shows a difference in timing of peak abundance of Calanus finmarchicus of two weeks between the north and south, which is similar to the difference in time of cod spawning. On the Scotian Shelf the timing of peak abundance of Calanus in spring is over a month later close to the Laurentian Channel than it is on Emerald Bank and this coincides with the differences in timing of cod spawning (Fig 10). Production timing may therefore affect the timing of cod spawning, but this can only be examined by looking at the relationship on a sufficiently fine scale.

The process of bringing together information on North Atlantic cod for comparative purposes and for modelling population dynamics is an iterative one in which preliminary evaluation and interpretation suggest new questions and ways of defining and measuring things. So far the checklist exercise has helped to shake some of the historic (but unpublished) material out of the woodwork and the plan is to edit the contributions for publication by ICES next year. If the approach has any value beyond this, it is probably as a means of bringing together information which can be used to test existing hypotheses or models which arise from programmes such as Cod and Climate. For example it would be very useful to complete Table 2 in order to follow up Pepin and Myers (1991) suggestion that variability is a function of duration of the pelagic phase.

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Table 1. Timing and location of cod spawning throughout the North Atlantic, from the checklists of cod spawning characteristics.

TIMING AND LOCATION OF COD SPAWNING

NW ATLANTIC

NAFO DIVISION	DEPTH (m)	PEAK TIMING	RANGE
5Z		FEB-MAR	DEC-MAY
4X		APR	FEB-MAY
4VSW		APR-MAY	FEB-JUN
			OCT-DEC
4T4VN	35 - 90	late MAY-mid JUNE	MAY-SEP
3PN4RS			APR-MAY
3PS			MAY-JUN
3NO			MAY-JUN
2J3KL			APR-MAY

CENTRAL ATLANTIC

LOCATION	DEPTH (m)	PEAK TIMING	RANGE
WEST GREENLAND	600 - 800	APR	MAR-JUL
EAST GREENLAND	170 - 400		MAR-JUL
ICELAND		APR	MAY-MAY
FAROE BANK		MAR-APR	FEB-MAY
FAROE PLATEAU	80 - 180	MAR	FEB-MAY

NE ATLANTIC

LOCATION	DEPTH (m)	PEAK TIMING	RANGE
WHITE SEA	15 - 100	APR	MAR-MAY
NE ARCTIC	100 - 500	APR	MAR-APR
NORWAY COAST	50		FEB-MAY
SKAGERRAK			FEB-APR
E. BALTIC	60		MAR-AUG
W. BALTIC	40 - 50		FEB-APR
N. NORTH SEA		APR	FEB-APR
C. NORTH SEA		end FEB	JAN-APR
S. NORTH SEA		mid FEB	JAN-APR
ENGLISH CHANNEL		early FEB	JAN-MAR
BRISTOL CHANNEL		late MAR	FEB-APR
IRISH SEA		MAR	MAR-APR

Table 2. Duration of pelagic stage for cod eggs and larvae.

NW ATLANTIC

NAFO DIVISION	DURATION (d)	DISTANCE (km)	FINAL SIZE (mm)
5Z			
4X			
4VSW			
4T4VN			
3PN4RS			
3PS			
3NO			
2J3KL			

CENTRAL ATLANTIC

LOCATION	DURATION (d)	DISTANCE (km)	FINAL SIZE (mm)
WEST GREENLAND			
EAST GREENLAND			
ICELAND			
FAROE BANK			
FAROE PLATEAU			

NE ATLANTIC

LOCATION	DURATION (d)	DISTANCE (km)	FINAL SIZE (mm)
WHITE SEA			
NE ARCTIC			
NORWAY COAST			
SKAGERRAK			
E. BALTIC			
W. BALTIC			
N. NORTH SEA			
C. NORTH SEA			
S. NORTH SEA			
ENGLISH CHANNEL			
BRISTOL CHANNEL			
IRISH SEA			

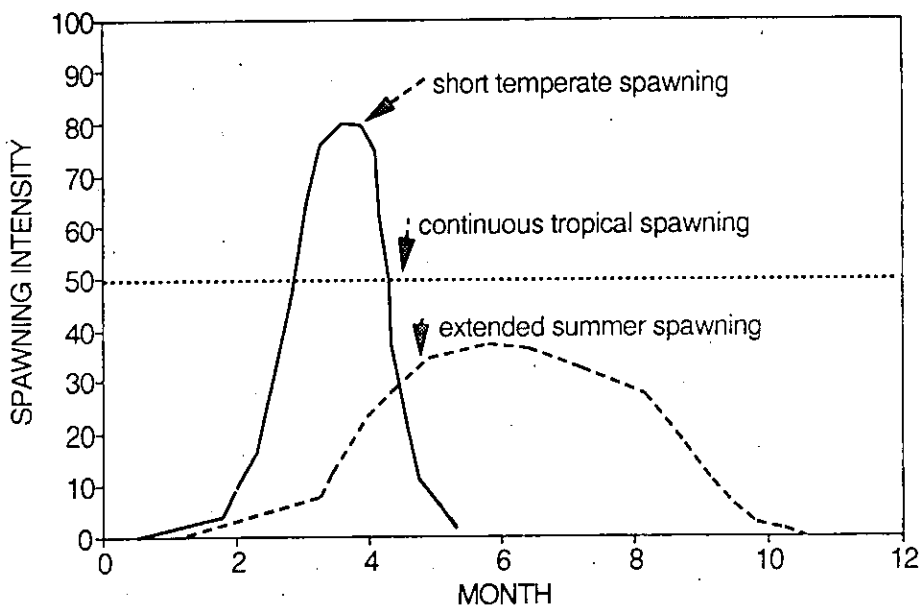

Fig. 1. Schematic graph of seasonal spawning characteristics.

