

Cruise Report

R/V SEWARD JOHNSON Cruise 9505 to Georges Bank

6-21 April 1995

Acknowledgements

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Purpose of the Cruise

The objectives of the cruise were to (1) determine the distribution and abundance of larval and juvenile cod and haddock on the eastern flank of Georges Bank in relation to water column conditions, and (2) conduct site studies to determine their vertical distribution, diel variability, predator-prey relations, and biochemical content.

In order to sample the same cohort of larvae, ARGOS/GPS/VHF drifting buoys with drogues were used to tag a parcel of water for the conduct of sampling operations.

Scuba diving operations were conducted to collect gelatinous organisms and record their distribution and behavior.

Cruise Narrative

Loading of the R/V SEWARD JOHNSON began on 5 April 1995. Severe weather conditions prevented us from leaving port on Wednesday 6 April 1995. The R/V SEWARD JOHNSON left Woods Hole, Massachusetts at 1300 h on 7 April 1995 to begin a bongo-net survey of the eastern part of Georges Bank. Along the way, 0130 h 8 April 1995, the two stratification moorings were seen on radar and visually observed their lights. Also observed lights on the LT1 mooring. Our first bongo station began at 0211 h 8 April 1995 at 40° 54.0', 67° 30.0'; stations continued towards the northeast on east-west transects, 10 miles apart (Figure 1). Stations were numbered consecutively from the previous cruise (SJ9503), starting with 19. The northeastern part of Georges Bank was completed at 1504 h 9 April 1995 with station 44, 42° 0.0', 66° 13.0'. The vessel then steamed to the southeast part to sample three stations (45-47) leading into a fine-scale grid of bongo-net tows on the southern flank.

Arrived at station 48, 0231 h, 10 April 1995, 40° 51.0', 66° 56.0', to begin the first of six transects on the fine-scale grid. Transects were oriented north-south and bongo stations were five miles apart, seven on a transect (Figure 1). Our progress was slowed due to 25 knot winds and 12-14' seas, but by evening sea conditions moderated. An Argos drifter (7a) was set out at 1820 h, 10 April 1995, on the 60-m isobath between stations 59 and 60, 41° 09.12', 67° 15.29'. Bongo stations continued on 11 April 1995; weather calm and sunny. At station 83, 1420-1530 h, scuba diving observations were conducted by E. Horgan and R. Coverdale. On the final bongo transect, moorings ST1 position was checked, and ST2 lights were checked after sunset. The last station 89 on the grid was completed at 2130 h, 11 April 1995, and the vessel then steamed to a deep site near bongo station 81 to commence MOCNESS CTD operations. Along the way the vessel attempted to find the initial Argos drifter released in the northeast corner of the grid. Since the drifter was not transmitting properly, it was brought aboard at 2348 h 11 April 1995, 41° 12.15', 67° 12.58'.

Arrived at the deep station 90 at 0218 h 12 April 1995, 40° 49.0', 67° 21.5', 93 m bottom depth. Another Argos drifter (6a) was deployed and MOCNESS CTD operations began following the drifter. An intense storm was approaching and in order to find safe haven, operations ceased with MOCNESS tow 32, 1418 h, 12 April 1995 and the vessel steamed to Nantucket.

Arrived at Nantucket harbor at 0130 h 13 April 1995 and set anchor; moved to dock at 0930 h. Left Nantucket at 1415 h 16 April 1994 and steamed to last reported drifter (6a) position on southeast part of bongo grid. Searched for drifter from 0441-0700 h 17 April 1995. Deployed another drifter (4a) at midflank in the bongo grid at 0705 h 17 April 1995, 40° 53.0', 67° 30.0', 75-m bottom depth. Continued to search for drifter (6a) and recovered it at 1058 h 17 April 1995, 40° 35.21', 67° 35.10', 105 m bottom depth. Steamed back to southwest corner of bongo grid about 11 miles and reset station 90 with a new drifter (7b) at 1250 h, 67° 25.0', 40° 44.5', 94 m bottom. MOCNESS (33) and CTD operations commenced following drifter 7b. Surface snorkeling from the vessel was done by E. Horgan and R. Coverdale from 1715- 1745 h 18 April 1995 to collect ctenophores for predation experiments. All activities ended for station 90 with MOCNESS 47 at 2127 h 18 April 1995. Drifter 7b was brought aboard at 2157 h 18 April 1995 at 40° 34.58', 67° 36.31', 105-m bottom drift. The vessel then steamed north to locate drifter 4a which was released 17 April 1995 at midflank.

Located drifter 4a at 0012 h 19 April 1995 at 40° 54.6', 67° 42.4'. Station 91, began MOCNESS 48 and CTD operations at 0053 h 19 April 1995. Deployed drifter 7c about a mile east of drifter 4a at 0856 h, 40° 51.36', 67° 39.26', 70-m bottom. SCUBA diving observations were conducted by E. Horgan and R. Coverdale at 1110-1220 h. Operations were suspended 2105 h 19 April until 0843 h 20 April 1995 because of 25-35 knot winds and 8-10 foot seas. Towards the end of the MOCNESS and CTD operations, drifter 4a was picked up at 1708 h 20 April 1995 at 41° 1.0', 67° 43.44', 58 m bottom depth. Drifter 7c was picked up at 1803 h 20 April 1995 at 41° 0.6', 67° 40.29', 63 m bottom depth. Operations at station 91 ended at 2000 h, 20 April 1995 and the vessel steamed for Woods Hole. Arrived at Woods Hole at 0900 h 21 April 1995.

