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Euphausiids on the Eastern Continental Shelf

by

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Abstract

Three species of euphausiids are commonly found on the continental shelf of the Maritime Region, *Thysanoessa rashii, T. inermis* and *Meganyctiphanes norvegica* . *M. norvegica* is the largest of the three species reaching a maximum length between 3 and 4 cm and is the target species for commerical exploitation. *M. norvegica* lives up to three years, but the majority of the animals will not live past two years of age. They mature at age one year with breeding occurring in late June and early July after which time many of the adults die. All species of euphausiids have a diurnal migration and are found in the top 50 m during the night and in deeper water during the day. *M. norvegica* prefers water depths greater than 200 m during the day and as a result they are concentrated in the basins on the Scotian shelf. This allows an accurate estimate to made of their population size. The population size and biomass are estimated with the use of multifrequency acoustics and special sampling gear. In Emerald Basin, on the Scotian Shelf, the population biomass of *M. norvegica* for the period 1984 to 1996 has shown large year to year fluctuations. The estimated average biomass standing stock of *M. norvegica* in Emerald and La Have Basins for June during the above period is over 52,000 mt, and for the entire Scotian Shelf and slope is over 123,000 mt.

Résumé

Trois espèces d'euphausiacés sont communément retrouvées dans les eaux de la plate-forme continentale de la région des Maritimes, notamment *Thysanoessa rashii, T. inermis* et *Meganyctiphanes norvegica*. Cette dernière, dont la longueur maximum de 3 à 4 cm en fait la plus grosse des trois espèces, est la cible d'une pêche commerciale. *M. norvegica* peut vivre jusqu'à trois ans, mais la plupart des individus n'atteignent pas plus de deux ans. L'espèce atteint la maturité à un an. La ponte a lieu vers la fin de juin et au début de juillet, après quoi nombre d'adultes meurent. Toutes les espèces d'euphausiacés effectuent une migration nycthémérale, fréquentant les 50 m de la surface pendant la nuit et les eaux plus profondes le jour. Comme *M. norvegica* recherche les eaux au-delà de 200 m pendant le jour, on la retrouve surtout dans les bassins du plateau néo-écossais, ce qui permet de faire une estimation précise des effectifs. La taille et la biomasse de la population sont estimées à l'aide de techniques acoustiques multifréquentielles et d'engins d'échantillonnage spéciaux. Dans le bassin d'Émeraude du plateau néo-écossais, la biomasse de la population de *M. norvegica* a beaucoup fluctué d'une année à l'autre entre 1984 et 1996. La biomasse moyenne estimée du stock actuel de l'espèce dans le bassin d'Émeraude et le bassin LaHave en juin de cette période se situe à plus de 52 000 tm, et à plus de 123 000 tm dans le cas du plateau néo-écossais et de la pente continentale.

Introduction

Three species of euphausiids are commonly found on the continental shelf of the Maritime Region, *Thysanoessa rashii, T. inermis* and *Meganyctiphanes norvegica. M. norvegica* is the largest of the three species reaching a maximum length between 3 and 4 cm (Fig. 1). The other two species are similar in length at maturity (approximately 2.5 cm). *Thysanoessa* species have a one year life cycle with planktonic eggs released in the spring (April to May). *M. norvegica* lives up to three years, but the majority of the animals will not live past two years of age. They mature at age one year with breeding occurring in late June and early July. Because *M. norvegica* is the largest of the euphausiids it has become the prime target of the fishing industry in the Maritime region. However, the *Thysanoessa* species are commercially fished in the Laurentian region and if concentrations of this genus were located in this region they also would be targets for commercial exploitation.

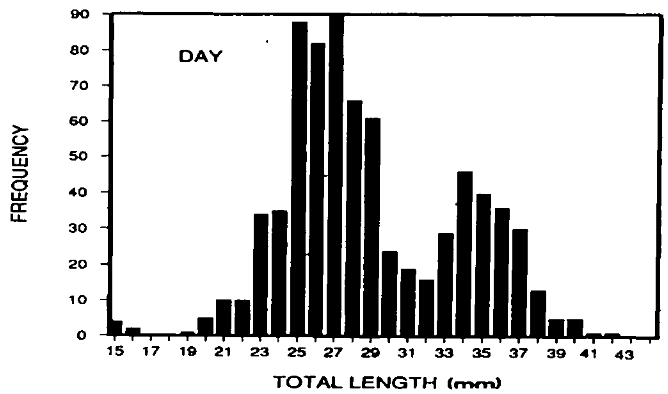

Fig. 1. The total length frequency distribution of *M. norvegica* collected between 200 and 255 m during daylight hours in Emerald Basin during June.