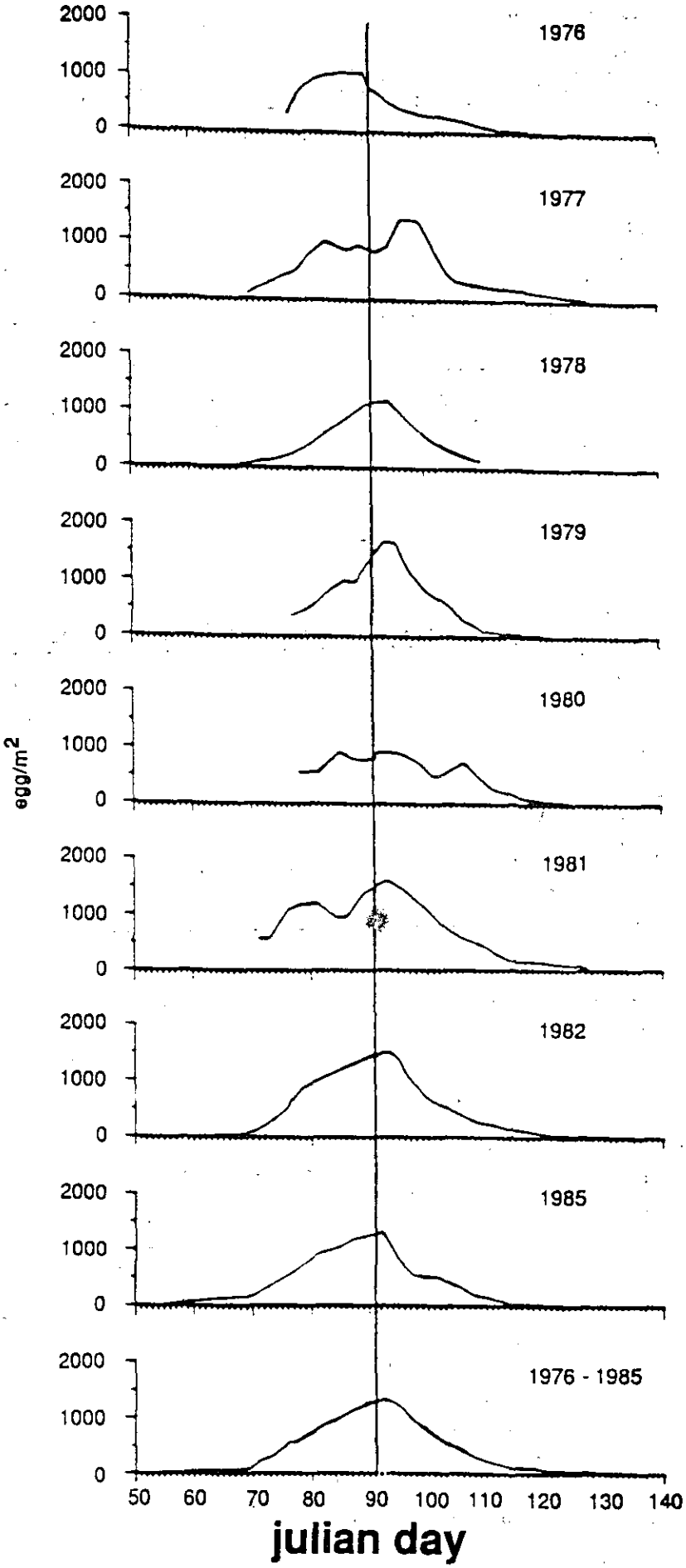

Fig. 2. Seasonal "spawning intensity" for the Arcto-Norwegian cod (from Pedersen 1984).

