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PHYSICAL PROCESSES AND YEAR-CLASS STRENGTH OF SILVER HAKE AND HADDOCK ON GEORGES BANK

by

Edward B. Cohen[1], David G. Mountain[1] and Wallace G. Smith[2]

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M. D. Grosslein

(APPROVING OFFICIAL)

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(DATE)

[1]National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachusetts 02543

[2]National Marine Fisheries Service
Northeast Fisheries Center
Sandy Hook Laboratory
Highlands, New Jersey 07732

*MARMAP Contribution MED/NEFC 83-06

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INTRODUCTION

Commercial fishing on Georges Bank is a billion dollar a year industry. The fisheries are largely dependent on one or two strong year classes for each species. However, the mechanisms controlling recruitment are largely unknown. Physical properties have been shown to exert an influence on fish production in other areas, e.g. the Peruvian anchovetta fishery, and off of the California coast. We are considering three physical parameters thought to be related to egg and larval mortality and thus influence year-class strength.

H_1: Entrainment of water off of Georges Bank by warm core rings is a major cause of egg and larval mortality.

H_2: Wind driven transport of water off of the southern flank of the bank is a significant cause of egg and larval mortality.

H_3: The location of the shelf-slope front is related to egg and larval survival through some unspecified processes. Bolz and Lough (1981) have presented evidence of this from larval herring mortality estimates. During periods when the front was in close on Georges Bank, abundance was low; when the front was further offshore, abundance was high. (A possible mechanism is that when the front is in close a greater proportion of the Georges Bank water is recirculated, promoting retention and survival and when the front is offshore, the shelf water organisms are more likely to be advected into the slope water and/or preyed upon by vertically migrating slope water predators such a myctophids.)

The Northeast Fisheries Center (NEFC) of the National Marine Fisheries Service has a long time series of data on adult stocks but only relatively recently has data on larvae and physical oceanography been taken. We have used the NEFC data set to calculate mortality estimates for the early life stages of silver hake (Merluccius bilinearis) and haddock (Melanogrammus aeglefinus). Mortality was calculated from eggs to larvae, and larvae to age 1. Mortality was calculated using a simple exponential model

$$N_{t+1} = N_t e^{-M\ t}$$

where: N_{t+1} = number at time t + 1 (e.g. number of larvae)

N_t = number at time t (e.g. number of eggs)

N = instantaneous mortality ($month^{-1}$)

t = time period (e.g. time from egg to larvae).

The number of eggs was calculated based on the stock structure from virtual populatins analysis (V.P.A.) and a fecundity at length relation for silver hake and a fecundity at age equation for haddock. The number of larvae are from ICNAF or MARMAP larval surveys. Young of the year (age 0 or YOYO) numbers are based on NEFC bottom trawl surveys. Age 1 fish are from NEFC survey and V.P.A. analysis.

Silver hake and haddock were chosen as they are two commercially important species and spawn at different seasons and areas of the bank. Silver hake spawn during the summer June-July

between the 100 m and 200 m isobaths on the southern side of the bank (Figure 1). The area in which they spawn should make silver hake eggs and early larvae extremely vulnerable to advection off of the bank by winds and warm core ring entrainment in the June-August and September-November periods. Haddock is a spring spawner (March-April) and spawns on the Northeast Peak of Georges Bank. The eggs and larvae generally follow the clockwise circulation of water on the bank. Haddock should be particularly vulnerable to the physical processes during the spring.

We will look at the seasonal indices of the physical parameters compared with the estimates of mortality and abundance for the early life stages of silver hake and haddock. We are focusing on the early life history because year-class strength is determined by the time fish reach age 1.

Entrainment of shelf water by rings is estimated by analysis of weekly satellite imagery. The index used is the total number of ring-weeks of entrainment that was observed (data supplied by A. Friedlander, NOAA/NMFS/AEG).

The index of wind driven transport used is the Ekman transport derived from monthly anomaly wind stress values (data supplied by M. Ingham, NOAA/NMFS/AEG). The location of the shelf/slope front is determined from satellite imagery and expressed as the average distance offshore of the 200 m isobath (data supplied by R. Armstrong, NOAA/NMFS/AEG).

RESULTS

The physical parameters are plotted in Figures 2, 3, 4, and 5 so that larger positive values correspond to conditions of greater mortality according to our three hypotheses. A comparison of the data on abundance and mortality (Figures 6, 7, 8, and 9) of silver hake and haddock with the physical parameters (Figures 2, 3, 4, and 5) reveals no discernable correlations. This data is summarized in Table 1. The results shown in Table 1 indicate that there is no consistent relation between the expected mortalities according to our hypotheses and the actual mortality during the egg to larval period or with year-class strength. For example, in 1975 haddock showed low egg to larval mortality and high recruitment which were both consistent with the frontal position hypothesis. In 1978, however, haddock again had high recruitment but the frontal position implied a poor year class. The silver hake results are similarly inconsistent. To complicate matters even further, there is no apparent relationship between the number of eggs, number of larvae and subsequent number of one year olds. The one promising note shown in Figure 10 is that mortality from age zero to age one for silver hake as determined from bottom trawl survey data and the number of one year olds from the V.P.A. is correlated with an R value = 0.67. This indicates that mortality during the post-larval (age 0) stage to age 1 is an important determinant of year-class strength. Further, it is an indication that for silver hake the trawl survey is a good measure of year-class

success. Unfortunately, the same is not true for haddock, the survey trawl catches more haddock/tow as they age from YOYO's through age 1.

DISUCSSION

Year-class strength appears to be determined to a large degree by processes occurring during the first year of life. Variations in mortality during this period do not appear related to seasonally averaged indices of the physical environment. The absence of a relationship, no doubt, could be due to the quality of the data used and assumptions made. For example, on the physical side, recent measurements show that the rate of entrainment of water by rings varies considerably, while for the biology, sampling of YOYO's and one year olds is known to be a problem. The data has not been subjected to a detailed statistical analysis because all parameters were available in only a few years.

