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Preliminary estimates of secondary production on Georges Bank

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Abstract

An estimate of the productivity of Calanus finmarchicus on Georges Bank was made on plankton data collected in the spring of 1940. This data although not ideally suited to this type of analysis did provide a preliminary estimate of the productivity of a major component of the zooplankton community. C. finmarchicus and Pseudocalanus minutus were the dominant species on all cruises. C. finmarchicus was most numerous around the periphery of the Bank while P. minutus was most abundant over the central portion. Plots of the distributions of both species indicate that neither population was encompassed completely by the sampling grid. Productivity was measured by a method similar to that described by Winberg et al. (1971) for populations in continuous reproduction. The total production of C. finmarchicus for the approximately 100 day period in spring was 79.46 mg C/m^2 per day. Due to the extrusion of smaller stages through the meshes of the sampling gear used, this estimate does not include naupliar stages and probably does not fully represent the contribution of the smallest copepodite stages.

Introduction

One of the major problems in understanding the trophic structure of marine ecosystems has been the lack of information on secondary productivity. Groundfish surveys and commercial catch records provide information on the abundance and production of the upper levels of the food chain, and methods to measure primary production are reasonably well defined and are applied routinely. However, the relatively short generation time of zooplankton necessitates frequent sampling, resulting in substantial investments in ship time. Furthermore, the processing of zooplankton samples is both tedious and time consuming. These factors combine to make estimates of secondary productivity a costly operation. Consequently data suitable for this kind of analysis for many oceanographic regions are rarely available. In an effort to estimate the secondary productivity of Georges Bank we have had to use available data which was less than ideally suited for analysis by established methods. The plankton data used were obtained on five surveys over Georges Bank in the spring of 1940 in connection with studies of the distribution of Sagitta elegans

(Clarke, et al., 1943). The cruise numbers and dates are listed in Table 1. Zooplankton was collected by means of quantitative oblique tows with Clarke-Bumpus samplers arranged vertically to divide the total depth of water into two or three strata. The samplers were equipped with 0.366 mm mesh nets and towed at a speed of 2 knots. Three depth strata were sampled depending on bottom topography: 0 to 22 m, 22 m to 56 m, and 56 m to 104 m.

Calanus finmarchicus and Pseudocalanus minutus were the dominant species caught on all cruises. The production of C. finmarchicus was estimated and its distribution was compared with that of P. minutus. C. finmarchicus was separated into copepodite stages I-V and adults (male and female) and P. minutus into immature and adults (male and female). For each station the number of C. finmarchicus and P. minutus instars per cubic meter was calculated for each depth stratum and the total number under a square meter of surface area determined by multiplying the No./m^3 for each station by the sampling depth and then adding the products. Metasome lengths and dry weights of the first two and last two developmental stages of C. finmarchicus overlap, so that for this study the stages were grouped as follows: Group 1 - copepodites I&II, Group 2 - copepodite III, Group 3 - copepodite IV, Group 4 - copepodite V+adults.

The mean abundances of the four developmental groups of C. finmarchicus and of immature and mature P. minutus for the five cruises are listed in Table 1, and their distribution during the period 19-27 June (Atlantis Cruise 100) is shown in Figure 1. Undersampling of early stage C. finmarchicus (copepodites I-III) due to extrusion is evidenced by the anomalous numbers of successive stages caught on consecutive cruises. As noted previously by Clarke, et al. (1943) P. minutus was most abundant over central Georges Bank ("mixed area") and C. finmarchicus occurred in greatest numbers around the periphery of the Bank. Unfortunately, the area sampled did not encompass the distribution of the entire populations of P. minutus or C. finmarchicus. Distribution patterns indicate incursions of individuals of both species from the northwest and occasionally from the northeast and excursions to the south and southwest.

Method

Initially the cohort production method (Mann, 1956) appeared most applicable to the C. finmarchicus data for computing productivity. However, the under-sampling of early stages and the apparent shift in the distribution of the population across the bank made it impossible to follow the development of cohorts through successive stages over the spring season. In view of these limitations production was estimated from a plot of instantaneous growth rates calculated for each of the five cruises. This is essentially the method described by Winberg, et al. (1971) for populations with continuous reproduction.

