

# EN319 CRUISE REPORT

21 February - 4 March, 1999

**Acknowledgments:** We wish to thank the crew of the R/V Endeavor for their professionalism and friendly support. Their cooperation and assistance made the success of this cruise possible.

This cruise was sponsored by the National Science Foundation and prepared by Ted Durbin, Jeff Runge, Melissa Wagner, and Barbara Niehoff.

## TABLE OF CONTENTS

Introduction.....	3
Cruise Narrative.....	4
Hydrography.....	5
Chlorophyll and Nutrients.....	13
Zooplankton Abundance.....	15
Egg Production Studies.....	25
List of Scientific Personnel.....	26
Event Log.....	27

## INTRODUCTION

The objective of the cruise was to determine egg production and growth rates, and physiological condition and mortality rates of the dominant copepod species on Georges Bank including the target species *Calanus finmarchicus* and *Pseudocalanus*. The general plan was to deploy ARGOS-tracked drogues on the NE Peak of Georges Bank and follow these for 8-10 days. Each day we planned to carry out a CTD and bottle cast (for chlorophyll a determinations) next to the drifter and sample the zooplankton with a plankton pump (5 replicate profiles) and a bongo net (3 profiles). At the same time we planned to carry out molting rate and egg laying rates on the *Calanus finmarchicus*. From these measurements we planned to determine stage specific mortality rates of *Calanus* using the population surface method and the vertical life table approach. At the beginning of the drifter deployment and every other day subsequently we planned to carry out a 1 m<sup>2</sup> MOCNESS tow to collect potential invertebrate zooplankton predators. Prior to deployment of the drifters we planned to carry out several CTD and bongo transects in an east-west direction between the 60 and 200m depth contours on the NE Peak. Information from these transects was intended to enable us to determine a suitable location for deployment of the drifters.

Following the drifter tracking study we planned to carry out a study of the abundance, stage and depth-distribution of *Calanus*, as well as determining egg laying rates and physiological condition, along transects in the Gulf of Maine. The objective was to determine the reproductive status of the overwintering *Calanus* population in the Gulf of Maine prior to the occurrence of the spring phytoplankton bloom. The first transect was planned to begin on the NE Peak and extend north to Maine Coastal waters adjacent to Mt. Desert Island. The second was to extend west across the Gulf to Cape Cod Bay. At each station we planned to deploy the CTD and collect water for chlorophyll a, carry out MOCNESS and pump deployments, and collect live animals for experiments. Stations were to be approximately 30 miles apart.

Because of extremely bad weather throughout the cruise with a succession of storms passing through we were unable to achieve most of these objectives. The cruise was initially delayed several days because of weather. When we reached the NE Peak of Georges Bank to begin the initial transects conditions were too rough to work. A major storm was forecast so we left to shelter in Portland, Maine. At this stage there was insufficient time to complete the planned drifter study. On returning from Portland we carried out a transect across the Gulf of Maine from Maine coastal waters at the mouth of Penobscot bay, across Jordan and Georges Basins, and onto Georges Bank, sampling zooplankton with a pump and Mocness, carrying out egg laying experiments, collecting animals for RNA/DNA measurements, and measuring growth and molting rates. This transect was also interrupted by weather. At the end of the transect we planned to carry out several diel studies of *Calanus* egg laying on Georges Bank. Bad weather prevented even these limited objectives so we returned to Narragansett.

Although most of our initial objectives were not met, we considered that the N-S Gulf of Maine transect provided useful and new information for this region during the winter.

## CRUISE NARRATIVE



We left GSO on Sunday, 21 February at 09:15 after a two day delay due to bad weather. We proceeded out through Buzzards Bay, Cape Cod Canal and to our station on the NE Peak of Georges Bank, arriving at the station at 08:00 am on the 22nd. Shortly before we arrived winds picked up to over 30 kts, gusting up to 40, and after readying the CTD for deployment we decided that conditions were too severe to start work. We began jogging slowly. Winds were predicted to remain between 30-40 for the rest of the day and we didn't expect to begin work until early Tuesday.

On Tuesday morning winds were still blowing around 30 kt and air temperatures were -7.0 C. However, winds were slowly decreasing so we turned around (during the storm we had jogged about 25 miles N of the station) and steamed back to the station (St 1), arriving there around 13:30. We carried out a CTD cast collecting water for chlorophyll. We then carried out two live tows with a 156 m, 1 m diameter net towed between the surface and near the bottom (47 m). Conditions during the casts were marginal and it would not have been possible to carry out either a 1 m<sup>2</sup> MOCNESS tow or a plankton pump cast. At the end of the station the Captain came down with news of more bad weather predicted for the Gulf of Maine and Georges Bank (storm level winds) beginning Wednesday night and wanted to break off work and head into shelter. Portland, Maine was decided upon since we felt it would provide an opportunity to carry out a transect from N to S in the Gulf of Maine as we returned to Georges Bank.

The live tows, meanwhile, were immediately sorted for *Calanus* and *Pseudocalanus* adult females and *Calanus* older stage copepodites. Groups of *Calanus* were preserved for RNA/DNA measurements. Additional females were sorted for egg laying measurements (Runge/Joly) and to lay eggs for the production of nauplii which would be used when we return to the bank in feeding experiments (Sandrin). *Calanus* was quite sparse at the station. Other copepods present included *Metridia*, *Pseudocalanus*, *Oithona* and *Centropages*.

