MAINE SCALLOP FISHERY: MONITORING AND ENHANCEMENT

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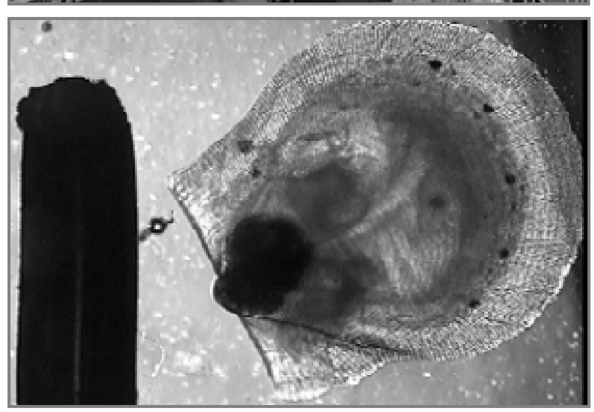
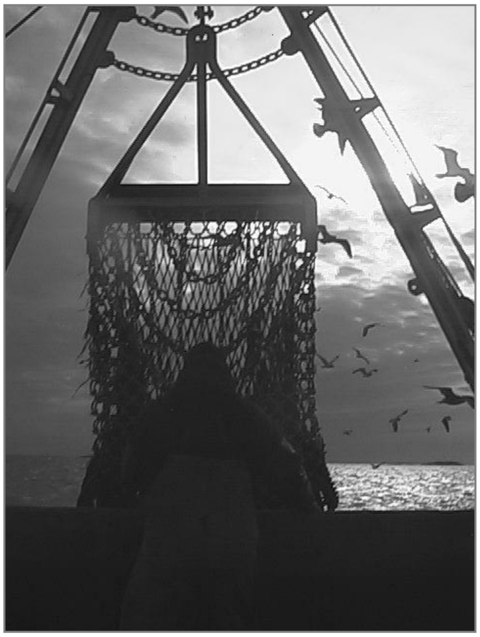


ABSTRACT



The catch and value derived from the Maine sea scallop fishery has varied since its inception in the late 1800's, but the resource has always been an important option for Maine fishermen – as evidenced by the more than 1000 scallop endorsements are issued by the state yearly. A steady decline in landings since the early 1990's coupled with uncertainty in other fisheries pointed to a need for a dedicated assessment program for inshore scallops in the Gulf of Maine. An interest in restoration was also spurred and industry efforts to adapt stock enhancement technology for this public resource called for participation and support from the DMR.   The positive focal point of enhancement further set the stage for this industry/science collaborative project which sought to design and implement a suite of monitoring programs including port and sea sampling and a fishery-independent survey.

Methodology for these monitoring efforts were honed and evaluated. Baseline data were collected to better document the current fleet and fishing practices and to characterize the resource in terms of spatial patterns in size structure, meat yield, relative abundance, CPUE, recruitment, habitat, and associated fauna. These data are especially pertinent in light of newly enacted regulations in the scallop fishery. This work culminated in an ongoing research program supported by a dedicated scallop fund and guided by an industry-chaired scallop advisory group. We initiated a GIS database of suitable spat collection areas and provided scientific support for enhancement activities including evaluation of reseeding in the form of diver surveys, tagging, and outreach.   A scallop enhancement conference was held at the end of the project to summarize past work and consider avenues for the future.

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> *"An effective assessment of the scallop resource in the state of Maine has never been done previously"* (Schick, in Coastal Research Priorities, Alden and Perkins, 2001).

> "*Scallop stocks down, scallop options up*" (headline from *Fisherman's Voice*, January 2000)

Several factors have pushed scallop management issues in Maine to the forefront during the formation of this project – providing impetus for better monitoring of this fishery.

Declining landings: Scallops have always been an important secondary fishery in Maine but landings have waned over the past ten-plus years while other drag fisheries such as sea urchins are in serious decline. The bulk of fishing income is dependent on the maintenance of high lobster abundance. A revitalized scallop resource could provide for needed diversification.

Complex biology/ environmental interactions: Sea scallops have a complex biphasic life cycle with a prolonged larval period. Environmental/ oceanographic variables can greatly impact the population dynamics of this species (e.g. recruitment, growth, meat yield, and reproductive output of adults). Research is needed to better understand these interactions in the Gulf of Maine.

Diverse fishing fleet: Maine's scallop industry is complex. Over 1000 fishermen are endorsed to fish scallops. Competing interests arise within the fleet, between draggers and divers, full and part-timers, and fishermen that roam the coast to pursue scallops and those fishing close to their home ports. There is a need for a better characterization of fishing practices, stakeholder communication, and documentation of existing fisher knowledge. The diffuseness of this fishery coupled with limited state resources calls for collaboration with industry members to collect data and supports a cooperative management approach.

Recent scallop management trends: The regulatory framework for this fishery in the past has relied on gear restrictions, a winter harvest season and shell size limits. More recently, specific area regulations (e.g. in Cobscook Bay) have come into effect. Concurrent with this project, extensive public meetings were held along the coast to discuss management alternatives including closed/rotational areas, broodstock sanctuaries, increasing the minimum legal size, and gear modifications. Furthermore, a move towards rotational closures and area-management in federal waters has yielded benefits in increased biomass. In order to effectively evaluate new or proposed management decisions, a resource assessment is paramount.

Promise and implications of enhancement – Industry members, also alarmed by declining landings but encouraged by international advancements in scallop enhancement technology from Japan, Canada, New Zealand and elsewhere, began experimenting with spat collection technology. The timely evolution of this effort provided a new avenue to gather knowledge about the resource. It also added to the management toolbox, and sparked collaborative efforts between scientists and fishermen. Conversely, it contributed a layer of complexity about future ownership and resource allocation issues, given the substantial harvest capacity of the current fleet, demanding a supportive regulatory policy environment if it is to flourish.

These elements underscore the justification as well as the challenges and opportunities for developing a sea scallop monitoring program for Maine. The second, related, goal of the project was to provide scientific support for the enhancement effort.

History, value, and nature of Maine's inshore scallop fishery

Maine fishermen have pursued sea scallops since the mid 1880's. Before the advent of diesel engines drags were towed by boats under sail (Wallace, 2000). In the 1970's and 80's, some also began collecting scallops by SCUBA.

The value of the inshore fishery has ranked as high as second behind lobsters, though more typically it is a secondary fishery – placing somewhere in the top ten valued marine species in the state. Economic choice, subject to market conditions and activity in other fisheries, as well as resource abundance, which may fluctuate widely, are the driving factors determining whether Maine fishermen will rig for scallop fishing during the season which runs from December 1 to April 15 each year. The fact that in 2002, 831 scallop dragging and 369 scallop diver endorsements were issued is testament to scalloping as an important source of supplemental income for Maine fishermen – even though many license holders fish only part or none of the season.

The scallop fleet and fishing practices are diverse. Lobstermen, during the winter season, draggers, who normally target ocean quahogs, sea cucumbers, or sea urchins, as well as sea urchin divers all may also fish for scallops. While a large portion of the scallop fleet is locally based, another segment fishes the majority of the season and is highly mobile, traveling the length of scallop-producing areas of the state. The majority of boats are 35-45 feet in length. About 35 boats hold permits under the 400 pound trip limit to harvest scallops offshore and only a handful of larger boats (70 feet or more) hold limited access federal permits (Alden and Perkins, 2001) and may also fish state waters during the season. The advent of hand-harvesting through SCUBA opened up scallop-producing areas of the state that were otherwise inhospitable to dragging. Both divers and draggers may at times target beds made up of predominately large scallops because of a premium price paid for large scallop meats. Although Maine "day-boat" caught scallops generally command a higher price than offshore scallops, state-harvested scallops contribute only approximately 2% of the overall U.S. sea scallop supply and price closely follows that of offshore scallops sold at New Bedford seafood auctions (Gardiner and Pinfold, 2001). Thus, federal management regulations have an important impact on the economy of Maine's scallop fishery.

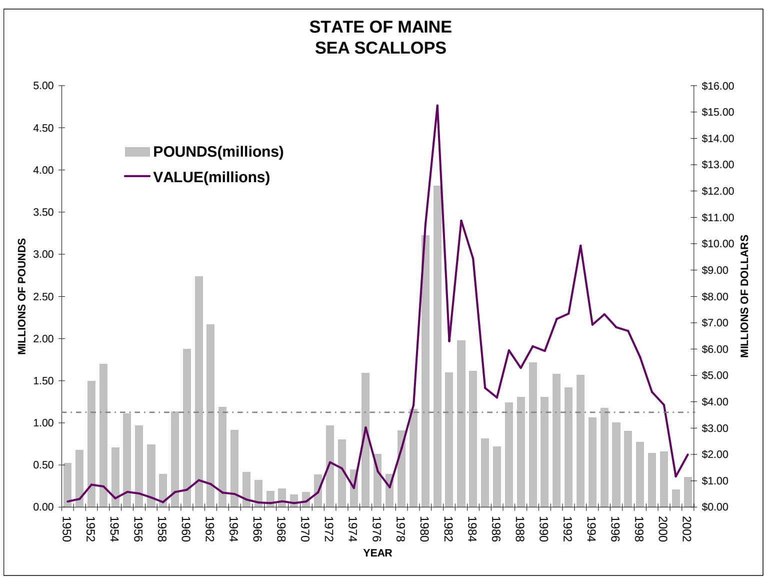

Figure 1. Maine Scallop Landings: Value and Pounds (meat weight). Dashed line represents mean catch over the time

In 2002, the value of the scallop fishery was estimated at just under $2 million - in 1993 just under $10 million. Landings for the most part have been in steady decline since 1993 – nearing historic lows in 2001 during the course of this study (Figure 1). Landings numbers rely on voluntary dealer reports and likely do not accurately represent the state of the resource; better measures are needed to track trends.

Biology

The sea scallop, *Placopecten magellanicus*, is indigenous to the Northwest Atlantic ranging from waters off Newfoundland and Labrador to Cape Hatteras, North Carolina at depths between 15 and 110 m (Posgay, 1957) - although Maine is rather unique among other states in having a resource that extends inshore within the 3-mile limit along most of its coast. Scallops are broadcast spawners with a 35- 40 day planktonic larval period, and thus successful recruitment is highly dependent on the environment. Scallop stocks worldwide are characterized as “cyclical”, “irregular”, or even “spasmodic” where they occur at the limits of their range (Caddy, 1989). Fluctuating levels of recruitment produce large inter-annual variations in landings, although in places with suitable habitat, biomass tends to remain within the same order of magnitude (Caddy, 1989). “Natural” fluctuations in combination with fishing pressure have caused boom-bust cycles in many scallop fisheries (Robinson, 1993).