Individual Reports

Physical Oceanography (Jim Manning, Glenn Strout)

Drifter Deployments

A set of three GPS/ARGOS/VHF drifters, as described in our previous report (SJ9503), were brought on board for this cruise⁽¹⁾. A summary of all five deployments for this cruise is given in Figure 2. The deployment code is according to the last digit of the instrument's serial number and a letter corresponding to the consecutive deployment of that drifter. The first deployment "7a", for example, was the first time SN#37 was deployed on this cruise. This deployment was conducted during the bongo survey II on the southern flank around the 60-m isobath. The first two tidal ellipse were as expected with a along-isobath residual towards the west but, as the wind veered from southwestward to northwestward in the afternoon of 11 April, the drifter moved shoalward with an eastward residual.

The next drifter (6a) was deployed at station 90 in the area of high larval concentration. Here the tidal ellipses varied from no overlapping in the first cycle to nearly exact overlapping in the next two cycles. The fourth cycle resulted in a large residual (~10 kms) towards the east and was followed by several cycles towards the southwest. Three days into the deployment the GPS transmitter failed but the ARGOS fixes were available. After more than five days when we had returned from Nantucket, we recovered the instrument on the 105-m isobath, 31.4 km from deployment. The overall residual flow was approximately 7 cm/s towards the southwest as expected.

Drifter 7 was redeployed in 90 m of water to mark a new station 90. This deployment was evidently affected by a period of southeastward wind (18 April) which resulted in a southwestward drift approximately 21 cm/s. This deployment and the sampling conducted around the drifting target are shown in more detailed in Figure 3.

When we arrived at station 91 we began to follow drifter 4a which we had deployed a few days earlier (prior to station 90 work). As depicted in Figure 4, the drifter had made a few tidal excursions with westward drift, but, when the wind shifted northward approximately mid-day on the 19 April, this drifter (4a) and another drifter (7c) which we deployed one mile to the east, moved shoalward and remained there for the next three cycles. As shown in Figure 2, these deployments (4a and 7c) are in the vicinity of

the two Process Mooring Sites ST1 and ST2.

At both station 90 and 91, drifters were fitted with VEMCO minilog temperature probes at the base of the holey sock. Together with the external temperature probe on the drifters themselves, this provided a record of the thermal stratification ($T@0m - T@15m$) over the period of the deployments. As depicted in Figure 5, both deployments recorded approximately $1.5^{\circ}C$ of stratification late in the day on 18 April. The gradient is less dramatic at station 90 due to the drogue surfacing and the MINILOG sensor being shallow. After this problem was discovered, the bottommost PVC hoop in station 91 drogues were drilled to allow water to enter and thereby reduce the buoyancy of the drogue at that site.

Shipboard Sensors

Five minute interpolated values of shipboard sensor data were loaded into a MATLAB routine for range and delta checks and then plotted in Figure 6 and 7. For the three variables in Figure 6, some data loss apparently occurred for several hours late in the day on 14 April and again on the following day. The fluorometer records are suspect during much of the time. Nevertheless, a rough contour of the surface temperature and salt generated just after each bongo survey at sea (not included here), provided a general hydrographic background to the biological distributions. While features such as Scotian Shelf Water appearing on the eastern side of the bank were depicted in the figures, a more detailed analysis and collaboration with data from the other GLOBEC vessels is needed.

In the case of the meteorological sensors (Figure 7), except for some loss of data around 11 & 14 April, the five minute interpolated values look reasonable. In all cases the "lost" data may eventually be recovered from the raw data which is available on a CD-ROM. Unfortunately, as is often the case with shipboard anemometer records, the wind data is virtually unusable. With the speed and direction of both the wind and ship varying so much especially in heavy seas, it is very difficult to obtain an accurate estimate of the wind. Consequently, the nearby NOAA buoy records are plotted on Figure 8. These two buoys (44008 and 44011) are stationed approximately 100 miles west and east of the study area but provide an adequate measurement of the local wind events.

Two RDI Acoustic Doppler Current Profilers were on board and operating at 150 and 600 KHz, respectively. Post-processing of these records has not begun.

Hydrography

A total of 98 CTD casts were conducted including 79 Seabird Profiler casts (Model 19) and 19 General Oceanics MarkIII cast. In addition, Seabird temperature (Model 3) and conductivity (Model 4) sensors were mounted on all 45 MOCNESS hauls.

The Profiler was attached to the wire just above the bongo-net frame. These cast were double oblique through the water column except for seven vertical cast taken with water bottle samples. While the main purpose of these deployments on the bongo hauls is to have a measure of depth (pressure) in real time, significant hydrographic information is gathered. A total of 10 cross-bank sections were conducted with five or more stations per section. Post-processing of this data is not complete.

As depicted in the upper left hand panel of Figures 3 and 4, most of the MarkIII cast were conducted at the drifting sites 90 and 91. These were taken every few hours during the day and a few cast during the night. All cast included three water bottle samples on the upcast typically at the bottom, near the thermocline, and near the surface. All cast included measurements from a fluorometer, a transmissometer, and a light sensor in addition to the standard CTD variables. While real time display and post-station hardcopy plots of each cast depicted fairly clean and useful data, each cast needs careful hand editing and post-processing before results are reported.

The most significant hydrographic observation in the analysis of the data thus far is the relatively quick setup of thermal stratification that occurred near the surface on April 18th. This was captured with both thermistors attached to the drogue (Figure 5) and a series of seven MarkIII cast conducted that day (Figures 3 and 4, upper left).

Ichtho-Zooplankton Studies

Bongo-net Survey (G.Lough, E. Broughton, M. Kiladis)

Bongo tows were made with a 61-cm frame fitted with 0.333-mm and 0.505-mm mesh nets using standard MARMAP procedures; i.e., double-oblique from surface to within 5-m of the bottom. A SeaBird CTD (Model 19) was attached to the towing wire above the bongo to monitor sampling depth in real time and to record temperature and salinity. The 0.505-mm mesh net was sorted at sea to provide counts on the number of cod and haddock eggs and larvae. Larvae from the bongo sort were frozen for biochemical analyses ashore.