We arrived in Portland on 24 February and departed at 06:00 on the 27th and headed out to the first station of our N-S Gulf of Maine transect off Manincus Island at the mouth of Penobscot Bay. The general approach at each station was to carry out a CTD and collect samples for nutrients and chlorophyll a, do a 1 m<sup>2</sup> MOCNESS and a pump cast, and then collect live animals for sorting for egg laying experiments with *Calanus* and *Pseudocalanus*. At each station a 75 m mesh net tow was preserved for egg ratio estimates of egg production by *Pseudocalanus*. Subsamples were taken from surface and deep MOC nets for RNA/DNA and C & N measurement on older stage copepodites and adult females of *Calanus*. At every other station *Calanus* nauplii were sorted for RNA/DNA.

The weather was great for two days and we completed two stations (St 2 and 3) the first day and then broke off for the night so that we could collect live animals during daylight at St 4. At St 2 we were in the lower salinity Maine Coastal Current. *Calanus* was present, both adults and nauplii, as well as *Metridia* and two spp of *Pseudocalanus*. At St 3 there were fewer *Pseudocalanus* and *Calanus*, but large numbers of *Metridia*. St 4 was started first thing in the morning and we completed 5 and 6 during the day. There was much large *Rhizosolenia* at these stations and appeared to be fewer *Calanus nauplii*. By evening the wind was picking up and since it was predicted to blow 30-40 kts overnight and the next morning we stowed everything on deck away. The next morning (March 1st) was warm, with the wind between 20 and 30 but the seas were large and confused. It rained off and on. By midday the wind began to drop but the seas remained large preventing any work being done that day. By 2000 hrs we decided to proceed to the NE Peak of Georges Bank to begin the 36 hr station the following morning. The swell was still large by morning but we took net tows at St 7 to see if the *Calanus* populations were suitable for the study of diel periodicity in egg laying and diel changes in egg and naupliar abundance in the water column. Unfortunately *Calanus* abundance was very low and it was not a good location for the study. We then completed regular sampling at the station and then headed north back to the Gulf of Maine to complete the last station on the GOM transect. This was completed at night in some rather wild conditions with the wind blowing around 30 kts and large swells. Everything was completed, however, with no mishaps.

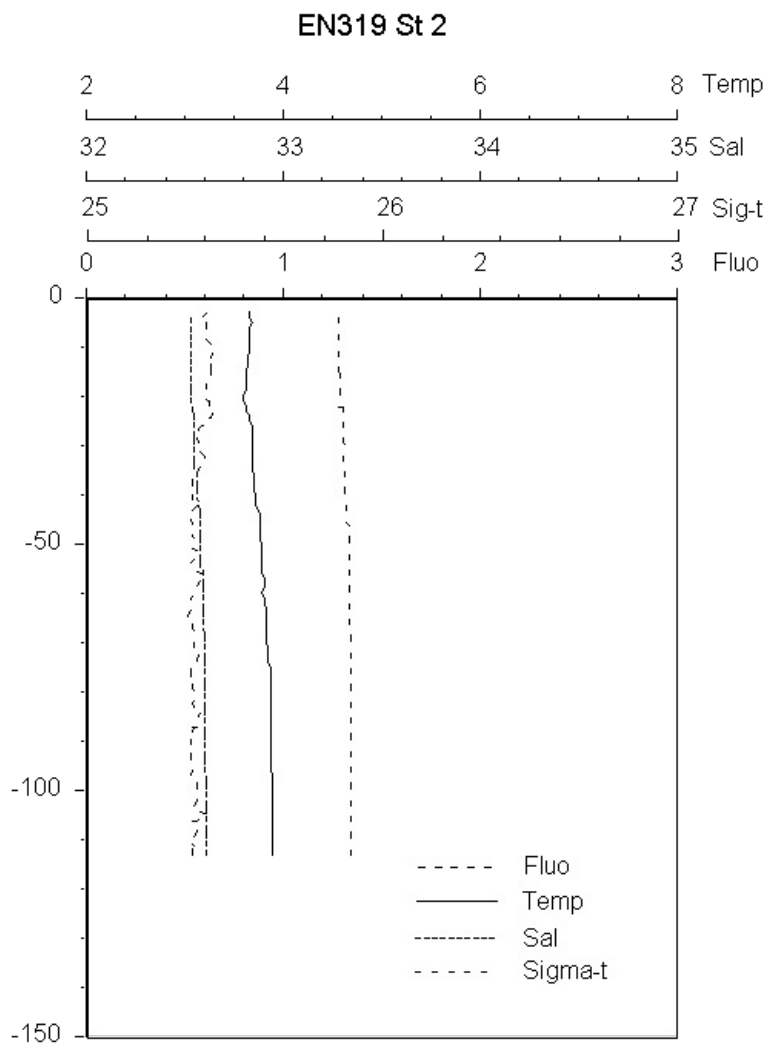
A large storm was predicted for Thursday with 40-45 kt winds on Georges Bank. This would preclude us carrying out any time series study in the GOM or on GB before we had to leave on Friday to come in. We decided to head into sheltered waters in Massachusetts Bay to see if we could find sufficient animals to carry out the 36 hr study in sheltered waters while the storm was blowing. We stopped in the western Wilkinson Basin and collected *Calanus* for experiments and proceeded to a location just inside Stellwagen Bank in Massachusetts Bay. Unfortunately a net tow revealed very few *Calanus* and incredibly large numbers of phytoplankton which clogged even a 333 m net which precluded us from carrying out the 36 hr study at this location. The weather forecast at this point was predicting high wind and 22 ft seas for the following day in the S Gulf of Maine Georges Bank area. At this point we decided to return to Narragansett since we would not have been able to accomplish anything significant on Friday morning (if we were able to work at all), before having to break off to return to Narragansett on Sat.