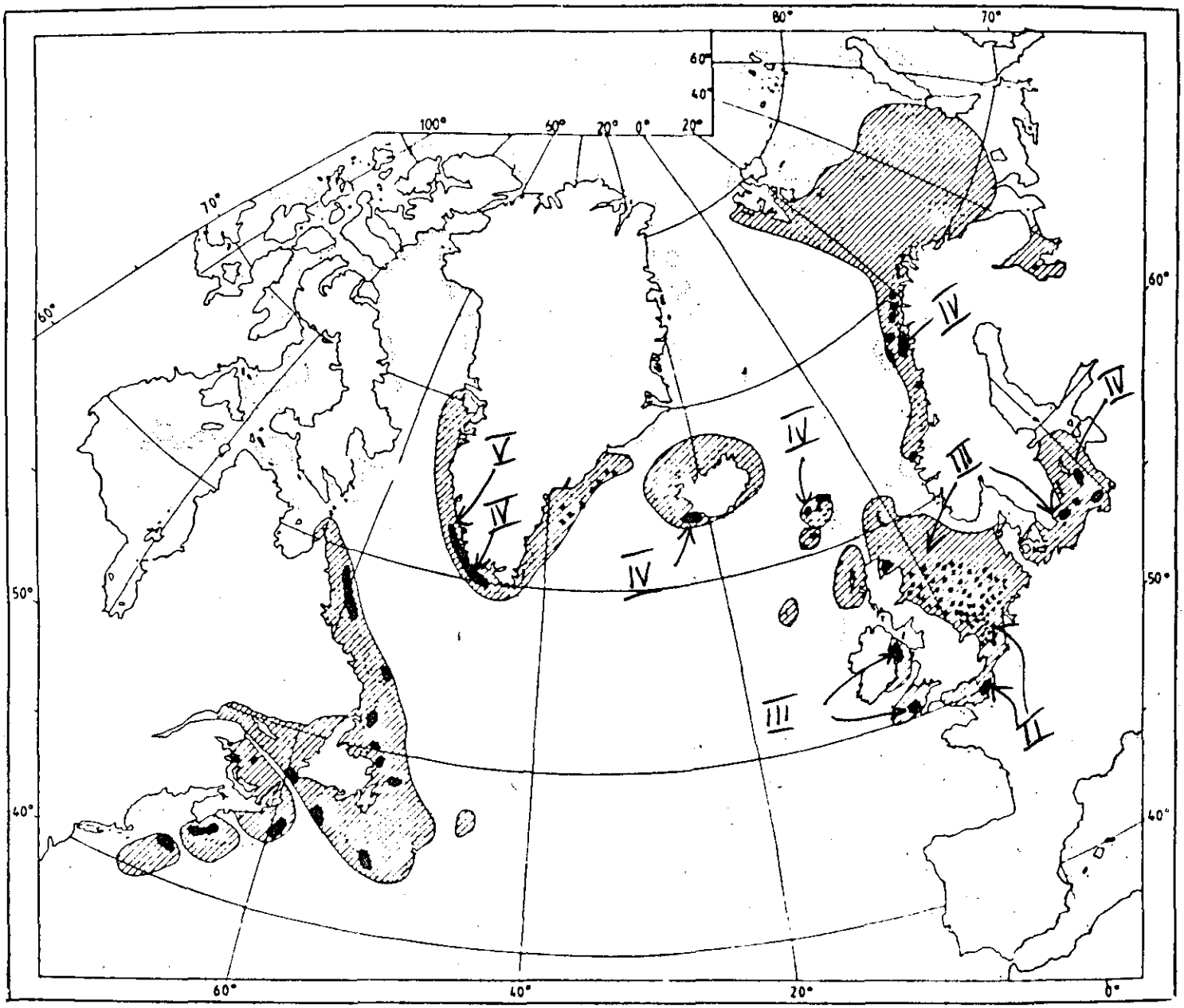

Fig. 3. Distribution of cod stocks in the North Atlantic, with their principal spawning sites and dates (month) of peak spawning (based on Anon. 1990).

