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POPULATIONS OF EUPHAUSID SPECIES IN THE BAY OF FUNDY AND THEIR SEASONAL MOVEMENTS

by

D. W. Kulka
Zoology Department, College of Biological Sciences,
University of Guelph, Guelph, Ontario

and

T. D. Iles
Department of Environment,
Fisheries and Marine Service,
Biological Station, St. Andrews, New Brunswick
Canada

INTRODUCTION

The Bay of Fundy area, near the entrances of Passamaquoddy Bay, was the site of the earliest record of "surface-swarming" of Euphausids (Smith 1879), a phenomenon that has since been found to be a common biological feature of this group in waters all over the world. There is as yet no satisfactory comprehensive explanation of the phenomenon either in relation to the hydrographic factors involved or as to its biological significance (Mauchline and Fisher 1967a). In the Bay of Fundy area itself, it is only relatively recently that it has been the subject of detailed study.

This has been carried out by one of us (D.W.K.) in the Passamaquoddy Bay area over the period 1971-74. Samples were taken at monthly intervals in the "passages" and in Passamaquoddy Bay itself (see Sketch Map, Fig. 1) as material for an investigation into the general biology of Euphausid species in the area.

Analysis of this material confirmed the seasonal nature of the occurrence both of *Meganyctiphanes norvegica* and of *Thysanoessa inermis* at and near the Passamaquoddy Bay entrances.

Both of these species make their seasonal appearance in the passages in large numbers about late June-early July. Abundance increases to a seasonal maximum about September and from November on numbers decline to a seasonal minimum about March. Surface swarming is a characteristic biological feature during the seasonal period of increasing and peak abundance and is associated with diurnal tidal movements (Gaskin 1973 ; Kulka, in preparation). This seasonal pattern varies in its precise timing from year to year. There is also a marked annual variation in absolute levels of abundance. During the period 1971-74 this was considerable (Kulka, ibid); records from two standard stations in the area, Prince 5 and 6 stations, occupied from the St. Andrews Biological Station at monthly intervals over a long historical period, show that in 1945, 1946 and 1957 abundance was so low that no Euphausids were found in zooplankton samples (Legaré 1958).

The seasonal occurrence of Euphausids in the passages implies annual immigration and emigration, but little was known of their distribution outside the Passamaquoddy Bay area and thus of the origin of the seasonal migrants.

MATERIALS AND METHODS

The Bay of Fundy area was sampled extensively and comprehensively as part of a herring larval survey programme (Iles 1971; Stobo and Iles 1973). Isaacs-Kidd trawls with small-mesh liners and, later, Bongo nets (505μ mesh) were used to sample as much of the water column as possible over a closely spaced grid of stations (Fig. 2).

Zooplankton samples from a number of these cruises were analysed, and the preliminary results form the basis of this communication. Individual Euphausid species were identified

and estimates of numbers of each at each station converted to numbers below each square metre of surface. Records of occurrence for larval stages were made, but these were not identified to the species level.

Wet formalin weight was determined for each species for each station to give biomass information.

RESULTS

The results are presented as distributional maps in Fig. 3 and 4. The following points can be made:

1. In both November and March the distribution of *M. norvegica* and *T. inenmis* is localized within the Bay of Fundy area. The centre of concentration for both species is the Grand Manan basin between Grand Manan and Digby Neck at the inner entrance of the Bay of Fundy. The distribution extends neither into the Passamaquoddy area nor far into the inner parts of the Bay of Fundy or onto the southwest Nova Scotia shelf.

2. Abundance varies considerably from year to year as does the degree of concentration.

3. There is very considerable overlap in the distribution of *M. norvegica* and *T. inermis; T. inermis* is a smaller species and occurs in smaller numbers so that *M. norvegica* is far more important in terms of biomass.

4. There is some indication of seasonal changes in the position of the *M. norvegica* population (compare Fig. 3A and 3B) and of greater dispersion of the *T. inermis* population (Fig. 4A and 4B), but whether these are characteristic and significant is yet to be confirmed.