Individual reports follow.

## HYDROGRAPHY

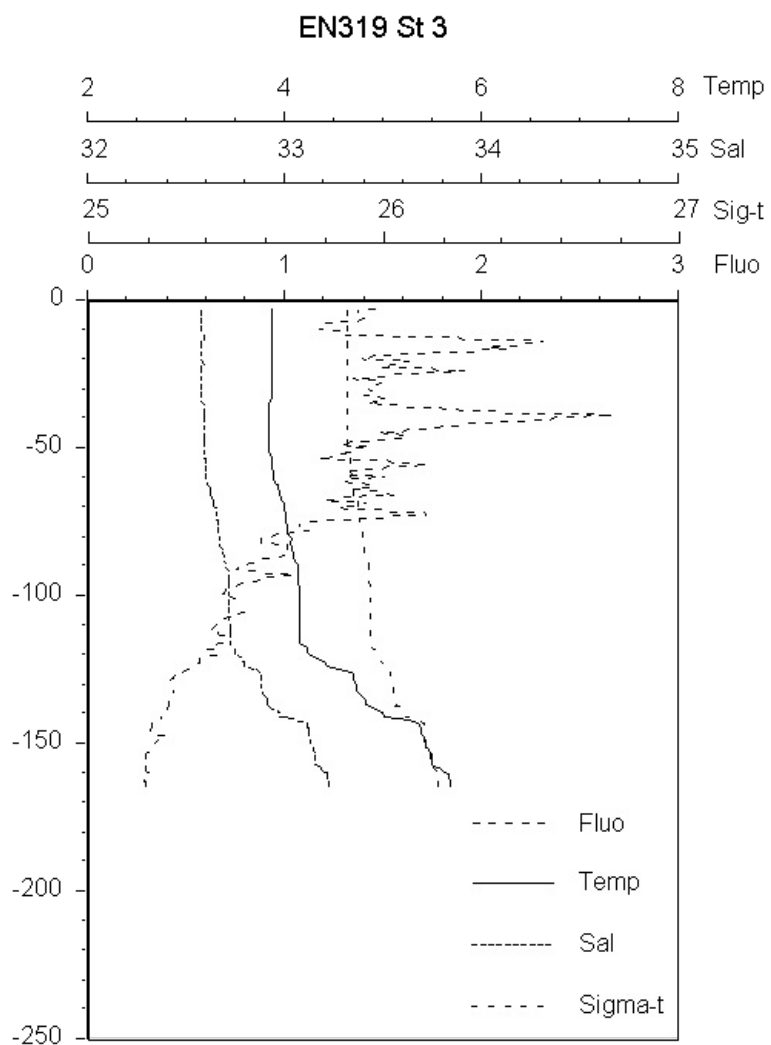
CTD profiles for St 2-8 are shown in Figures 2-9. Adjacent to the Maine coast at St 2, (Fig. 2) water was mixed to the bottom (120m) with temperature about 3.7 and salinity 32.5. Chlorophyll fluorescence was low. Across the Gulf at Sts 3-6 the surface mixed layer extended down to about 60m and there was high chlorophyll fluorescence within this layer. Surface temperature was between 3.5 and 4.5 and salinity between 32.4 and 32.6. At St 8 adjacent to Georges Bank the mixed layer extended down to 100m, the temperature warmer than at other stations in the GOM (5.2 C), and chlorophyll fluorescence low (Fig 8). On Georges Bank (St 7) there were suggestions of a slightly colder fresher layer at the surface and then a well-mixed water column beneath this (Fig 9). Water temperature and salinity was higher than in the GOM (6 C and 33 respectively).