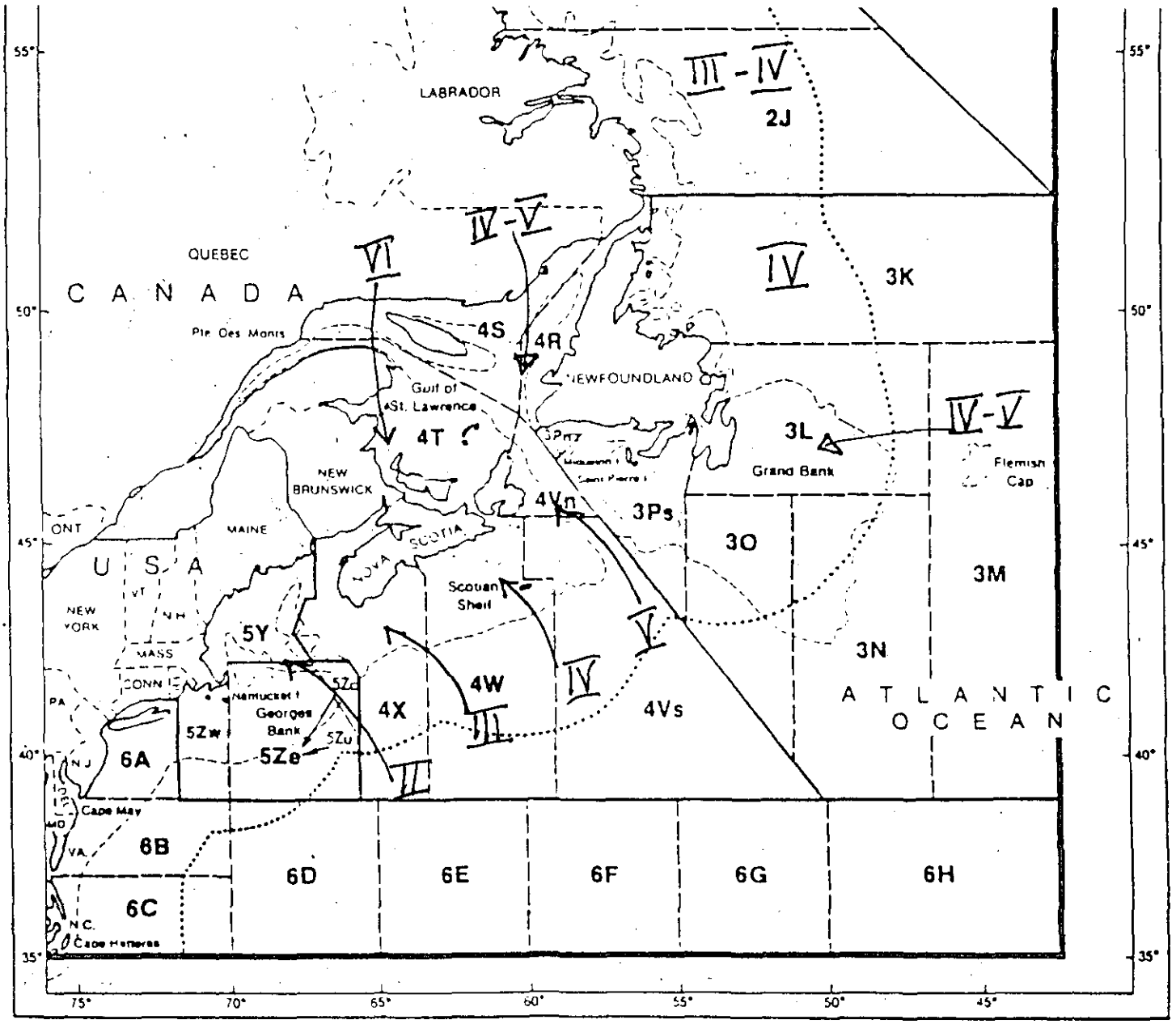

Fig. 4. Dates of peak spawning (month) for cod stocks in the NW Atlantic.

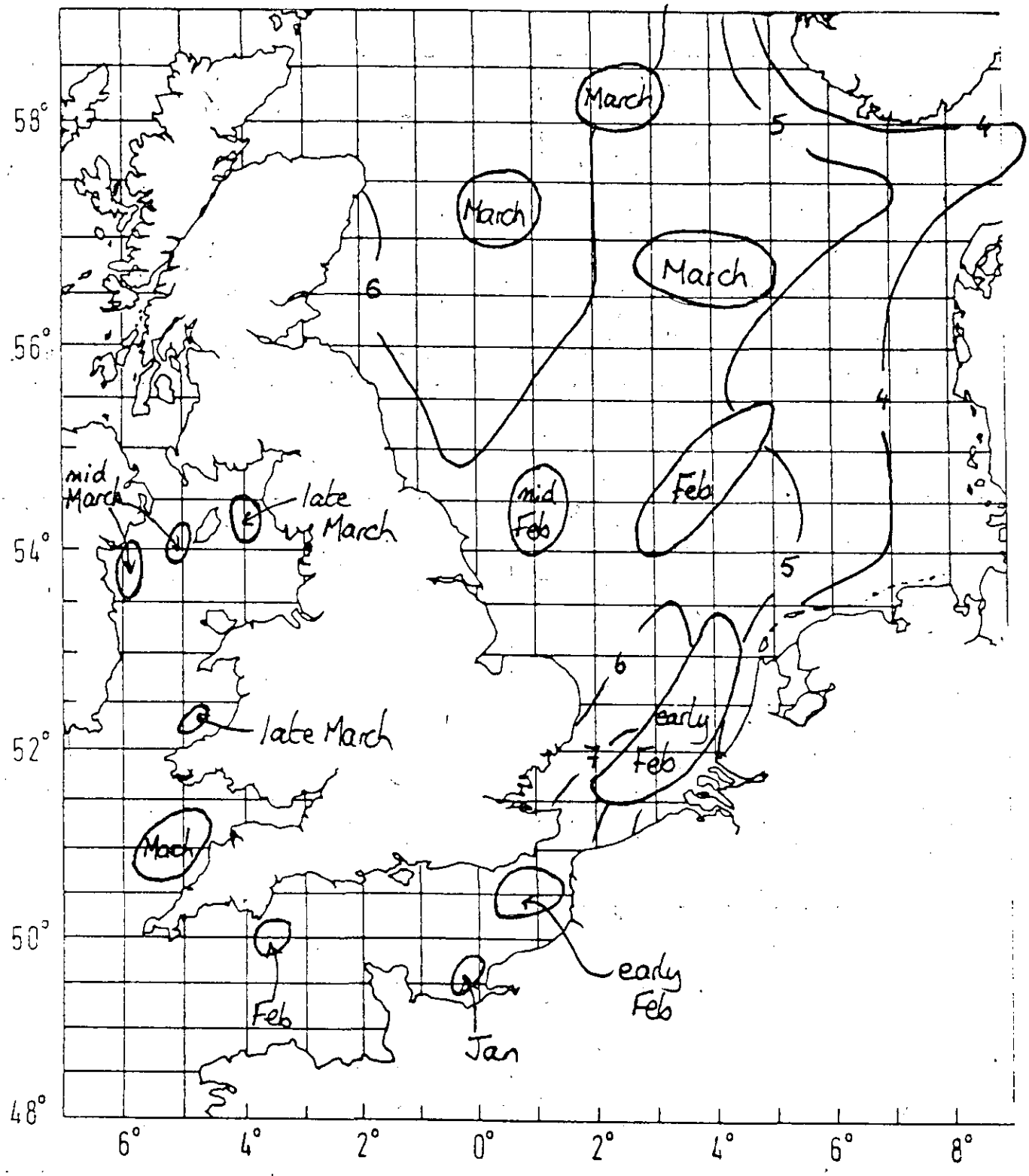

Fig. 5. Distribution and timing of cod spawning around the British Isles, with March surface isotherms for the North Sea.