5. There appears to be another population of *M. norvegica* in the extreme southwest of the study area which may represent a distinct "Gulf of Maine" population.

Seasonal feeding and growth

The distributional data in Fig. 3 and 4 suggest strongly that the summer populations found in the Passamaquoddy area represent the "dispersed" phase of the winter populations of the Grand Manan basin. The winter population is known to be a non-feeding phase with depressed seasonal growth (Hollingshead and Corey 1972); the summer phase is the feeding-growth stage of the life history (Kulka, in preparation).

The status of the Grand Manan basin populations

Manchline and Fisher (1967) recognize that "there are probably high degrees of isolation inherent in certain populations" (of Euphausids), and it is suggested now that for both species the Grand Manan basin populations represent isolated units or "stocks" which are largely distinct, genetically, from other populations in the general area, and particularly from those of the Gulf of Maine. This hypothesis is being tested directly in more detail but there is circumstantial evidence that supports it in the distribution data.

Breeding and life history patterns

Spawning for both species is known to be seasonal in the area. It occurs over the period March-October, but there is a marked seasonal peak of spawning activity in May (Hollingshead and Corey 1972; Kulka, in preparation) i.e., towards the end of the concentrated phase. The non-quantitative distribution of larval Euphausids is shown in Fig. 5. Larval distribution is to the south and to a lesser extent the southwest of the "parent" population. In particular, the larval distribution extends onto the Nova Scotian shelf. Figures 6a and 6b show the distribution for the ratio, formalin wet weight/numbers. This is an estimate of the mean weight of individuals at each station. For both species a well-marked pattern exists with a trend of increasing mean size from the south and west into the Bay of Fundy. All this suggests that the life history of these populations can be completed within the Bay of Fundy area.

Length-frequency data and variation in year-class size

Preliminary analysis of length frequency data indicates polymodality, and from knowledge of growth rates of the species involved the modes can be equated to year-classes (Kulka, in preparation). Considerable variation in year-class size can be inferred which implies that year-to-year changes in population size is a recruitment phenomenon.

Occurrence of other Euphausid species

Figure 6 is an occurrence plot for other Euphausid material in the collection. *T. longicaudata* is not common. It is characterized as an "offshore species", more abundant to the south of the Bay of Fundy (Manchine and Fisher 1969). *T. raschii* is a neritic species and is common and abundant in Arctic and northern coastal waters. The Bay of Fundy thus represents almost the southern extreme of its range. *T. greganá* is a southern species here occurring at the northern limits of its range, as is *Nematoscelis megalops*, which, in addition, is another "offshore" form. *Euphausia krohnii* was recorded as a single specimen caught off Digby Neck. It is not normally found in coastal waters.

DISCUSSION

The Bay of Fundy is well known as an area of extremely energetic hydrographic conditions both tidal and non-tidal (see Iles this meeting). That, despite this, populations of zooplanktons may not only maintain a characteristic localized and concentrated position from year to year, but also within the year, carry out seasonal movements on an apparently organized basis argues for subtle and biologically significant behaviour in relation to water movements. Confirmation of the "stock" status of these Euphausid species is therefore of the greatest importance and perhaps because of this demands strong supporting evidence. That discrete population units of other crustacean zooplanktons may exist in the area has recently been suggested for

Mysis stenolepis by Amaratunga and Corey (1975) within Passamaquoddy Bay. Here the discreteness of the population is explainable by its occurrence in a body of water with well marked physical features conducive to isolation. The occurrence of distributional limits in the "open sea" raises different kinds of questions, and it would appear that the Bay of Fundy is an ideal study area for investigation. For it seems possible that a number of zooplankton species exist within it as discrete stocks (Iles 1975a, this meeting) so that their interaction and the interaction with populations of fish species, for example, may throw a great deal of light on what may be referred to as the ecological structure of marine systems.

The Euphausids are of more obvious interest as the food of both adult and juvenile herrin in the Bay of Fundy. In particular, the summer-fall distribution of surface-swarming Euphausids corresponds quite well with the area of highest catches of "sardine" herring (Iles 1975b, this meeting) so that more detailed study is of both practical and biological significance.

