Environmental Monitors on Lobster Traps
Annual Report 2005

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Project objectives and scientific hypothesis:

In the early phases of the eMOLT project, we had hoped to track the migration of water-mass advection along the coast by monitoring both temperature and salinity on lobster traps. While the temperature project was very successful and still ongoing today, monitoring salinity was not as easy. The combination of fine-grain sediments fouling the conductivity sensors and the difficulty in obtaining calibration samples proved this phase of the study not practical given the allocated resources. An alternative strategy was developed in phase IV to measure transport more directly with the use of satellite-tracked drifters. This proved to be the most suceesful phase. So, while the approach to the science has evolved over the years, the scientific agenda holds steady.

The eMOLT project continues to involve lobstermen in collecting physical oceanographic data. Taken directly from previous annual reports: "by monitoring the temperature and salinity at dozens of fixed sites around the Gulf of Maine region, we hope to quantify the scales of variability. One of the long-term scientific goals is to distinguish between advective and locally driven events that influence the bottom water conditions. Given multiple time series along the coast and within different basins, we expect to track the influx and transport of remote source waters".

Analysis of the multi-year temperature records is ongoing. It is now possible to generate estimates of seasonal cycles at each location and therefore calculate “anomalies” relative to this longterm mean. Given the hourly records however, we have also begun to investigate much shorter time scale variation. After documenting the large degree of temperature variation associated with the semidiurnal tide at some frontal locations, for example, questions have arised concerning the adult lobsters reaction to this environment. Lobster biologist from various labs (UNH, Univ. of Virginia, and Lobster Conservancy) have accessed the eMOLT records for their scientific research on lobster habitat.

Now that we have nearly completed the phase IV study, the drifters deployed thus far have logged well over 50,000 kilometers of ocean. These gulf-wide surface-current observations have documented the degree of transport between basins and illustrate the dynamic exchange of water masses. While they do not provide evidence for processes occurring in the deep basins, they clearly demonstrate the potential redistribution of particles near the seasurface. The tracks do not resolve all the complexity of the circulation throughout the gulf but they do provide valuable data to help in evaluating numerical circulation model simulations. The drifter data collected in eMOLT phase IV should help biologist address questions on the physical processes of the lobster larval stage and recruitment variability.

All eMOLT phases were conducted as pilot studies to demonstrate the concept of lobstermen collecting physical oceanographic variables. Having designed and tested these low-cost GPS drifters with Northeast Consortium funding in 2004, we subsequently received additional research funding in 2005 (from both NOAA and the Woods Hole Center for Coastal Ocean and Human Health) to investigate the transport of zooplankton into and around the Great South Channel and harmful algal blooms along the coast of Maine, respectively. So, while our initial objective was to examine the movement of lobster larvae along the New England coast, we have recently been able to leverage our NEC experience to help other research parties in related studies. Given alternative funding source in the future, we hope to utilize the sampling protocol and network of observers to take an active roll in an ongoing "ocean observing systems". The existing temperature probes purchased with NEC funds will remain activated for as long as their battery life allows (~2-3 more years).

Methods and work plan:

The approach to data collection has evolved slightly over the years but remains simple. Representatives from each of the four major lobstermen associations are charged with a) distributing equipment/sensors, b) training the individual lobstermen to maintain mooring & deployment logs, and c) compiling logs in electronic form. These representatives contact the participants on a near-quarterly basis and review protocols, the most important of which is maintaining fix sites/depths. The temperature sensors are now collected on an annual basis just prior to the forums when many of the participants gear is out of the water. The data is downloaded, and the sensors are returned to the individuals. The data is then processed, plotted, archived, posted on the web, and mailed to each participant.

In the case of the both the salinity and drifter study, approximately one participant from each association is charged with deploying the instruments. Unlike the simple temperature probes, these require days of preparation, assembly, and sampling effort. These individuals are compensated for their time.

Work completed to date:

In the last 12 months, eMOLT operations have progressed on three fronts: 1) continued bottom-temperature observations, 2) a reevaluation of bottom-salinity measurements, and 3) surface current observations (ie drifters). Since the first of these is described in several previous reports, we will limit the results presented here to a series of representative plots (one for each lobsterman association) that depict the interannual variations. A variety of data presentations are available to the reader on the temperature results page of emolt.org. In the case of all the inshore associations (Figure 1a, 1b, and 1c), the last few years 2003, 2004, and early 2005, have been consistently colder than the first few year of eMOLT records. It is important to note, however, that the data presented in this series of plots has been filtered to a "weekly average". The highly-variable hourly record would hide the interannual signal.