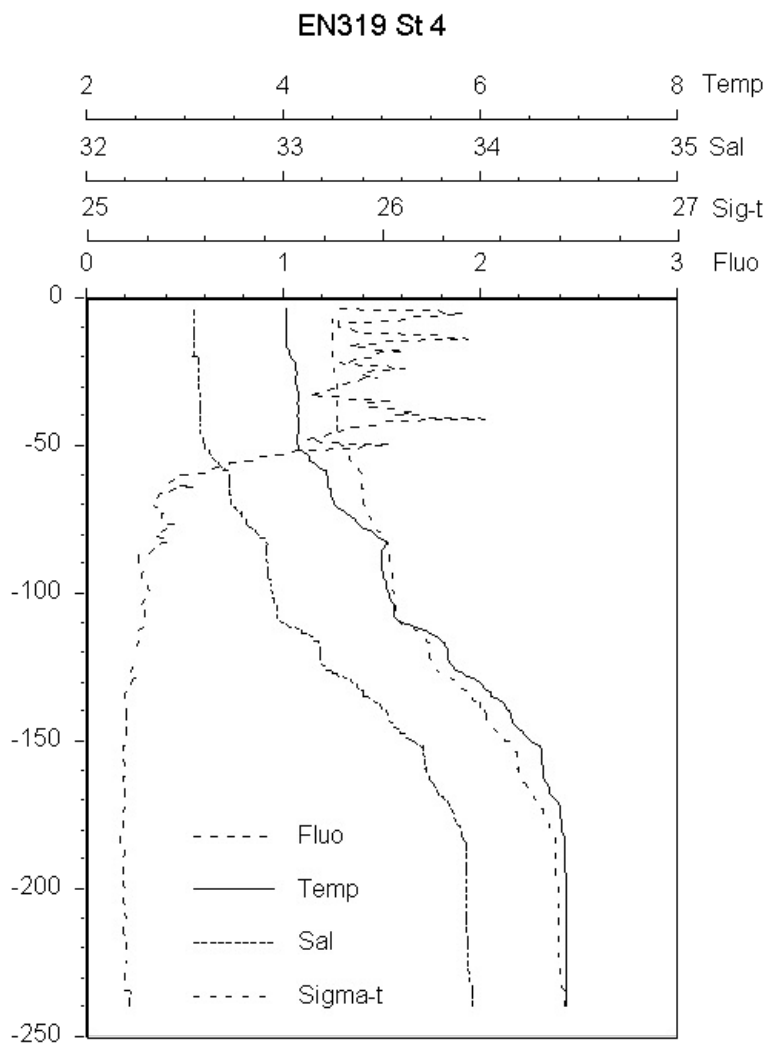
..... Figure 2. Station 2 CTD profiles





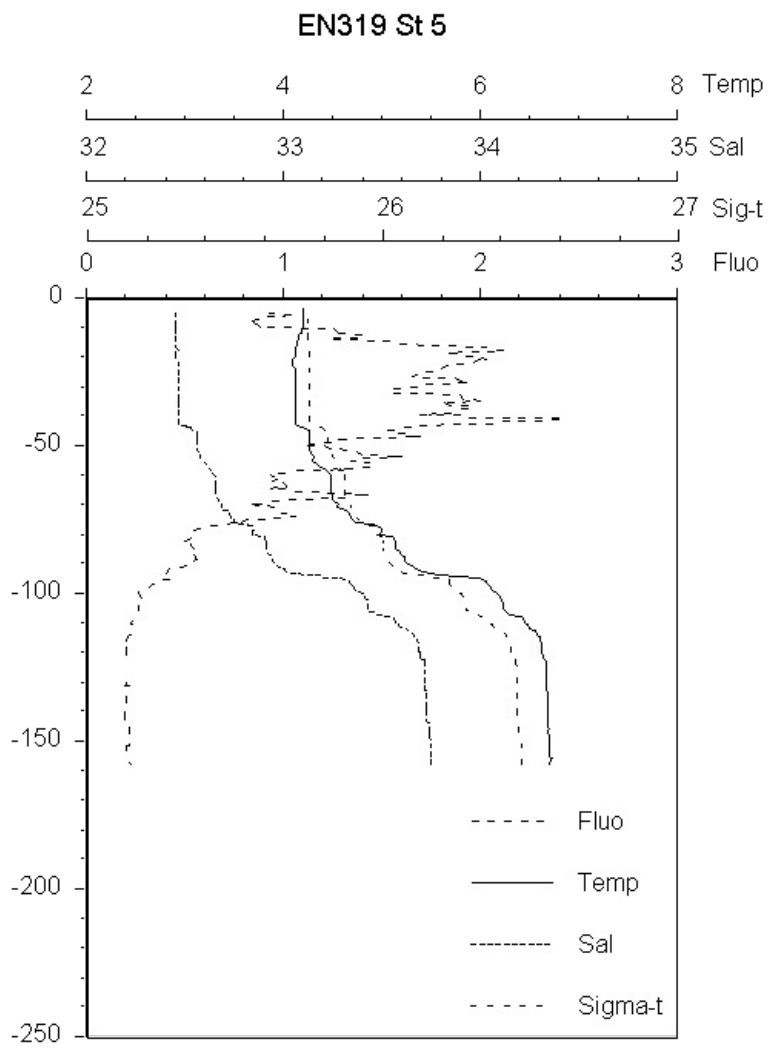
..... Figure 3. Station 3 CTD profiles





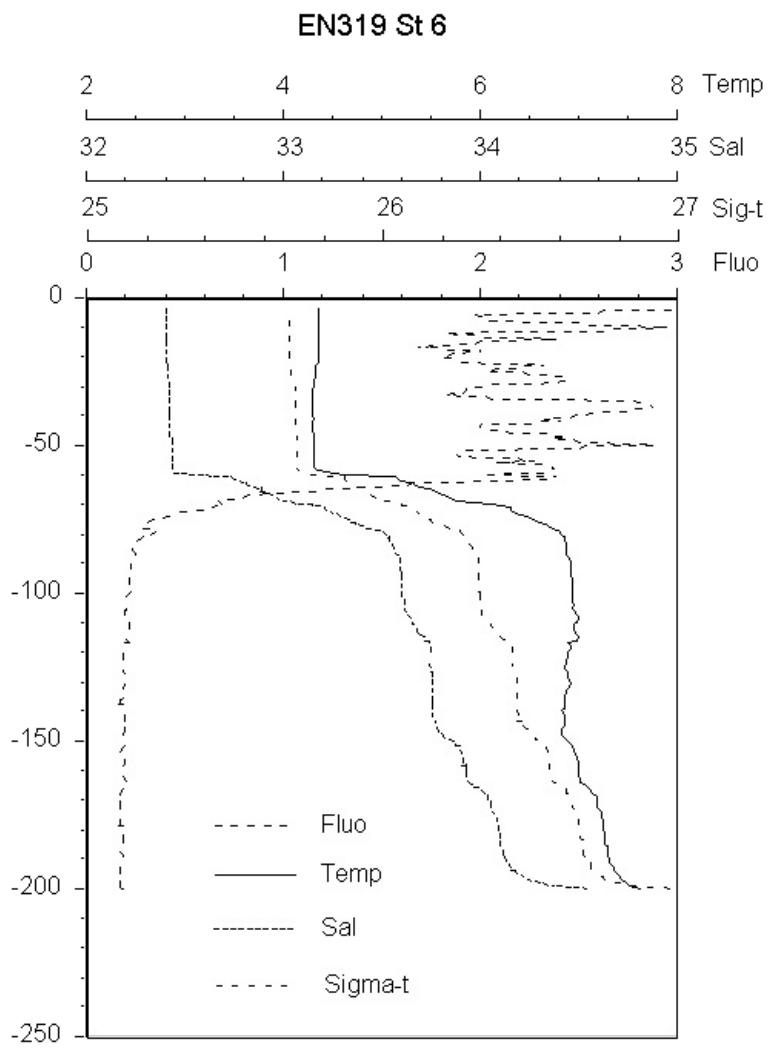
..... Figure 4. Station 4 CTD profiles





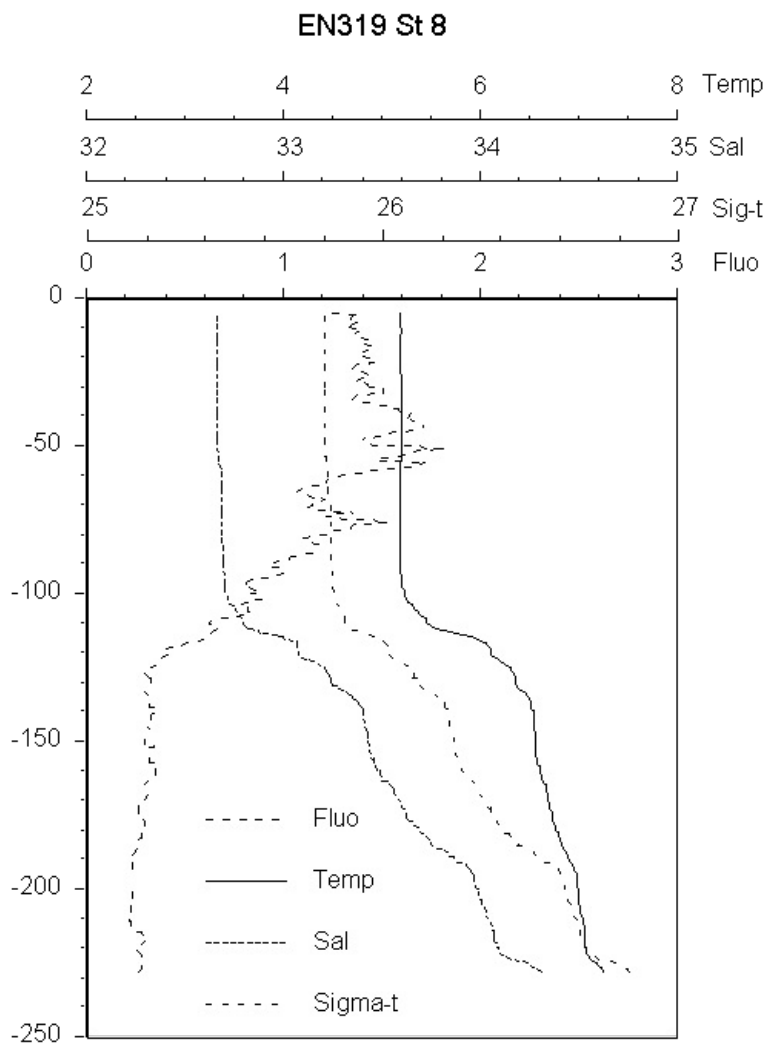
..... Figure 5. Station 5 CTD profiles





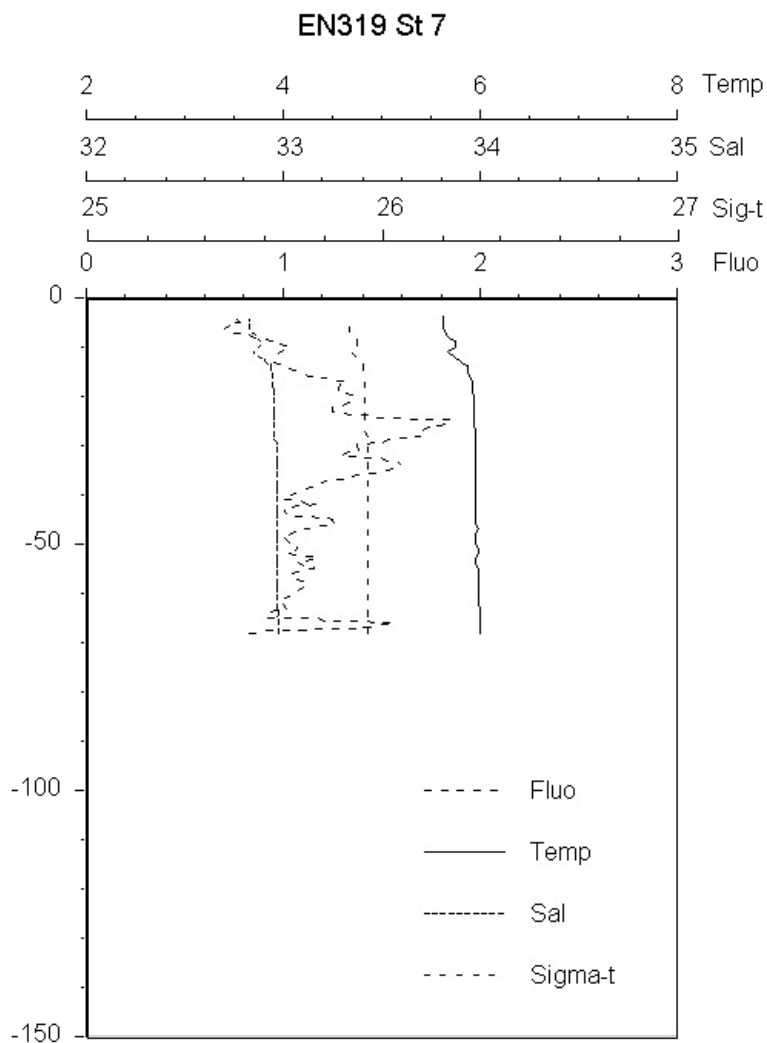
..... Figure 6. Station 6 CTD profiles





..... Figure 8. Station 8 CTD profiles





..... Figure 7. Station 7 CTD profiles

### CHLOROPHYLL and NUTRIENTS

At each station size-fractionated chlorophyll a (<5,µm and Total) and nutrients (NH<sub>4</sub>, NO<sub>3</sub>, NO<sub>2</sub>, PO<sub>4</sub>) were measured at 10 m intervals down to 60 m and at the bottom. Values are shown in Table 02. At St 2 in Maine Coastal Water chlorophyll a was <1 µg l<sup>-1</sup> with most being in the <5 µm fraction suggesting that the spring bloom had not yet begun. Nitrate and phosphate were high (>10 µM and > 1.0 µM) and the same throughout the 112 m water column. At St 3-6 across the Jordan and into the northern edge of Georges Basin total chlorophyll a was between 2 and 7 µg L<sup>-1</sup>. Most