The method requires estimation of the weight change in the population as the various instars progress through successive molts. Length data from measurements of over 4,000 C. finmarchicus taken on Albatross IV 75-03 were used to generate a weight frequency histogram based on the length vs. dry-weight relationship developed by Schwartz (1977). The range of weights occurring in each stage provided a measure of the weight gained. This weight gain divided by the stage duration in days (Marshall and Orr, 1955) represents the weight increase per individual per day (Table 2). Production per day was computed by multiplying the weight increase per individual per day by the number in each stage for the Atlantis cruises and summing over all stages. In order to account for natural mortality during each instar the number in each copepodite stage was averaged with the number in the succeeding stage to estimate the number surviving to the next molt. Because stage V and adults were combined and there is no growth past the adult stage, these counts were averaged with zero. Hence, production per day is calculated from the formula:

$$P = \frac{W_B - W_A}{t} \quad \frac{(N_1 + N_2)}{2}$$

Where: W_A = weight at the beginning of a stage

W_B = weight at the end of a stage

t = stage duration in days

N_1 = count of organisms in a stage

N_2 = count of organisms in the succeeding stage

The production per day for all stages was summed for a total production rate for each cruise (Table 3). The total production rate was plotted against the duration of the sampling period for each cruise. The area under the curve was taken to give total production for the approximately 100 day period (Figure 2).

Results and Discussion

The total production estimated from this method equaled 198.65 mg dry weight/m^2 per day or 79.46 mg carbon/m^2 per day using a conversion factor for dry weight to carbon of 0.40 (Mullin, 1969). This is in excess of but in the same order of magnitude as the value of 46 mg C/m^2 per day as calculated by Mullin (1969) for data from Cushing and Vucetic (1963) for a copepod patch consisting mainly of *C. finmarchicus* for the same time period in the North Sea. Heinle (1966) reported a production of 77 mg/m^2 per day for *Acartia tonsa* in the Chesapeake Bay in the summer. However, it should be pointed out that most studies of secondary productivity are done with much finer nets, so that not only are the copepodites sampled adequately but also naupliar stages and egg counts are included. The contribution of these stages is possibly quite substantial and could lead to even higher rates. The situation is further complicated by the fact that the population of *C. finmarchicus* does not appear to have been encompassed by the sampling grid. Incursions and excursions of portions of the population may lead to wide fluctuations in the productivity depending upon the sampling interval.

This attempt although limited by the inherent sampling biases, represents a first approximation to estimating secondary production in the Georges Bank area. The estimate will be refined as data become available from the MARMAP ichthyoplankton/zooplankton surveys now underway in the region.

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Table 1. Mean abundance (No./m^2) of *Calanus finmarchicus* and *Pseudocalanus minutus* on Georges Bank during spring, 1940.

Atlantic Cruise No.	Date	*C. finmarchicus* I&II	III	IV	V,♂,♀	Total	*P. minutus* Imm.	♂,♀	Total
95	25 Mar-2 Apr	0	147	286	958	1391	14255	7365	21620
96	17-29 Apr	7819	3399	1012	887	13117	11860	6910	18770
97	9-16 May	23452	12948	7537	3850	47787	21837	10465	32302
98	1- 8 June	8282	7723	21249	10395	47647	35375	19001	54376
100	19-27 June	211	2102	23932	18564	44809	33275	26372	59647
	Mean	7953	5264	10803	6931	30951	23320	14023	37343

Table 2. Weight gain and duration of stages of *Calanus finmarchicus* from *Albatross IV* 75-03

Stage	Weight Change (mg)	Stage Duration (days)	Weight Gain/Day
I&II	.00850	5	.00170
III	.01450	3	.00483
IV	.03850	3 1/2	.01100
V+adults	.23000	10 1/2	.02190

Table 3. Production of *Calanus finmarchicus* by stages and total production by cruise in mg dry weight/m^2/day

Cruise		I-II	III	IV	V+adult	Total
Atlantis	95	.1250	1.0457	6.8420	10.4901	18.5027
	96	9.5353	10.6526	10.4445	9.7127	40.3450
	97	30.9400	49.4713	62.6285	42.1575	185.1973
	98	13.6043	69.9674	174.0420	113.8253	371.4389
	100	1.9661	62.8721	233.7280	203.2758	501.8420