The initial bongo survey, 8-10 April 1995, covered eastern Georges Bank with 28 stations (19-47) spaced 10 miles apart (Figure 9). Transects were run east-west, from about the 90-m to 40-m isobaths. Few eggs/larvae were found on the northeast part where high densities of gadid eggs were sampled during the previous cruise R/V Seward Johnson 9503, 13-24 March 1995. Instead, eggs and larvae were found on the southeast part of Georges Bank near the mouth of Georges Canyon, 20-60 miles south west. Cod larvae were more abundant than haddock. The number of cod per net ranged from 1-32 ($1-23/100 m^3$); whereas haddock ranged 1-11 per net ($0-8/100 m^3$). Gadid eggs only were observed in the samples at four stations in deeper water, 80-90m, with relatively low densities, less than 100 eggs per net. Most of the cod and haddock larvae were recently hatched with yolk sacs.

The fine-scale bongo grid on the southeastern flank of Georges Bank was conducted on 10-11 April 1995. Stations were five miles apart on six transects ranging from about 50 m to the 95-m isobaths (Figure 10). Larval cod, 5-8 mm, were collected on all 42 stations (Figure 10). The number caught per 0.505-mm mesh net ranged from 2 to 122 ($3-65/100 m^3$). The highest concentrations were generally on the southwestern part of the sampled grid. This pattern is more clearly evident for haddock larvae where the highest numbers were caught on the southeastern part and zero catches on the northeastern part of the grid (Figure 10). Haddock larvae were an order of magnitude less abundant than cod ranging from zero to 18 larvae per net tow ($1-8/100 m^3$). In both cases, the western limit of relatively high numbers was not defined by the bongo grid due to lack of time.

MOCNESS and CTD operations followed a drifter as the station marker (Figure 3). The 1-m MOCNESS with nine 0.333-mm mesh nets was used to sample larval fish and larger zooplankton. The 1/4-m MOCNESS also is equipped with nine 0.064-mm mesh nets, which are designed to sample the smaller plankton such as copepod nauplii. The tow profile for these two samplers was nominally 10-m strata within 5 m of the bottom; extra nets were used for special collections. The 1-m MOCNESS nets typically sampled for 5 minutes to filter about 250 m³ of water; the 1/4-m MOCNESS nets for 2-3 minutes to filter about 30 m³. The MOCNESS and CTD operations generally were alternated. The 10-m MOCNESS equipped with five 3.0-mm mesh nets generally was used twice per 24 h, once at midnight and again at midday, to collect the larger and rarer nekton. Sampling intervals for the 10-m MOCNESS were 20 m, keeping the same alternate depth horizons (0-20, 20-40, 40-60, and 60-80 m) as the 1-m MOCNESS. Each net was opened for about 10 minutes to sample about 5,000 m³ of water.

A deep-water drifter (6a) site, station 90A, 40° 49.0', 67° 21.5', 86-93 m bottom depth, was occupied from 0218 h 12 April 1995 to 1418 h 12 April 1995. The water column was isothermal 4.8-5.0 °C. Four 1-m MOCNESS, two 1/4-m MOCNESS, and one 10-m MOCNESS tows were made in very calm seas. MOCNESS-1 m 29 was sorted ashore for cod and haddock eggs and larvae. Cod larvae were an order of magnitude more abundant than haddock larvae; few gadid eggs were observed. Cod and haddock larvae were distributed through the water column; however, cod larvae were most abundant at the surface, 54/100 m³, decreasing with depth to <12/100 m³ below 40 m to bottom (Figure 11). Haddock larvae were more abundant, 10-12/100 m³, at middepth (30-50 m) and <3/100 m³ elsewhere. Larvae from this tow ranged in size from recently-hatched to 10 mm preserved SL. Modal lengths were 5 mm for cod and 4 mm for haddock, indicating that larvae of this size had hatched the previous 1-2 weeks.

Following the storm period, 12-17 April 1995, the deep-water site, station 90B was restarted with a new drifter (7b) at 67° 25.0', 40° 44.5', 94 m bottom depth (Figure 3). Between 1250 h 17 April and 2157 h 18 April 1995, nine 1-m MOCNESS, three 1/4-m MOCNESS, and two 10-m MOCNESS tows were made. While most of the water column remained 5.3-5.4 °C, under sunny skies and calm seas the 5-10 m surface water temperature increased to 6.4-7.0 °C. MOCNESS-1 m 46 was sorted ashore and the vertical profiles for cod and haddock larvae are shown in Figure 12. Similarly low numbers of cod and haddock larvae were observed with similar profiles. The highest densities, 4-8 larvae/100 m³, were observed in the surface 10 m and at middepth, 30-50 m. The length frequencies for cod and haddock were the same for this tow as in MOCNESS-1m 29 (station 90A).

A shoal station 91 began at 0053 h 19 April 1995 following drifter 34 at 40° 54.6', 67° 42.4', 70-m bottom depth, and continued until 2000 h 20 April 1995. During this period nine 1-m MOCNESS, five 1/4-m MOCNESS, and two 10-m MOCNESS tows were made. The water column remained fairly well-mixed and isothermal, 5-6° C. MOCNESS 1-m 57 was sorted ashore. Cod and haddock larvae numbers were relatively low (<8/100 m³) and their vertical profiles were similar to that observed in MOCNESS-1 m 46 (station 91B) (Figure 13). Highest densities of cod and haddock larvae were at middepth, 20-40 m, or near surface. The range of length frequencies was from recently-hatched to 10 mm, but the modal size of cod (7 mm) and haddock (8 mm) was larger than those collected at station 90.