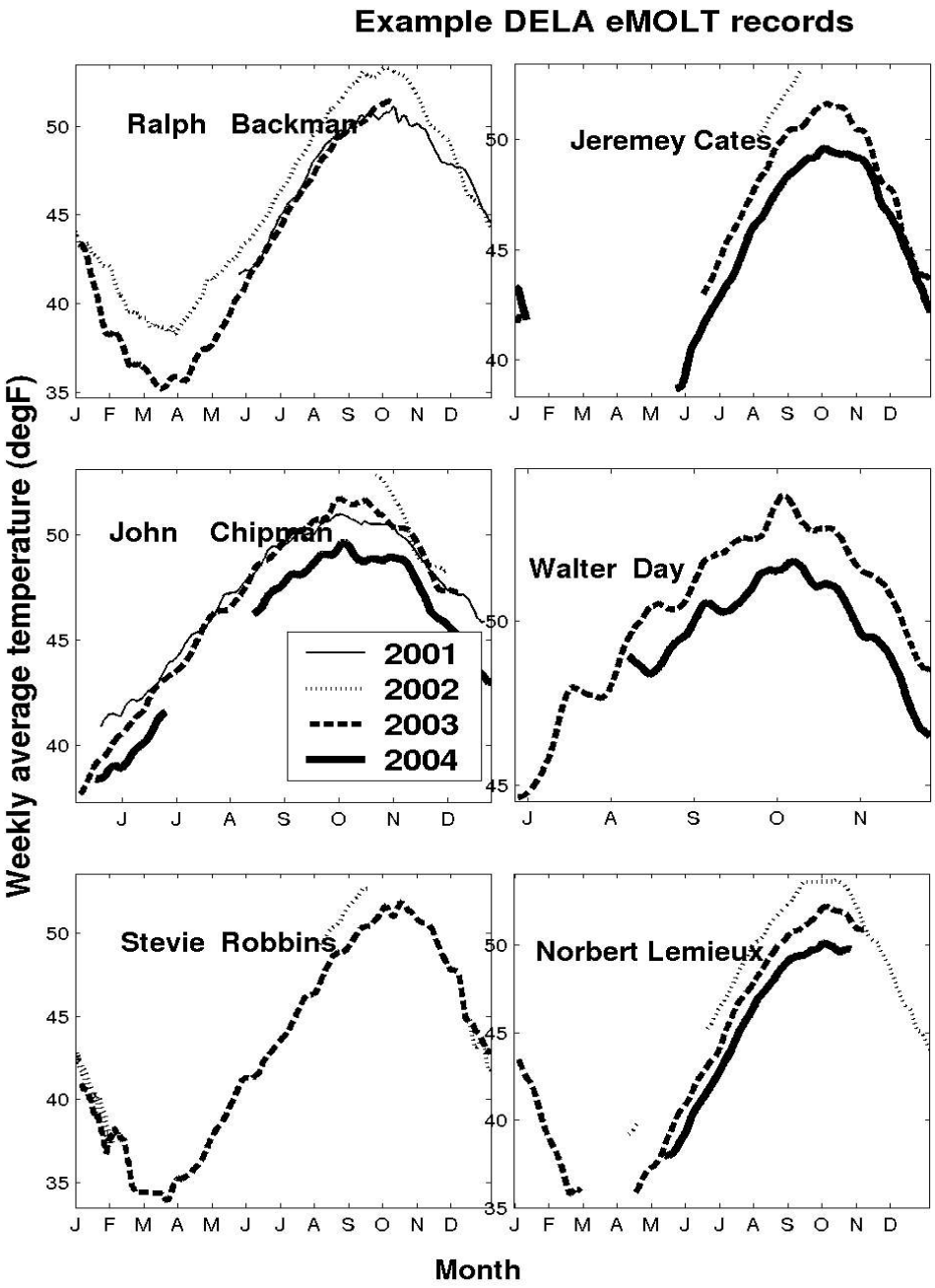

Figure 1a. Downeast Lobstermen Association mulit-year temperature records.

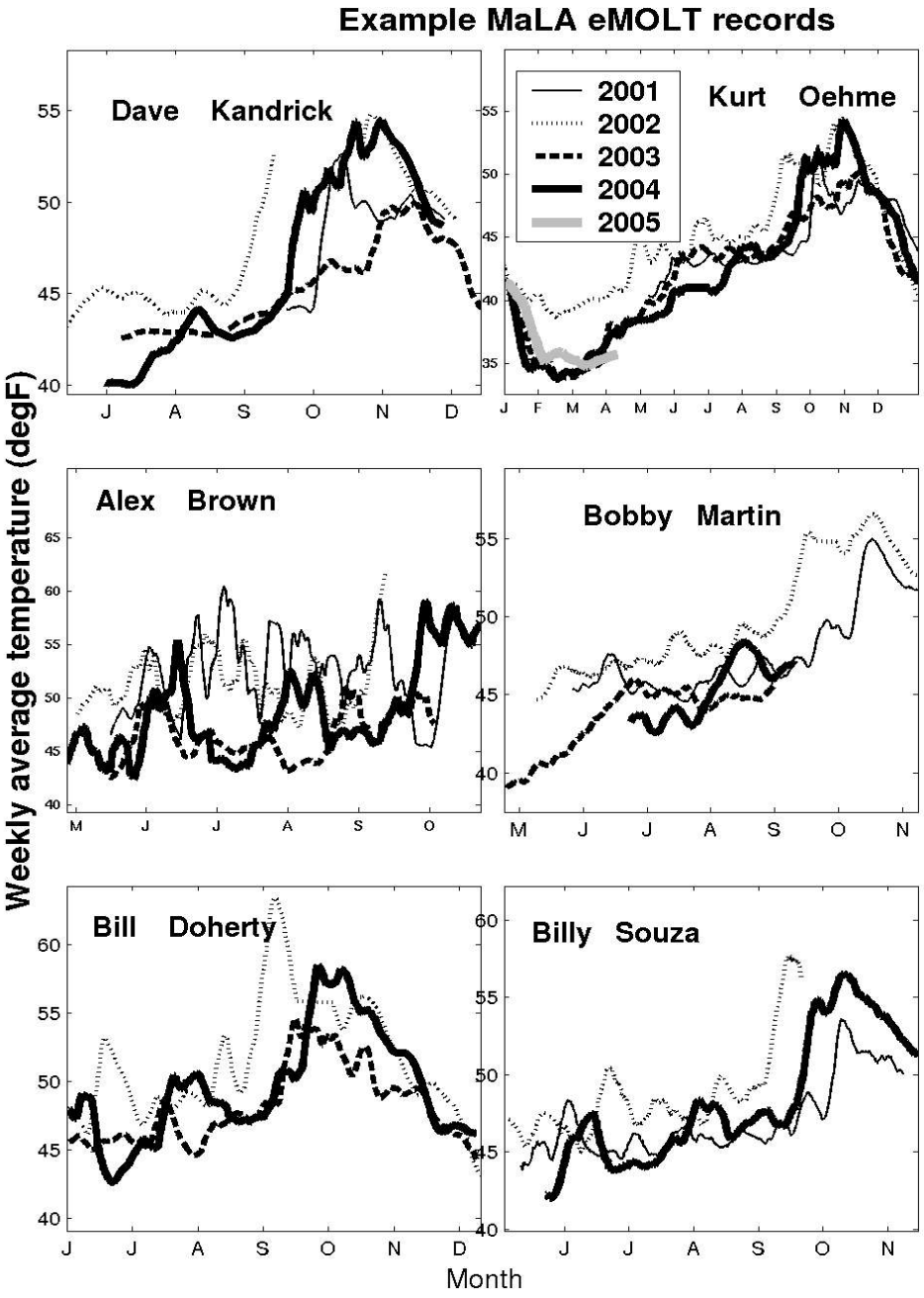

Figure 1b. Mass Lobstermen Association multi-year temperature records.