Environmental factors related to depth, temperature, and food availability, not only affect recruitment success but may dramatically affect growth and meat yield of sea scallops. Bourne (1964) found that meat weights from the same sized scallops varied by as much as 50% between five different areas. MacDonald and Thompson (1985) demonstrated a decrease in scallop growth with depth even from 10 m to 30 m in most areas of their study. Whole tissue dry weight was 1.85-2.15 times greater for scallops from shallow water populations than deep water populations in a previous Maine study (Schick et al. 1988). The semi-sedentary nature of scallops coupled with phenotypic variability due to changing environments, creates a spatial component to scallop stocks that should be taken into account in the context of managing the fishery.

Scallop management

Management of the resource in Maine has been geared primarily towards protecting young scallops through a minimum shell size, and by limiting the harvest to winter months. The latter regulation acts as a conservation measure, but it was largely implemented to reduce gear conflicts between mobile scallop gear and fixed lobster gear. Effort limitations have also taken the form of drag width regulations (maximum ten and a half feet) and area-specific regulations: drag size is further limited to five and a half feet in certain bays such as Cobscook and four and a half feet in Gouldsboro; other areas have a delayed season opening. Recent regulations have mirrored the New England Fisheries Management Council’s Sea Scallop Fisheries Management Plan by enacting a three and a half inch minimum ring size phased in starting in 1997 from three inches to three and a half inches in December 2000. A law was also passed for the 2004 scallop season to further increase the scallop minimum shell size, through culling rather than by an increase in ring size, to three and three quarter inches which will follow with a four inch rule for the 2005-2006 season. This measure was solicited directly by several industry members, and though controversial, underscores the concern over the state of the scallop resource.

Cooperative management: The diffuseness of Maine’s scallop fishery and limited state resources necessitate a cooperative management approach. Combined with the resurgence in attention to the scallop resource, enhancement, and the large number of fishermen licensed to be in the fishery, an opportunity has been forged to develop cooperative management methods for monitoring the resource which will hopefully lend credence to future management measures and build trust between industry and scientists and managers.

Closed/ Limited Access areas and area management measures: The great increase in scallop biomass reported for the scallop closed/ limited access areas in federal waters have also added closed areas and rotational harvest schemes to the discussion of management of Maine’s scallop resource. In Maine, area specific measures have recently come into play with some local fishermen’s organizations pursuing legislative initiatives regarding the scallop resource in their areas. The Cobscook Bay Fisherman's Association successfully sponsored several area-specific rules immediately prior and during this work, including a daily take limit (15 gallons of meat per day) and minimum meat count rule for Cobscook Bay – an area traditional fished by boats with distant home ports during the first month of the season.

Enhancement

An initiative to introduce scallop spat enhancement techniques began in the summer of 1998 with a trip to Aomori, Japan sponsored by the Maine DMR and the Maine Aquaculture Innovation Center (MAIC) and attended by industry and state representatives (Beal et al., 1999). A number of meetings followed upon the group's return and several "grassroots" industry-based initiatives began as a result. Spat enhancement efforts centered originally in Cobscook Bay, Penobscot Bay, and Saco Bay, and further expanded (in part through this project) to trials along other sections of the coast. The development of this initiative has fostered cooperation between diverse groups and has promoted increased attention to the scallop resource as a whole. It has also pointed to a need for additional research into questions surrounding settlement, predation, and dispersal. More formalized studies were needed to begin to evaluate the effectiveness of enhancement as a general management or local restoration tool. Lastly, it has further broadened the scope of debate around scallops to include questions concerning resource ownership and access allocation as the line between fishing and aquaculture has become somewhat blurred.

Developing a monitoring program for Maine's scallop resource

In the context of the items outlined above: a declining important resource, complex population dynamics and environmental interactions for this species and a diverse fishing fleet, the advent of enhancement as a possible management tool in Maine, and newly enacted regulatory measures with a broadening of proposed area specific measures - the need for credible scientific monitoring of Maine's scallop resource is clear. The industry enhancement initiative offers new avenues with both scientific and management implications. It is hoped that a sound scientific footing will help to provide a basis for revitalizing Maine's scallop industry – providing increased opportunities for Maine fishermen.

PROJECT OBJECTIVES

Rationale

Data collected during this project will provide a baseline to compare future trends, promote better modeling of the population dynamics of this stock, provide insights into planning more experimentally-based studies, and help to better characterize the scallop fleet and fishing practices. Management issues most often are not yes or no decisions but matters of degree (Hilborn and Walters, 1992), and in this sense, consistent feedback through monitoring is needed as well as a better understanding of spatial and biological variability in the resource. The goal of this project is to develop on-going monitoring methodologies for the inshore scallop resource. We took an ambitious multi-pronged approach in order to address the various data needs, to compare logistics and cost-effectiveness across different sampling programs, and to provide a gauge of "certainty" behind trends identified by comparing the results of more than one sampling program.

Objectives

Specific objectives were to: 1) initiate scallop port and sea sampling programs, 2) begin a fishery-independent survey utilizing commercial boats, and 3) provide outreach and scientific support for the industry-based enhancement effort.

A last objective was to begin to correlate the age structure, population densities by location, and recruitment patterns with physical data from GOMOOS, the Gulf of Maine Oceanographic Observation System – a comprehensive coastal hydrographic monitoring system recently deployed, and to characterize productive scallop beds through mapping with ROXANN, a bottom profiler that can be ground-trusted to known habitat types and used to generate three-dimensional maps color coded by habitat type. This last objective was not fully completed due to problems and competing uses with the ROXANN instrument – but some initial habitat studies were performed through diver/ video surveys. Correlating the stock structure and abundance data from our work with GOMOOS data is also not yet completed, but additional environmental and habitat information was collected during the course of our work. A substantial shell collection was generated from the surveys and we will undertake analyzing these samples for age and growth in the near future.

Data collected through the programs will aid in:

-*mapping the spatial distribution of the stock*
-*documenting stock structure – i.e. age/ size/ relative abundance in different areas*
-*forecasting future trends by monitoring seed abundance as well as identifying areas characterized by consistent or sporadic recruitment (as evidenced by single or multiple year classes)*
-*determining how meat yield and growth vary with location/ environment*
-*characterizing the fleet and fishing practices*
-*documenting existing fisher knowledge*
-*providing an initial index of abundance through direct surveying and catch/ effort data*
-*monitoring bycatch associated with the fishery*
-*building valuable relationships between industry and scientists*

Study scope

Research priorities (Alden and Perkins, 2001) identified through public meetings with fishermen, academic and government scientists and managers stressed the need to determine a realistic purpose for a scallop assessment. It was suggested that statewide work may not be the best use of limited resources and that a focus on specific areas was warranted. Along these lines, program activities were conducted nearly statewide (from Saco Bay east to the St. Croix River) to provide an overview snapshot of the resource - but additional sampling efforts were focused on areas of greatest fishing activity such as Cobscook and Gouldsboro Bay for more comprehensive work.

Enhancement

Enhancement formed the other major part of our work. The goal was to collaborate with key industry members and Maine Sea Grant to provide outreach, scientific guidance, and monitoring capabilities to aid this effort. Spat bags and netron were purchased and provided to any fishermen interested in trying spat collection. Staff aided in site selection, measuring, tagging, and monitoring subsequent seeding events through diver surveys. We also served as a data repository for growth measurements, seed counts, and bag deployment locations in order to begin to develop a map of suitable areas for spat collection.

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PARTICIPANTS

During the initial formulation of the project, while many fishermen expressed an interest in working on the project, none wanted to be named as a coauthor or key collaborator. Despite this initial hurdle, several people were key to carrying out this project, including:

Wallace Gray, Survey Captain, F/V Foxy Lady
PO Box 178, Stonington, Maine 04681

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METHODOLOGY OVERVIEW

Data collection

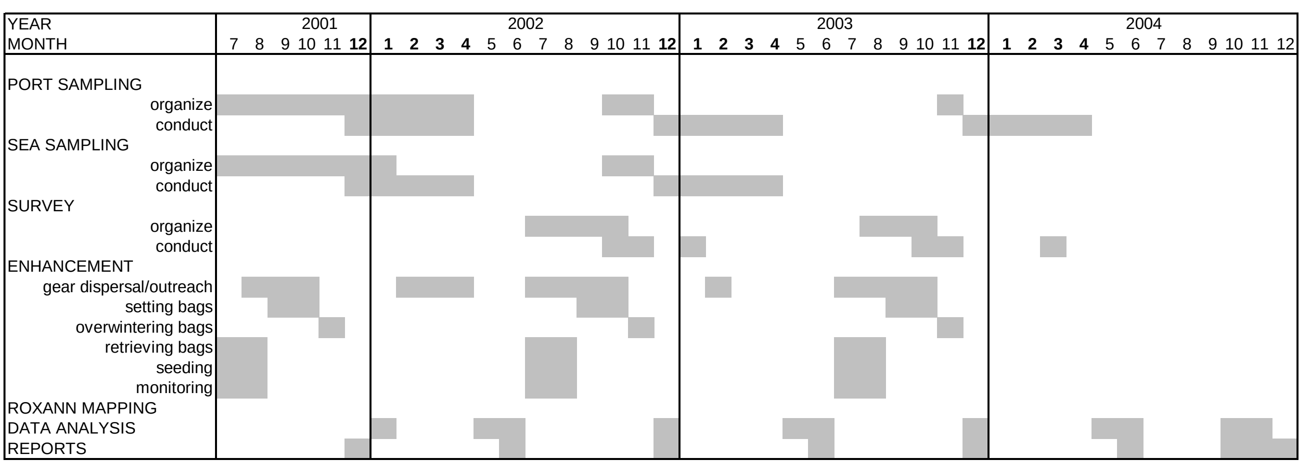
An Allegro™ ruggedized handheld computer with RS232 serial port inputs for digital calipers (Sylvac Mark V), an Ohaus Navigator balance, and a Garmin Map76 handheld GPS unit was used in data collection. This set up allowed for rapid entry of shell measurements, meat weights, and location information in the field. Data entry screens for the sampling programs and survey were configured using Data Plus Professional™ software, which aided in standardizing data entry, providing error checks, and minimizing subsequent data auditing and keying.