All three species of euphausiids have a diel vertical migration. During the day they are found in deep water and at night they usually migrate to the upper 50m of water. *Thysanoessa* has a shallower daytime depth preference than does *M. norvegica. Thysanosessa* spp. are found at about 150 m during daylight hours, whereas *M. norvegica* prefers depths greater than 200 m during the day. The daytime depth preference influences where the different species are found on the shelf. *Thysanoessa spp.* may be found anywhere on the shelf in low concentrations, but we cannot predict where large concentrations of these species will be located. Because of *M. norvegica*'s behavior in preferring a daytime depth of greater than 200 m we can predict where concentrations of this species will be found. On the Nova Scotian Shelf, Bay of Fundy, Gulf of Maine and the edge of the continental shelf concentrations will likely occur between 200 and 1000 m depth (Fig. 2).

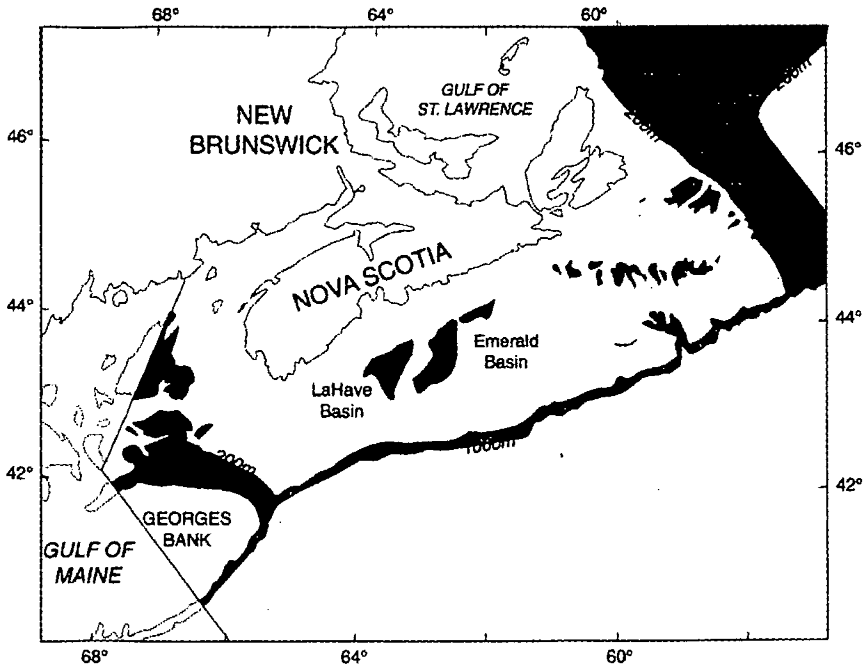

Fig. 2. Regions on the continental shelf (shown in black) of the Maritime Region in which *M. norvegica* is concentrated.

Euphausiid concentrations and biomass are difficult to estimate because of their ability of avoid plankton nets due to their keen eyesight. Therefore special sampling techniques have been developed to provide accurate estimates of euphausiid abundance. These involve sampling with strobe lights mounted on the BIONESS (Sameoto et al. 1993) and BATFISH (Herman et al. 1993 and Sameoto et al. 1990) that blind the animals and reduce net avoidance, plus the use of multi-frequency acoustics between frequencies of 200 and 12 kHz. The BIONESS samples are used to ground truth the presence of the euphausiids in observed acoustic scattering layers. Good agreement has been found between the biomass and concentrations of euphausiids made from net samples and the acoustic estimates (Sameoto, Cochrane and Herman 1993).