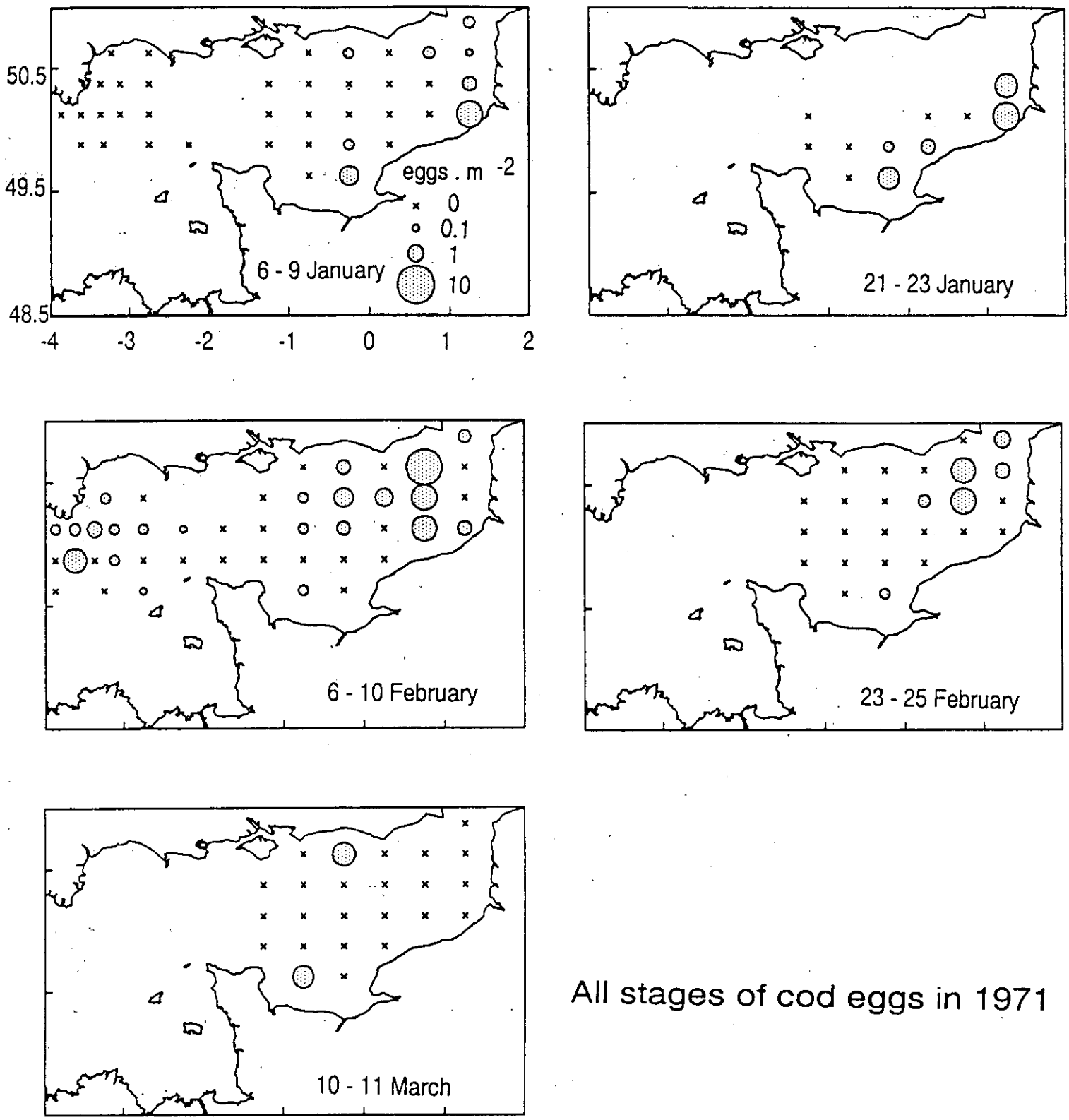

Fig. 6. Distribution of all stages of cod eggs in the English Channel in Jan - March 1971.