Timetable

Participation in all of the sampling programs was voluntary. Port and sea sampling programs were conducted during the scallop season which runs from December 1 to April 15 yearly. The fishery independent survey was conducted immediately prior to the scallop season in 2002 and 2003 – although because of interference with fixed lobster gear at some sites during November, additional trips were made during the season to sample these areas (Table 1). Enhancement activities occurred throughout much of the year corresponding with the scallop's life history cycle. Spat collectors were distributed in the summer and set in September to October, transferred to overwintering locations, then assessed in the spring. Re-seeding took place in the summer- fall when scallops had grown substantially but before collectors became too fouled.

Table 1. Overview of project timeline.

Project Timeline Overview (actual)



General limitations and deviations

The scope of the project was large – both geographically and logistically. A staff scientist was assigned to this project half time, a part time project position designated for a few months over two seasons, and one month's time of the PI contributed as outlined in the proposal. Outreach activities working to make fishermen aware of the project and gain input in planning took considerable effort. Time dedicated to enhancement activities was also greater than originally anticipated. Efficiencies were sought but, unpredictable winter weather, the vagaries of individual fisher's schedules, and a reduced active fleet, despite the number of permit holders acted to slow some of the sampling efforts – hampering our initial hopes of a comprehensive random sampling design for port and sea sampling. The focus of the work shifted yearly in response to logistics and time constraints. In 2001-02, work focused on developing and testing the methodologies for the two sampling programs. Increased attention was paid to sea sampling during the first year as a way to form industry contacts, train staff in existing commercial practices, and to develop on-board sampling techniques that could be used later in the survey. The port sampling program did get started during the same time. Weekly sampling was not possible, but landing sites were mapped and dealers willing to participate in the program identified. Logistics were discussed with fishermen in each region and preliminary sampling carried out. Efforts after the initial year were streamlined since equipment, detailed methodologies, and industry contacts were in place for things to proceed smoothly. Because we had just conducted the fishery independent survey immediately prior to the 2002-2003 season – which gave us much of the same area-specific information obtained during sea sampling, we refocused data collection towards port sampling. A no-cost extension was granted to enable a second year of surveying to take place prior to the 2003-04 season, and we also continued port sampling activities for this third season.

Report format

The methods, results, and future work sections of this report will be broken down into the individual project components – port sampling, sea sampling, fishery-independent survey, and enhancement. Selected data and results are presented in this report to show some of the analyses done to date as well as indicate various ways the data can be used. The complete dataset will be entered into and made publicly available through the DMR MARVIN database. The authors may be contacted for more information.

PORT SAMPLING

Port sampling - Methods

<u>Conceptual approach</u>

The commercial port sampling program collects catch, effort, meat weight frequency, and price information and provides a characterization of active vessels, gear types, and locations fished. The program designed, initiated, and tested during the 2001-2002 scallop season and expanded for the 2002-2003 season was modeled after an earlier DMR scallop port sampling program developed in the 1980s. Sampling continued during the 2003-2004 season. Sampling was conducted at landing sites and at dealers where catch was sold.

<u>Sampling design</u>

During the 2001-02 season, sampling was irregular with a focus on gaining industry contacts and testing methodology. After this initial phase, we had hoped to design a random sampling scheme weighted towards counties with the highest landings. Landings have declined since 1993 and fishing activity has been only sporadic in some areas compared to previous years. There was no existing database of dealers specifically retailing scallops (just wholesale seafood dealers) and many of the dealers contacted in 2001 indicated that they would allow sampling at their facilities but they were not currently buying – or were supplied by only 1-2 boats. Given sporadic activity in the fishery and limited manpower for dockside visits we adjusted the sampling design to focus on repeated sampling of the most active areas - mainly downeast (Washington and Hancock counties) in Eastport, Jonesport, Addison, Mount Desert Island, and Stonington. A number of additional ports, including Cutler, Bucks Harbor, Wiscasset, and Portland, were also visited irregularly in attempts to gather more information and to expand the program. Sampling intensity during 2002-03 and 2003-04 was comparable to a similar port sampling program conducted by DMR in 1986-87.

<u>Sample and data collection</u>

Data collection consisted of a standardized fisher interview and a random sample of scallop meats from each boat's catch. Separate interview forms were designed for draggers and divers. Because larger scallop meats fetch a higher price, meats may be size-sorted on board. In this case, a separate 1 L sample (ca. 2.1 pounds) was obtained from each size class of meats. Otherwise, replicate 1 L samples were taken from the mixed catch. Meats from each sample were then weighed individually. Subsequent phone interviews were necessary to collect total catch weights and price information if a boat/ diver did not sell the catch at the dock. Contact information for captains willing to take on at-sea observers was also obtained during sampling visits. An overview of the data fields and associated variables is depicted in Table 2.

Table 2. Overview of data fields for the port sampling program.

PORT SAMPLING: DATA COLLECTED OVERVIEW

TRIP	VESSEL					CATCH		SAMPLE
	VESSEL INFO	LOCATION INFO	EFFORT INFO	GEAR INFO	OTHER	LANDINGS	VALUE	
Date	Vessel number	Area fished	Time sailed	Drag type	Sea sampling volunteer?	Sort designation**	Price per pound	Individual meat weights
Sampler(s)	Vessel name	10-minute square	Time landed	Rig type	Captain phone	Pounds	Value	
Port	Captain	Depth range	Time away	Number of drags	Comments	Meat volume	*Total value*	
Dealer/ Pier	Vessel length		Time first dredge out	Drag width				
County	Horsepower		Time last dredge out	*Total width all drags*				
Wind and sea state	Crew Size		Lost time					
Precipitation			*Total hours fished*					
Temperature			Average bottom time per tow					
Comments			Total number of tows					
			Tows per hour					
			Total tow hours					

* - italicized = calculated field
** - sorted by meat count or mixed catch

In general, fishers were willing to be interviewed and have their catch sampled although all sampling was voluntary and occasionally only incomplete information could be obtained or an interview might be granted but not a catch sample. Over the course of the program, 38 trips were made, 143 interviews (118 dragger and 25 diver) conducted, 339 samples of meats taken, and over 11,500 individual meats weighed .

Data analysis

All data was audited and entered into a Microsoft Access database for each season and for draggers and divers separately. Reported fishing locations were assigned a grid number corresponding to a 10-minute square delineated chart using ArcView™ 3.2 software and maps of fishing activity (based on the number of boats reporting per grid) generated. Dragger landings statistics were calculated for several catch/effort and economic parameters including: lbs/foot of dredge width/tow-hour, dollars/foot-dredge width/ tow-hour, pounds/ man-hour fished, and dollars/ man-hour fished. Diver catch/effort statistics were calculated for lbs/dive-hour and dollars/dive-hour. Various measures of CPUE were evaluated. "Tow-hour" was calculated as the total number of tows performed multiplied by the average bottom time of each tow. In a number of cases, captains would report the total number of hours fished (i.e.: time last drag out – time first drag in – time lost) but not remember (or disclose) the total number of tows made. A regression of lbs/ foot dredge width/tow-hour against lbs/ foot dredge width/ hour fished showed a suitable correlation (R^2= 0.85; figure x) between the two measures and a correction factor applied to incomplete interviews in order to standardize the CPUE data to "tow-hours".

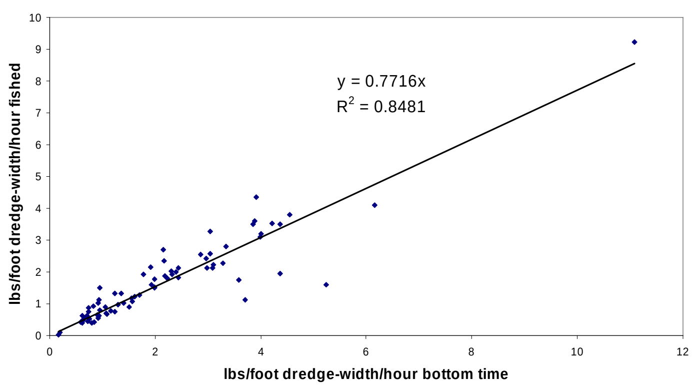


Figure 2. Relationship between two measures of CPUE.

Meat-weight data from catch samples were weighted according to: expansion factor = total weight of catch from which the sample was taken divided by the total sample weight. Meat weight frequency histograms were then charted using Systat™ software. Data were summarized by fishing season and by county. Results were compared to those from the earlier 1986-87 port sampling program.

Port sampling – Data and Results

Fishing locations

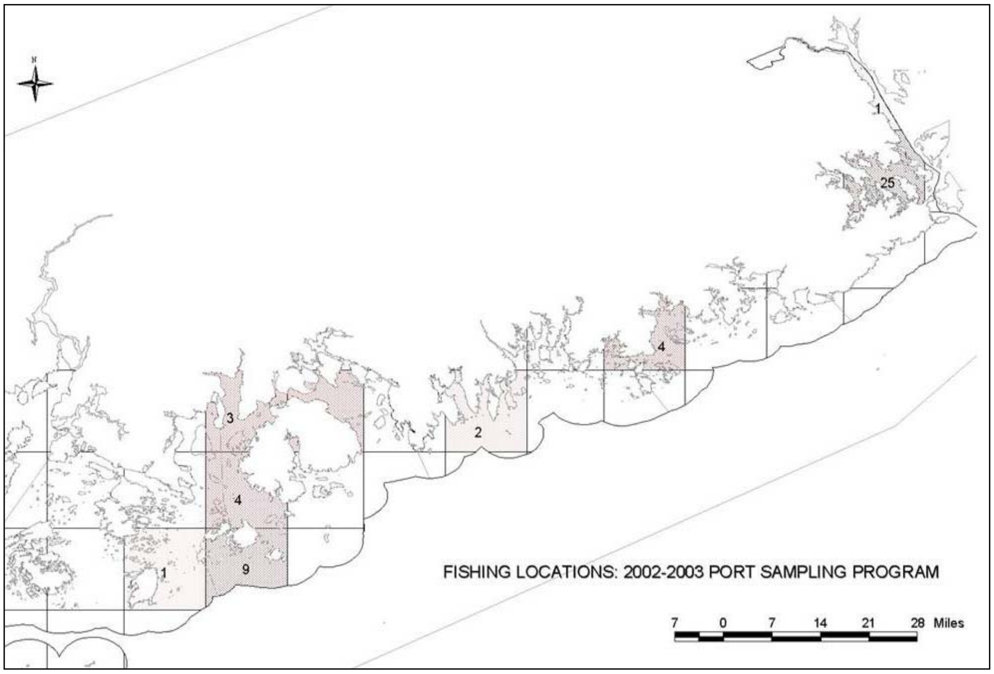


Figure 3 shows a chart of ten-minute squares for state waters in Washington and Hancock counties in which commercial fishing occurred on sampling days (2002-03 season example shown; dragger interviews).