Acoustic Backscattering

The most accurate method of estimating the biomass of krill is to use multifrequency acoustics and an appropriate acoustic backscattering models for krill (Stanton et al. 1994). It is necessary to use multifrequency acoustics in order to separate the backscattering echos of the euphausiids from fish. Acoustic backscattering levels at 153 kHz were recorded throughout the water column along the Halifax Line during April, July and October 1995 using a RDI ADCP (Cochrane et al. 1994, Zhou et al. 1994, RD Instruments 1990). The recorded backscattering was primarily from macrozooplankton and micronekton in the size range of 0.5 - 4 cm length. On the Shelf the principal acoustic scatterers at this frequency are euphausiids both juveniles and adults (Cochrane et al. 1994, 1991). Therefore these acoustic data are good indicators of comparative euphausiid abundances both across the shelf and between different months of the year. The changes in volume backscattering strength from euphausiids correspond to changes in their biomass concentration or population density, (i.e. a 10 dB change in backscattering corresponds to a 10 fold change in biomass density).

Simultaneous with the recording of the RDI data, acoustic backscattering data at 12, 50, 105 and 200 kHz were also recorded using conventional echosounders. The 12 kHz frequency provided information on the relative abundance and distribution of juvenile and adult fish throughout the water column. **(In the following discussion the term 'fish' will mean any fish in the water column including ground fish.)** During the spring the dominant pelagic and larval fish on the shelf was sandlance; in the fall it was the silver hake. By comparing the levels of backscattering at 12 kHz and 200 kHz it is possible to detect changes in the relative abundance of fish and euphausiids between different locations and seasons as well as to detect year to year abundance variations.

Seasonal Changes in 153 kHz Backscattering

April 1995

High daytime levels of 153 kHz backscattering were detected in the region of Emerald Basin extending from a depth of 200m to near bottom (Fig. 3). The levels of backscattering were as high as any we have recorded in the last 10 years. In contrast to the 153 kHz values the 12 kHz levels were quite low over the Halifax Line except for a small region in the deepest region of Emerald Basin and few small patches of high scattering on Emerald Bank. These data suggested a large population of euphausiids on the shelf and a low population of pelagic fish. There was little evidence for significant numbers of pelagic fish larvae and / or juveniles.