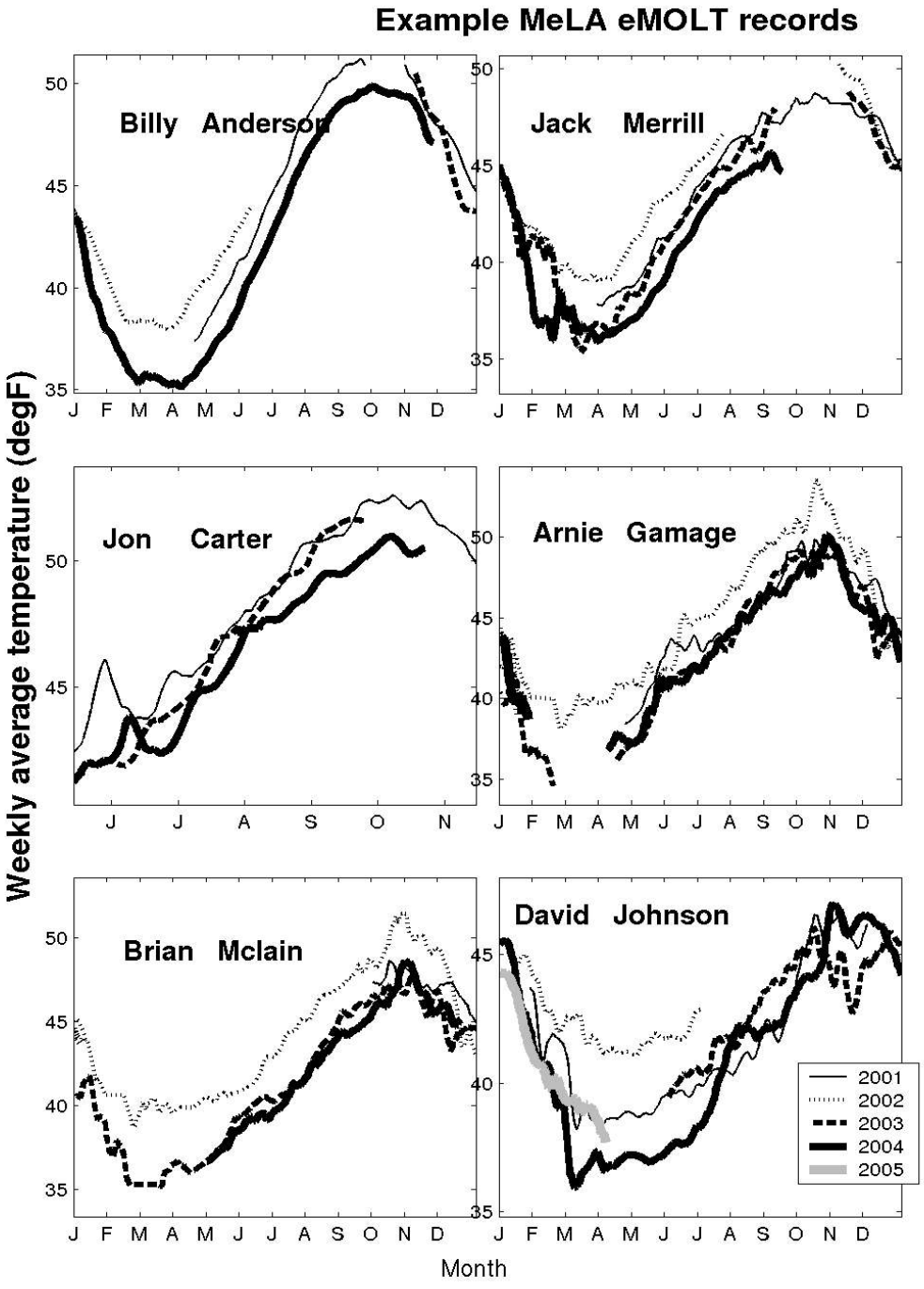

Figure 1c. Maine Lobstermen Association multi-year temperature records.

The Atlantic Offshore Lobstermen Association fish in a very different oceanographic regime with very little seasonal cycles to compare. The variations in bottom temperature at their sites has more to do with the position of the shelf/slope front position which in turn is affected by Gulf Stream ring activity. As depicted in Figure 2, there is a great deal of variability in both space and time. Efforts are under way to investigate certain events when individuals have reported significantly changes in their catch that is potentially related to the influx of various oceanic water masses. The quality of the AOLA data has improved significantly this past year with the addition of pressure sensors on probes. Since many of these individuals fish on the shelf edge, it is often necessary to monitor the depth of the probe as it may vary from haul to haul. With the discontinued use of the electronic Thistle loggers that previously provided accurate positions, it was necessary to install pressure sensors to mark the depth at which the probe falls.