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Figure 3. Fishing locations by 10 minute square: 2002-2003 data example.

Overall mean depth fished was 62.1 feet (ranging from 7 to 288 feet; combined data, Table 3). All dive-boat samples (not shown above) came from the Mount Desert Island area (Southwest Harbor, Northeast Harbor, or Bass Harbor).

Fleet Characterization

Draggers: The length of fishing vessels ranged from 31 to 45 feet for draggers (mean= 36.7). Crew size (including the captain) ranged from 1- 4 people. Mean tow time was 11.8 minutes, ranging from 4 to 20 minutes, and between 2 and 8.5 tows were made per hour. A mean of 57.1 pounds of meats were landed for every trip (ranging from 2-180 lbs) generating $334.04 on average (Table 3a). Chain sweeps were the drag of choice for 76.4% of the fleet overall (88.3% of these were rigged to haul over the stern and 11.7% side-rigged while 23.5% used rock drags (68% side-rigged and 23.5% stern-rigged). Drag width ranged from 4.5 feet to 10 feet. Trends in cutting bar size depend on the local area fished by boats (e.g. boats fishing Gouldsboro Bay are limited by rule to 4.5 feet, Cobscook Bay to 5.5 feet. Many boats around the Stonington area and those that fish out of state waters have 8 foot drags. Very few vessels use a 10 foot drag.

Divers: Boats transporting divers ranged from 16 to 42 feet in length (32.4 feet on average) crewed by from 2-3 people. Time on bottom for each dive ranged from 25 minutes to 1 hour with a mean of 42 minutes with from 1.3 to 6.7 hours total spent under water. An average of 37.6 pounds of meats were landed on a given trip worth $357.18 (Table 3b).

Table 3. Fleet characterization; (a) top - dragger summary statistics, (b) below – dive boat summary statistics

DRAGGER (all data combined)	mean	sd	min	max
Boat length	36.7	*3.5*	31.0	45.0
Crew size	1.9	*0.6*	1.0	4.0
Depth (ft)	62.1	*37.6*	7.0	288.0
Bottom time per tow (min)	11.8	*3.9*	4.0	20.0
Tows per hour	4.5	*2.0*	2.0	8.5
Pounds (meat) per trip	57.1	*38.7*	2.0	180.0
$ per trip	$334.94	*184.00*	$29.45	$934.60
Total drag width (rock and chain)	6.15*	*1.5*	4.5	10

* 7.61 (+/- 2.23) in Hancock county
5.69 (+/- 0.71) in Washington County

DIVER (all data combined)	mean	sd	min	max
Boat length	32.4	*6.5*	16	42
Crew size	2.4	*0.5*	2	3
Depth (ft)	39.1	*13.0*	20	65
Bottom time/ dive (min)	42.2	*9.0*	25	60
Dive hours per trip	3.5	*1.7*	1.3	6.7
Pounds (meat) per trip	37.6	*31.4*	2.4	139.8
$ per trip	$357.18	*290.23*	$13.20	$1,256.00

Market price

Over all three years of sampling, average price per pound paid to harvesters was: $5.00 for unsorted catch, $4.49 for the 'run' (ca. 20 count and below; ranging from $3.00-$4.75), $6.65 for 15-count (ranging from $6.00 to $8.00), $9.91 for 10-count (ranging from $9.00 to $11.00 or $12.00 for diver-caught scallops), and $10.95 for 6-count meats. Thus there is a large premium paid for large scallops although the price for >20 count scallops (the "run") is fairly soft compared to previous years. Price paid at the start of the season varied from year to year and even between ports depending on which dealers were buying.

Catch per unit effort (CPUE)

CPUE calculations are presented by season and county in Table 4. The measure ranged from 0.93 to 3.95 pounds/ foot of dredge width/ tow-hour. In every year during our study, CPUE, and value per unit effort, was higher for Washington county than for Hancock county. Only limited sampling occurred during the 2001-02 season. The higher mean CPUE numbers for this year may be explained by the fact that the sampling trips were conducted during the first month of the season when beds had not yet been fished down. CPUEs from 2002-03 to 2003-04 are slightly higher than those reported for 1986-87 (DMR, 1988; Table 4). Little difference in CPUE between counties is shown in the 1986-87 data compared with the recent data, where Washington county shows a higher dragger CPUE than Hancock County for all years.

Table 4. CPUE calculations by season and county compared to an earlier study (below).

PORT SAMPLING SUMMARY

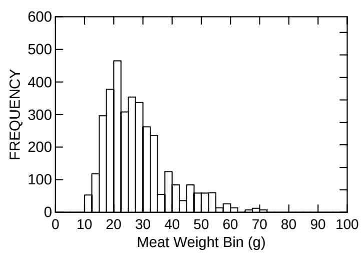
		COUNTY																			
		LINCOLN					HANCOCK					WASHINGTON					OVERALL				
SEASON		n	mean	sd	min	max	n	mean	sd	min	max	n	mean	sd	min	max	n	mean	sd	min	max
2001-2002	*# trips*						1					1					2				
Dragger	*pounds/ ft/ tow-hr*						3	3.28	*0.99*	2.44	4.37	8	3.95	*0.83*	2.46	5.29	11	3.77	*0.88*	2.44	5.29
	$/ ft/ tow-hr						3	$13.07	*2.75*	$11.02	$16.20	8	$14.82	*2.11*	$12.58	$18.50	11	$14.34	*2.30*	$11.02	$18.50
no divers sampled																					
2002-2003	*# trips*	2					12					10					24				
Dragger	*pounds/ ft/ tow-hr*	2	0.97	*0.18*	0.84	1.09	21	0.93	*0.44*	0.53	2.40	38	2.1	*1.37*	0.17	5.43	61	1.56	*1.19*	0.17	5.43
	$/ ft/ tow-hr	2	5.79	*1.07*	5.03	6.55	21	$8.45	*3.26*	$5.25	$18.68	38	$13.58	*6.75*	$4.63	$27.85	61	$10.66	*5.75*	$4.63	$27.85
Diver	*lbs/ dive-hr*						24	10.46	*5.92*	1.92	27.96						24	10.46	*5.92*	1.92	27.96
	$/dive-hr						24	$99.10	*55.80*	$10.56	$251.20						24	$99.10	*55.8*	$10.56	$251.20
2003-2004	*# trips*						1					11					12				
Dragger	*pounds/ ft/ tow-hr*						2	1.71	*1.04*	0.97	2.45	44	2.42	*1.42*	0.19	6.16	46	2.38	*1.40*	0.19	6.16
	$/ ft/ tow-hr						2	$11.19	*2.12*	$9.68	$12.69	44	$13.16	*7.58*	$1.73	$32.29	46	$13.05	*7.39*	$1.73	$32.29
Diver	*lbs/ dive-hr*							5.67													
	$/dive-hr							$52.33													

		COUNTY													
1986-87 Comparative data		LINCOLN			HANCOCK			WASHINGTON			OVERALL				
Ted Creaser, DMR retired		n	mean	se	n	mean	se	n	mean	se	n	mean	se	min	max
Chain sweeps	*pounds/ ft/ tow-hr*	5	1.59	*0.33*	13	1.56	*0.17*	13	1.56	*0.19*	31	1.57	*0.11*	0.66	3.03
	$/ ft/ tow-hr										31	$10.13	*0.78*	$4.07	$21.21
Rock Drags	*pounds/ ft/ tow-hr*	6	1.16	*0.23*	25	1.06	*0.11*	9	0.96	*0.15*	40	1.05	*0.08*	0.24	2.52
	$/ ft/ tow-hr										40	$6.39	*0.52*	$1.61	$14.65

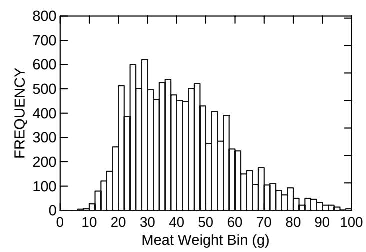
Meat weight frequency distribution

Expanded meat weight frequencies for each sampling season and county are presented in Figure 4a. These graphs include meat weights from both draggers and divers (most diver samples were obtained in Hancock County in 2002-03). Divers tend to target larger scallops- but plots excluding diver catches showed no great changes in the shape of the meat weight frequency histogram. Note the larger scale on the y-axis for Washington county graphs. This shows much higher landings in Washington than Hancock County. Although the mean size of meats is smaller in some of the counties and during some of the years of this project's sampling efforts compared to plots for 1986-87 data (Figure 4b), the mode of the recent frequency histograms is approximately 2-3 grams higher than for the previous dataset – probably due to the increase in the minimum shell height in place since 2000. It is important to note that bias in the histograms, demonstrated by the broader weight distribution in 2002-2003, may result from under-sampling and non-random sampling. An expanded port sampling program would allow for a further breakdown of the data by port and month of sample, and would help alleviate the issue of potential bias. For example – once the "run" of scallops are fished down boats may target beds of older, more valuable animals later in the season. Thus the date of sampling can have a significant effect on the size composition of meats landed.