Most importantly, however, we believe that variation in the mortality induced by the physical environment may be episodic in nature, i.e. concentrated in short term events in which the relevant physical process acts at the time and place where the larval fish population is concentrated. For example, Figure 11 shows the Experimental Ocean Frontal Analysis for 17 May 1978 overlaid on the larval distribution from the spring MARMAP survey. The large concentration of larvae near 68°W on the south

side of Georges Bank is located in the mouth of an entrainment feature associated with a Gulf Stream meander. The larval mortality between April and June 1978 was the largest observed in this study (Figure 10) and presumedly was related to the loss by entrainment of the larval concentration at 68°W. This type of relationship would be difficult to observe in a historical perspective. It also appears that it had little affect on year-class strength of either haddock or silver hake, both of which had fairly strong 1978 year classes.

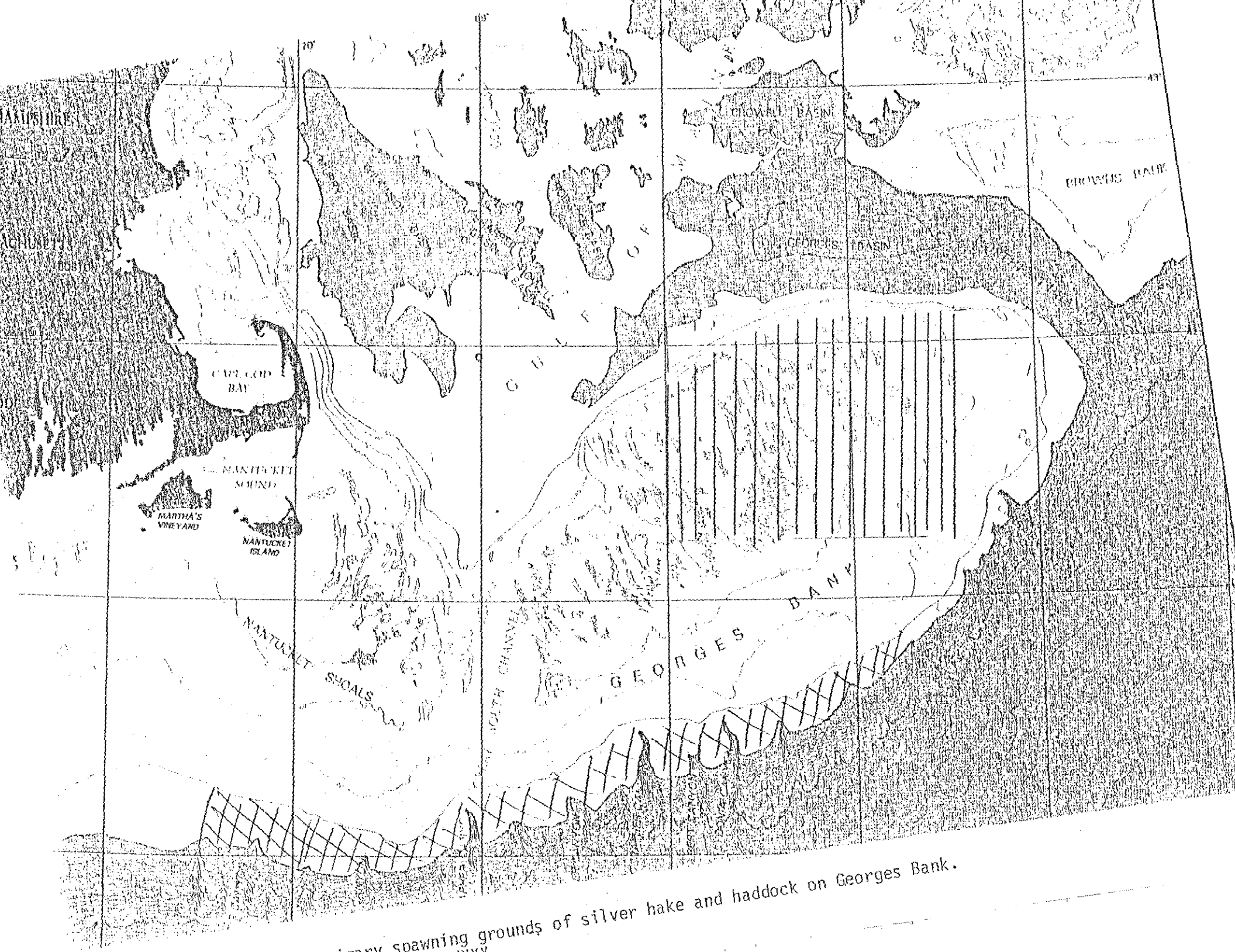
In order to purse the role of physical processes in regulating year-class strength, we will need to consider the time dependence (episodic nature) of the physical processes as well as of the biological distributions in time and space. A comprehensive sampling program for the early life stages of the fish species on Georges Bank is a necessity.

LITERATURE CITED

Bolz, R.G. and R.G. Lough. 1983. Retention of ichthyoplankton on the Georges Bank Region during the Autum-Winter seasons of 1971-1977. J. Northw. Atl. Fish. Sci., vol. 5. In press.

Table 1. This table compares the expected mortality from wind stress, ring activity and position of the shelf-slope front with observed larval mortality and year-class strength for silver hake and haddock. The period March-May was chosen for haddock and June-August for silver hake as the period when eggs and larvae are most susceptible to loss through these physical processes.

	Expected Mortality		Haddock			
	Low	High	Egg-Larval Mortality Low	Egg-Larval Mortality High	Recruitment Poor	Recruitment Good
March-May						
Wind	79,80	77	75	77	all others	75,78
Rings	81	77,79				
Front	75	74,78, 29, 81				
June-August						
Wind	74		77,79	72,75,81	75-80	72,73,78
Rings		77,78				
Front	73-75	78,81				



imary spawning grounds of silver hake and haddock on Georges Bank.