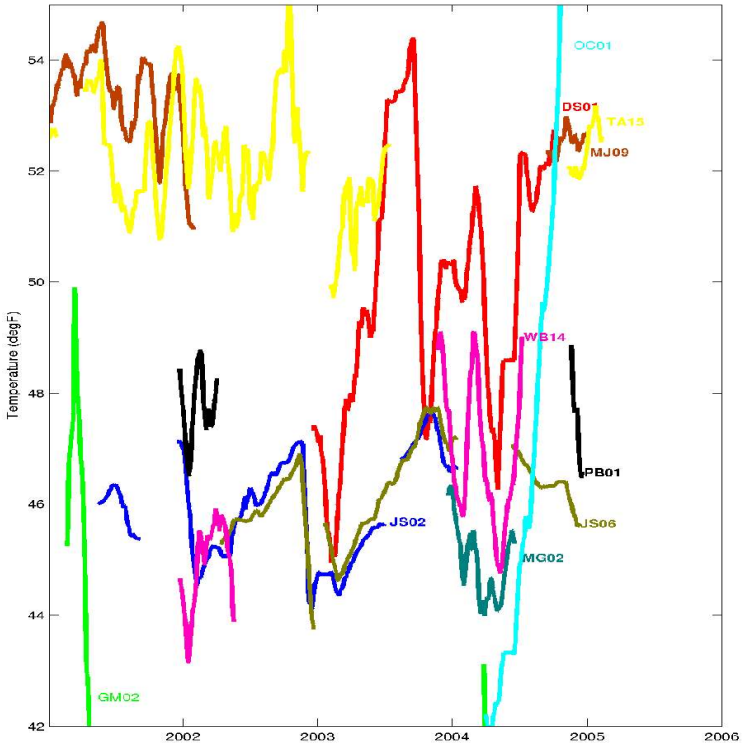

Figure 2. Atlantic Offshore Lobstermen bottom temperature records 2001-2005 with site codes denoted at the end of each record.

The eMOLT objective is to maintain all 70+ temperature records distributed along the coast for years to come. To see the general locations of these sites, readers are invited to visit the "interactive mapping utility" linked from the temperature results on the "emolt.org" home page.

As noted in last year's annual report, a reevaluation of the protocol for measuring bottom salinity was to take place. After many of the salinty records from Phase II of eMOLT were potentially fouled due to episodic fouling of the conductivity sensors, the instrumentation was tested in Quohog Bay in the Fall of 2004. Two of the units (Seabird Microcats) were secured to a frame (Figure 3) and lowered to the bottom for a two month deployment in over 20m of water.

Figure 3. Seabird Microcats secured to frame after two months in Quohog Bay.

One of the units was placed near the top of the frame (approximately 1.2 meter above the bottom) while the other was located very near the bottom where is would be if within a trap (0.3 mab). While we were hoping to find better data from the elevated unit, the results were negative in that both units recorded a continous decline in conductivity that one gets with a gradual fouling of the sensor. Both sensors showed very little biofouling but we suspect that there may have been some chemical fouling of the sensors given the site location so close to shore and boat traffic. Readers interested in the analysis of these records asked to visit http://sole.wh.whoi.edu/~jmanning/lob/quohogbay.html. This project was conducted in collaboration with Ed Laine, professor of marine geology at Bowdoin College who is interested in the potential existence of "submarine freshwater discharges" in this area. Plans are now underway to conduct additional experiments with these same sensors. For example, discussions are underway to potentially a) conduct another deployment in Quohog Bay in the Fall of 2005 and b) installing them on Nantucket Sound fish weirs. This latter collaboration would be with both Chatham fishermen and scientist from the Provincetown Center for Coastal Studies.

Finally, most of the eMOLT effort in the past 12 months was directed at development, deployment, and processing of satellite-tracked drifters. The NEC-funded project was completed as planned in 2004 and was essentially repeated with with other funding, as mentioned above, in April and May 2005. Figure 4 depicts the volume of tracks now available from the student-built eMOLT drifters.