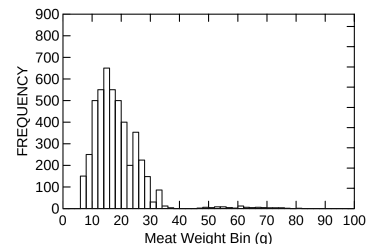
2001-02
HANCOCK COUNTY
n=183; ū = 27.8 ± 0.19 se; #boats=3



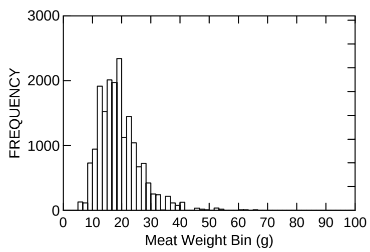
2002-03
HANCOCK COUNTY
*n=2637; ū = 41.7 ± 0.16 se, #boats=45



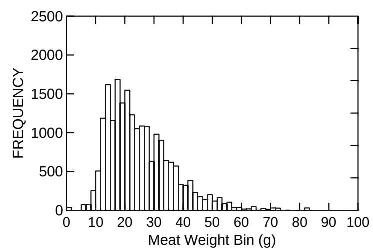
2003-04
HANCOCK COUNTY
n=372; ū = 18.2 ± 0.12 se, #boats=2



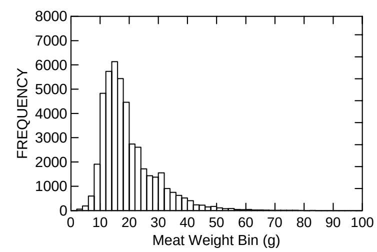
WASHINGTON COUNTY
n=447; ū =19.16 ± 0.05 se; # boats=8



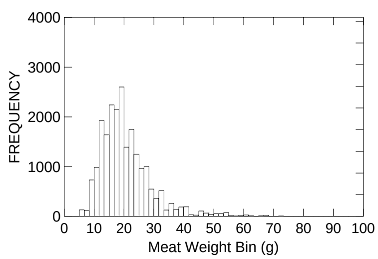
WASHINGTON COUNTY
*n=2675; ū = 25.5 ± 0.08 se; # boats=38



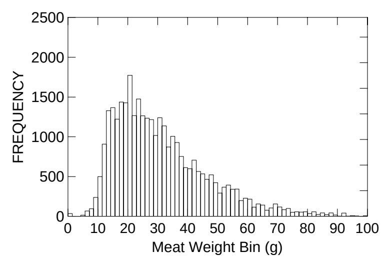
WASHINGTON COUNTY
*n=5233; ū = 19.57 ± 0.04 se; # boats=44



ALL DATA
n=630; ū = 20.54 ± 0.06 se; # boats=11



ALL DATA
n=5312; ū = 31.16 ± 0.09 se; # boats=83



ALL DATA
n=5605; ū = 19.5 ± 0.04 se; # boats=46

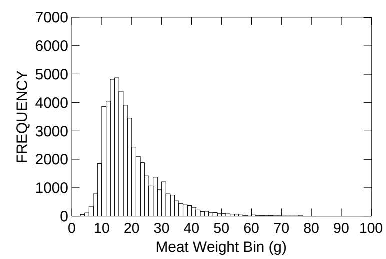
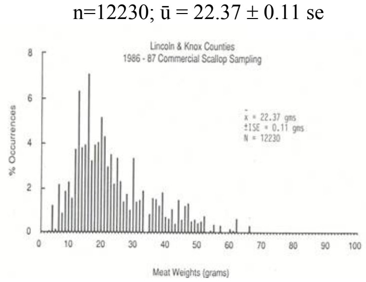
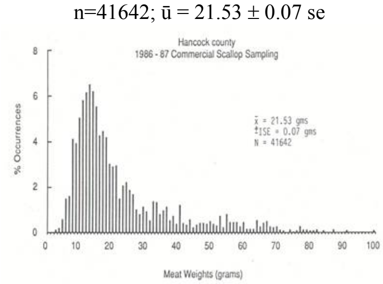


Figure 4. (a) above - Combined meat weight frequencies by year and county. n= sample size of meats (not expanded), u = mean size (g) +/- standard error, and number of boats sampled. (b) below - shows data from a 1986-87 port sampling program for comparative purposes (n= meat sample expanded by catch)

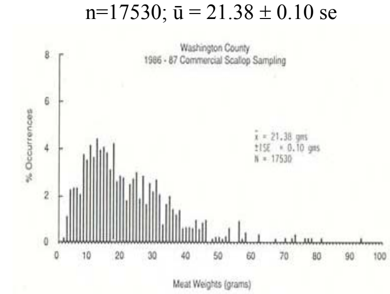
1986-87 LINCOLN & KNOX CTY
n=12230; ū = 22.37 ± 0.11 se



1986-87 HANCOCK COUNTY
n=41642; ū = 21.53 ± 0.07 se



1986-87 WASHINGTON COUNTY
n=17530; ū = 21.38 ± 0.10 se



Port sampling - Conclusions

Major trends

Despite the data-qualifications noted above, it is interesting that in 1986-87 the center of fishing activity was around Mount Desert Island (Hancock county) followed by Jonesport (Creaser, 1988). Creaser's data shows that a larger proportion of meats in Hancock county were small compared to Washington county and he suggested that this points to a greater degree of exploitation in Hancock county. Our recent data shows the opposite, with, in general, proportionally more large meats harvested out of Hancock county and smaller ones taken from Washington. This trend in the meat weight frequencies, the decreased CPUE shown for Hancock county, and the increased number of boats from Washington county reporting shows a shift of increased fishing activity and catch rates towards the east, and perhaps decreased abundance and recruitment of smaller scallops in waters off Hancock county since 1987. Survey data also supports a higher abundance of scallops in Washington county compared to Hancock and counties to the west.

The trend of slightly higher CPUE for the most recent sampling data compared to the earlier program is somewhat counter-intuitive given that landings were nearly twice as high (though still well below the highest recorded landings) during 1986-87 compared to today, and the fact that most of the drags had 2 ½ or 3 inch ring-bags. Increased efficiencies due to heavier drags in use now or the use of GPS technology helping fishermen to easily relocate beds are some possible explanations for the trend. It may also be due to a greater number of boats fishing in 1986-87 or inconsistencies in the sampling design. The range in pounds landed per trip over the course of our study (max 180 pounds per day) is nowhere near anecdotal historical highs of greater than 400 pounds per day on productive grounds (such as Cobscook and Gouldsboro Bays) although catch per trip in Cobscook was limited by rule in 2001 to 135 pounds of meats per day in order to provide a longer season for local boats.

Measures of CPUE

Pounds per foot of dredge width per hour-towed was chosen as the standard measure of CPUE in our study. Including crew-size as an additional effort factor in the analysis only increased variability. Generally, during the course of this study, the crew (regardless of size) is able to keep up with the demands of shucking while the drag is under tow – so additional crew have no effect on catch rate. Creaser (1988) also calculated CPUE in terms of the area of the dredge opening (width x height of the dredge "mouth"). This was to account for the swimming response or vertical dimension involved in the catchability of the scallop. Although we initially attempted to collect this measure of gear size, it most often went unreported. The best response rate from fishermen is elicited when the data collected is as simple as possible so we dropped this field from the interview form.

Measures of CPUE are most useful when they correlate well with stock abundance – but even in a program with random/ unbiased sampling there are many reasons why this relationship might vary: Fishing grounds are made up of many variously sized individual spatially discrete beds. Fishermen's choice between alternative species and target areas and factors such as proximity of the fishing area to a boat's home port are also involved. Measurable variables such as vessel size, gear type, even the presence or absence of a piece of equipment that might affect efficiency can be taken account using generalized linear models (GLM) as a statistical technique. This method aids in understanding which factors affect the fishing power of individual vessels and can be used to correct for changes in fleet composition over time. GLM methods should be used in the future once the sampling design is modified (see below) and a dataset covering a longer time period is available.

Limitations

The first step towards obtaining useful CPUE data that can be used in the management process was successful during the project – that of establishing a routine for accumulating the relevant data. Two problems were encountered in the course of this study: obtaining a better sampling intensity and designing a sampling scheme that is representative of the entire fishery. Welsh in his 1950's thesis on Maine scallops noted that "very substantial quantities of scallops cannot be accounted for by the usual means". Boats land at small docks everywhere and often the catch is disposed of directly from the boat or sold locally. During recent years of decreased abundance of scallops, this diffuseness of the fleet causes logistical and sampling design problems. In the 1986-87 study, no dealer was sampled more than once during the season. While this provides for broader coverage, it also biases CPUE trends and landings which can vary greatly month to month (highest during the start of the season and varying depending on other fisheries and markets: i.e. a variable shrimp season, or the urchin market during winter holidays). Interpretations of and comparisons with the 1986-87 data should be viewed with some caution as sampling designs differed, though similar methodologies were employed. In an effort to sample the most boats possible – and obtain representative averages based on the entire season we chose to repeat sample the most active ports – focusing on Hancock and Washington Counties, while no dealer was sampled more than once in Creaser's work.

Port sampling – Future research

Additional staff resources, though difficult during times of reduced state budgets, need to be allocated to the port sampling program in the future. A dedicated seasonal position or part time samplers residing near individual ports could allow for a more formalized sampling regime. A cluster sampling design, similar to ours, may be more appropriate than a random sampling of all available landing sites. Increased sampling should be carried out during the start of the season in order to obtain data from all included ports during the start of the season. If future sampling were conducted in this way, CPUE data could be broken down by individual ports or by area fished (nearest 10-minute square) and analyzed using GLM techniques. Random selection of landing site/ dealer visits from a comprehensive list may result in a lot of wasted sampling trips when no boats are landing that particular day and wasted resources by allowing only 1-2 boats to be sampled per day. Supplemental catch and effort data could also be collected through a logbook program.

The challenges inherent in the port sampling program support the need for auxiliary monitoring programs, such as direct surveys, to help better define the resource. Despite the limitations noted, the data do show some important trends that are corroborated by the fishery independent survey (see below).

SEA SAMPLING

Sea sampling - Methods

Conceptual approach

The sea sampling program was designed to obtain area-specific biological data and detailed information on catch rates, effort, and bycatch. It also provided an opportunity to record anecdotal local/ historical knowledge of various grounds and document fishing practices. Further it served as a primer in data collection methodologies and logistics for the independent survey.

Technical approach/ data collected

Vessels accepted observers on a voluntary basis. A list of captains willing to take on sea samplers was generated initially through various planning meetings and later through port sampling interviews. Trips were fit in between port sampling efforts with the majority of trips taken during the 2001-2002 season. An effort was made to select trips covering a broad area of the coast (Figure 6). Data recorded (Table 5) mirrors the federal scallop observer program with some modifications. Sampling intensity (number of tows per trip sampled) depended on catch rates. With two observers on board nearly every tow could be worked up – or usually every other tow for trips with only one observer present. For sampled hauls, when the bag was dumped a digital picture was taken, the catch sorted, and both legal and sublegal sized scallops retained and weighed on a spring scale (Figure 5). Bycatch and trash (seaweed, shell, rock and cobble etc.) were evaluated using a categorical scale (0-5 corresponding to absent, present, some, common, abundant, and very abundant). Scallop shell height, the length from the umbo to the growing edge, perpendicular to the hinge line, was measured on either the entire catch or a subsample, and the total pounds and volume of legal and sub-legal shellstock recorded. Legal sized scallops from selected hauls were shucked into separate containers and individual meats weighed back at the dock. The number of "clappers", empty paired scallop shells still attached at the ligament, was also recorded on some trips. Additionally, a sample of shells from the area was sometimes retained for later growth analyses. Catch rates were standardized by tow length (recorded on a GPS unit) and drag width. A summary of recorded data fields is provided in Table 5.