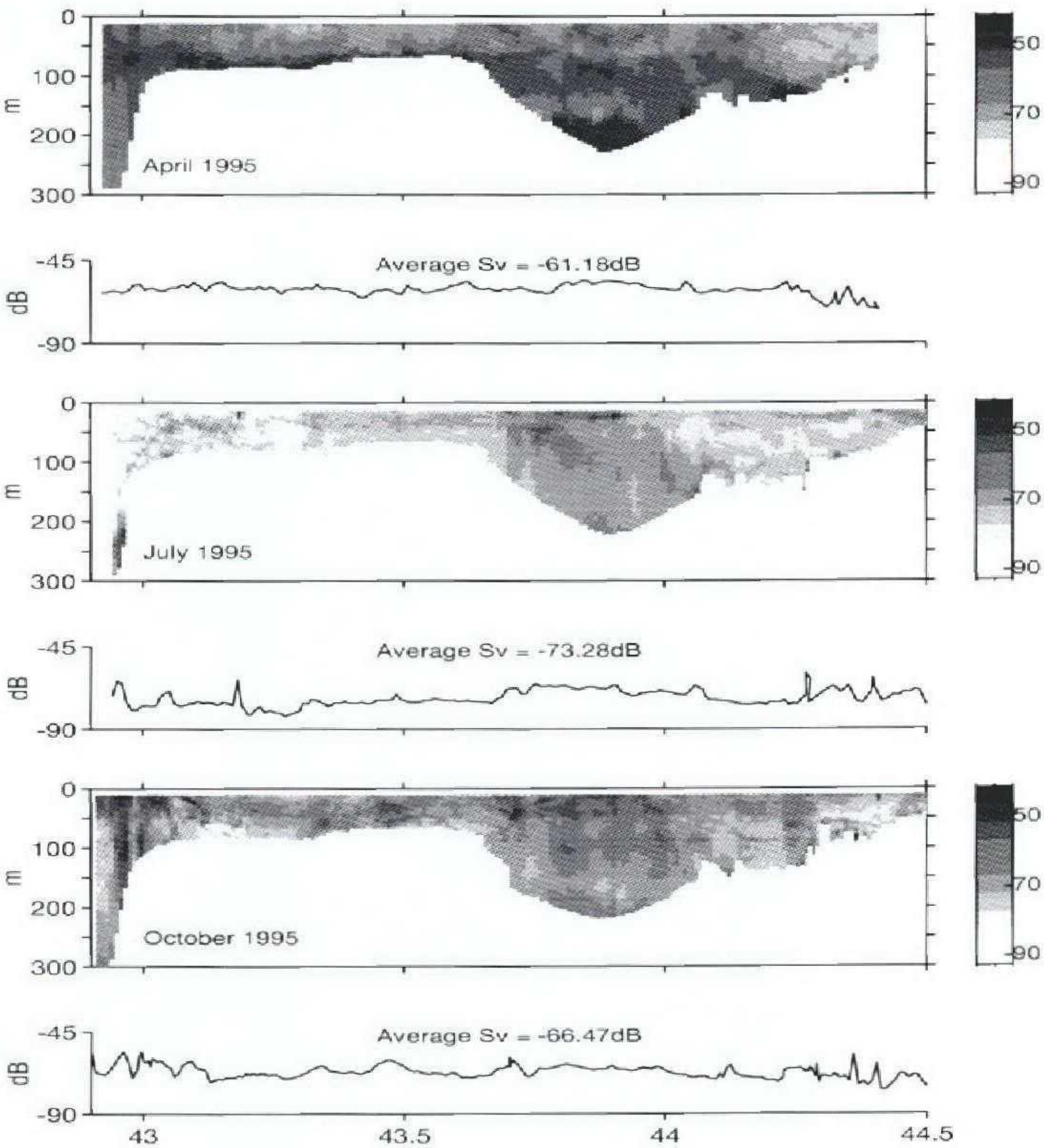

Fig. 3. ADCP (153 kHz) volume backscattering strength (Sv) across the Halifax Line during April, July, and October 1995 showing the dB contours and color bar plus the average water column backscattering per m^3 (line drawing) and the spatially averaged dB per m^3 for the entire Line.

July 1995

In July the levels of 153 kHz backscattering on the Halifax Line were significantly reduced (by a factor of 16 times) from those seen in April (Fig. 3). This reduction was due primarily to the normal die-off of euphausiids after their reproduction in June. However, it is possible that the abnormally warm water on the shelf at this time may have also adversely affected the growth of young euphausiids. The mesozooplankton (< 1 cm) abundances in this warm water layer were also extremely low.

October 1995

In October, 153 kHz backscattering levels were lower than those in November, 1992, (the only other year in which we have ADCP data for the fall period). Preliminary analysis of BIONESS samples of euphausiids confirmed that concentrations were abnormally low in October.

Euphausiid and Silver Hake trends 1984-1995

Acoustic data collected over the last decade in Emerald Basin has shown a close relationship between the integrated volume backscattering at 12 and 200 kHz (Fig. 4). The 12 kHz data reflect the concentrations of pelagic fish in the basin and the 200 kHz frequency data provide an accurate estimate of euphausiid concentrations. The levels at these two frequencies over the years 1985 to 1995 showed a significant positive correlation. Levels at both frequencies showed a general increase between 1985 and 1994 followed by a significant decrease in 1995. These data indicate a close relationship between pelagic fish and euphausiid abundance in Emerald Basin. Silver hake and redfish, the two dominant pelagic species, feed primarily on euphausiids in the Basin (Waldon, 1988). Preliminary results from June, 1996, indicate that the *M. norvegica* populations in Emerald Basin have increased compared to April, 1995.

VOLUME BACKSCATTERING AT 12 AND 200 KHZ IN EMERALD BASIN

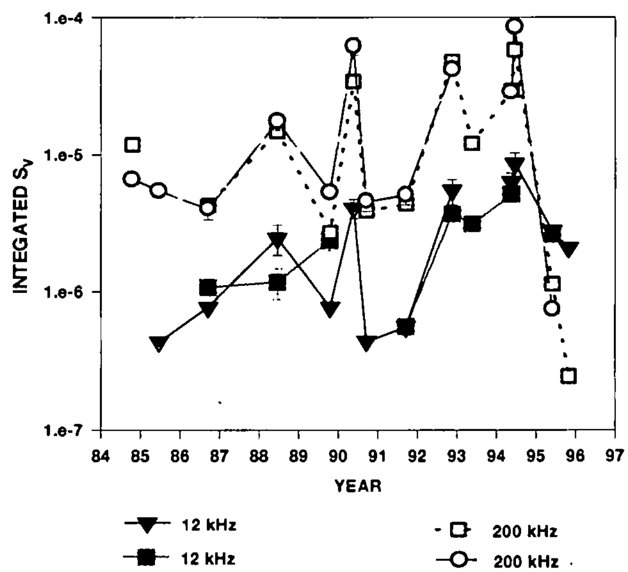

Fig. 4. Relationship between integrated volume backscattering for the pelagic fish (12 kHz) and euphausiids (200 kHz) in Emerald Basin from 1985 to 1995. Integration depth limits were chosen to separate the fish and euphausiid populations.