SUMMARY

During the course of a 4-year study (1971-74) on the distribution, abundance and life-history of Euphausids in the Passamaquoddy Bay area, one of us (D.W.K.) found evidence to suggest regular seasonal movements in and out of the study area. Material collected during herring larval survey cruises from 1969 to 1975 in the Bay of Fundy area - outside Passamaquoddy Bay - was made available in 1975.

Analysis of this material confirmed the existence of seasonal migrations of Euphausids in and out of Passamaquoddy Bay and allowed their description as part of wider distributional patterns and movements.

The Bay of Fundy distribution apparently represents seasonally expanding and contracting units of concentration with recognizable centres of origin. The appearance of Euphausids inside Passamaquoddy Bay is then seen as an incursion during a

summer-fall expansion of the population. The winter-spring distribution (November-June) is the contracted phase found in the Bay of Fundy proper. During this period growth is relatively very slow. Breeding occurs towards the end of this period (April-June) and the subsequent distribution of larvae is observed to be largely to the south of the adult distribution.

During the expanding phase Euphausids exhibit the phenomenon of "surface swarming" at and near the entrance to Passamaquoddy Bay, more obvious in the younger stages. This is probably associated with special hydrographic conditions in the area.

Similar distributional patterns and seasonal migratory movements have been described, within Passamaquoddy Bay, for *Mysis stenolepis*.

The following seven species of Euphausid have been identified in the study area:

Meganyctiphanes norvegica	(M. Sars)
Thysanoessa inermis	(Krøyer)
T. longicaudata	(Krøyer)
T. raschii	(M. Sars)
Euphausia krohnii	(Brandt)
T. gregaria	G. O. Sars
Nematoscelis megalops	G. O. Sars

Of these, the last three are new records for the area.

ACKNOWLEDGMENTS

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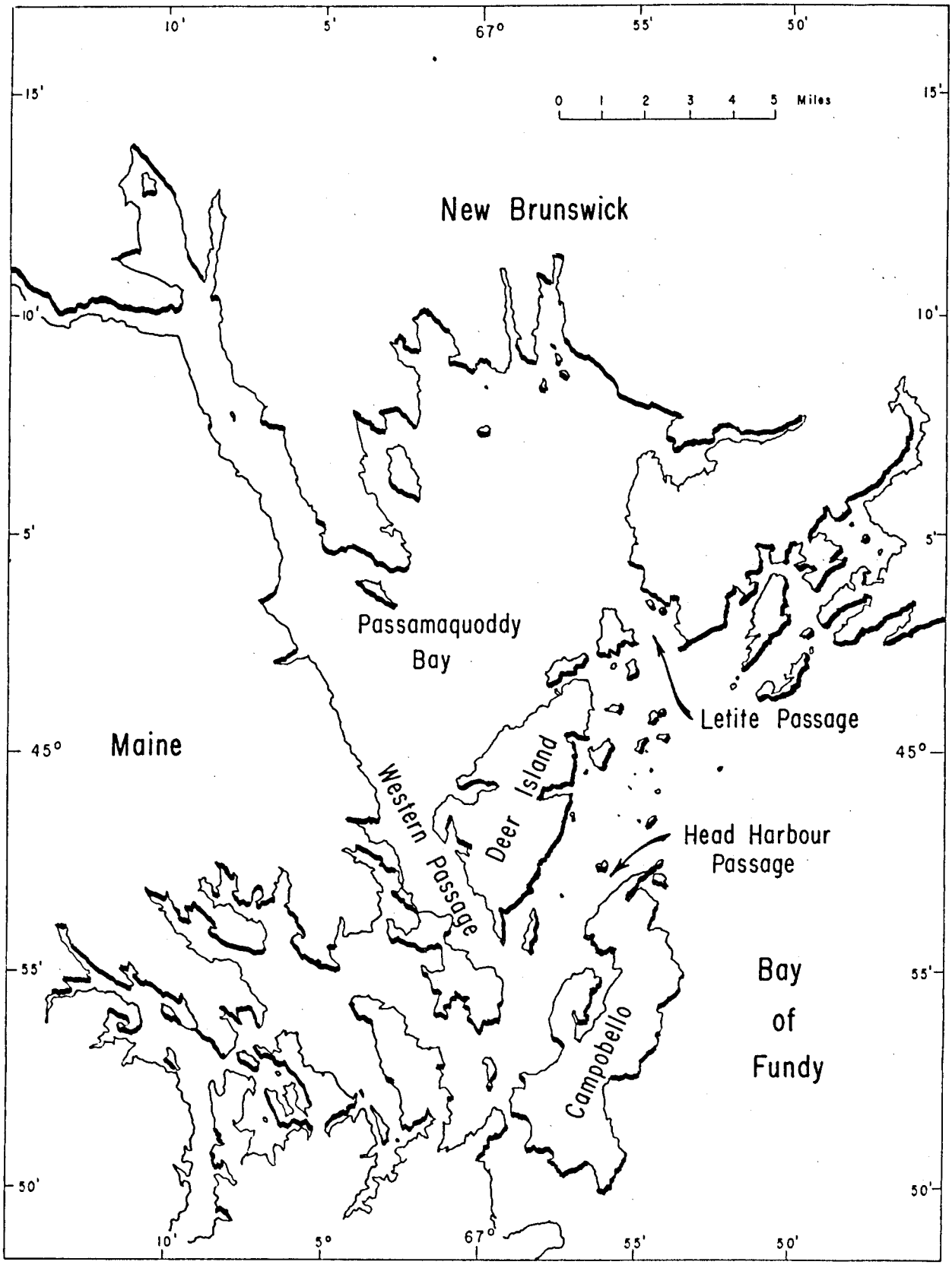