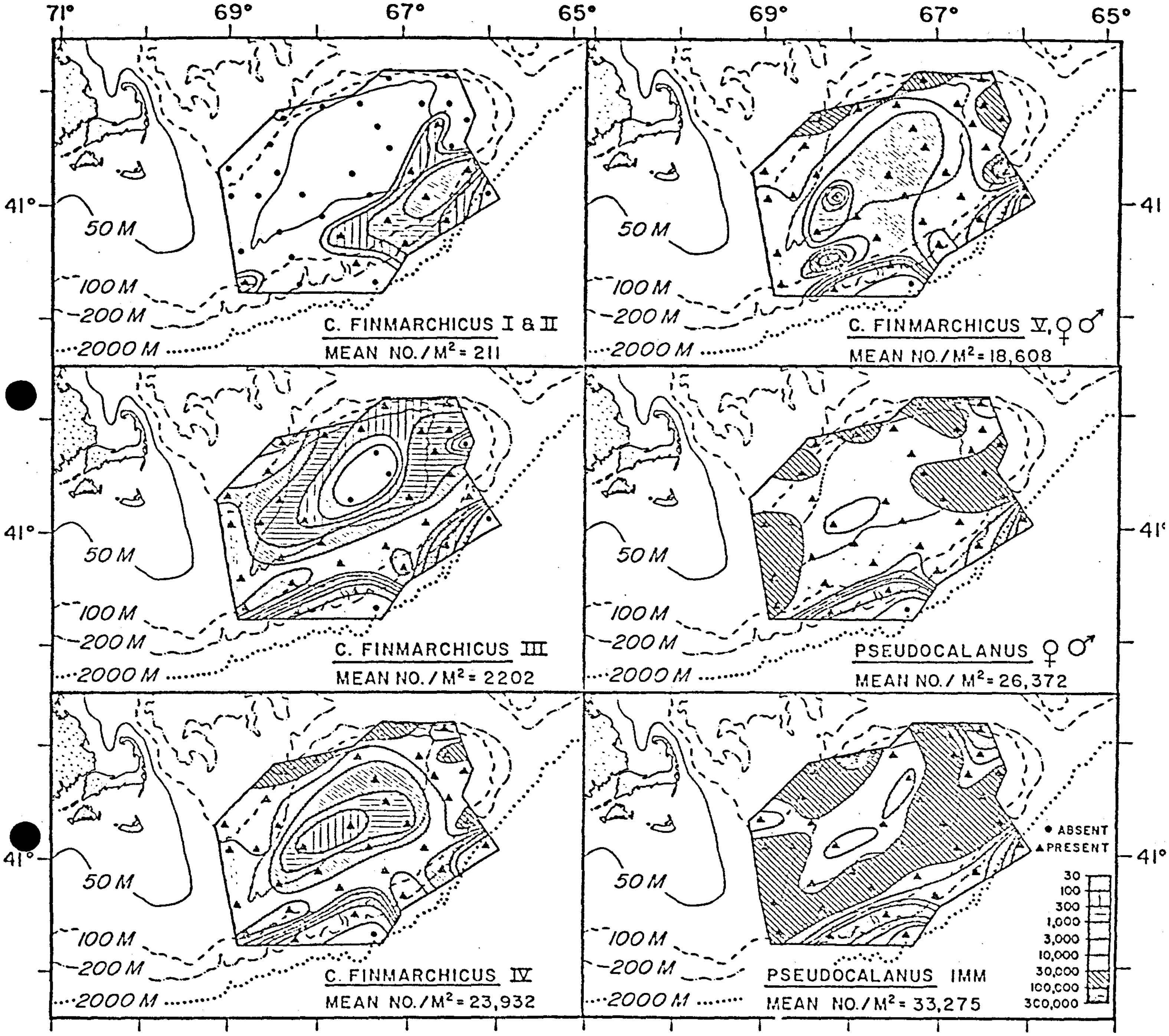

Figure 1. Plots of the distribution of *Calanus finmarchicus* and *Pseudocalanus minutus* for R/V *Atlantis* cruise 100. 19-27 June 1940.