Biochemistry Studies (E. Broughton, L. Buckley, M. Morss)

Samples for biochemical and age analysis were taken from 48 0.505-mm mesh 61-cm bongo nets, three 0.064-mm mesh 1/4-m MOCNESS tows, and 19 0.333-mm mesh 1-m MOCNESS tows. All samples were rinsed from the nets using minimal seawater pressure and transferred to buckets containing ice packs. Plankton from nets that were not to be sorted for biochemical samples was preserved immediately using 4% buffered formaldehyde in seawater. Plankton samples sorted for fish or invertebrates were picked in seawater filled translucent sorting trays on ice covered light tables. Every effort was made to keep samples cold during processing to delay decomposition. Plankton remaining after removal of samples was preserved with 4% buffered formaldehyde and seawater.

Table 1. Numbers of samples removed for analysis:

Investigator	Species	Bongo	MOC 1	MOC 1/4
Buckley	<i>G. morhua</i>	356	562	
Buckley	<i>M. aeglefinus</i>	56	327	
Burns	<i>G. morhua</i>	30		
Burns	<i>M. aeglefinus</i>		1	
WHOI	<i>G. morhua</i>	174	207	
WHOI	<i>M. aeglefinus</i>	44	131	
WHOI	<i>H. platessoides</i>	9	12	
WHOI	<i>C. finmarchicus</i>		328	
WHOI	<i>Pseudocalanus</i>		80	
WHOI	phytoplankton			11 ml

Larval fish collected for Buckley were video taped on board for measurements then individually frozen in liquid nitrogen. The larvae will be analyzed for their RNA, DNA, protein content, age, and length. The data will be used to determine the nutritional condition and growth rate of the individual fish. A comparison will be made of fish taken from the deep and shoal sites and also along discrete depths at each site. Buckley also froze 12 nets of plankton, about 10 pounds, (mostly copepoda) as food for larval fish being raised in the laboratory.

Juvenile fish collected for Burns were measured to the nearest 0.01 mm (SL) using a Wild M5 stereomicroscope equipped with an optical micrometer then preserved in EtOH. These fish will have their age determined by otolith analysis.

Larval fish collected for WHOI were measured to the nearest 0.01 mm (SL) using a Wild M5 stereomicroscope equipped with an optical micrometer then individually frozen by suspension above liquid nitrogen. *Pseudocalanus* collected were frozen grouped by net by suspension above liquid nitrogen. Half of the *Calanus finmarchicus* collected were individually frozen by suspension above

liquid nitrogen and half were chemically fixed. Phytoplankton samples were sieved into two size categories (<0.505 mm and >0.333 mm, and <0.333 mm and >0.0640 mm) then frozen in approximately 0.1 ml aliquots by suspension over liquid nitrogen.

Cell Growth Studies (J. Stegeman, M. Moore, M. Morss)

Cod, haddock, plaice, *Calanus finmarchicus* and *Pseudocalanus* and mixed phytoplankton were collected by MOCNESS and Bongo. Samples were frozen for later analysis of proliferating cell nuclear antigen expression by dot blot. Samples will be analyzed in comparison with those from Seward Johnson Cruise 9503 (Table 1, page 6) and the May 1995 Seward Johnson Cruise. Fish samples were measured for total length before freezing.

The following numbers of each species were preserved individually:

Cod 341
Haddock 146
Plaice 29
Calanus 140
Pseudocalanus 21
Phytoplankton 116 (mixed)

Preliminary laboratory analysis of these samples shows good preservation of proliferating cell nuclear antigen. Analysis of these and samples preserved on SJ Cruise 9503 is underway.

Predation Studies

WHOI Predation Studies (E. Horgan, M. Butler)

Sampling by the GLOBEC Predation Group on this cruise included:

1. 5 MOCNESS-10 m collections (2 night, 1 day at station 90 and 1 night, 1 day at station 91).
2. Dives - 1 daytime dive at station 83(1420), 1 evening dive at station 90(1715), 1 daytime dive at station 91(1110).
3. Parts of MOCNESS-1 m collections at stations 90 and 91.

Immunological Studies

A total of 147 large predators were removed from the MOCNESS-10 m hauls and from Dive 2 and preserved for antibody analysis for the presence of *Calanus* in the gut contents. A list of these predators can be seen in Table 2. In addition to these 147 samples, we also fed some starved *Crangon septemspinosa* adult female *Calanus* and preserved them immediately after ingestion occurred. Replicates of *Crangon septemspinosa* fed 1 and 5 adult female *Calanus* were preserved using the same technique employed for other immunological samples.

Table 2. Immunological Studies

# on vial	STATION	net#	taxa	#
1	MOC10-027	4	Hyperid Themisto gaudichaudi	10
2		4	Gammarid Monoculodes sp.	3
3		4	Euphausiid Thysanoessa inermis	5
4		4	Shrimp Pandalid larvae	1
5	MOC10-034	3	Hyperid Themisto gaudichaudi	10
6		3	Euphausiid Thysanoessa inermis	1
6		3	Euphausiid Meganctiphanes norvegica	2
7		4	Pleurobrachia	6
8		0	Hyperid Themisto gaudichaudi	5
9	MOC10-039	4	Hyperid Themisto gaudichaudi	10
10		4	Euphausiid Thysanoessa inermis	6
10		4	Euphausiid Meganctiphanes norvegica	3
11		2	Hyperid Themisto gaudichaudi	10