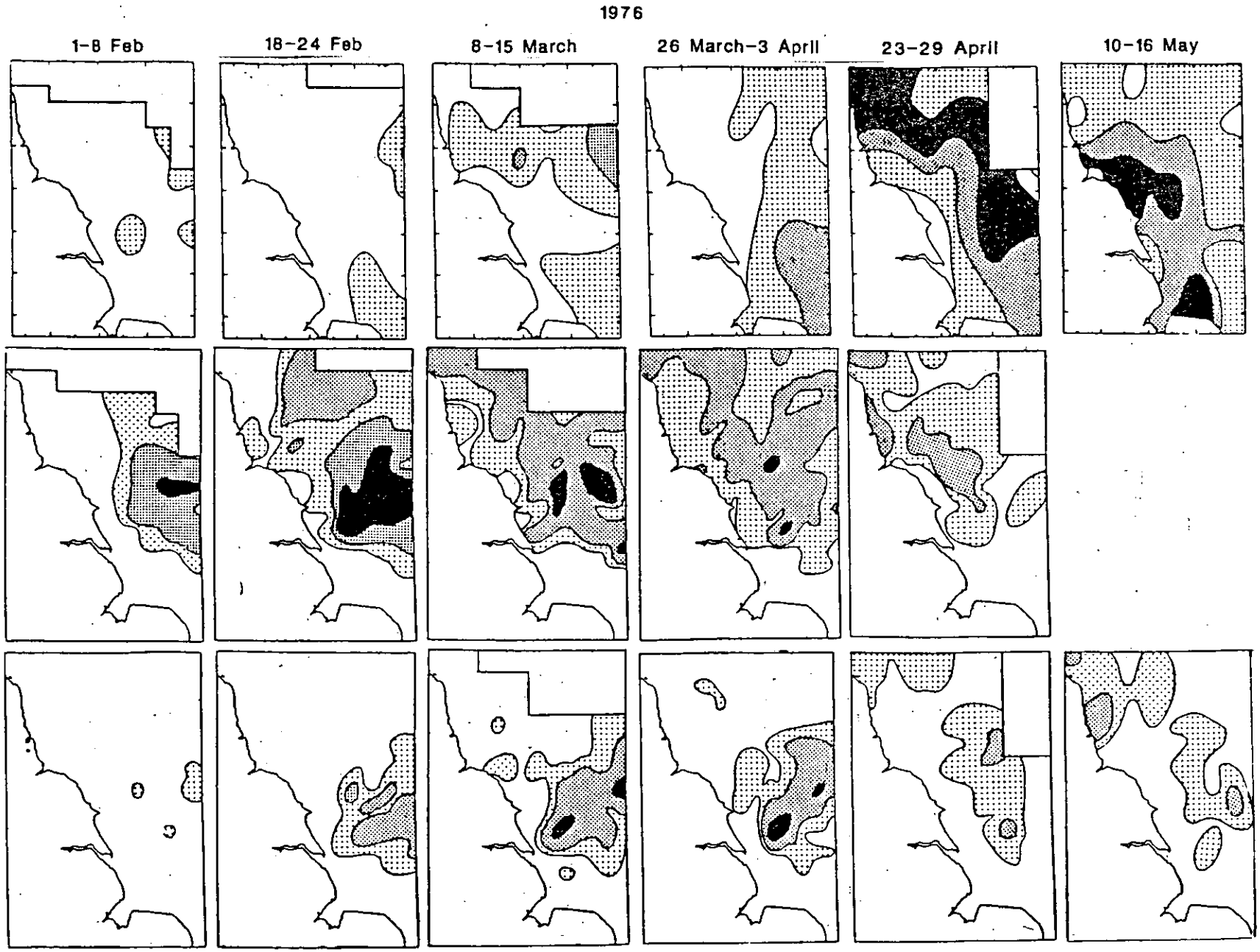

Fig. 7. Distribution of surface chlorophyll 'a', stage 1 cod eggs and total cod larvae off the north-east coast of England in Feb - May 1976.