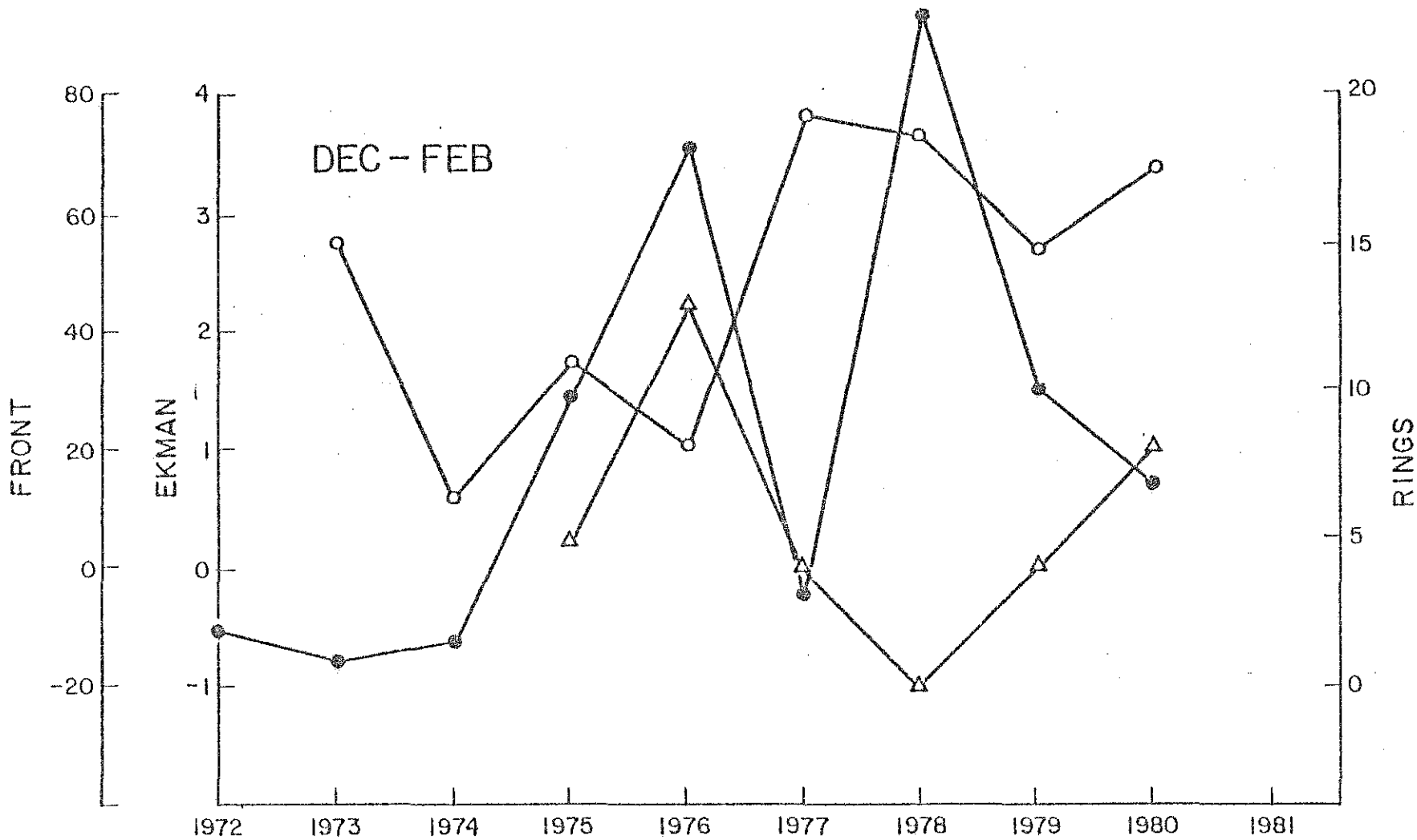


Figure 2. Monthly averaged physical processes December-February. Positive direction on scale corresponds to increased mortality under our hypotheses.

0—0 - Shelf/slope front - distance offshore of 200 m isobath (km)
●—● - Southward Ekman transport anomaly (0.1 m^3s^{-1}/m)
Δ—Δ - Entrainment by Warm Core Rings (ring weeks)