12		1	Gammarid Monoculodes sp.	1
13		1	Hyperid Hyperia galba	1
14		1	Shrimp Crangon septemspinosa	5
15		1	Shrimp Dichelopandalid leptocerus	1
16		0	Pleurobrachia	6
17	DVE 2		Nanomia	1
18	DVE 2		Nanomia	1
19	MOC10-049	4	Isopod Cirolana polita	10
20		4	Shrimp Crangon septemspinosa	2
21		4	Gammarid Monoculodes sp.	3
22		3	Shrimp Dichelopandalid leptocerus	6
23		3	Shrimp Crangon septemspinosa	5
24		3	Isopod Cirolana polita	5
25		2	Pleurobrachia	6
26		1	Shrimp Crangon septemspinosa	10
27		1	Hyperid Themisto gaudichaudi	7
28		1	Gammarid Ampelisca verrilli	1
29		0	Hyperid Hyperia galba	2
30		0	Shrimp Pandalid larvae	2
31			Crangon septemspinosa	1 (fed 5 adult female Calanus)
32			Crangon septemspinosa	1 (fed 1 adult female Calanus)
33			Crangon septemspinosa	1 (fed 1 adult female Calanus)
34			Crangon septemspinosa	1 (fed 5 adult female Calanus)

Other live predators, mainly *Crangon septemspinosa*, from tows were used in laboratory experiments in an effort to determine gut passage times. A series of gut clearance rate measurements were made on *Crangon septemspinosa* and *Dichelopandalid leptocerus* (See Table 3a). Measurements were made using *Calanus* prey stained with a variety of dyes including fluorescent beads, Toluidine Blue, and Carmin Red. We found that *Calanus* readily consumed fluorescent beads, but *Crangon* feces produced after consuming these *Calanus* did not obviously fluoresce. Staining *Calanus* with Toluidine Blue made them more easily visible, but the dye was not transferred to the *Crangon* feces. The blue dye appeared to be absorbed into the *Crangon*'s body. In a few hours, *Calanus* consumed Carmin red and produced bright red fecal pellets. Subsequently, *Crangon* feces produced after consuming these carmin-fed-copepods took on a reddish color.

The initial experiments were conducted on starved animals. Gut passage times (GPT)'s range from .87 - 10.60 hours for starved *Crangon septemspinosa*. The highest average GPT's were found when animals were starved for 120 hours (n=3). Two experiments were conducted on non-starved *C. septemspinosa*., one ship-board and one on shore (n=7 and n=4). Ship-board experiments were run at 5-7 C, and laboratory experiments done on shore were at 9 C. In these experiments, the non-starved animals were fed a mixed assemblage of copepods or artemia for several hours and then given a pulse of carmin-stained *Calanus*. Next, they were observed until red feces were produced. GPT's from these experiments ranged from 2.00 - 12.00 hours and averaged about 4.5 hours.

Dichelopandalid leptocerus were also used as predators in one laboratory experiment (See Table 3b). GPT's range from .90-5.32 hours (n = 7). This experiment was run in the laboratory on shore where the temperature was 9 C.

One ship-board experiment was attempted using *Cirolana polita* as a predator. Crangon injected with carmine was used as the prey. The isopods readily consumed the dyed crangon turning their guts bright red. However, no red feces had been produced after 42 hours. Perhaps they were retaining food in their guts due to the pre-experiment starvation period (Murtough, 19??).

Table 3a. *Crangon septemspinosa* gut passage time from SJ9503 and SJ9505

Date (place)	state of predator	prey-dye	time ingested	time egested	GPT (hours)	cops. consumed before defec.	length of predator (mm)
3/29 (WHOI)	starved	none	1325	1725	< 4.0	4	
3/29 (WHOI)	starved	none	1326	1712	< 3.77	4	
4/10 (RV/SJ)	starved (44-47 hrs)	fluorescent beads	0124	0332	2.13	6	24
4/10 (RV/SJ)	starved (44-47 hrs)	fluorescent beads	0125	0547	4.40	3	13
4/10 (RV/SJ)	starved (44-47 hrs)	fluorescent beads	0125	0223	0.97	3	
AVG (RV/SJ)					2.50		
4/12 (RV/SJ)	starved (32hrs)	Toluidine Blue	1602	1838	2.60	3	24
4/12 (RV/SJ)	starved (32hrs)	Toluidine Blue	1642	1933	2.85	2	12
4/12 (RV/SJ)	starved (32hrs)	Toluidine Blue	1621	1838	3.28	2.5	12
4/12 (RV/SJ)	starved (32hrs)	Toluidine Blue	1600	1810	2.20	2	13
4/12 (RV/SJ)	starved (32hrs)	Toluidine Blue	1557	1842	2.75	1	12
4/12 (RV/SJ)	starved (32hrs)	Toluidine Blue	1558	1650	0.87	2	24
AVG (RV/SJ)					2.43		
4/18 (RV/SJ)	starved(120 hours)	Carmine Red	1906	2042	1.60	2	17
4/18 (RV/SJ)	starved(120 hours)	Carmine Red	1917	0450	9.50	4	13
4/18 (RV/SJ)	starved(120 hours)	Carmine Red	1951	0626	10.60	2	16
AVG (RV/SJ)					7.23		
4/20 (RV/SJ)	not starved	Carmine Red	1641	1958	3.30	3	~30
4/20 (RV/SJ)	not starved	Carmine Red	0706	1300	5.95	1	~30
4/20 (RV/SJ)	not starved	Carmine Red	0506	0706	2.00	3	~30
4/20 (RV/SJ)	not starved	Carmine Red	0046	0806	7.30	5	~30
4/20 (RV/SJ)	not starved	Carmine Red	1426	1738	3.20	1	~30
4/20 (RV/SJ)	not starved	Carmine Red	0313	0513	2.00	3	~30
4/20 (RV/SJ)	not starved	Carmine Red	0047	1247	12.00	1	~30
AVG (RV/SJ)					5.11		
4/28 (WHOI)	not starved	Carmine Red	1213	1507	2.9	3	26
4/28 (WHOI)	not starved	Carmine Red	1122	1407	2.75	6	35
4/28 (WHOI)	not starved	Carmine Red	1125	1414	2.81	3	24
4/28 (WHOI)	not starved	Carmine Red	1129	1708	5.65	6	33
AVG (WHOI)					3.53		