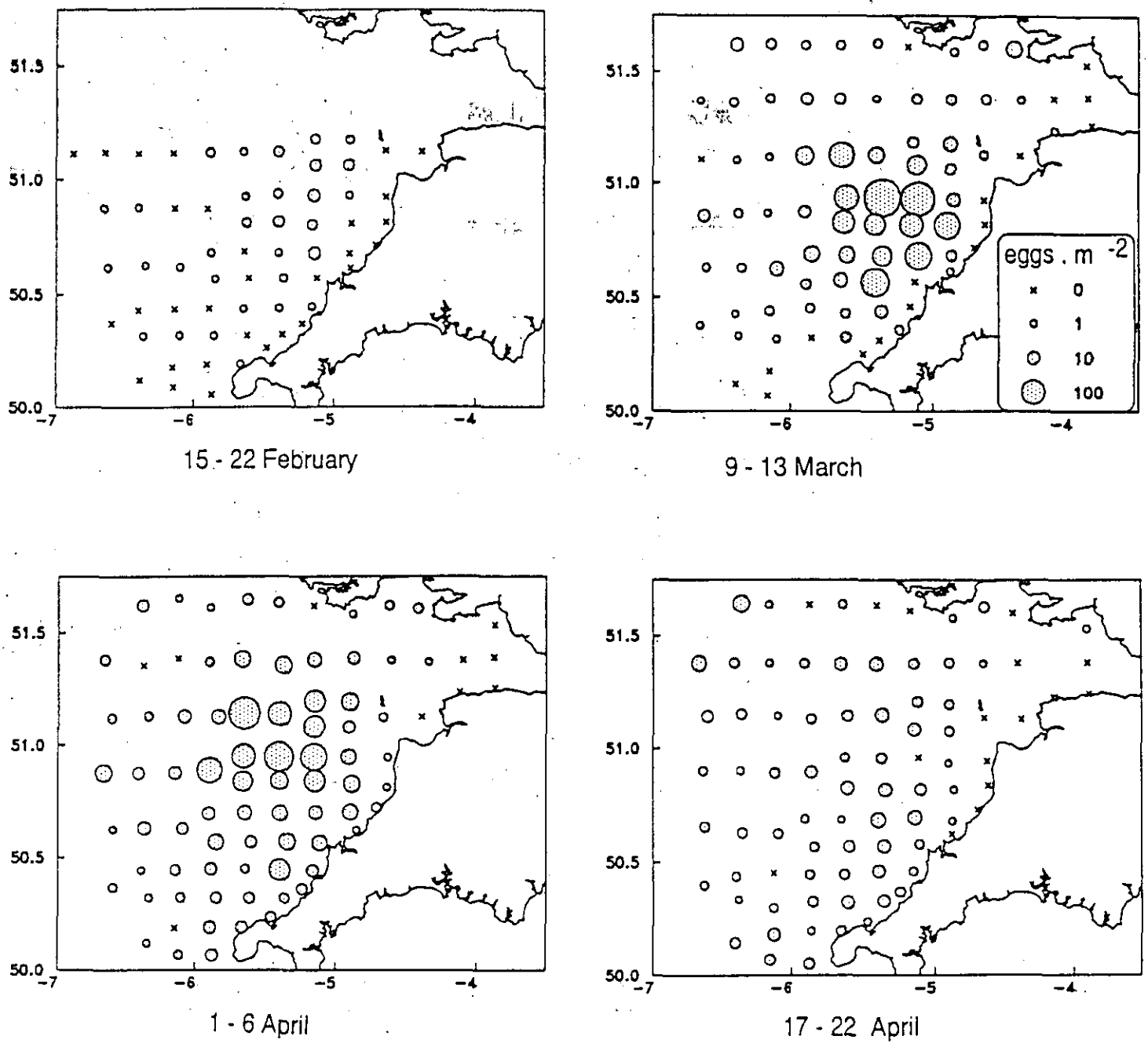

Fig. 8. Distribution of stage 1 cod eggs in the Bristol Channel in 1990.