During the day *M. norvegica* forms layers that are often times found 10 to 20 m above layers of pelagic fish such a silver hake. At night the *M. norvegica* starts its upward migration just before sunset and is usually concentrated near the surface at midnight. If there are silver hake in the same waters as *M. norvegica* they migrate upwards starting at sunset just after the krill and are also found in the upper 50 m at night.

A high correlation was seen between the BIONESS net estimates of the biomass of *M. norvegica* and the acoustic estimates made from backscattering at 200 kHz (Fig. 5). In general the net estimates are much more variable because of the patchy distribution of the krill. The acoustic methods sample a much larger volume of water and therefore average out much variation due to patchiness resulting in a more accurate estimate of the true biomass.

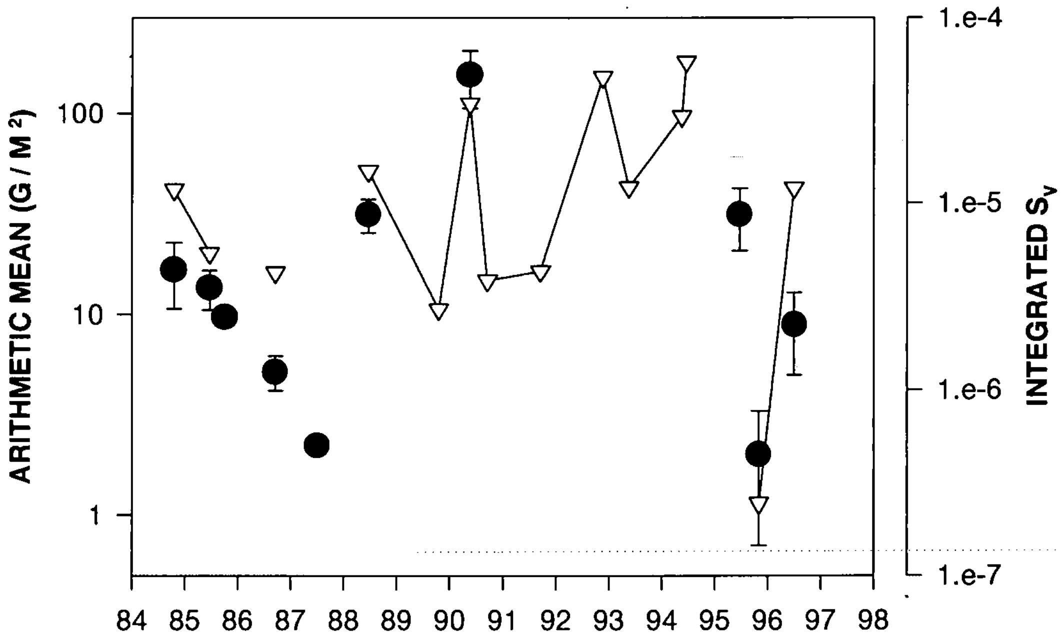

Fig. 5. Relationship between integrated 200 kHz volume backscattering (S_v) (the triangles)and BIONESS net estimates as arithmetic means (grams per m^2), solid circles are means and vertical lines are the standard errors of the mean. The arithmetic mean was used in order to make a valid comparison with S_v.

Importance of *M. norvegica* in the Pelagic Ecosystem

Thysanoessa spp. are primarily phytoplankton feeders and *M. norvegica* is an omnivore feeding on copepods, primarily *Calanus finmarchicus*. *C. finmarchicus* concentrates in the deep basins on the continental shelf during its seasonal migration and this may explain why *M. norvegica* concentrations are found in these regions.

Euphausiids are prey for most fish species on the shelf at some stage in the fish's life cycle. In addition euphausiids are preyed on by whales, seals, seabirds and are a primary prey of squid (Mauchline and Fisher, 1969). This makes euphausiids the major link in the food web between phytoplankton, small zooplankton and the large predators, such as fish, in the top trophic level.