Figure 1. Sketch map of Passamaquoddy Bay and the "passages".

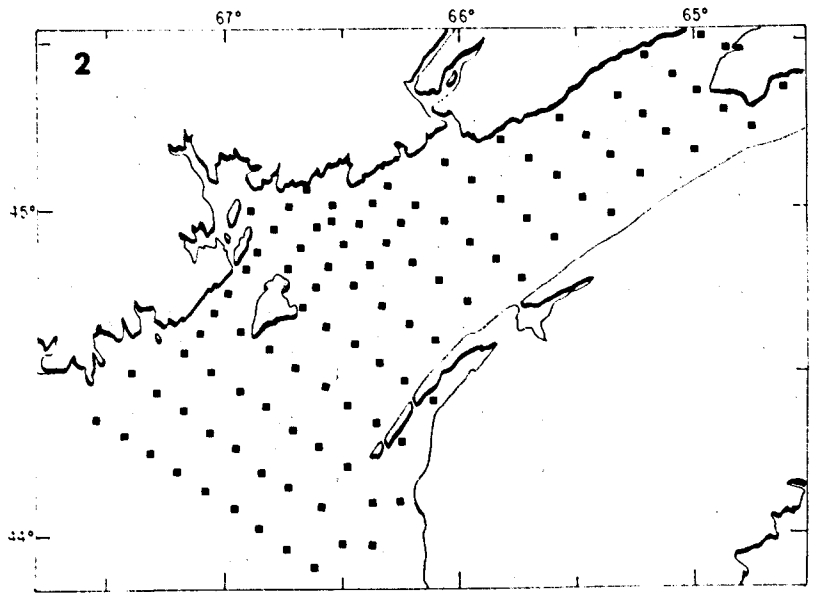