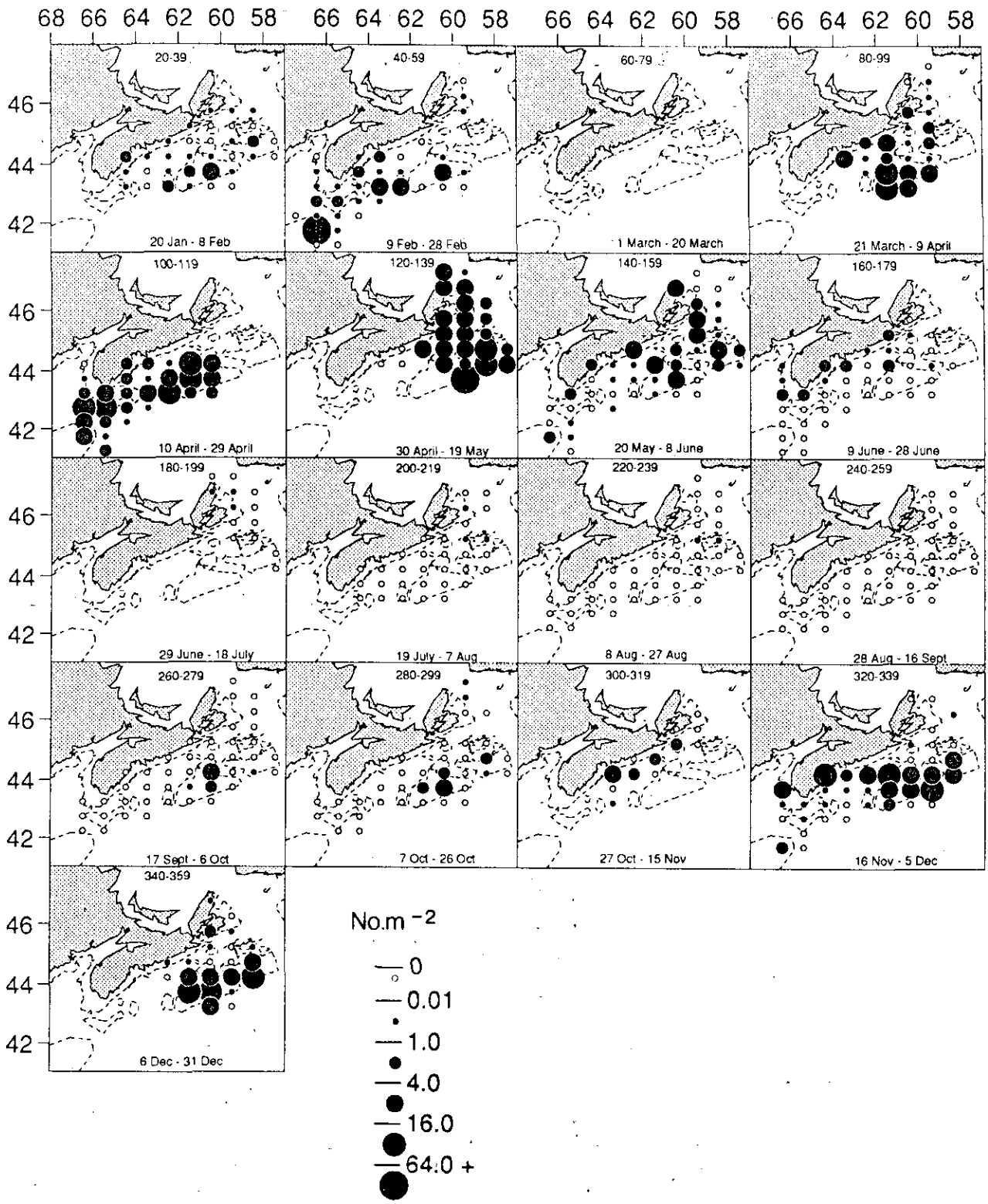

Fig. 9. Stage 1-3 cod eggs from SSIP surveys in 1979-1981 (from Brander and Hurley, in press).

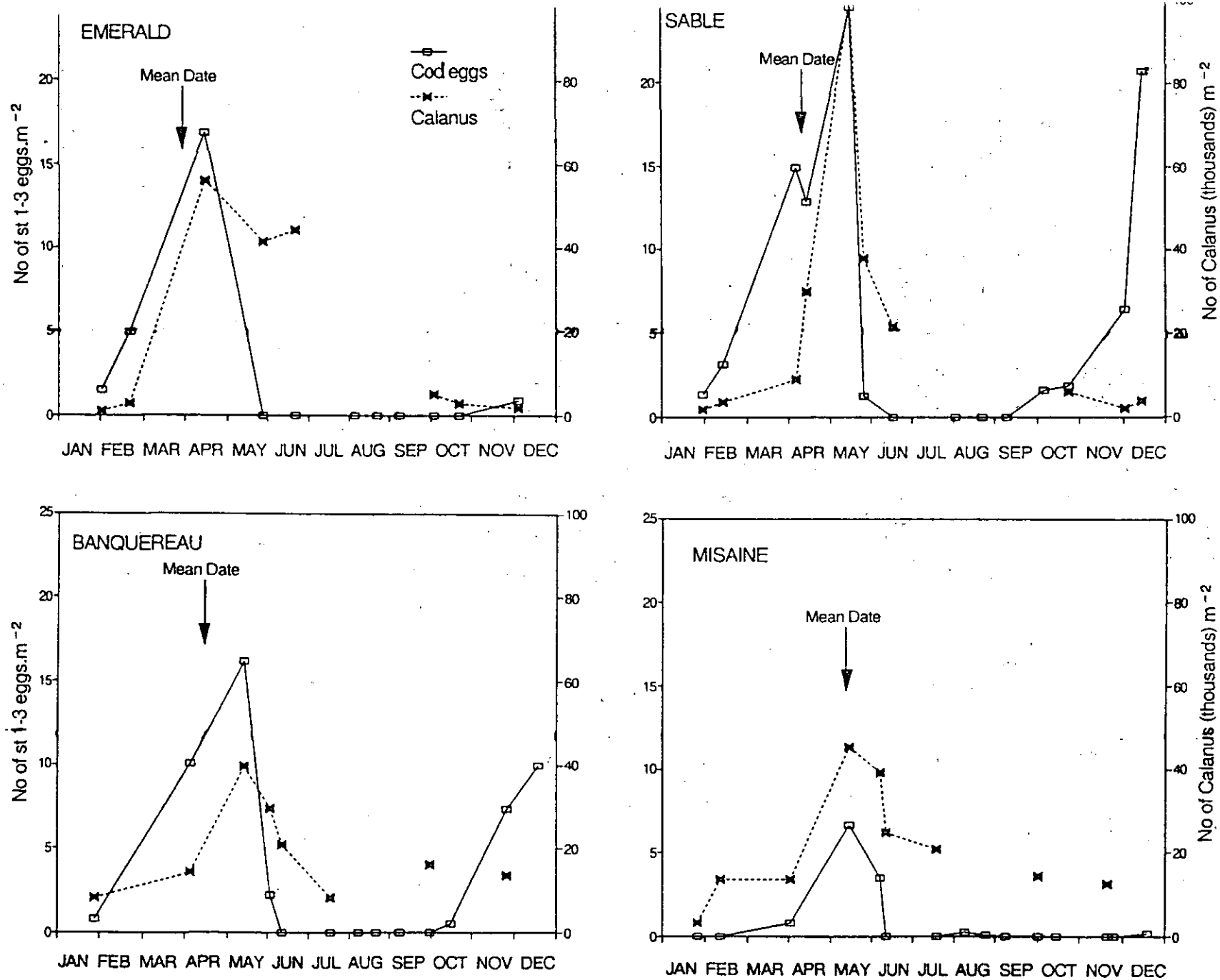

Fig. 10. Number m $^{-2}$ of stage 1-3 cod eggs and Calanus finmarchicus on a) Emerald Bank b) Sable Bank c) Banquereau d) Misaine Bank; averaged for the years 1979-1981 (from Brander and Hurley, in press).