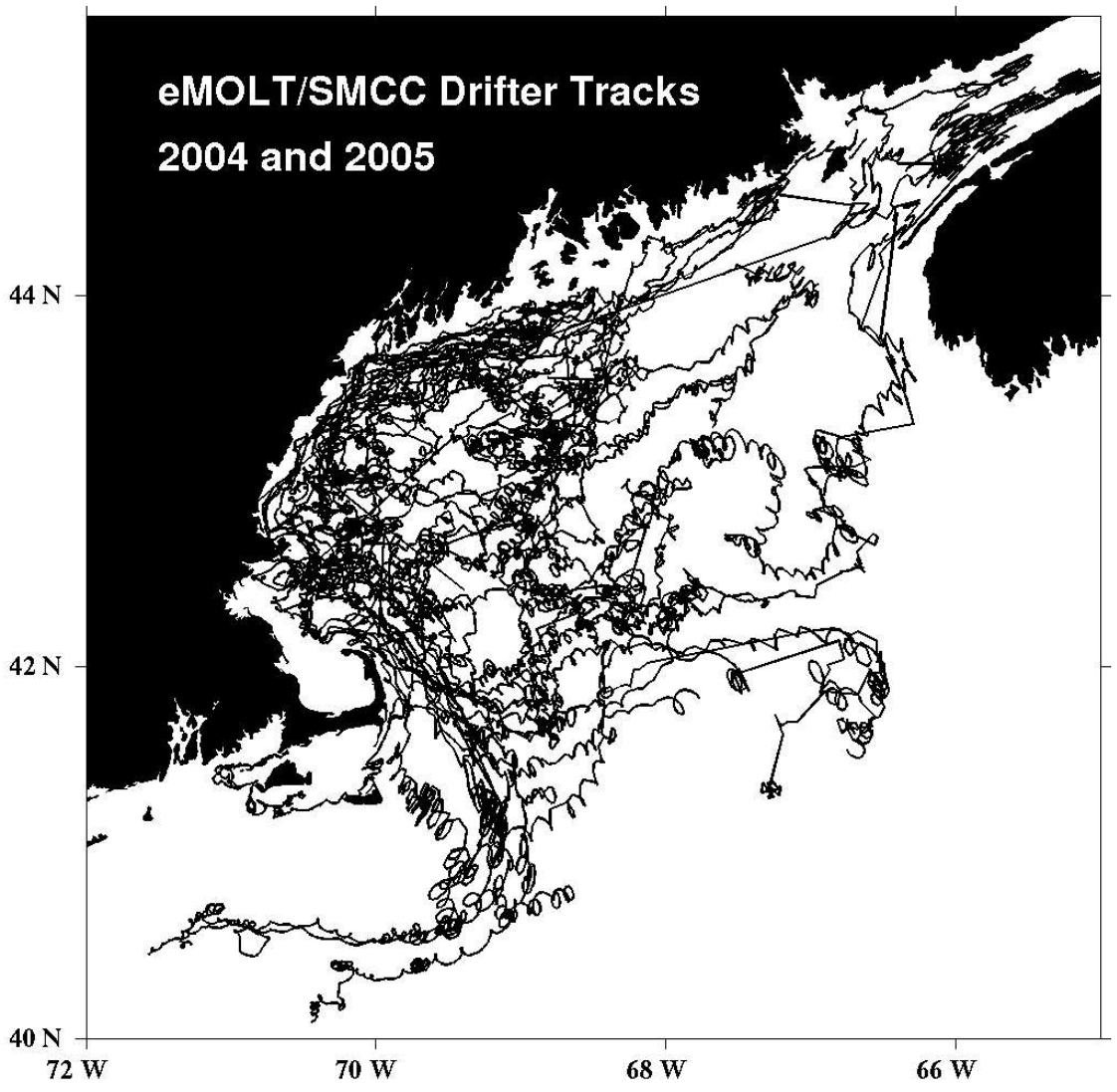

Figure 4. Student-built drifter tracks 2004-2005.

The Southern Maine Community College students have successfully built the drifters needed for these deployments as well as additional drifters for other projects. The most significant update on this effort is their recent design and construction of holy-sock drogues in 2005.

Figure 5. Student-built holey-sock drogues made at Southern Maine Community College.

Results to date:

Before presenting the results of the drifter studies, it is worth noting the continued success of the phase I temperature project. As noted in Table 1, the data base is growing steadily. The number of temperature observations is expected to exceed 2 million by the end of 2005 with several locations now having four years of data. These time series are demonstrating a large degree of interannual variability. Where 2001 appeared to be a "normal" year, 2002 was warm, and the last few years 2003 and 2004 were colder than normal. Note that the seasonal cycles do not always follow a clean sinusoidal function. The temperatures at the bottom of Mass Bay, (Kandrick & Oehme's for example in Figure 1b) document a stable summertime period followed by a rapid warming in the fall. Alex Brown's data from the eastern side of Mass Bay demonstrates the variability due to upwelling and downwelling. We look forward to adding more lines to these plots in the years to come and to be involved with modeling activity that attempts to simulate these observations.

The results of the salinity project can be found in a separate document, the final report on phase II completed in mid-August 2004. See emolt.org "Updates/Reports" page.

Table 1. eMOLT database statistics as of 15 June 2005

# eMOLT mooring sites	233
# total temperature readings	1669914
# total salinity readings	95464
# total drifter readings	41000
# total drifter sightings reported	62
# people who have actually returned data	112

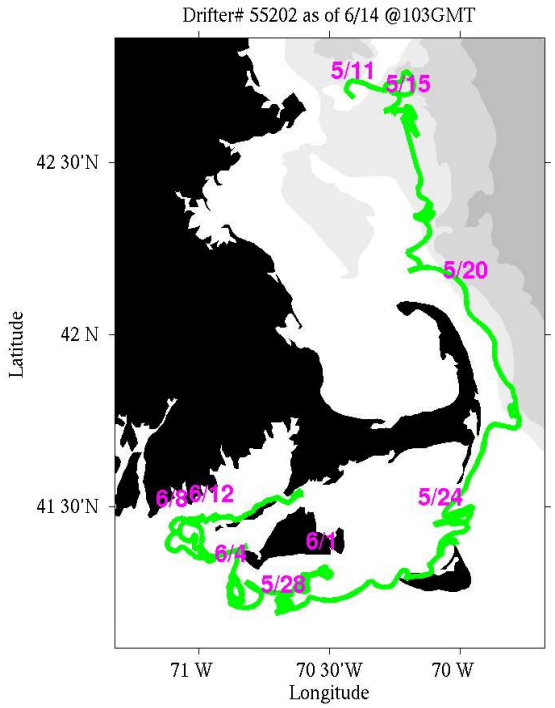

Figure 6. Example trajectory of eMOLT drifter deployed off Cape Ann that washed ashore on Surf Drive Beach in Falmouth Mass.

Nine of the drogued-drifters mentioned above were deployed in the Bay of Fundy by the Woods

Hole Oceanographic Institute to study red tide advection in mid-May 2005. At the time of this writing one is located off the NH coast and still transmitting. According to a fishermen's phone call yesterday, it still had its drogue. This drogued unit and many of the surface units (Figure 6, for example) will help diagnose one of the most severe red tide episodes on ever recorded in New England. Clam flats will be closed for weeks all along the coast of Southern New England.

Finally, one of the most exciting developments is the eMOLT collaboration with LFA34 lobstermen from the southwest corner of Nova Scotia. After a number of gatherings this past spring (forums, FSRS meetings, "town meeting", etc), LFA 34 lobstermen are interested and willing to participating in the eMOLT drifter study. We mailed one of the lobstermen, Ashton Spinney, an eMOLT drifter and he deployed it in July 2004. The track of that drifter is plotted in Figure 7. While we do not expect to resolve the Northeastern Gulf of Maine coastal current system with any statistical confidence with one or two drifters, we have, at least, fostered a relationship with our fellow fishermen on the opposite side of the gulf.