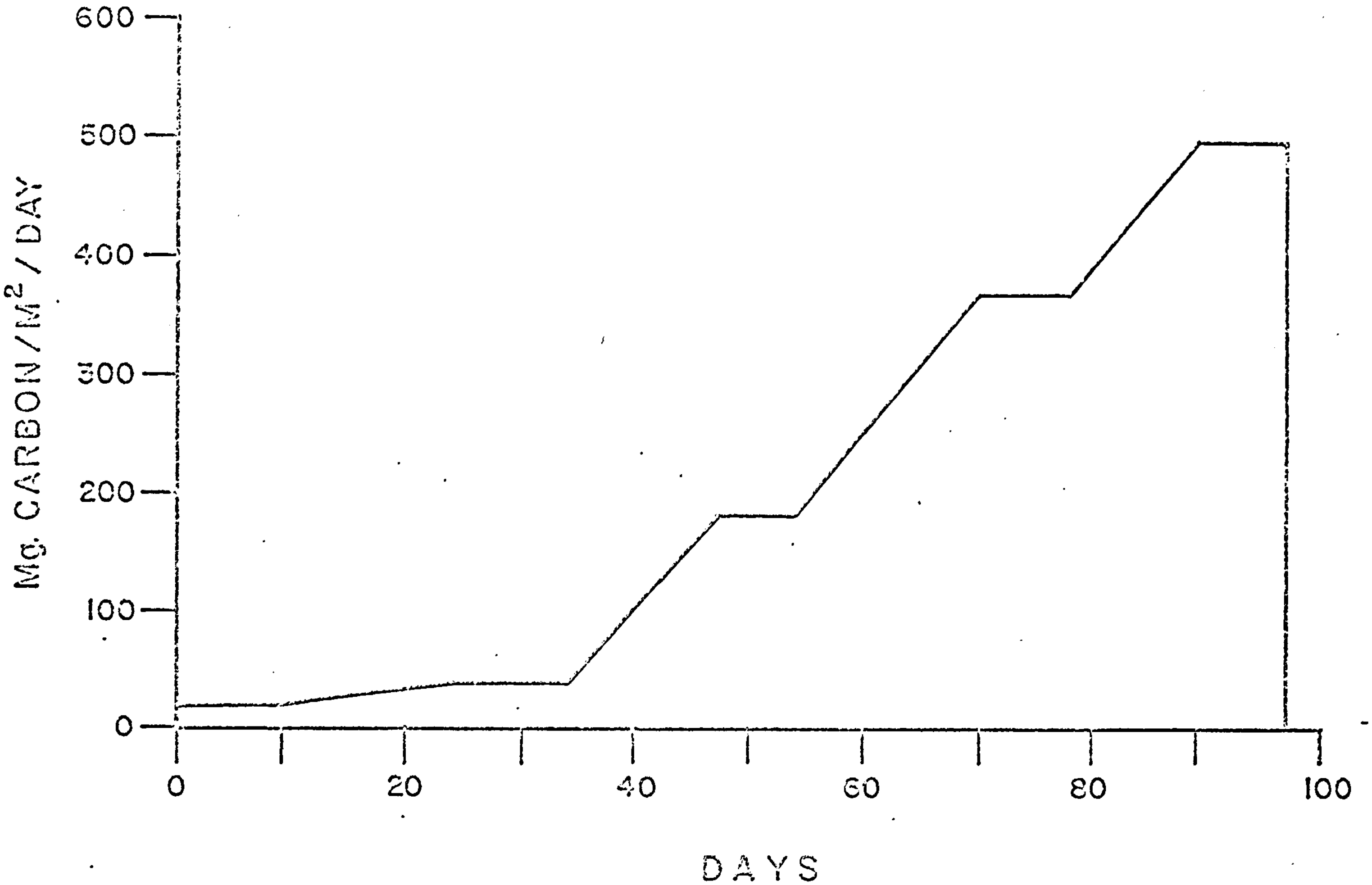

Figure 2. Plot of production rates of C. *finmarchicus* over the four month sampling period.