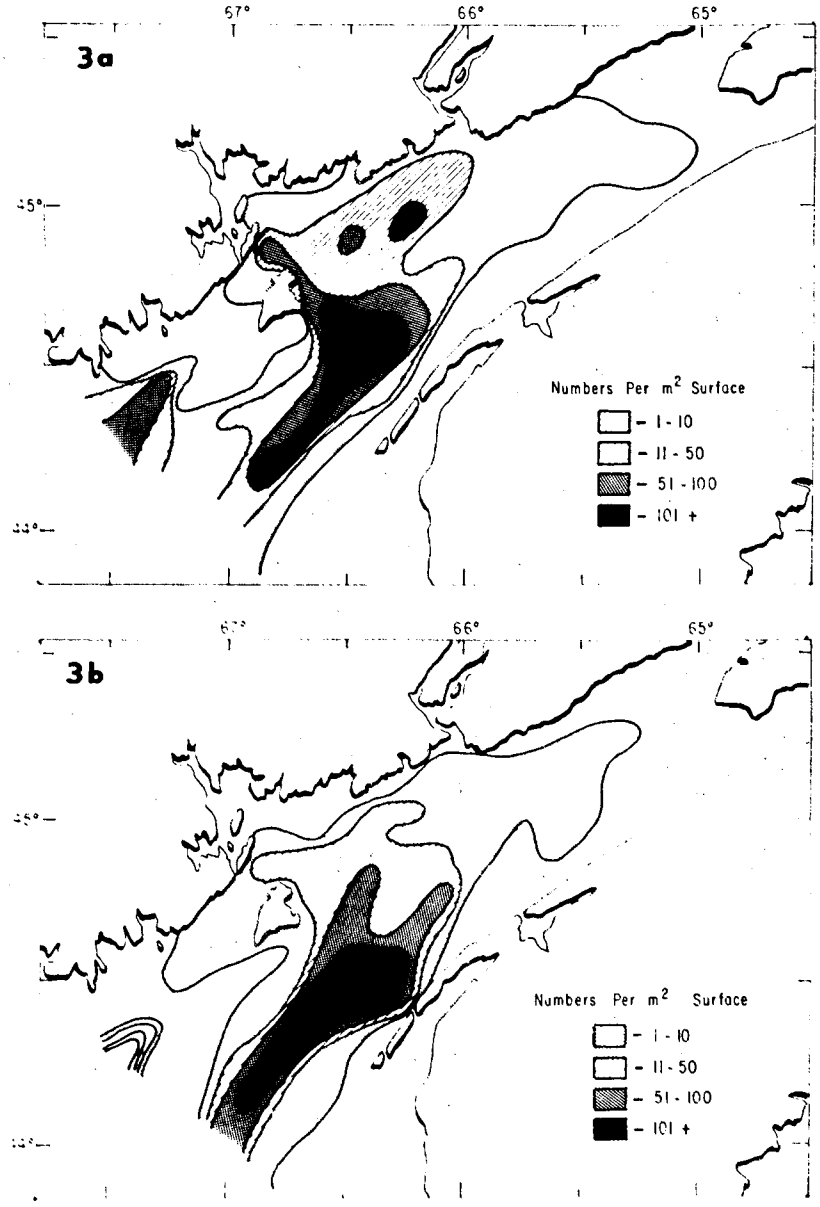


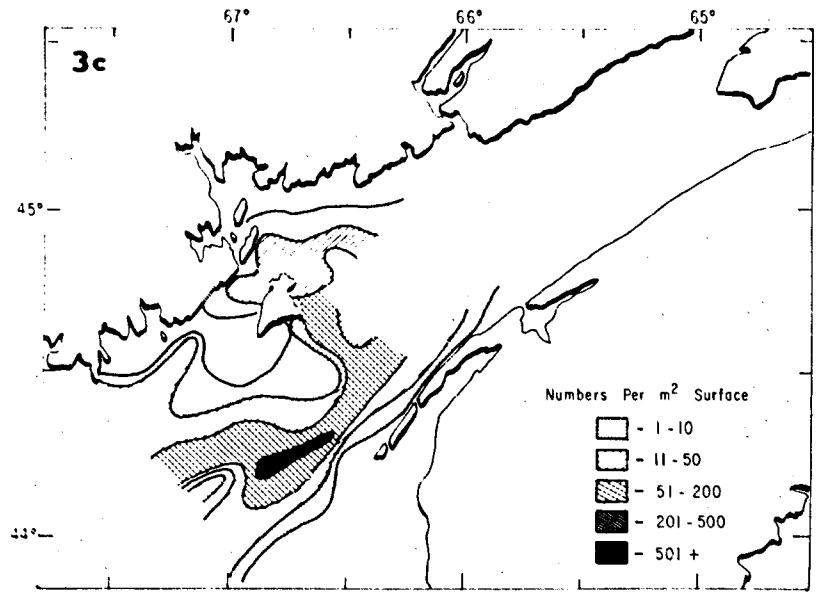
Figure 2. Plankton sampling stations.