Table 3b. *Dichelopandalid leptocerus* gut passage time from SJ9503 and SJ9505

Date (place)	state of predator	prey-dye	time ingested	time egested	GPT (hours)	cops. consumed before defec.	length of predator (mm)
3/30 (WHOI)	starved	none	1258	1710	4.2	5	
4/18 (RV/SJ)	starved	carmin	0017	0629	6.5	2	>50
4/27 (WHOI)	non-starved	carmin	1414	1508	0.90	1	50-60
4/27 (WHOI)	non-starved	carmin	1057	1317	2.30	5	60-65
4/27 (WHOI)	non-starved	carmin	1058	1319	2.30	5	45-50
4/27 (WHOI)	non-starved	carmin	1143	1510	3.45	8	45-50
4/27 (WHOI)	non-starved	carmin	1147	1326	1.65	2	50-55
4/27 (WHOI)	non-starved	carmin	1151	1328	1.62	2	50-55
4/27 (WHOI)	non-starved	carmin	1154	1513	5.32	4	55-60
AVG					2.51		

On all three dives both large (up to 10 cm) and small (<1cm) *Bolinopsis* were locally abundant. *Pleurobrachia* and *Beroe* were also present although not in as great numbers as *Bolinopsis*. Fragments of hydroid colonies were not observed on any of these dives.

On the first dive (station 83), *Pleurobrachia* ranged in size from 1-2 cm. in diam. *Beroe* were the least abundant of the larger jelly animals measuring approximately 4 to 10 cm. in length. The physonect siphonophore, *Nanomia* sp., was locally present but infrequent. They measured up to 50 cm. in length. Nine individuals were preserved: 7 *Bolinopsis*, 2 *Pleurobrachia*., and fifteen individuals were collected for shipboard studies: 8 *Bolinopsis*, 4 *Pleurobrachia*, 3 *Beroe*.

On the second dive (station 90). In addition to the *Bolinopsis*, some large *Pleurobrachia* and small *Beroe* were seen, but infrequently. *Nanomia* sp. were common with individuals up to 60 cm. in length. Thirteen individuals were preserved for immunological analysis: 11 *Bolinopsis*, and 2 *Nanomia* sp. Nine individuals were collected for shipboard studies: 8 *Bolinopsis*, 1 *Beroe*.

On the third dive both large and small *Bolinopsis* with their guts packed full of copepods were still locally abundant. Both large and small *Pleurobrachia* individuals were also locally abundant. Medusae of *Staurophaura*, to 1 cm. diam., and *Cyanea*, to 3 mm. were locally common.

Other plankters noted include the pteropods *Limacina* and *Clione* which were abundant, and the pelagic polychaete *Tomopteris* was also observed frequently. Nine *Bolinopsis* were preserved and eleven individuals were collected for shipboard studies: 10 *Pleurobrachia*, 1 *Beroe*.

URI Predation Studies (G.Klein-MacPhee, D.VanKeuran, H.Jeon)

Introduction:

The role of our complement of the predation group in the Georges Bank GLOBEC program is to identify potential gelatinous predators on the target species (cod, haddock, *Calanus* and *Pseudocalanus*); to determine their biomass on Georges Bank coincident with the target species; to determine their potential impact on survival of cod and haddock, either directly as predators on eggs and larvae, or indirectly as competitors for their food, *Calanus* and *Pseudocalanus*; and to determine the effects of increased temperature on predator impact.

In the pilot field study conducted in April of 1994, we identified two potentially important groups of predators, drifting colonial hydroids and chaetognaths which were collected in large numbers. We conducted several laboratory experiments which showed that the hydroids and hydromedusae were capable of capturing and ingesting *Calanus* eggs, and cod eggs and larvae, and conducted some experiments on gut passage times. Although these hydroids were described by Bigelow in 1924, they have not been mentioned in recent surveys and we were not sure whether their presence was a transient phenomenon produced by storm conditions or whether they were a regular component of the plankton.

Objectives:

In the April 6-21 cruise our goals were:

- To describe potential gelatinous predators on the target species (cod, haddock, *Calanus*, *Pseudocalanus*) and describe their vertical distribution and abundance both day and night at a shallow (mixed) and deep site.
- To estimate predation rates of selected predators on target species from feeding rates obtained from gut analysis of preserved specimens together with gut passage times
- To look for the floating hydroids which were present in 1994, quantify their abundance, and determine if their distribution occurred coincidentally with early life stages of cod and haddock
- To perform shipboard experiments on digestion rates of hydroids on *Calanus* eggs

- To perform shipboard experiments on freshly collected gelatinous predators using target species (*Calanus* or *Pseudocalanus*) labeled with dye as prey to determine gut passage time at a controlled temperature
- To collect live hydroids as a fresh source of specimens for laboratory culture

Methods:

Plankton collections were made using a 1-m MOCNESS with nine nets (0.333-mm mesh) at shallow and deep stations in the day and at night, where cod larvae and *Calanus* were determined to be present. Nets were fished at eight depths in the deep stations and five depths in the shallow stations. The nets were rinsed with sea water and the contents preserved immediately in phosphate buffered formalin.