Geographic Distribution and Standing Stock Estimates of *M. norvegica*

M. norvegica is found concentrated in basins on the shelf that are deeper than 200m. They are also located along the edge of the continental shelf between the 200 and 1000 m contour. These areas (Fig. 2) represent about 178000 km^2 or about 12 % of the area of the continental shelf. The highest concentrations of krill occur in Emerald and La Have Basins. These two basins together represent an area of about 5296 km^2. Based on net and acoustic data we estimate the average biomass of krill to be 10 g per m^2 in these two basins, therefore the total standing stock in the period between April and June is estimated to be about 31000 tons. After June the standing stock declines rapidly as a large percentage of the population dies after spawning.

If the average biomass in all waters greater than 200m was 2 g per m^2 , than the total estimated biomass in the regions would be about 263900 tons. The estimated standing stock of krill is given for different areas of the shelf in Table 1.

Table 1. The standing stock estimates of *M. norvegica* per km^2 in regions of the shelf deeper than 200 m and between 200 and 1000 m on the continental slope during the spring and summer.

Location	Area (km^2)	Krill biomass (mt)
Emerald and La Have Basin	5296	52960*
Basins in eastern half of Shelf	2399	4800**
Fundy Channel and Jordan Basin	7714	15000**
Continental shelf edge including Laurentian Channel (200-1000m)	25406	51000**
Total shelf		123760

* Based on an average biomass of 10 g per m^2.
** Estimates are based on the assumption of a biomass of 2g per m^2.

The regions likely to be fished the heaviest are Emerald and La Have Basins because of the predictability of the krill populations in these areas. During the last ten years the biomass of the krill population has fluctuated greatly, with year to year changes of up to 290 times. Ulmestrand and Hagstrom (1991) reported year to year changes in the krill populations of the Skagerrak and Kattegat over an eight year period of up to 60 times. Therefore it is not unusual to see large fluctuations in populations of krill. Because of the extreme changes that can occur in a period of one year it will be important to continually monitor the krill populations if a significantly large fishery for krill develops.

Discussion

M. norvegica is the only species of krill that we know exists in sufficiently high concentrations to be commercially exploited. *Thysanoessa spp.* are common and form high concentrations in isolated swarms, but at our present state of knowledge it is impossible to predict when and where they will be found.

The type of fishing gear that will be used to capture the krill will be a large fine mesh net (~2 to 10 mm mesh) with a relatively large mouth opening (~ 100 m^2). The nets will be fished at depths greater than 200 m during the day if the fishing boat has the proper acoustic sounders to locate the layers of krill. At night the nets will be towed at depths near the surface (the top 30m). Other possible fishing methods may involve lights mounted on the mouth of the nets or lights used to attract the krill to a large volume pump near the surface at night. The pump would bring water containing krill into a filtration net on the deck of the ship.

The proposed level of krill harvest (~ 1000 tons) would have an insignificant effect on the population even if the entire harvest is taken in the region of Emerald and La Have Basins. We don't know if populations in the Basins are replenished from other regions of the shelf by ocean current advection or by animal migration; but it is probable that some advection occurs. The major concern we have about a future fishery is the amount and type of bi-catch that will occur in the fine mesh nets. The main fishing effort will be during the months of March to June and therefore only pelagic species found in the water column during this period will be effected by the fishery.

Commercially fished euphausiids will be used to enhance a fish starter diet for young salmon. Roem and Kelly (1991) reported that salmon fry fed a diet supplemented with krill showed significantly better growth, feeding efficiency and survival than fish fed no krill or only krill. The krill meal also enhanced the feeding activity of the fish.

Future Scientific Work

There are number of scientific concerns and unknowns that need to be addressed in the future if a commercial fishery for krill is developed. These are :

a) Are krill stocks concentrated in the Shelf Basins rapidly replenished by passive advection or active migration from different regions of the shelf or are they largely self sustaining?

b) Undersampling the variability of krill stocks is a concern. At present major stock areas are sampling at most twice a year. Orders of magnitude variability occur between two consecutive samples (e.g. Emerald Basin between October 1995 and June 1996).

c) What is the best acoustic target strength for converting acoustic scattering levels to numeric concentrations for krill. There is much uncertainty in the existing models. We must improve our acoustic equipment calibration techniques in order to obtain more accurate population size estimates.

d) Acoustic assessment of krill populations on the continental slope is less advanced than in the Shelf Basins. More attention needs to be given to the stocks on the continental edge, particularly in the region of Georges Bank.

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