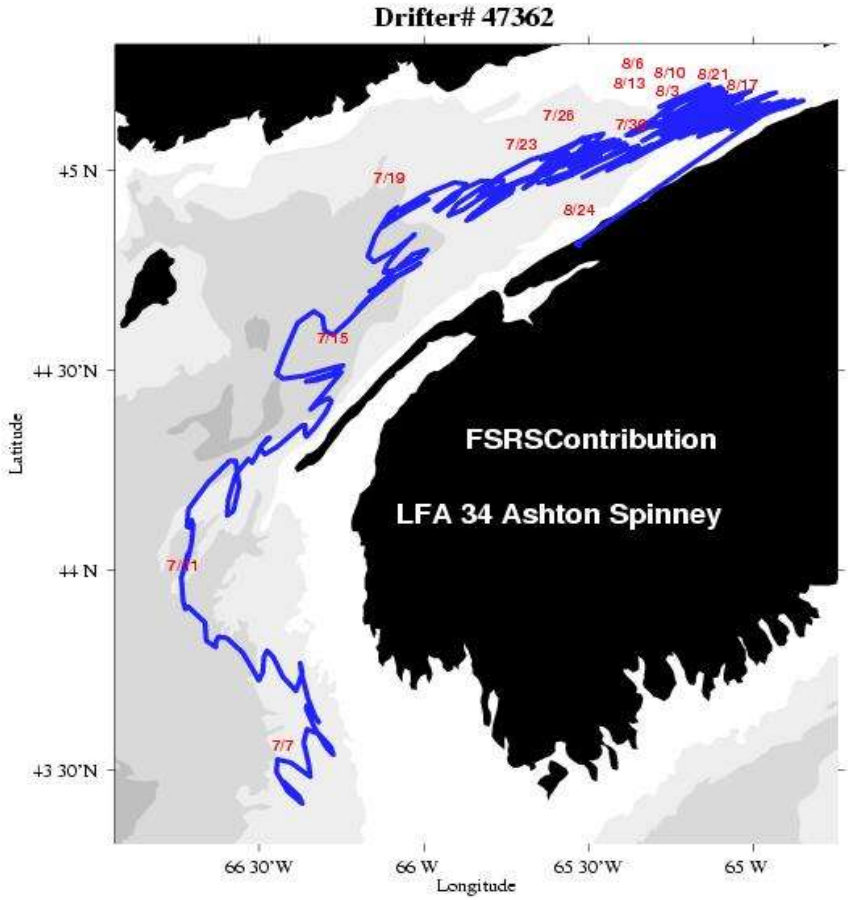

Figure 7. Trajectory of #47362 deployed by Canadian fisherman.

This figure appeared in a series of presentations at the Bedford Institute of Oceanography last fall as investigators examined the track of a dead whale on that side of the province. Numerical modelers used the data to validate simulations and confirm the presence of a retention zone on the eastern side of the Bay of Fundy. The track was also considered the following spring by US scientists investigating the hypothesis that this retention zone (or "sticky spot" as it is referred to by local fishermen) may be a sink for Alexandrium cyst beds.

A question often heard in the lobster science world is: "How are larvae transported in the surface waters along the coast and what processes regulate their fate?" The deployments of 60+ GPS drifters in 2004 and 2005 have demonstrated the potential for advection along the Maine coast. While there is some debate on how well these standard surface drifters follow the water parcels (ie affected by the wind), there can be no doubt that they are caught up in a very fast coastal current system that is capable of moving larvae half the length of the state in little more than a week's time despite the persistent southwesterlies.

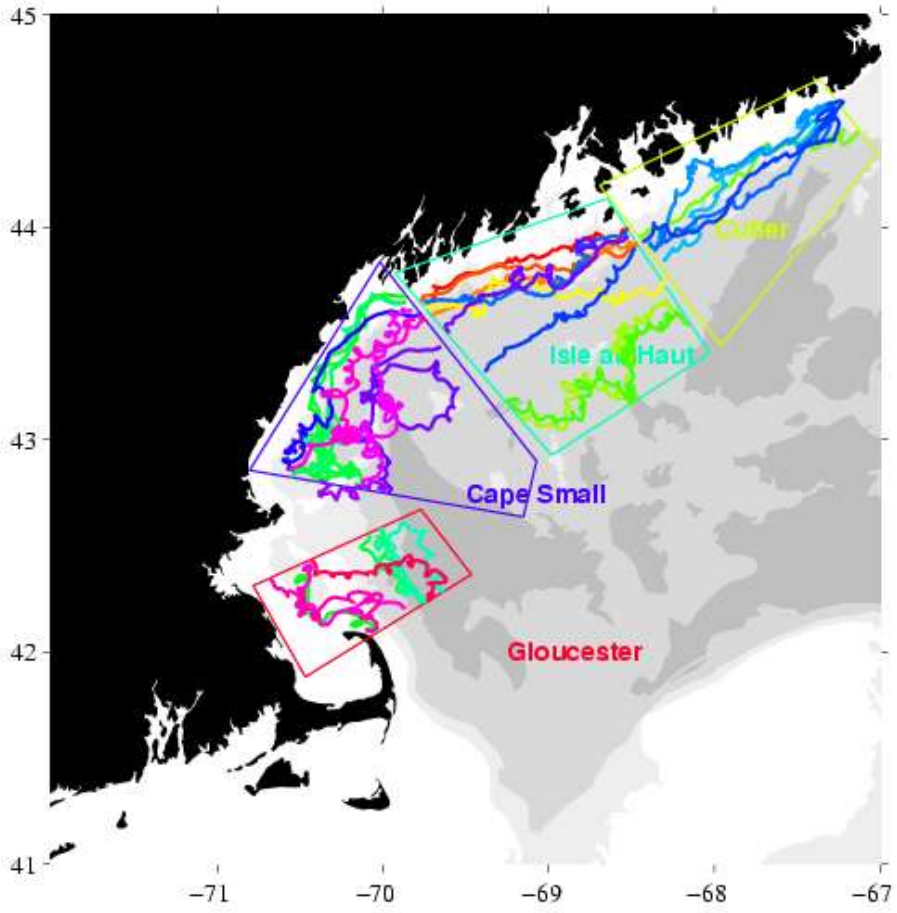

Figure 8. Demonstrating box statistics for various regions of the coast.

While the individual tracks noted above are often of interest, it is the combined datasets of all the drifters that is of particular value. We can now begin to generate statistics of the Lagrangian flow along various regions of the coast. As depicted in Figure 8, the regions can be subdivided into arbituary boxes and statistics such as residence times, % flow through, mean velocities, and integral time scales can be calculated. While there have been a series of moored and drifter observations collected in various parts of the gulf in the past, the eMOLT drifter data is now providing observations in areas never resolved before. Statistics on such parameters as tidal flow amplitudes and wind-current gain factors can also be obtained from the data collected already.