Figure 5. Evaluating bycatch and selecting a subsample for shell height measurements after the haul is dumped.

Table 5. Data field summary for sea sampling program.

Vessel	Trip	Haul	Bycatch	Catch	Length Frequency	Meat weight frequency
-Name -Length -Horsepower -Crew size -Gear Desc.	-Date -Port -Time sail -Time return -Weather -Sea state -Total catch	-Tow speed -Wire out -Location & time dredge in/ haulback -Depth	-Species & abundance -Trash -Bottom type	-Lbs/ volume kept or discarded	-Shell height -clappers	-Individual meat weight frequency

Sea sampling – Data and Results

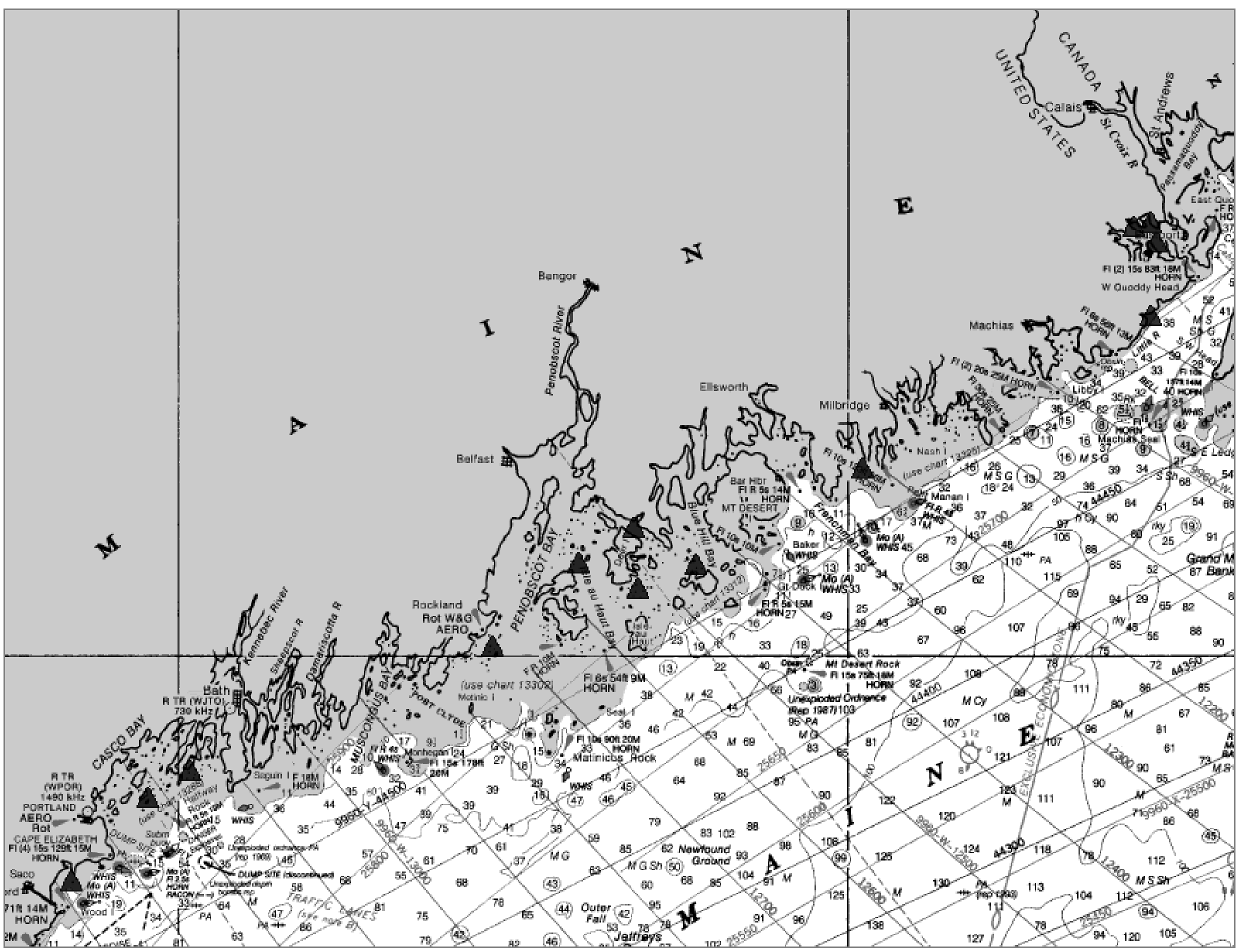


Figure 6. Sea sample trip locations.

Fourteen sampling trips were completed. Ports sailed from included Eastport, Cutler, Corea, Stonington, Harborside, Spruce Head, Chebeague Island, Orr's Island, and Saco. Trips were conducted in different areas of the coast – except for one repeat sample in the same fished area (South Bay in Cobscook Bay) two weeks following the initial trip (Table 6). Two trips were conducted from dive boats while all others were made from vessels engaged in dragging- but these represented a wide range of drag sizes/ types/ and rigs from small specialized rock drags towed off a pot hauler to five and a half foot stern rigged drags typical of Cobscook Bay boats to eight and a half foot side rigged drags (see appended photo gallery for some examples).

Catch rates were highest in Cobscook Bay with up to 2 bushels of shellstock landed per 10 minute tow (5.5 foot drag). Gouldsboro Bay also had higher catch rates compared to other areas sampled which ranged as low as 5-10 scallops per tow. Tow times over all sites varied between 7 to over 25 minutes. Bycatch occurrence was highly variable as might be expected in an inshore fishery occurring over an area of widely varying habitats. Common animals encountered include: sea stars, green, rock, and jonah crabs, lobster, the ten-ridged whelk, sea urchins, sea cucumbers, and flounder.

Sea sampling – Conclusions and Future Research

While sea sampling provided insights into the range of fishing practices encountered and variations found in the diverse scallop beds of Maine's inshore waters, sampling was not intense enough to draw conclusions about different areas or between different boat and gear types. Because of this, detailed results will not be presented here. One drawback with the sea sampling program is that it is general practice for a boat to work in a single area for the trip, so that only information on one small section or bed is obtained – even if all 20-30 tows made are characterized. Each area sampled is also obviously impacted in terms of the scallop size composition and abundance by recent fishing activity in the area. This was demonstrated in the one repeat sampled area – South Bay within Cobscook Bay which showed similar mean sizes between legal and sub-legal sized scallops (greater or less than 3 ½ inches shell height respectively for 2001) – but a more than 300% decline in catch per standard tow just two and one half weeks from the first and second sample (Table 6). Although sampling was carried out onboard two different boats – there was an obvious impact in catch from recent fishing activity over the two plus weeks between the start of the season and second sample day. In this sense, sea sampling might best be carried out as an intensive effort during the first month of the season, but to do this would require more available staff during this period. Repeat sampling of the same areas covered early in the season - or a comparison with the same sites covered in the independent survey might provide a gauge of fishing pressure in various areas.

Table 6. Sea sampling trip comparison of a single site at two sampling times.

SEA SAMPLE LOCATION: SOUTH BAY IN COBSCOOK BAY		
TRIP DATE	*12/2/2001*	*12/19/2001*
Mean size legal* scallops (mm)	99.7	101.64
Mean size sub-legal scallops (mm)	73.4	71.3
Mean meat weight legal scallops	16.9	18.65
Number legal/ sub-legal ratio	2.39	0.92
Standardized catch (pounds shellstock per 1000 m towed)**	143.9 (+/- *48.8*)	43.6 (+/- *13.9*)

* > 3.5 inches
** drag width 5.5 feet

Industry response to the start-up program has been largely positive and many vessel captains have expressed an interest in taking observers on board. Although some of the information provided by the sea sampling program is redundant when the same areas are covered by the independent survey, its value lies in the chance to note anecdotal information from various captains and get a first hand feel for fishing practices employed by different vessels. It also provides a more realistic documentation of bycatch – since a standard, 3 ½ inch ring, chain bag is being used rather than one with smaller rings. An alternative to observer coverage might be a program similar to the "Thistle Box" program for lobsters where volunteer captains collect data in exchange for technology that also is useful for them.

FISHERY INDEPENDENT SURVEY

Survey - Methodology

Conceptual approach

The purpose of the survey was to develop methodology, and to map and characterize the scallop population along the coast. Specifically, we aimed to examine geographic variability in population size structure, meat yield, seed occurrence, and relative abundance. The dataset will also provide a basis for exploring faunal associations and trends occurring with depth, bottom type and with environmental data. Our preliminary survey was conducted in the fall of 2002 followed by a second survey carried out in the fall of 2003. Each relied on industry vessels using a standardized survey drag. Work took place coast-wide, but with an emphasis on current and historic fishing grounds – primarily east of Portland. Given this large scope, we did not design the overall survey to calculate a statewide biomass for the scallop population. Nonetheless, the data do show abundance trends within each area. Also, for two important scalloping grounds, Cobscook Bay (presented in this report as an example) and Gouldsboro Bay, we did carry out a stratified random sampling design to allow a direct assessment of abundance in these sub-areas.

Technical approach

Survey frame and timing: Eleven coastal zones within the three-mile line from Kittery to Calais were delineated (Figure 7). Scallop areas within these zones were mapped based on fisher information, prior survey data, surficial sediment maps, and coastal wildlife inventory maps (Maine State Planning Office, 1970). The survey zones mirrored existing lobster zones with some added divisions and reflected logistical aspects as well environmental demarcations of the survey frame. Sites in each zone were within range (1-2 hours steam time) from the ports used for the survey (Lubec, Cutler, Jonesport, Winter Harbor, Southwest Harbor, Stonington, Spruce Head, Boothbay Harbor, and Portland) and the zones were sized to provided a manageable balance between zone area and sampling intensity.

Both surveys (2002 and 2003) took place immediately prior to the scallop season in October and November each year. Outreach and planning was conducted in the months preceding the survey. Information on current and historic fishing grounds was obtained at several scallop meetings. Because of interference from lobster gear, a few sites could not be sampled during these months so additional trips were added during the season after most gear had been moved further offshore.

Survey design: Sampling-sites were assigned in one of three ways. In zones where good information on the spatial extent of scallop fishing grounds existed (e.g. Cobscook Bay, Gouldsboro Bay) and interference with lobster gear was minimal, survey stations were selected randomly within each mapped fishing ground - a stratified random design using individual fished areas as separate strata. In a number of commercially important beds, permanent stations were also placed systematically (non-randomly). In waters where only poor information on resource distribution was available, exploratory tows were conducted to locate and map beds. Over the two survey years, we attempted to sample as many known scallop beds as possible.