of the phytoplankton was in the larger size-fraction. Nitrate and phosphate were lower than in Maine Coastal Water and decreased from towards the south (St 6) where nitrate was around 6 µM and phosphate 0.7 µM. These higher chlorophyll values coupled with lower nutrients, indicated that the spring bloom had already begun. This is very early for the central Gulf of Maine where typically high chlorophyll values are not seen until April and May (O'Reilly and Zetlin 1999). Perhaps it reflected the calmer weather experienced up until the time of the cruise.

**Table 1. Chlorophyll a and nutrients from EN319.**

Station	Depth, m	<5 µm Chl a ug L <sup>-1</sup>	>5 µm Chl a ug L <sup>-1</sup>	Total Chl a ug L <sup>-1</sup>	DIP uM	NO3 uM
1	0	0.58	1.17	1.75		
1	5	0.50	1.01	1.51		
1	10	0.67	0.92	1.59		
1	20	0.53	1.26	1.79		
1	30	0.54	1.13	1.67		
1	40	0.63	1.12	1.75		
1	44	0.49	0.94	1.43		
2	0	0.40	0.20	0.60	1.10	11.04
2	5	0.40	0.40	0.80	1.07	10.82
2	10	0.40	0.10	0.50	1.07	10.61
2	20	0.38	0.29	0.67	1.08	10.72
2	30	0.40	0.14	0.54	1.13	10.73
2	40	0.30	0.06	0.37	1.08	10.93
2	60	0.27	0.33	0.60		
2	112				1.12	10.93



3	0	0.75	2.06	2.81	0.99	8.66
3	5	0.80	2.16	2.96	0.96	8.70