The wind obviously governs the paths variance & irregularity of this flow, but the dominant forcing is evidently associated with a classical coastal current system. The fact that the Maine Coastal Current system is affected by episodes of river input and upwelling/downwelling has been known for decades. But, thanks a team of lobstermen located all along the coast, the monthly deployments during the summer of 2004 provided an unprecedented synoptic picture of the entire system. Drifter deployments in the past have been limited to single locations along the coast. We can now say, for example, what degree of offshore perturbations occur at different locations under the influence of a single weather system across the gulf. Given the SMCCeMOLT drifters, together with the Gulf of Maine Ocean Observing Systems (GoMOOS) data (mooring and radar installations) and new highly developed modeling routines, we should be able to reconstruct the time-varying physical system better than any other period of investigation. While the end result may not be very far off from what Henry Bigelow suggested nearly a century ago, we have documented the process more completely. A preliminary report on this analysis was presented at the "Coastal Ocean Circulation" Gordon Research Conference in early June 2005 and will be submitted to journal publications within the coming year.

Data:

All the eMOLT data is accessible on the internet through the emolt.org web site. Most of it is also served through the Open Data Access Protocal (formerly DODS) system and may be veiwed on an interactive web mapping utility.

Impacts and applications:

As noted in last year's annual report, there are two approaches to physical oceanographic observations. One is to charter a research vessel for a certain period of time (typically a few weeks per year) with a particular process to test. This approach is usually conducted in a particular area of the ocean with set of equipment that is specially designed to observe a particular phenomenon. The second approach is to deploy a set of less sophisticated, less costly equipment over a larger span of the ocean for a longer period of time in hopes of

documenting the process of interest in a large-scale long-term sense. The eMOLT concept can easily fit into the ocean observing system. We hope to make contributions to the Northeast Regional Ocean Observing System currently under development.

As eMOLT temperature database is gradually discovered by various scientist, it is being used in ways not anticipated. Mary Kate Worden, a lobster biologist from Univ. of Virginia for example, has been downloading certain time series and using the data to document the degree of temperature variability associated with fixed sites in an adult lobsters habitat. Bruce Estrella, a Massachusetts state lobster scientist, has downloaded eMOLT temperatures to help describe the environment of a proposed site for gas line construction.

One of primary end uses of the drifter data is the local ocean circulation modeling community. In order to initialize and validate numerical simulations of the Gulf of Maine circulation features, data is needed. For example, Jim Churchill, an investigator from the Woods Hole Oceanographic Institution, has deployed a set of eMOLT drifters in the Sheepscot River Estuary in mid-July 2004. He has developed a circulation model for the area near the Maine Yankee Nuclear Power Plant outfall over the past few years and is now interested in evaluating his simulations with real observations. Dr. Dennis McGillicuddy (WHOI) has deployed a total of 32 eMOLT drifters in the GoM in the last few years to track the advection of Alexandrium. NOAA right whale investigators have deployed several eMOLT drifters in the Great South Channel this past month to track the advection and dispersion of Calanus concentration. Dr. Huijie Xue and students (U Maine Orono) have used eMOLT drifter tracks to test and evaluate the runs she has conducted on the Gulf of Maine using the Princeton Ocean Circulation Model. Mike Mickelson, lead scientist with the Massachusetts Water Resource Authority, has recently borrowed eMOLT drifters to track effluent from Boston's sewage outfall site. Dr Lew Incze will deploy 14 eMOLT drifters off the mouth of Penobscot Bay next month to track the advection of lobster larvae. The upcoming meeting of the Regional Association for Research in the Gulf of Maine will be discussing the importance of data in initializing and validating models.

Related projects:

As noted in several previous eMOLT documents, the eMOLT project has greatly benefited from collaboration with many other projects. Some of the partnerships we continue to foster are listed at http://www.nefsc.noaa.gov/~jmanning/lob/fishmeet.htm . Of the organizations listed, those

that we have had the closest connections with are the Gulf of Maine Ocean Observing System (GoMOOS). The GoMOOS connection is natural. We hope to act as a supplementary data source for the Ocean Observing System they have developed for the Gulf of Maine. They have been gracious in helping us serve temperature and salinity data on the web through their professional postings. They have developed a website where users can click on lobster zones, select eMOLT sites, and view time series plots. The objective in the next few years is to extend this capability north and south of the current region to include both the Canadian and the Southern New England bottom temperature data.

Another very productive collaboration has evolved harmful algal bloom projects. In both 2003 and 2004, we were able to deploy prototype drifters off the R/V OCEANUS during a MERHAB cruise. This provided a mutually beneficial situation where a set of eMOLT-funded drifters were deployed along side MERHAB-funded drifters.. We have recently provided drifter support in 2005 to the Woods Hole Center for Oceans and Human Health, a NOAA funded project to study harmful algal blooms.

In scanning the extensive list of projects under the NEC web site and searching the category of "habitat", eMOLT is only one of dozens of projects. One in particular entitled "Long-Term Ecosystem Monitoring in the Gulf of Maine" seems similar in scope but has a more biological focus relative to eMOLT. One can imagine however some collaboration with this type of project in relating, for example, the change in taxonomic composition of zooplankton to water mass properties off the NH coast. While these shipboard observations can document the changes in the environment, it may be helpful to demostrate the episodic and time-dependent nature with eMOLT moored observations. Ideally the data from both projects will eventually be fed to a biophysical model of the entire ecosystem.

Published reports and papers:

While very little has been published in the scientific literature, several press reports have featured the eMOLT operations including those in the Commercial Fisheries News, Bar Harbor Times, Courier Gazette, New Bedford Stadard Times, and the Cape Cod Times. Most of the effort in relaying results of the eMOLT project has been spent with web-based proesentations and little in the way of written published reports. As mentioned earlier, however, a draft manuscript entitled “Observations of coastal current drift in the Western Gulf of Maine” is in preparation to be submitted in the coming year.