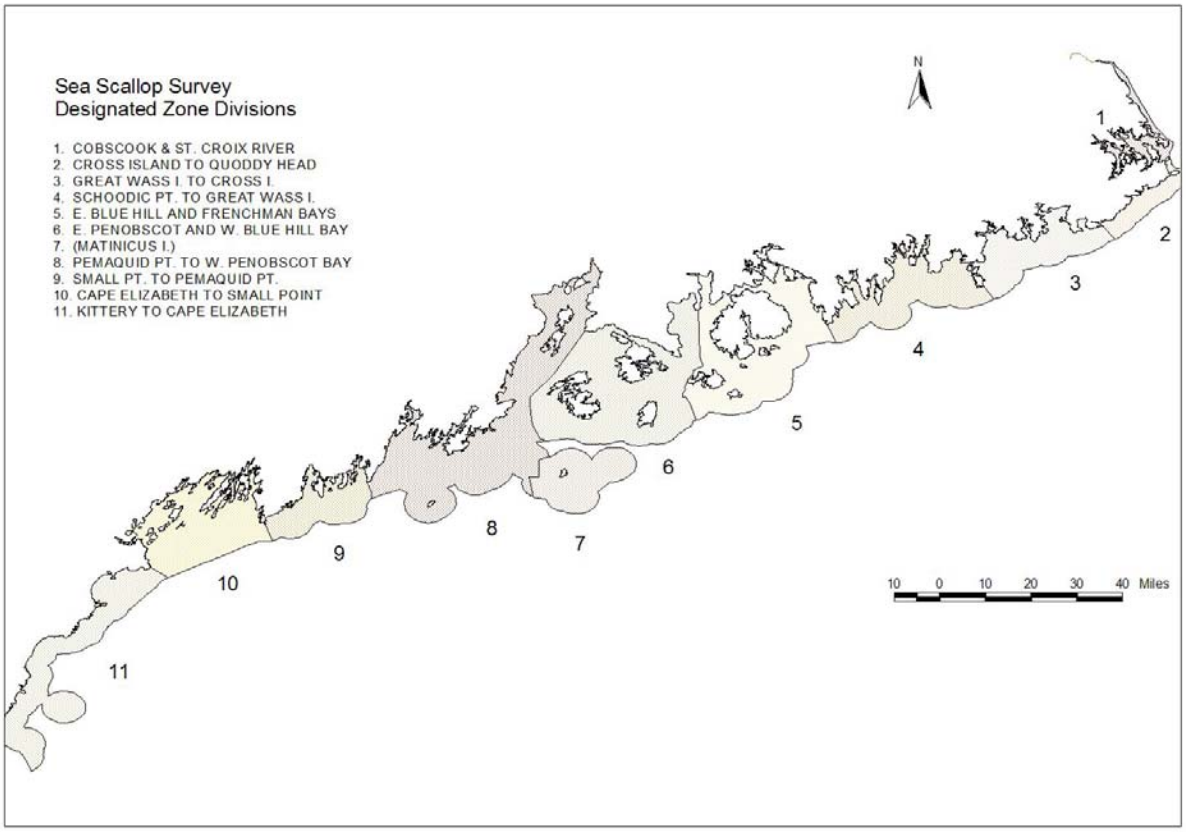


Figure 7. Designated survey zones.

The sampling design deviated from our original proposal where we suggested that all known fishing grounds would be stratified based on areas of high consistent production and lower, less frequent production, and then tows assigned randomly within these areas to locate beds, and finally sampled systematically to more clearly define the beds. The final approach we arrived at evolved out of planning talks with industry members, an evaluation of the current state of information on scallop bed location, and the logistics involved with a coast-wide randomized design. A number of concerns prompted us to adopt this more flexible sampling regime: 1) Even with much information provided by fishermen, there was not the adequate understanding of the spatial distribution of the stock over the entire coast needed to map all the fishing grounds or to delineate areas of consistent and sporadic production. 2) Interference from lobster gear would likely make sampling some sites difficult and in turn would bias the results of a strictly random design. 3) the sampling intensity needed to produce reliable statistical estimates for the entire resource, even while focusing on known fished grounds, was not realistically obtainable given the total number of survey days allocated and expected variability in scallop abundance. Therefore, our modified approach represented a compromise between better coverage and mapping of the resource given the time available, concentrating sampling efforts in commercial fishing grounds in order to best characterize the fished population (avoiding many tows with 'zero' catch), while at the same time testing sampling approaches that could be used to estimate stock abundance. Previous reports have also commented on the contagious distribution and smallness of individual aggregations as posing constraints when attempting these type of surveys (Naidu, 1991).

In Cobscook Bay and Gouldsboro Bay (zone 1 and a specific area in zone 4; Figure 7) where a formalized stratified random sampling approach was taken, strata were based on spatially contiguous fished areas determined in consultation with industry members from this area. Sampling stations were based on a 1000 meter grid – sized to be appropriate for a mean tow length of approximately 500-700 meters. Specific identifiers were assigned to each grid square and stations selected randomly without replacement within each strata using Systat™ and ArcView™ 3.2 software. The number of stations assigned within each region was roughly proportional to the size of the strata although fewer stations were assigned in areas considered to be only of minor importance. Individual stations were then plotted using TheCaptain™ software which was used onboard by the survey captains to navigate.

We also conducted preliminary work to estimate dredge efficiency – comparing scallop densities and length frequency distributions from SCUBA-sampled transects to drag hauls at each of two sites in Cobscook Bay.

Survey gear: The survey drag was a seven foot wide chain sweep with a ring bag made up of two and one half inch rings in order to retain small scallops (Figure 8a,b,d). An effort was made to obtain 2" rings for the chain bag – but these were unavailable except in large bulk quantities. Rubber cookies were also incorporated into the bag. The head bail was made of 1 ¾ inch stock. Two of these drags were purchased from Blue Fleet welding company in New Bedford, MA. The size and weight of the drag represented a compromise between being heavy enough to sample deep waters and wide enough to cover the most area per tow while still being small enough to use a large pick-up truck to transport the gear. The drag specifications were decided in consultation with several industry members and then further tuned by the survey captains and rock chains added prior to the shake-down cruise. A smaller than standard twine-top was used (3 ½ inches; double hung) without a liner.

Survey vessels: In the 2002 survey year, the majority of the survey from the St. Croix River to Stonington was conducted from the F/V Foxy Lady - a 36-foot dragger/ lobster boat out of Stonington, ME owned by Wallace Gray (Figure 8b). The F/V Shearwater out of Owl's Head and owned by Gary Hatch covered sites in western Penobscot Bay to Casco Bay, and the F/V Sea Ryder (Spruce Head, owned by Erik Waterman) was used for more detailed sampling in western Penobscot Bay. The use of three vessels for the first survey year was a compromise between standardizing survey results, by not using a different boat for each zone, while taking advantage of local knowledge of the three survey captains involved, each most familiar with their respective areas. Mostly day trips were made from selected ports, but the survey scientist stayed on board for the leg covered by the F/V Shearwater.

In 2003, all work was conducted on the F/V Foxy Lady. One additional crew member was also on board in addition to the lead scientist.

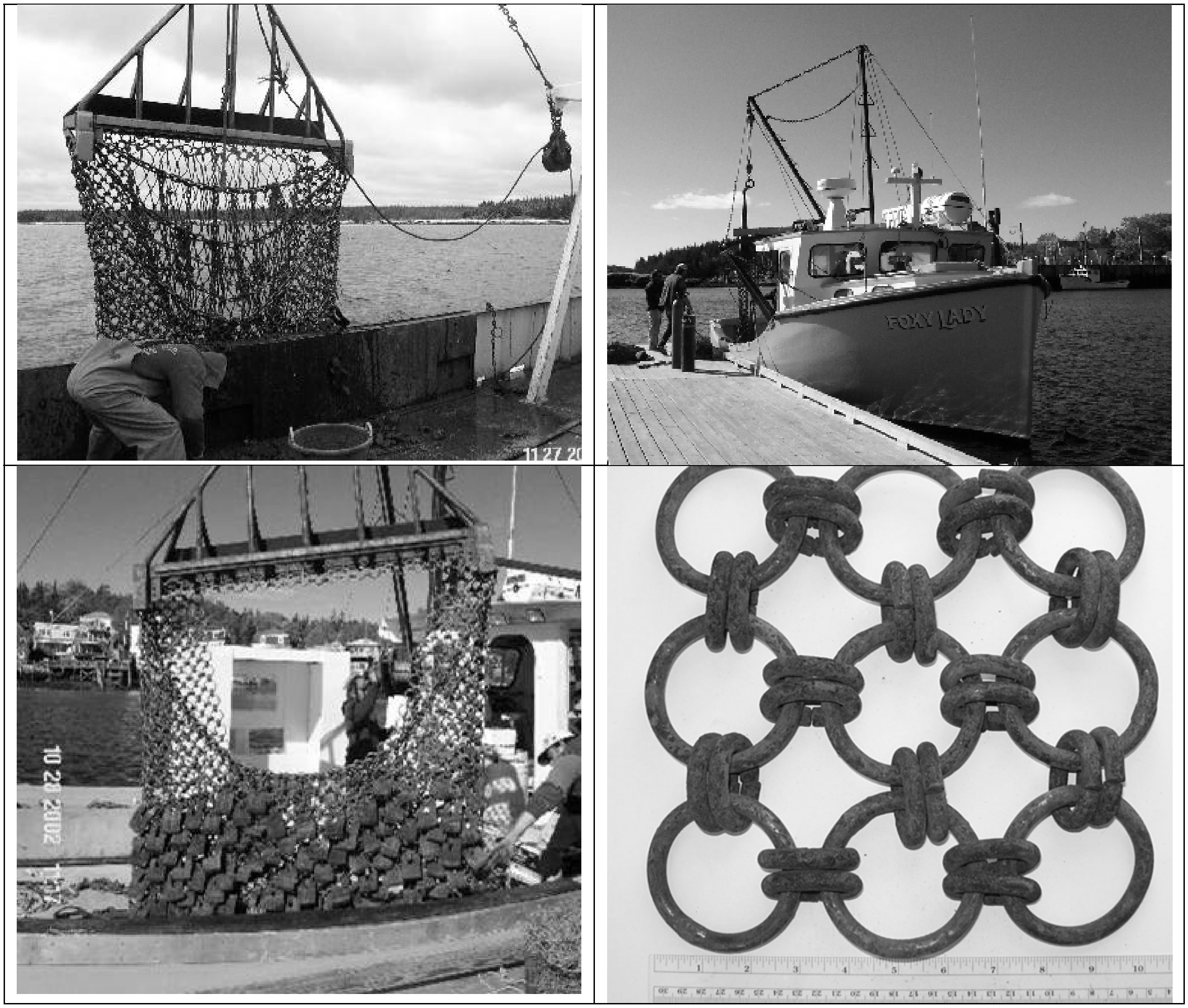


Figure 8 (a-d). Left: Two views of the survey gear. Tuning the gear (bottom left) and drag with twine top and rock chains in place (top left). Survey vessel – F/V Foxy Lady (top right). (bottom right) The ring bag was made up of 2 ½ inch rings (64 mm). 3 ½ inch rings are the current industry standard in Maine. Inter-ring space was approximately 71mm with double links.