Additional collections of gelatinous predators were made by divers, and delivered live in plastic bags filled with sea water or preserved *in situ* with buffered formalin. The live organisms were placed in 4 quart plastic containers in filtered seawater and kept in a temperature control room at 7 C.

The most abundant gelatinous predators encountered at the dive stations were the ctenophores *Bolinopsis infundibulum*, *Pleurobrachia pileus*, and *Beroë* and the siphonophore *Nanomia*. The ctenophores were used for gut passage experiments. Three series of experiments were conducted. The ctenophores were starved for 12 hours and then transferred by dipper to quart glass jars containing clean sea water, one individual per jar. They were allowed to acclimate for 1 hour then presented with several dyed *Calanus* adults. *Calanus* were stained with Toluidin blue dye, about 1 gm in 200 ml filtered sea water (concentration of about 0.5%) (Mari Butler personal communication). The *Calanus* were stained bright blue and were clearly visible in the gut. The animals were placed in quart jars containing 20µ filtered sea water, 10 dyed *Calanus* were placed in each jar, the ctenophores were allowed to feed for one half hour, then transferred to clean filtered water. The water from the jars they were removed from was filtered and the remaining *Calanus* counted so we would know how many animals were ingested. The ctenophores were then observed every half hour. When the animals appeared to have completely digested the food, they were removed from the jars, measured and returned to their holding containers. The jars were filtered through a 20 µm screen and the filtrate examined for remains of digested copepods. Complete digestion was determined to have occurred when dyed feces were observed in the jar.

Colonial hydroids were used in three digestion experiments. In two, hydroids collected from a 30 minute Bongo tow (0.505-mm mesh) were given the opportunity to ingest *Calanus* eggs. Hydroids were maintained in the dark at 7 C and observed hourly for over 48 hours. A third group of hydroids collected from the 1m mocness already contained what appeared to be *Calanus* eggs. These were maintained and observed in the same way. Eggs were judged to be starting to digest when the membrane of the egg was no longer visible, and totally digested when the hydroid gut was no longer expanded.

Attempts were made to determine feeding rates by colonial hydroids on various prey. A pint jar with 50 hydranths and 40 small copepods and copepodites was placed in the 7C environmental chamber with air bubbling through the water to keep the animals in suspension. Periodic observations were made over 12 hours. In a second feeding rate experiment 10 hydromedusae of *Clytia* were placed in a pint jar containing 35 *Calanus* eggs. Starved *Clytia* hydroids were also added to the jar, along with 30 small copepodites, and maintained and observed in the same manner. In a third experiment nauplii were added to a pint jar containing 61 hydranths, and maintained and observed in the same manner.

Observations were also made of feeding by Bongo collected colonial hydroids on various prey from the same source. Feeding by hydromedusae provided by Erich Horgan was also observed under the microscope.

Results:

We collected 4 MOCNESS 1-m sets of samples, preserved them and stored them for sorting (Table 4).

Table 4. MOCNESS 1-m URI Samples

Date	Time (local)	Tow Number	Description of Tow
4/12/95	1418	Moc 1-028	Day Deep
4/12/95	0415	Moc 1-032	Night Deep
4/19/95	2000	Moc 1-047	Night Shallow
4/20/95	1209	Moc 1-060	Day Shallow
3/23/95	1705	Moc 1-026	Evening Shallow (40m)

Ctenophore Experiment

Experiment 1 -*Bolinopsis* ingested the dyed copepods within 1 hour. Average digestion time was hours (Fig 14). In Experiment 2, *Bolinopsis* took longer to digest copepods (average about 6 hours Figure 15). Examination of the filtrate at the end of the experiment showed that the animals were producing eggs and I believe this might have accounted for the longer average digestion time. In experiment 3, *Pleurobrachia* were fed *Calanus*. The average digestion time was about 11 hours (Figure 15). This was longer than the average time recorded (8 hours) in the previous cruise. Examination of the filtrate showed that they were also producing eggs.

Hydroid Experiments

During the first two egg digestion experiments *Calanus* eggs ingested by colonial hydroids were digested within 20 to 48 hours at 7C, which compares well with the observed digestion time of 14 to 34 hours observed at 9C during the March cruise. In both cases a few eggs remained undigested in hydranths that became dormant during the lengthy digestion period. These eggs, while no longer in the population, were not of benefit to the colonial hydroid. In the third experiment, with eggs already ingested at time of collection, 5 of nine eggs were still visible after 21 hours, but only 2 remained in withdrawn cells after 33 hours. Although the colonial hydroids readily ingest *Calanus* eggs and do eventually digest them, the rate is very slow at low temperatures.

The feeding rate experiments were inconclusive, prey densities did not seem to be high enough for many animals to catch prey.

During observations under the microscope it was determined that densities of nauplii must be very high (several hundred animals in a small dish) before captures are made by either hydroids or medusae. During the first feeding rate experiment described earlier, no prey had been ingested after 8 hours. In the second jar one egg was ingested after 2 hours and one copepodite after 4 hours. The feeding experiment using nauplii did not demonstrate that any nauplii were eaten after 5 hours.

During observations under the microscope, hydroids were found to ingest parts of large copepodites and digest off antennae or caudal rami of these animals. The animals were released when dead. Hydroids and medusae were much more likely to ingest nauplii than copepod eggs when both were offered, taking in the nauplii instantly. When eggs of *Calanus* were placed under the bell of hydromedusae of *Clytia*, they were expelled within 15 minutes.

Observations were made of a large (25 cm) colonial hydroid, probably *Obelia*, collected by Grace MacPhee on April 20, 1995 from 1-m MOCNESS 61. The basal area was examined, and dark fibrous material found in association with this area. The fibrous material appeared to be fungal with interspersed diatom fragments, pieces of dinoflagellates, and many small, nearly-colorless flagellates. It is likely that this large colonial hydroid had, until shortly before collection, been attached to the bottom.