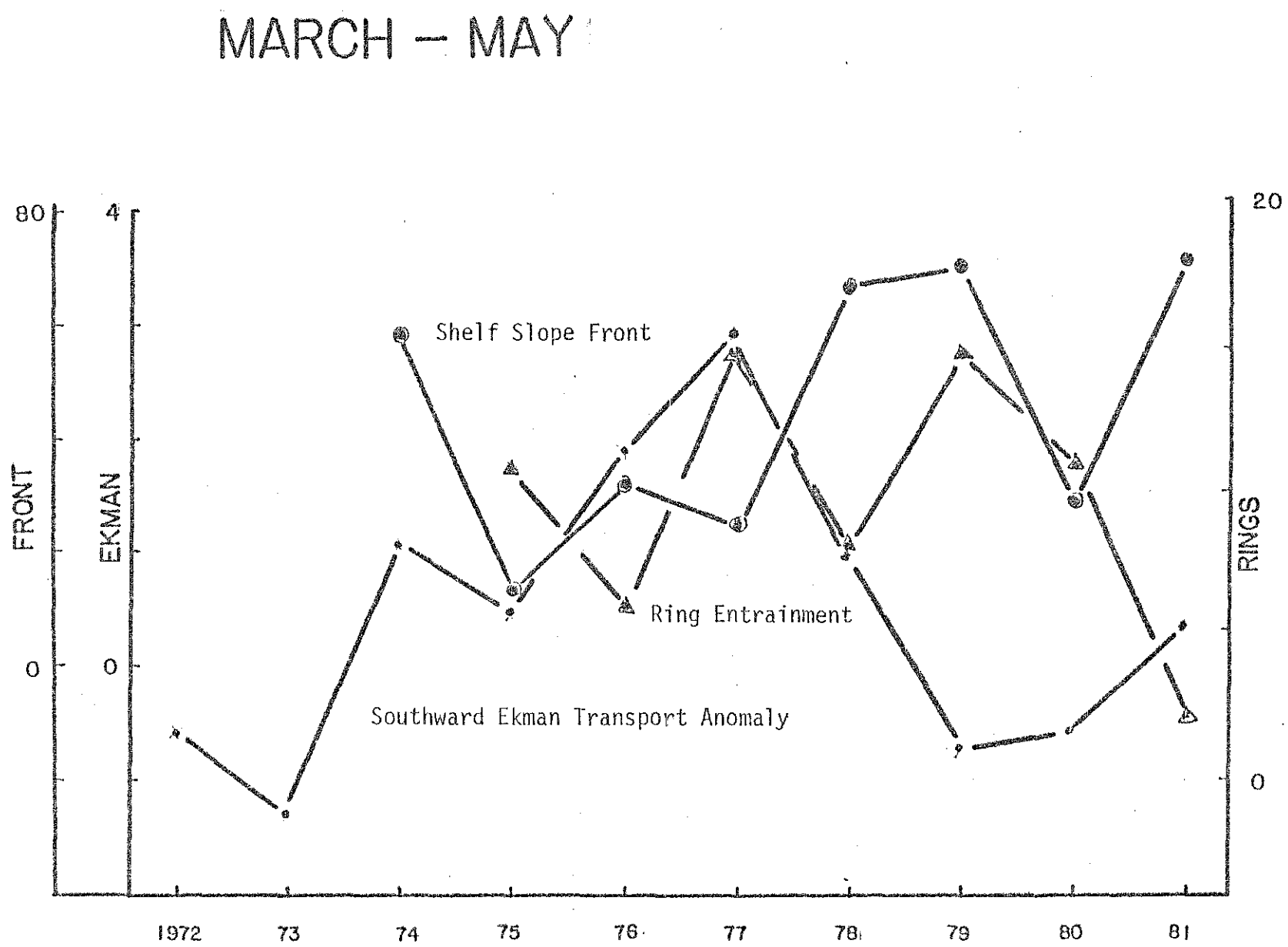


Figure 3. Monthly averaged physical processes March-May. See Figure 2 for details.

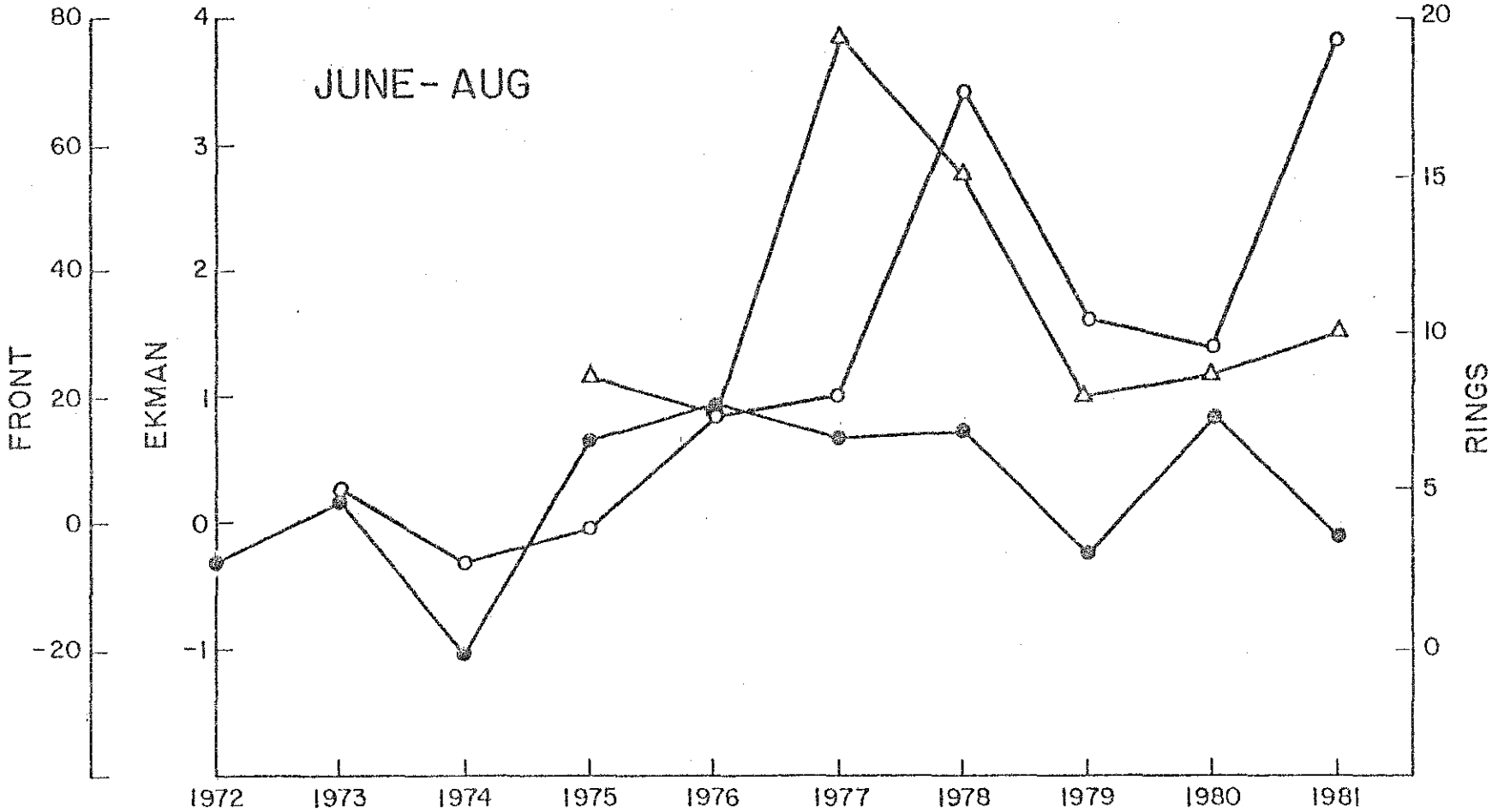


Figure 4. Monthly averaged physical processes June-August. See Figure 2 for details.