3	10	0.95	1.86	2.81	0.94	8.45
3	20	0.80	2.11	2.91	0.96	8.64
3	30	0.90	1.61	2.51	0.95	8.77
3	40	0.85	1.76	2.61	0.95	8.61
3	60	0.05	0.15	0.20	0.94	8.58
3	168				1.35	13.86
4	0	0.66	1.97	2.63	0.93	8.19
4	5	0.73	1.74	2.47	0.90	8.20
4	10	0.73	1.55	2.28	0.90	8.19
4	20	0.70	1.82	2.51	0.90	8.23
4	30	0.66	1.58	2.24	1.00	8.46
4	40	0.31	0.73	1.04	1.24	8.86
4	50	0.02	0.01	0.04	1.11	9.69
4	239				1.55	18.99
5	0	0.66	2.32	2.98	0.83	7.06
5	10	0.58	2.43	3.01	0.84	7.01
5	20	0.77	2.09	2.86	0.81	7.12
5	30	0.70	2.43	3.13	0.84	7.27
5	40	0.71	4.18	4.89	0.82	7.05
5	60	0.70	2.40	3.09	0.84	7.32
5	157				1.39	16.83
6	0	0.62	2.28	2.90	0.75	6.25
6	10	0.77	2.47	3.25	0.72	6.09
6	20	0.70	2.16	2.86	0.74	6.22
6	30	0.62	6.34	6.95	0.73	6.27
6	40	0.77	2.05	2.82	0.72	6.27
6	60	0.85	2.32	3.17	0.79	7.18
6	199				1.39	19.81
8	0	0.62	1.35	1.97	0.90	8.96
8	10	0.73	0.89	1.62	0.90	8.78
8	20	0.77	1.08	1.85	0.92	8.70
8	30	0.77	1.24	2.01	0.90	8.99
8	40	0.93	1.24	2.16	0.91	8.98
8	60	0.66	1.12	1.78	0.93	8.93
8	226				1.47	18.40
7	0	0.58	1.28	1.85	0.80	10.05
7	10	0.35	1.12	1.47	0.80	7.66
7	20	0.35	1.12	1.47	0.81	7.93
7	30	0.46	1.39	1.85	0.81	7.93
7	40	0.39	1.51	1.89	0.82	7.95
7	66	0.62	1.08	1.70	0.76	8.03