Accomplishments:

We collected replicate day and night discrete depth samples at a shallow and deep station. Predator abundance, distribution and gut content analysis will be for predators will be determined from these samples.

We collected floating hydroids at both of the stations and will examine the preserved samples to determine abundance, distribution and gut contents.

We determined digestion times of hydroids on dyed and undyed *Calanus* eggs at 7C in shipboard experiments.

We collected an additional potential predator, the ctenophore *Bolinopsis infundibulum*, which was not present in large numbers during the April 1995 cruise; and determined digestion times using dyed *Calanus* adults as prey at 7C. We repeated digestion experiments on *Pleurobrachia*. *Bolinopsis infundibulum* was collected in the May 1994 cruise by Madin in large numbers, but it disintegrates in formalin, so does not appear in the preserved samples. Divers collected and preserved *Bolinopsis* individually in situ for gut content studies.

We collected live hydroids from net tows and ctenophores from diver collections and brought them back to the laboratory as culture stock. We will perform additional laboratory experiments using these animals.

Personnel List

Scientific

Name Title Organization

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SEWARD JOHNSON Officers and Crew

19. Daniel Schwartz Master
20. John Jetter Chief Mate
21. Graydon Henrikson Second Mate
22. George Fisher Chief Engineer
23. Michael Riordan Assistant Engineer
24. Stewart Moreaux Second Assistant Engineer
25. Charles Garrett Seaman
26. Anthony Monocandilos Seaman
27. Christian Koegel Seaman
28. Jason Grant Steward
29. Bruce Ellzey Assistant Steward
30. Donald Cucchiara Electronics Technician
31. Walter Maxwell Electronics Technician

Appendix I. Event Log

Figure Captions

Figure 1. Area of Operations on Georges Bank for the R/V Seward Johnson Cruise 9505, 7-21 April 1995, showing two bongo surveys (Eastern Georges and Southern Flank) and three drifter sites:

- Site 59 (60 m), Site 90(m), and Site 91 (60-m).

Figure 2. Summary of drifter deployments on SJ9505. One deployment (7a) was made at the start of the bongo survey and two deployments were made at each Site 90 (7c and 4a) and Site 91 (6a and 7b). In the case of 7b, the GPS failed mid-way through the deployment but ARGOS fixes were available to provide a rough estimate of its trajectory in its last three days. GLOBEC mooring locations are denoted by asterisks.

Figure 3. Sampling locations at Site 90 relative to ARGOS/GPS/VHF drifter elliptic path. Straight lines indicate start and stop path of ship during net hauls. Numbers indicate cast number and start position. For example, the 1-m MOCNESS tow #33 was taken on a west-northwestward tack. The drifter path indicates a residual flow towards the southeast (21 cm/s). The 100-m isobath is included in the upper-right panel.

Figure 4. Sampling locations at Site 91 relative to ARGOS/GPS/VHF drifter elliptic path. Straight lines indicate start and stop path of ship during net hauls. Numbers indicate cast number and start position. For example, the 1/4-m MOCNESS tow #56 was taken on a west-northwestward tack. The drifter path indicates a residual flow towards the west and then towards the north. The 60-m isobath is included in the upper-left panel.

Figure 5. Record of temperature at the surface and subsurface as measured by the drifters and Minilog probes attached to the bottom of the holey sock. The top panel is the results from Site 90 (17-19 Apr) and the bottom is from Site 91 (17-20 Apr). In the case of Site 90, the holey sock was too buoyant to sink to its intended depth. At both sites, the thermal stratification increased to nearly 2 C late in the day on 18 April 1995.

Figure 6. Examples of shipboard meteorologic sensor data interpolated to five minute intervals (see text) .

Figure 7. Examples of shipboard hull-mounted sensor data (seasurface temperature, salinity, and fluorescence) interpolated to five minute intervals (see text) .

Figure 8. Wind as measured at NOAA Buoys 44008 and 44011.

Figure 9. Results of bongo survey on eastern Georges Bank, April 8-10, 1995. Top left panel shows bongo station location and number. Left middle and bottom panel show the number of cod and haddock larvae from the 0.505-mm bongo net (unstandardized); the right hand panels show the standardized value. The 60-m-isobath runs through the center of each figure with the 100-m and 200-m isobaths shown in the lower right corner.

Figure 10. Results of bongo survey on eastern Georges Bank, April 10-11, 1995. Top left panel shows bongo station location and number. Left middle and bottom panel show the number of cod and haddock larvae from the 0.505-mm bongo net (unstandardized); the right hand panels show the standardized value. The 60-m-isobath runs through the top of each figure with the 100-m and 200-m isobaths shown in the lower right corner.

No. larvae/100m³

No. larvae/100m³

Figure 11. Vertical distribution of cod and haddock larvae (top panel) and their length frequency (bottom panel) from deep-site 90A, 1-m MOCNESS tow 29, 12 April 1995, 0934-1018 DST, 87-m bottom depth.

Figure 12. Vertical distribution of cod and haddock larvae (top panel) and their length frequency (bottom panel) from deep-site 90B, 1-m MOCNESS tow 46, 18 April 1995, 1818-1901 DST, 100-104-m bottom depth.

Figure 13. Vertical distribution of cod and haddock larvae (top panel) and their length frequency (bottom panel) from shallow-site 91, 1-m MOCNESS tow 57, 19 April 1995, 1828-1901 DST, 64-72m bottom depth.

Figure 14. Digestion time of Ctenophores (see text).

Figure 15. Digestion time of Bolinopsis fed Calanus (see text).

1. ¹The fourth drifter (SN#35) was returned to the factory for repair and not available.