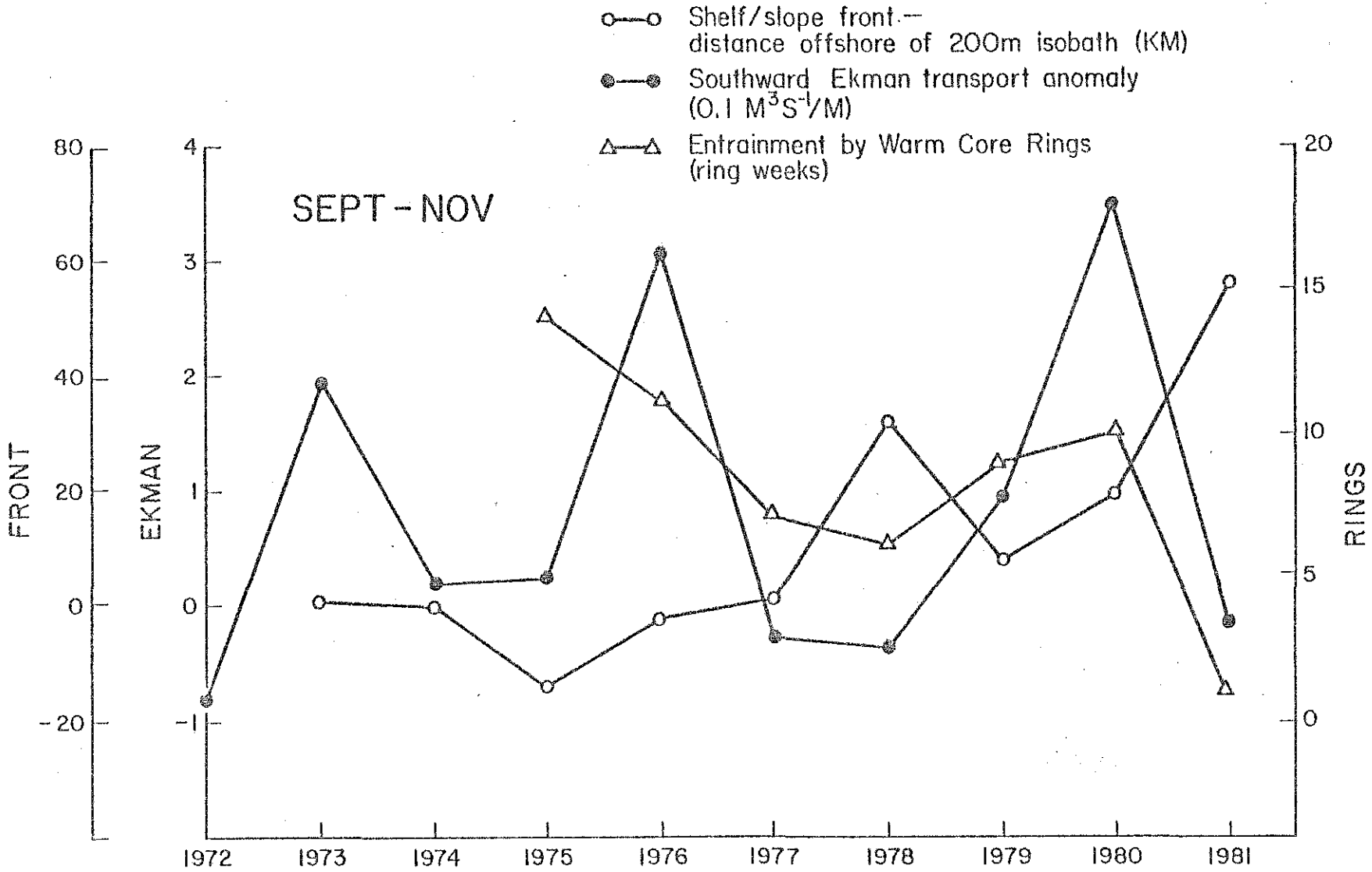


Figure 5. Monthly averaged physical processes September-November. See Figure 2 for details.

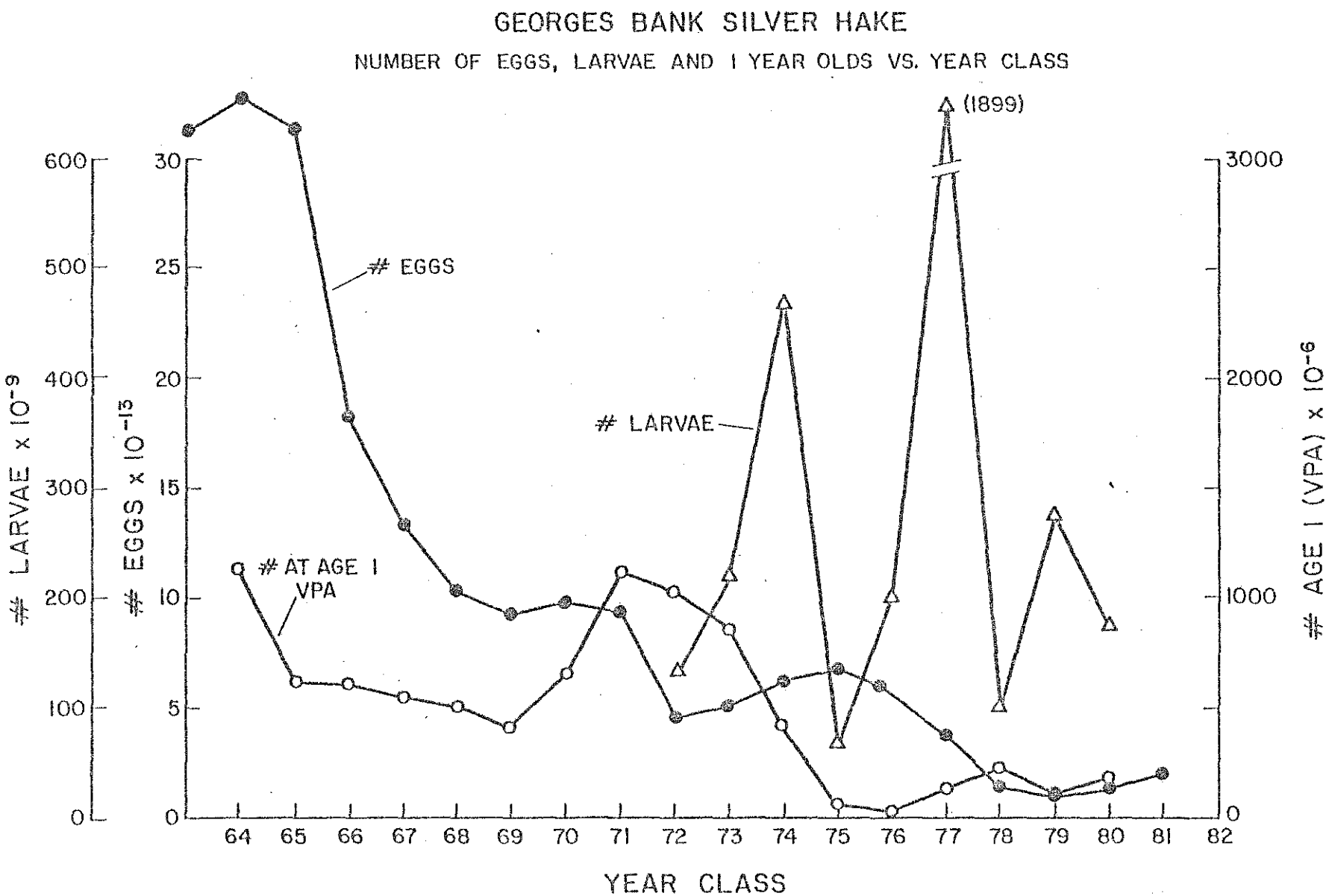


Figure 6. Numbers of eggs larvae and 1 year olds by year class of silver hake on Georges Bank.