## ZOOPLANKTON ABUNDANCE

Below we present zooplankton pump counts. At this stage the MOCNESS samples have not been enumerated.

**Plankton Pump Counts.** Zooplankton pump samples were collected and counted using standard GLOBEC Broadscale Survey Procedures. Samples were normally collected from 100-70m, 70-40m, 40-15m and 15-0m. Table 2 shows the abundance of *Calanus finmarchicus* stages for the different depths, while Table 3 shows the total abundance of *Calanus* over the whole water column at each station. At all stations there was a population of young nauplii and copepodites. Abundance of nauplii was lowest at St 8, adjacent to Georges Bank (8,700 m<sup>-2</sup>); elsewhere across the Gulf numbers were between 23,000 (St 2) and 55,000 m<sup>-2</sup> (St 5). On Georges Bank (St 7) abundance of *Calanus* nauplii was higher (76,000 m<sup>-2</sup>), but there were relatively fewer older stages present compared with St 2-6 in the Gulf of Maine.

Other abundant copepod nauplii included *Oithona*, *Calasocalanus/Paracalanus*, *Metridia* and *Pseudocalanus* (Table 5). *Oithona* was particularly abundant with total numbers >1,000,000 m<sup>-2</sup> at all stations but St 2 and 4. *Microsetella* was quite abundant but was present mostly as copepodites at depth.

**Table 2. Abundance of *Calanus finmarchicus* nauplii copepodites and adults within each depth range from plankton pump samples.** Numbers are the number per square meter for each pump depth range.

ST	TOW	NET	DEPTH	N1	N2	N3	N4	N5	N6	C1	C2	C3	C4	C5	FEM	MAL
2	1	4	15-0	0	398	1820	1820	3355	1535	512	114	284	114	171	455	0
2	1	3	40-15	0	702	3367	2666	3227	1122	281	281	0	0	0	140	0
2	1	2	70-40	0	775	339	0	97	97	145	48	0	48	0	0	0



2	1	1	100-70	121	483	241	0	121	1328	121	0	0	0	0	241	0
3	2	4	15-0		0	3808	2240	1344	1792	0	448	672	448	0	0	0
3	2	3	40-15	0	606	4040	2424	2222	808	202	404	808	202	0	202	202
3	2	2	70-40	0	0	4144	0	2486	4972	0	829	829	829	0	0	0
3	2	1	100-70	0	253	0	253	505	253	0	0	0	0	0	0	0
4	3	3	15-0	66	1052	3089	1577	2300	1709	657	460	460	131	0	66	0
4	3	2	70-15	0	2987	7767	1195	2390	2390	2987	1195	4182	0	0	597	0
4	3	1	100-70	0	0	342	0	0	0	0	0	0	85	0	0	85
5	4	4	15-0	239	1196	8371	3348	3348	1674	1435	718	1435	0	0	0	0
5	4	3	40-15	1853	1853	6949	3706	3706	4633	3706	463	1853	463	0	463	0
5	4	2	70-40	1099	4395	4212	1465	549	732	2014	549	366	0	0	0	549
5	4	1	100-70	0	119	119	0	0	119	0	0	0	119	0	119	119
6	5	4	15-0	647	3019	6686	2372	5608	2804	2157	863	3235	2588	216	216	0
6	5	3	40-15	544	6527	5439	2719	0	2176	3807	544	1632	0	0	0	0
6	5	2	70-40	342	2052	2394	0	0	0	1710	342	0	0	0	0	0
6	5	1	100-70	0	128	0	64	0	0	0	0	0	64	64	0	0
7	6	3	15-0	247	2721	16822	4948	1484	1237	990	247	742	247	0	0	247
7	6	2	40-15	0	7357	16350	2997	272	1635	817	545	0	545	0	0	272
7	6	1	70-40	895	8053	6860	1193	1790	1193	1491	895	597	0	0	0	0
8	7	4	15-0	0	204	409	818	204	613	818	0	409	613	0	0	0
8	7	3	40-15	0	0	1738	579	290	290	290	434	0	145	0	145	0
8	7	2	70-40	0	933	466	466	933	0	0	466	466	466	0	0	466
8	7	1	90-70	0	501	250	0	0	0	0	0	0	0	0	0	0

**Table 3. Total water column abundance of *Calanus finmarchicus* nauplii copepodites and adults from plankton pump samples.** Samples were collected between 0-100m or 0 and the bottom, if it was less than 100m.