Presentations:

Several presentations on eMOLT were made in the last year including hour-long seminars at both the Mass Lobsterman's Weekend and the Maine Fishermen's Forum. Results were presented to scientist at both the RARGOM workshop in July 2004 and the Gordon Research Conference in June 2005.

Student participation:

More than a dozen students have been involved with the engineering and production of drifters. A few of the students have become so involved with the project they have subsequently taken summer internships (both 2003 and 2004) with the Gulf of Maine Lobster Foundation. Two of them went on to university level studies in the physical sciences. We expect many more marine science students to be involved with these drifters in the years to come. The full list of faculty & students involved is listed in Appendix II.

The students are also involved with the handling of drifter data. Tom Long, who teaches the Geographic Information System course at SMCC, has reportedly downloaded the eMOLT drifter data (freely available on the web) and is incorporating it into his curriculum.

A total of 50 letters of appreciation and eMOLT baseball caps went out to individuals from the general public who had called in a drifter sighting. Attached to the letter was a full description of the project, its science objective, and plots of the drifters including details of those sighted. Many

of these individuals were very interested in the project and were happy to help in our efforts. A database of their names and contact information is maintained.

Appendix I: List of participants who have contributed data:

Lastname	Firstname	Home Port
ANDERSON	WILLIAM(Bill)	LUBEC
Alberts	Jeff	Orleans Ma
BEAR	Ted&Faith	ORRS ISLAND ME
Backman	Ralph	Beals Island
Baines	BobANDSusan	Spruce Head Me.
Bennett	Paul	Newport RI
Bridges	Leroy	Deer Isle
Brown	Alex	Provincetown Ma.
CARTER	JON	HULLS COVE ME
Campanale	RobRoy	Pt. Judith
Carroll	Emmett	Chilmark Ma
Carter	Shane	Bar Harbor Me
Carver	John	Green Harbor Ma.
Carver	Dwight	Jonesport. Me
Cates	Brian	Cutler
Cates	Jeremy	Cutler
Chipman	Roger	Birch Harbor Me.
Chipman	John Sr.	Birch Harbor Me.
Christopher	Scott	Pt. Judith
Colbert	Bob	Sandwich
Colbert	Denny	Sandwich Ma
Connelly	Rob	Sandwich
Cote	Bro	Hyannis Ma
Dassatt	Mike	Belfast Me
Dauphinee	Fred	Scituate
Day	Walter	Vinalhaven
Doherty	Bill	Hingham
FLANIGAN	PETER	RYE NH
Farrin	Clive	BoothbayHarbor
Faulkingham	Michael	Winter Harbor Me.
Fernald	Bruce	
GOLTER	JOE	
Gamage	Arnold Jr.&Gail	S. Bristol Me.
Grey	John	Plymouth
Haviland	John	Green Harbor
Hunt	Ed	Cape Small
INGALLS	ROBERT(Bobby)	BUCKS HARBOR ME
Jesse	Todd	Plymouth Ma
Johnson	David	Long Island Me.
Kandrick	David	Sandwich
Keane	Stephen	Marshfield Ma.
Lemieux	Norbert	Cutler Me
Lemieux	Nick	Cutler
MCLAIN	BRIAN/Roxanna	NEW HARBOR ME

MacVane	Tom	Long Island
Marcella	Bob	Hull Ma
Martin	Bobby/Rob	Plymouth Ma
Mason	Phil	Marshfield
Mason	Pete	
Mataronas/Buffington	Gary	Tiverton RI
MerrillIII	JOHN (Jack)	NORTHEAST HARBOR ME
Miller	Dan	
Moore	Grant	Westport Ma.
Morowski	Robert	Saco
Newcomb	Randy	
NuddJr	Bob	Hampton NH
Oconner	Mike	Sandwich
Oehme	Kurt	Sandwich
Palombo	Marc	Sandwich
Peabody	John	Pt. Judith
Robbins	Stevie	Stonington Me. 04681
Ryan	Skip/Chris	Squantum Ma
Sauvageau	Therese	Beverly
Sawyer	Arthur/Sooky	Gloucester Ma. 01930
Shafmaster	Jonathan	Newington NH
Smith	Jay	Nobleboro Me.
Souza	Billy	Provincetown Ma.
Spencer	David	Newport
Stribley	Russell	New Bedford
Thomas	Elliot	
Thomson	Mattie	Monhegan
Tripp	Jim	Spruce Head Me.
Tufts	Mike	Glouchester
Tupper	Mike	Rockport Ma
Violet	Jim	Newport RI
Wells	Mark	Phippsburg

Appendix II: List of SMCC faculty & students involved with eMOLT drifter production.

Contact	Phone	Title	email
Chuck Gregory	207-767-9643	Chair of Marine Science	cgregory@smccme.edu
Marc Meglo	207-883-0813	Class of 2004	marcmegs@mac.com
Dave Laliberte	207-874-8039	Class of 2004	
Wyeth Bowdoin	207-878-4971	Class of 2004	wyethb@msn.com
Heather Tetreau	207-318-5125	Class of 2003	heathertetreaultkellet@maine.edu
Tom Alexler	207-392-1520	Class of 2003	tomandexler@juno.com
Rachael Clemens Grisham	207-767-5667	Class of 2004	rclem144@yahoo.com
John Harriman	207-329-7724	Class of 2003	capesk8r@hotmail.com
Marissa Call	207-775-7333	Class of 2004	
Maryann Griffin		Lab Tech	mgriff621@yahoo.com
Bob Siegal	207-767-9644	Instructor	
Tom Long	207-767-9641	Lab Manager	tlong@smccme.edu
Monica Whitney		Class of 2004	
Graham Norton		Class of 2005	Gerby@aol.com
Sarah Whitford			
Rebecca Leeman		Class of 2006	Leemanr@maine.rr.com
Tom Manseau		Class of 2006	tmanseau@maine.rr.com
Corey Hodges		Class of 2006	
Dan Dorsky		Class of 2006	Dandorsky@aol.com