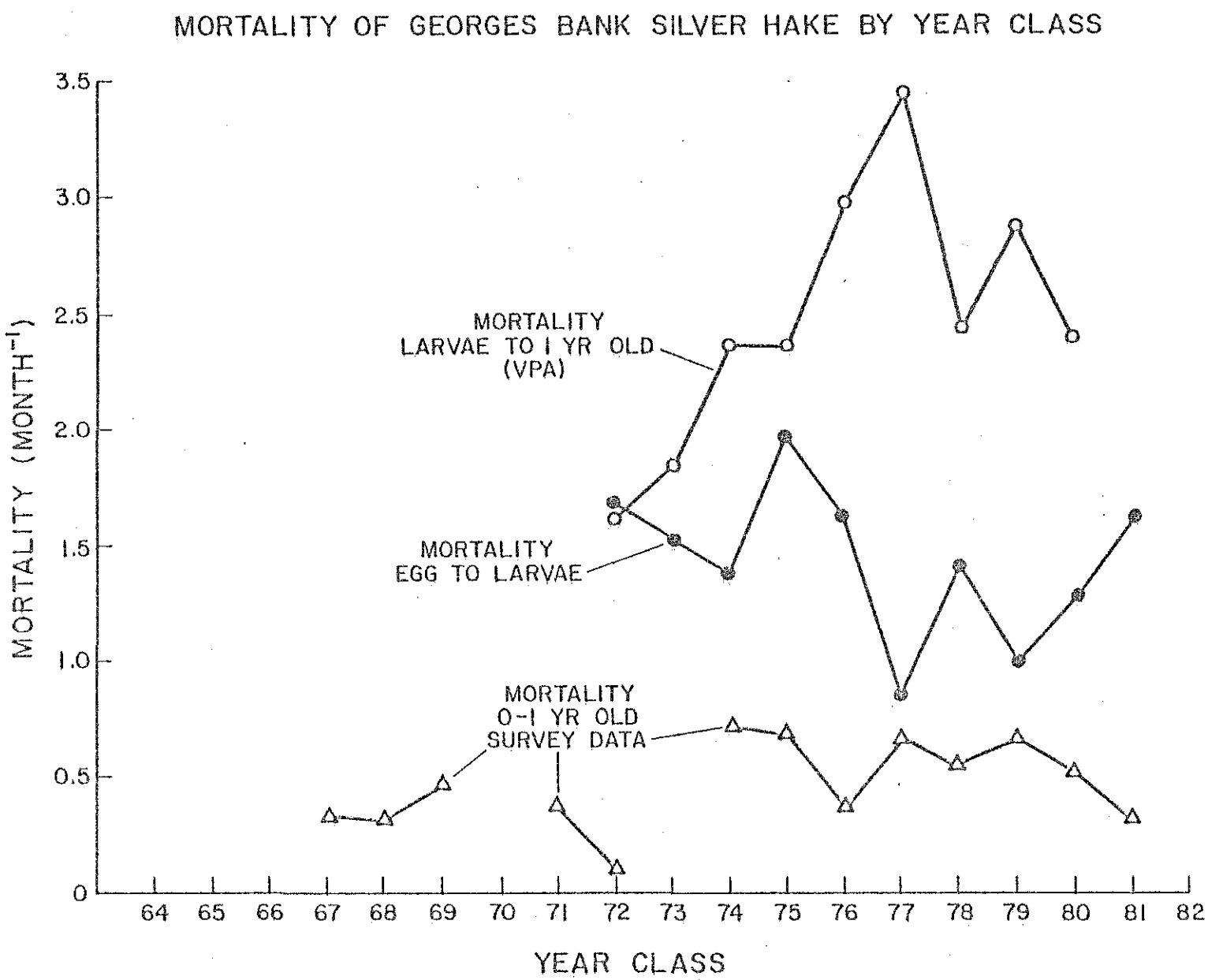


Figure 7. Mortality of different life stages of silver hake on Georges Bank by year class.

