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Characteristics of egg production of the planktonic copepod, *Calanus finmarchicus*, on Georges Bank: 1994–1999

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Abstract

We present here a synthesis of observations of egg production rates (EP) of the planktonic copepod, *Calanus finmarchicus,* carried out during process cruises of the US GLOBEC Northwest Atlantic/Georges Bank program between January and June 1995, 1997 and 1999. Female *C. finmarchicus* produced eggs at relatively high rates in at least some regions of Georges Bank during all months between January and June. Median, monthly EP varied between 24 eggs female^{-1} d^{-1} in January to 50 eggs female^{-1} d^{-1} in April–June; the highest mean EP was 86 eggs female^{-1} d^{-1}. Mean egg diameter was negatively related to ambient mean water-column temperature (0–100 m or bottom), decreasing from 149 to 142 μm between January and June. Direct measurements of body C or N or prosome length–mass relationships were used to determine mass-specific egg production rates. The relationships between estimates of chlorophyll *a* standing stock (mg chl. *a* m^{-2}) and both C- and N-specific rates (% d^{-1}) are reasonably well ($r^2 = 0.42$) described by Ivlev curves. It is likely that chlorophyll standing stock serves as a proxy of both phytoplankton and microzooplankton food concentrations available to adult females. Chlorophyll standing stocks were below the critical concentration (at which EP is 95% of the calculated maximum) at approximately 55% of stations occupied over the study period, indicating frequent food limitation to varying extent. There were periods (e.g., over at least 6 d in April, 1997 on the southern flank) during which food limitation was severe. There was no detectable influence of mean water-column temperature on mass-specific EP. Hatching success varied between 50% and 95% without any seasonal trend. Our qualitative observations suggest the possibility that a significant proportion of hatching nauplii incubations were non-viable, meriting further study.

Keywords: Zooplankton; Copepod; Calanus; Egg production; Reproduction; Georges Bank

1. Introduction

The Gulf of Maine and Georges Bank are close to the southerly limit of predominance of the subarctic, planktonic copepod, *Calanus finmarchicus*, in the northwest Atlantic. Because of its relatively large size and high abundance, *C. finmarchicus* dominates the biomass and production of the copepod assemblage in the Gulf of Maine (e.g., Bigelow, 1926), especially in spring (Davis, 1987), and serves a key role in the transfer of planktonic production to fish, marine

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mammals and planktivorous seabirds in the region. For these reasons, *C. finmarchicus* was designated a target species for study in the US GLOBEC Northwest Atlantic/Georges Bank (GGB) Program.

To achieve the goal of connecting physical forcing and processes with an understanding of the population dynamics of *C. finmarchicus* in the Gulf of Maine and Georges Bank, there was a need in the GGB Program for knowledge about the vital rates controlling the population growth rate, including egg production, growth, development, and mortality rates. Towards this end, a series of process-oriented cruises was undertaken during the tenure of the field component of the GGB program. In this paper, we present a synthesis of results from the study of *C. finmarchicus* egg production rates and egg hatching success that was part of this process cruise component.

While the egg production rates and, to a lesser extent, hatching success of *C. finmarchicus* have been investigated in the Gulf of St. Lawrence, Scotian Shelf, and Labrador Sea (Plourde and Runge, 1993; Runge and Plourde, 1996; Cabal et al., 1997; Campbell and Head, 2000; Head et al., 2000; Plourde et al., 2001) no study of *C. finmarchicus* egg production had been conducted in the Gulf of Maine, apart from some measurements on Browns Bank (Runge, 1985a), prior to the GGB program. Campbell et al. (2001a) and Durbin et al. (1997, 2003) have previously reported on a subset of these egg production and hatching success measurements; we present here the complete set of measurements undertaken between 1994 and 1999 during the GGB process study.

The main purposes of the egg production and hatching success measurements were to: (1) estimate across-bank, seasonal, and interannual variation in egg laying and hatching success, (2) estimate the extent to which food limits egg production on Georges Bank, (3) develop quantitative understanding and relationships that can serve the needs of coupled physical–biological models of *C. finmarchicus* population dynamics, (4) develop a relationship between egg production rate and a preserved-female reproductive index that could be applied to the estimation of egg production in preserved broad-scale survey samples, and (5) measure recruitment rate into the *Calanus* population for estimation of mortality rates of early life history stages. Here we address in particular objectives 1–3; objectives 4–5 have been addressed elsewhere (Niehoff and Runge, 2003; Ohman et al., 2002, 2004).

2. Methods

2.1. Collection at sea

Egg production rate, hatching success, and adult female body size and mass of *C. finmarchicus* were measured during 10 process cruises spanning the 1994–1999 study period (Table 1 and Fig. 1). The process cruises were multidisciplinary, serving a variety of separate research projects, and sampling protocols among stations and cruises varied. On some occasions, a single station location was occupied for more than 1 day; hence there may be more than one sampling date at each station. On each sampling date for egg production measure-

Table 1
Cruise details and number of separate egg production measurements in each regions

Cruise	Dates	Number of measurements				
		Crest	GMaine	GSC	NEPeak	SFLK
CI9407	28 May–15 June 1994	1	1		8	6
END259	11–21 January 1995	1	3	2	1	1
END262	26 February –8 March 1995	2	1		6	
END264	28 March–4 April 1995	2	1		4	1
END266	27 April–5 May 1995	3				5
END267	23 May–18 June 1995	4	1	2	2	12
END319	27 February–3 March 1999		6	1	2	
END321	18–30 April 1999	2			2	13
OCE301	4–16 April 1997				1	10
OCE303	8–21 May 1997					13

Crest: Georges Bank inside 60 m isobath; GMaine: Gulf of Maine; NEPeak: northeast peak of Georges Bank; SFLK: southern flank of Georges Bank; GSC: Great South Channel.