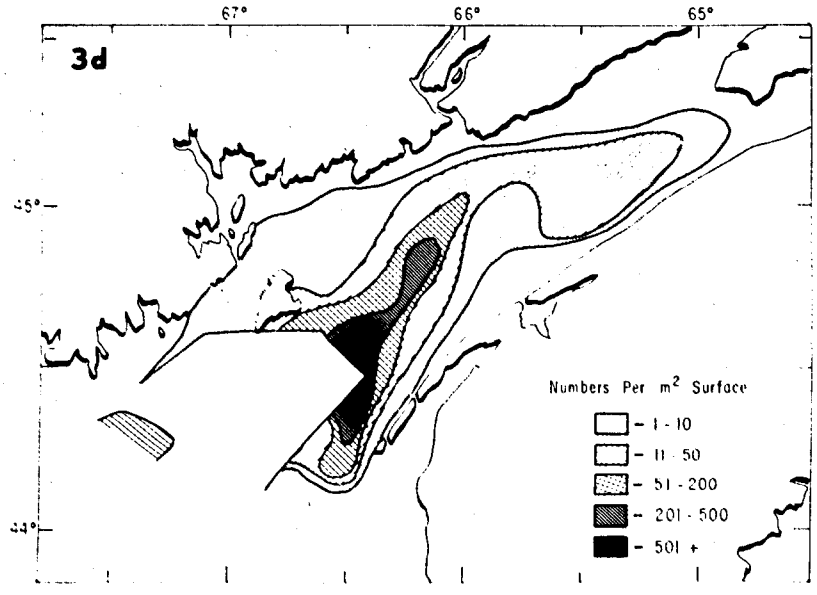
November 1972

March 1973

Figure 3. Distribution of *Meganyetiphanes norvegica*.



March 1974



November 1974

Figure 3 (continued). Distribution of *Meganyctiphanes norvegica*.