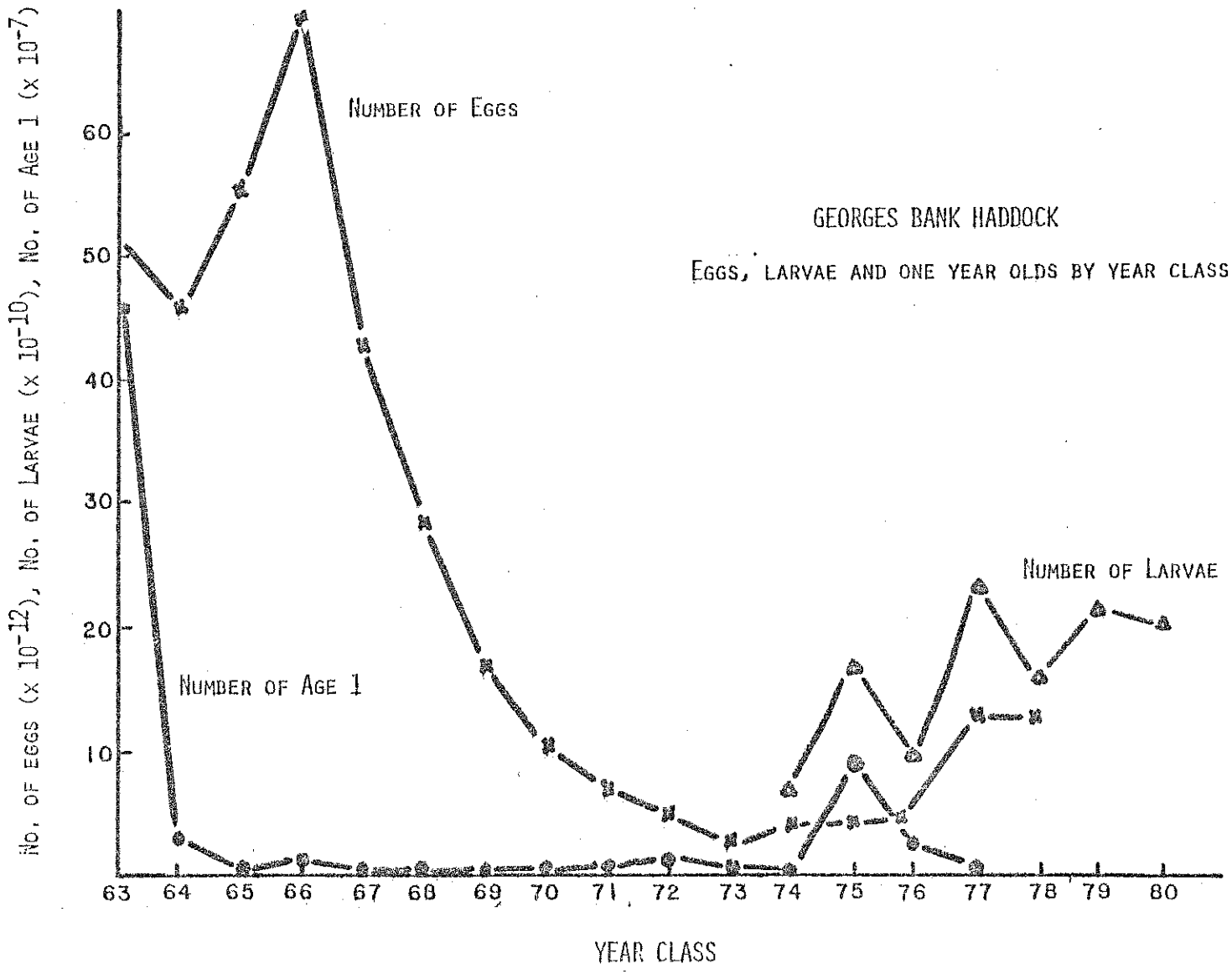


Figure 8. Numbers of eggs, larvae and 1 year olds by year class of haddock on Georges Bank.

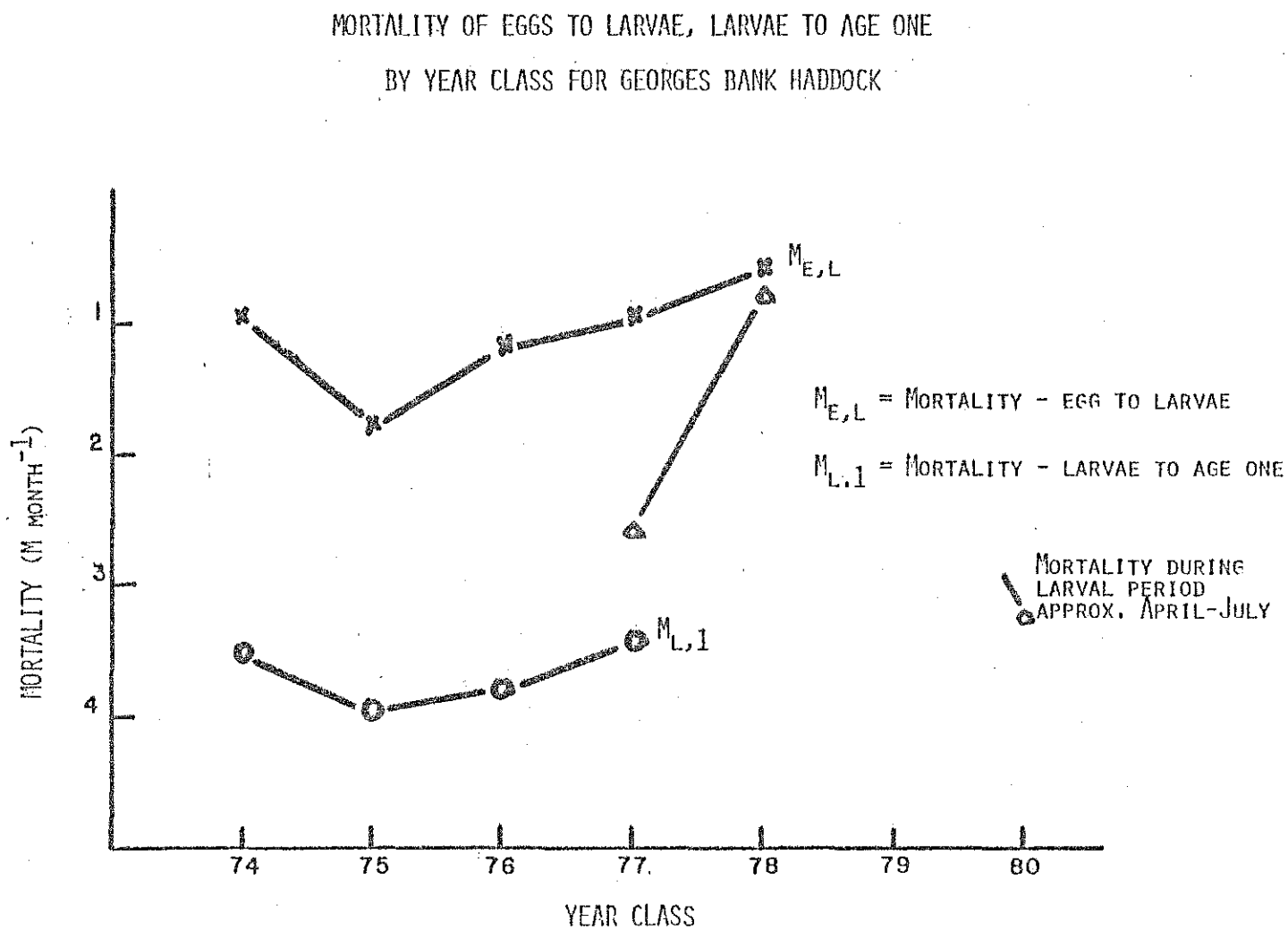


Figure 9. Mortality of different life stages of haddock on Georges Bank by year class.