ST	TOW	N1	N2	N3	N4	N5	N6	C1	C2	C3	C4	C5	C6F	C6M	Tot Naup	Tot Copeps	Tot Adults	M2Tot Cop
2	1	121	2,357	5,767	4,486	6,800	4,083	1,058	443	284	162	171	837	0	23,613	2,118	837	26,568
3	2	0	859	11,992	4,917	6,558	7,825	202	1,681	2,309	1,479	0	202	202	32,151	5,670	404	38,225
4	3	66	4,039	11,198	2,772	4,690	4,099	3,645	1,655	4,642	217	0	663	85	26,864	10,159	749	37,772
5	4	3,191	7,563	19,651	8,519	7,604	7,158	7,155	1,730	3,654	582	0	582	668	53,686	13,122	1,251	68,059
6	5	1,533	11,726	14,519	5,156	5,608	4,979	7,674	1,749	4,867	2,652	280	216	0	43,522	17,221	216	60,959
7	6	1,142	18,131	40,032	9,138	3,546	4,065	3,298	1,687	1,339	792	0	0	520	76,055	7,116	520	83,691
8	7	0	1,638	2,864	1,864	1,427	903	1,107	901	875	1,225	0	145	466	8,695	4,108	611	13,415

**Table 4. Total water column abundance of zooplankton taxa from plankton pump samples.** Samples were collected between 0-100m or 0 and the bottom, if it was less than 100m.

## EGG PRODUCTION STUDIES Feb-Mar. 1999

J. Runge, B. Niehoff, P. Joly

Egg production rates of *Calanus finmarchicus* and *Pseudocalanus* spp. and hatching success of *Calanus* were measured along the Gulf of Maine transect. To measure egg production rates, females from vertical live tows were sorted immediately after capture. At each station 40 female *Calanus finmarchicus* were placed individually in petri dishes (30ml). At 8h intervals, eggs were counted and removed from the incubation vials. *Pseudocalanus* spp. females were kept in groups of 5 in scintillation vials (45ml) containing either filtrated seawater or a feeding mixture containing *Skeletonema costatum* and *Nannochloropsis* sp. After 24 hours, the females were preserved for later analysis of egg sac number and size. Part of the live tows for the egg production measurements was preserved in formaldehyde and glutaraldehyde for studies of gonad development, including determination of the reproductive index and staging of gonad development. Hatching success of *Calanus* eggs produced during incubations was measured by incubation of batches of 50 randomly selected eggs for a 72 h period at 5-7 °C.

Egg production rates of *C. finmarchicus* varied between 15 and 62 eggs female<sup>-1</sup> d<sup>-1</sup> (Table 01). Clutch size ranged between 39 and 53 eggs. Hatching success varied between 63 and 92%, indicating maternal nutritional conditions were not a significant factor in determining egg survival. The lowest egg production rates were observed at the most nearshore Gulf of Maine station. Egg production rates at deeper stations in the central Gulf were relatively constant at 45-53 eggs female<sup>-1</sup> d<sup>-1</sup>. The *Pseudocalanus* incubations were preserved for later analysis.



**Table 5. Summary of egg production data for *Calanus finmarchicus*.** EPR denotes egg production rate (eggs female<sup>-1</sup> d<sup>-1</sup>) and clutch size is mean eggs female<sup>-1</sup>. Standard error in parentheses (n= 36-40). Hatch success represent percentage of eggs hatching to nauplii Standard error (n=5) in parentheses. No data for GOM-2 and GOM-9.

Date	Station	Time	EPR	Clutch Size	Hatch success (%)
23 Feb.	GB-01	1400	34, (3.3)	40 (3.0)	92
27 Feb.	GOM-2	1310	15, (3.4)	39 (3.5)	-
27 Feb.	GOM-3	2020	62, (7.3)	53 (2.6)	63 (7.4)
28 Feb.	GOM-4	0920	57, (5.3)	48 (2.3)	79 (3.2)
28 Feb.	GOM-5	1410	40, (5.2)	49 (3.0)	79 (2.0)
28 Feb.	GOM-6	2000	53, (5.6)	49 (2.4)	80 (2.2)
02 Mar.	GOM-7	1115	56, (6.2)	45 (2.9)	86 (2.5)
02 Mar.	GOM-8	2130	34, (3.9)	36.(2.7)	72 (1.6)
03 Mar.	GOM-9	1035	55, (6.1)	46 (3.1)	-

**EN319 List of Personnel**

Name	Title	Organization
Dr. Edward Durbin	Chief Scientist	GSO, URI, Narragansett, RI
Dr. Jeffrey A. Runge	Scientist	Institut Marice Lamontagne, Quebec
Dr. Robert G Campbell	Marine Scientist	GSO, URI, Narragansett, RI
Ms Maria Casas	Research Associate	GSO, URI, Narragansett, RI
Ms Melissa Wagner	Graduate Student	GSO, URI, Narragansett, RI
Dr Barbara Niehoff	Post Doc.	WHOI, Woods Hole, MA
Pierre Joly	Technician	Institut Marice Lamontagne, Quebec
Isabelle Berube	Technician	Institut Marice Lamontagne, Quebec
Ms Guylaine Morrier	Graduate Student	UQAR, Rimouski, Quebec
Ms Sandrin Guittard	Graduate Student	UQAR, Rimouski, Quebec
Mr David Field	Graduate Student	Scripps Inst Oceanogr., UCSD, CA
Mr Sean Smith	Student	Univ. New England, Biddeford, ME

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