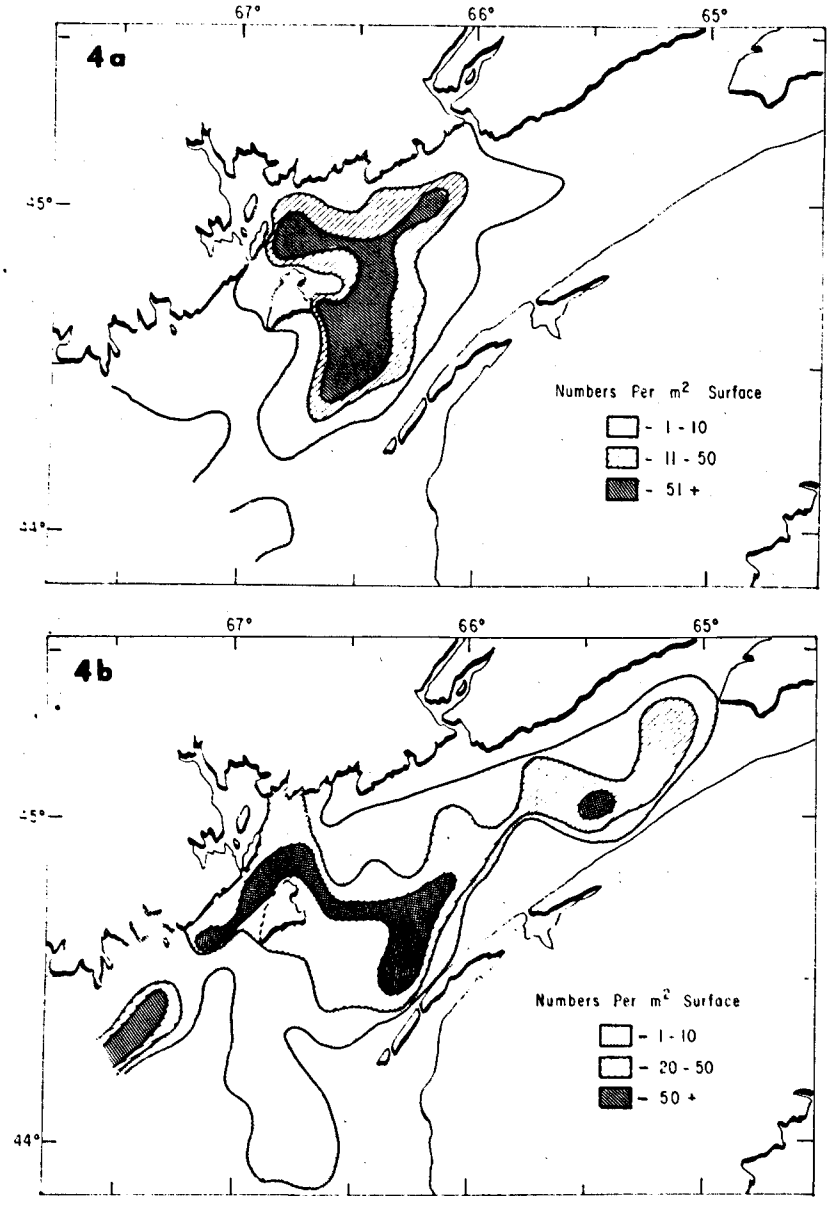


Figure 4. Distribution of *Thysanoessa inermis*.