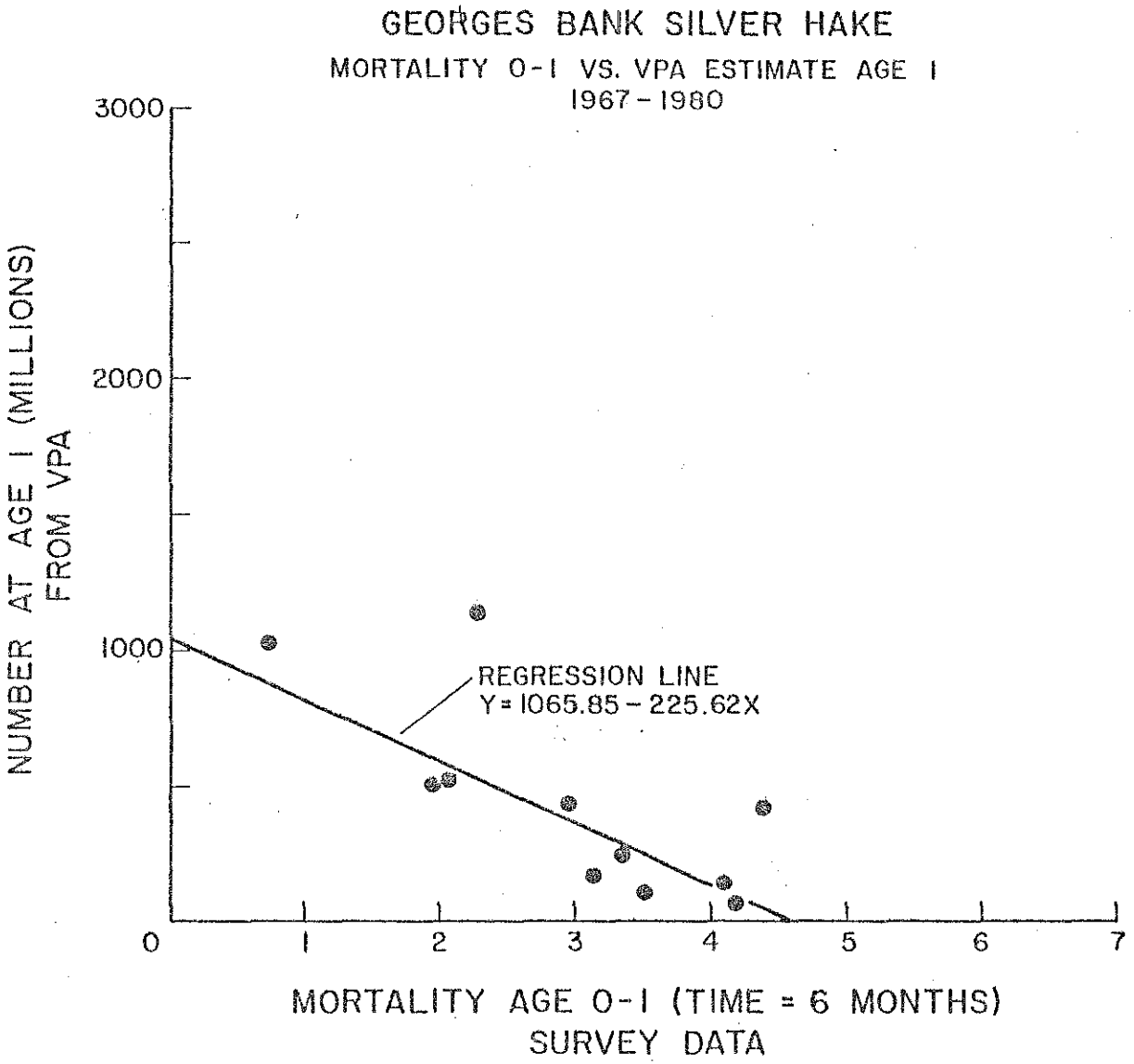


Figure 10. Regression of morality from age 0 to age 1 from survey data and the number at age 1 from VPA for Georges Bank silver hake.

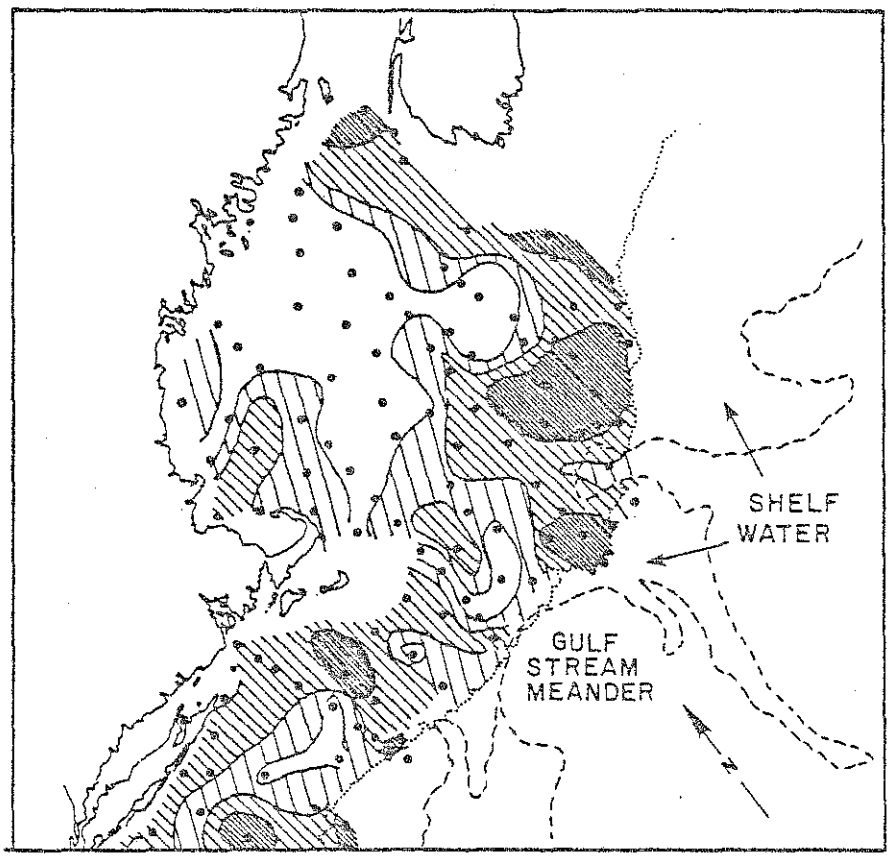


Figure 11. Overlay of satellite derived frontal analysis from 17 May 1978 onto larval distribution from a May cruise (Argus 78-09). A high concentration of larvae is in the mouth of an entrainment feature associated with a Gulf Stream meander or ring.