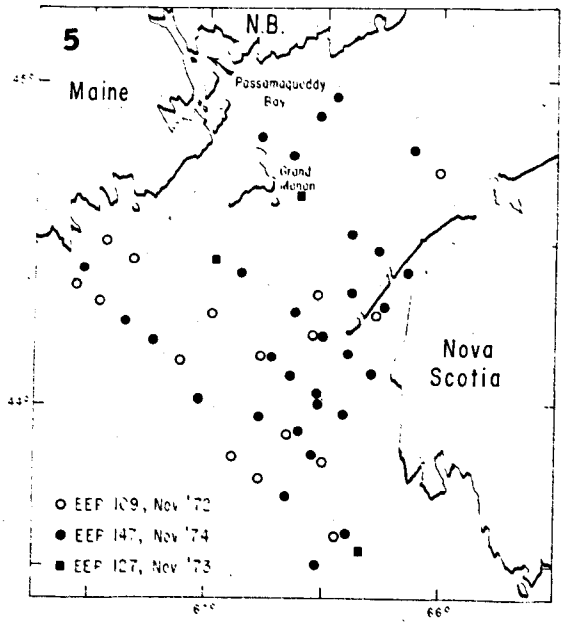
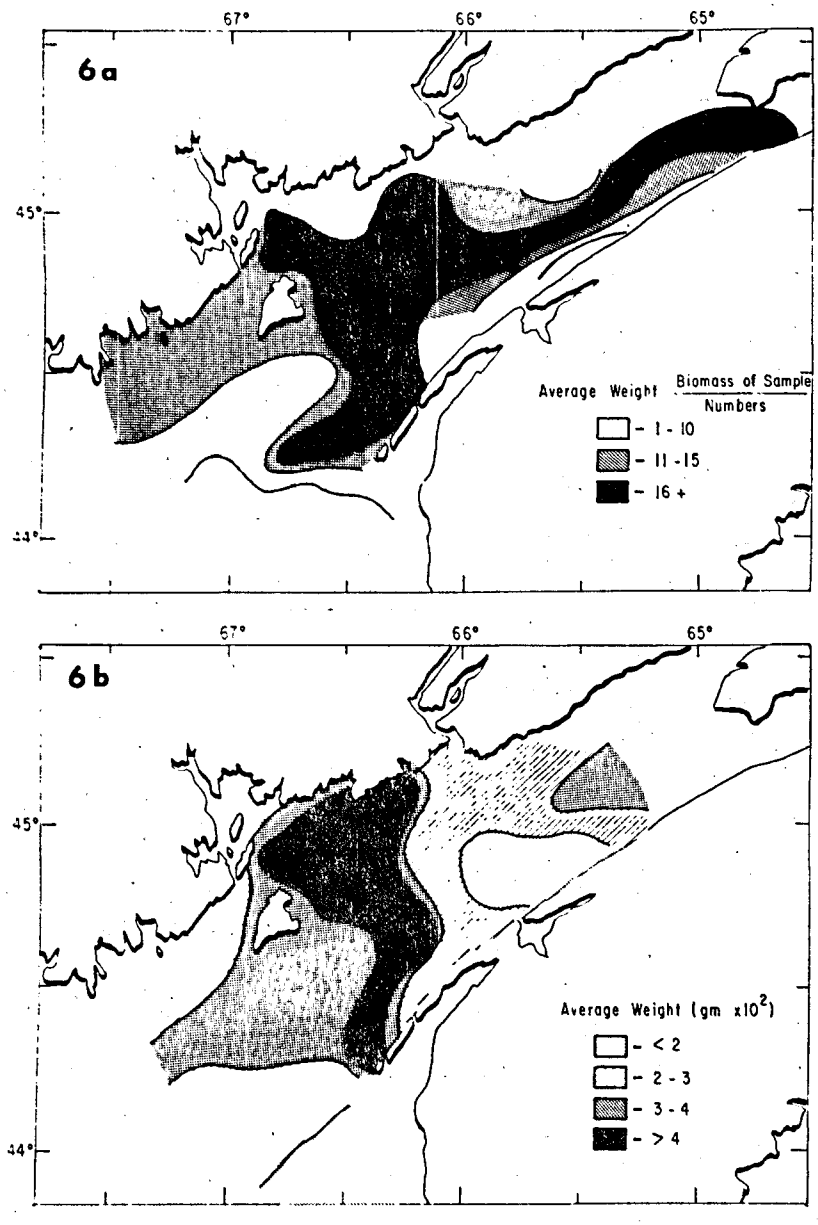


Figure 5. Distribution of larval euphausids. Combined occurrence for month of November 1972, 1973 and 1974.



Meganyctiphanes norvegica

Thysanoessa inermis

Figure 6. Distribution of average weight (Formalin wet weight/biomass).

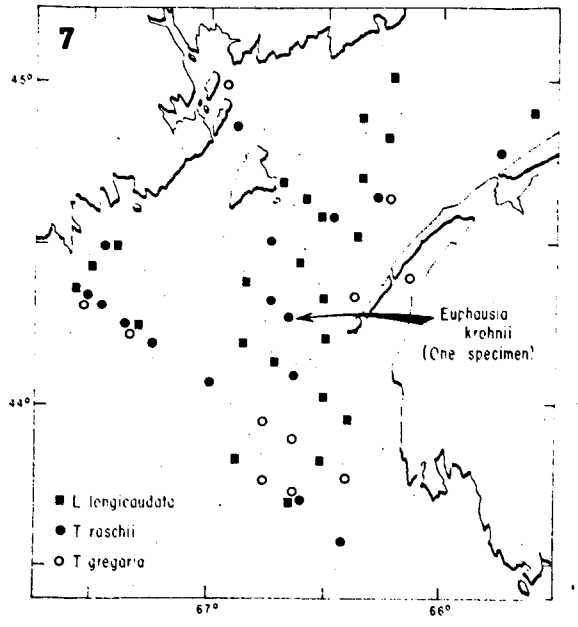


Figure 7. Records of other species of Euphausids in study area.