Survey procedure: Drag times varied, depending on bottom type, scallop abundance, and the density of lobster gear present in the area, between two and eight minutes. The tow track was recorded on board using ArcPad™ software connected to a handheld GPS and an external antenna. Tow distances were automatically calculated in ArcPad™ using the distance that the boat traveled between the start of towing, after running out the wire, and the start of haulback, as a proxy for the distance that the drag moved on bottom. Stations were sampled using a straight-line tow. Boat speed averaged about 3.5 knots.

The following protocol was employed:

1) Station information was entered from the wheelhouse (boat speed, tow duration, depth, bearing).

2) Bottom type was recorded as combinations of mud, sand, rock, and gravel based on sounder information, charts, and dredge contents. For example “Sg” designated a primarily sand substratum with some gravel (after Kelley et al., 1998).

3) Once the drag was emptied, a digital picture of the haul was taken.

4) Scallops, sea cucumbers, and ocean quahogs were culled from the pile for subsequent measurement. Catch of the later species was quantified because of their importance in other drag fisheries. While the chainsweep is not a suitable sampling device for ocean quahogs – their presence in the catch suggests the existence of a bed below the sediment.

5) A representative sample of bycatch was set aside and enumerated using a 0-5 qualitative abundance scale (corresponding to “absent”, “present”, “rare”, “common”, “abundant”, and “very abundant”).

6) The total weight and volume of the scallop (and sea cucumber and ocean quahog) catch was recorded.

7) The shell height (distance from the umbo to the outer edge, perpendicular to the hinge line) of individual scallops was measured. Most often the entire catch was measured, but for very large catches the pile was sometimes halved or quartered carefully with a shovel and then a smaller portion measured.

8) On selected tows, a sub-sample of 24 scallops, chosen to represent a wide size range of the catch, were measured (shell length, width, and height), shucked, and the meats placed in a compartmentalized box, in the order that the animals were measured so that weights could be matched to the corresponding shell measurements when weighed on shore (Figure 9).

9) Shells were saved from selected stations for later age and growth analyses.

10) A Seabird SBE19plus CTD was deployed at stations within each sampling region to record the temperature/ salinity profile of the water column.

<u>*Data collected*</u>: Data fields are summarized in Table 7.

Figure 9. Compartmentalized box used to "match" onboard shell height

Table 7. Collected data fields for survey database.

COLLECTED DATA - FIELD SUMMARY

TRIP	**STATION INFORMATION** IDENTIFIERS	TOW LOCATION	TOW INFO	ENVIRON. DATA
Trip identifier	Tow identifier	Dredge in (Lat, Lo, Time stamp)	Tow time elapsed	Bottom type
Trip date	Zone	Tow start (Lat, Lo, Time stamp)	Depth	Bottom temperature
Port sailed from	Strata	Haulback (Lat, Lo, Time stamp)	Bearing	
Weather	Location (description)	Drag off-bottom (Lat, Lo, Time stamp)	Wire out	
Precipitation	Tow number	Distance towed	Tow speed	
Wind/ sea stata	Sample type			
Return time	(random, exploratory, "fixed", other)			
Comments				

SCALLOP DATA CATCH	SIZE STRUCTURE	BIOMETRICS	BYCATCH
Number scallops caught	Shell height	Shell height	Tow photo ID
Volume of catch (shellstock)		Shell length	Species
Weight of catch (shellstock)		Shell depth	Abundance (1-5 scale)
Proportion of tow sampled (100, 50, 25%)		Meat weight	Trash type
Number of clappers			Trash amount (1-5 scale)
Coments			Comments

AUXILLARY DATA QUAHOG CATCH	SEA CUCUMBER CATCH	CTD DATA
Number of quahogs	Number of cucumbers	Location (lat/ long)
Shell height	Catch weight	File identifier
Shell length	Catch volume	
Shell depth	Coments	
Shell (dead) abundance (1-5 scale)	Size index (SL x diam 1 x diam 2)	

Preliminary dredge efficiency study: Two sites in Cobscook Bay were selected for a preliminary study of drag efficiency. At each site, a weighted buoy was dropped and a two hundred meter transect line was run out. Divers collected scallops falling within one meter either side of the transect (using a one meter pipe as a guide) and brought them to the surface. All scallops were then measured for shell height. Three transects were sampled at each site. Three tows were then made at each site and scallops enumerated and measured. Efficiency was estimated for seed, sub-legal, and legal size classes (see below) by comparing diver and standardized drag catches. Because of the limited number of sites and tow/ transect comparisons, selectivity was not calculated.

Data analysis: Survey data were entered into Microsoft Access™ and into a GIS database using ArcView™ 3.2 software. Catch data were standardized to scallops per meter squared based on tow length, using the distance and the width of the drag (7 feet/ 2.1 m). Total catch was further broken down into seed (less than 2 ½ inches = 63.5 mm), sub-legal (2 ½ to less than 3 ¾ inches = 63.5 – 95.25 mm), and harvestable size classes (3 ¾ inches or greater = > 95.25 mm). The 3 ¾ inch harvestable size class was chosen because this was the legal standard for the 2003-2004 season. The 2 ½ inch transition between "sublegal" and "seed" size corresponds to the 2 ½: ring size of the survey drag. Data on scallop catch from the Gulf of Maine trawl survey, which covered many additional sites further from shore, was also added to the database.

Total abundance estimates, and estimates for the three size classes, were calculated for Cobscook Bay and Gouldsboro Bay using the classic Cochran approach (Cochran, 1977). The finite population correction factor was ignored since the proportion of area sampled was small compared to the total area of each stratum. In order to estimate the "harvestable biomass" for these areas, we calculated the area-specific shell height to meat weight relationships and applied the regression equation parameters to the legal-sized scallops caught in each tow. From this data we calculated the total meat weight that could be harvested from each survey tow – standardized to grams per meter-squared. Confidence intervals (90% and 95%) for the abundance and harvestable biomass estimates were also calculated. The total number of fishing days that could be supported by the resource in Cobscook Bay was calculated by dividing the harvestable biomass estimate by the trip limit (an area-specific rule for Cobscook bay limiting daily scallop harvest to 135 pounds of meats per day). Data are presented with and without preliminary dredge efficiency estimates applied.

Data from all survey zones were examined at three different spatial scales (large scale, regionally, and patch scale or tow by tow) to look at relative abundance, size structure, recruitment, and meat yield trends. For comparative purposes, the meat weight to shell height relationship was fitted to the allometric equation: $\log W = a + b \log H$ where W is the meat weight in grams and H is the shell height in mm. Multiple regression analyses were used to explore possible relationships between meat yield and site depth and study area.

The percent occurrence and abundance ranking of bycatch species over all sites was examined. Additional analyses will be run comparing abundance data with associated fauna as well as available environmental data.

<u>Limitations</u>

Other than some delays caused by weather, the work proceeded smoothly. The first year of the survey took place in the fall of 2002 rather than during the fall of 2001 as anticipated in the project proposal because additional lead-up time was needed to get the survey underway. Also – it was important to experience a season of sea and port sampling prior to the start of the survey. Gear conflict with lobster traps was sometimes a problem during November. Usually the survey boat was able to make short tows in places where some gear was still present if sea conditions were right. When too much gear was present the survey continued on to another area rather than risk disturbing gear – returning at a later date after traps had been moved farther offshore. In a couple of areas the sampling date extended into the start of the scallop season.

Survey – Data and Results

Sampling intensity/ coverage

In the 2002 survey year, 24 trips were made covering 236 stations from Casco Bay to the St. Croix River. All but two trips were made in between October 26 to November 30; the other two were made in January. Approximately 7880 scallops were measured and 3380 scallops shucked and individual meats weighed. Fifty-one CTD-drops were performed

In 2003, we made 23 trips covering 255 stations from Casco Bay to Cobscook Bay. Sites in Zone 9 were sampled in March 2004 due to gear conflicts prior to the season, but otherwise the survey was conducted between October 20 and November 26. We also attempted to survey additional sites in Zone 11, but the trip was cut short due to bad weather. A total of 10,578 scallops were measured and 1704 meats weighed. The maximum shell height measured was 179.8 mm and maximum meat weight was 107.8 grams. A total of 28 CTD-drops were performed.

An overview of all sampling sites covered is shown in Figure 10. Stations sampled ranged in depth from 20 to 200 feet. Lobster gear made sampling some deeper water areas difficult so we examined results from the DMR trawl survey to assess the relative abundance of scallops in these areas. Their data shows some concentrations of scallops within state waters near the New Hampshire border (where our survey coverage didn't extend to) as well as beds located just outside of state waters in areas south of Muscongus Bay, Isle au Haut, and Mount Desert Island. However, their data did not show extensive areas of scallop grounds in deeper areas within state waters (Figure 11j).

Spatial distribution, seed occurrence, size structure, & relative abundance

Figures 11a-11j show the sampling sites for each survey year and for each survey zone. Pie charts plotted on each zone map show the proportion of seed, sublegal, and legal-sized scallops in the catch as white, light gray, and dark gray shaded areas respectively. The overall size of each pie chart is proportional to the standardized catch at each site. In this way, the charts relate: survey coverage as well as the relative abundance of scallops and contribution of individual size-classes on a tow by tow basis for each zone. CTD drop locations are also indicated by a circle with a cross through it. A box-plot of the shell height distributions measured for individual tows in the zone/year is shown to the right of each map. These depict the median shell size as the centerline, the mid-range or middle 50% as the "box", and values outside this midrange are designated by the "whiskers". The upper and lower limit lines drawn horizontally across the graph represent the size transition between sublegal/legal and sublegal/seed-sized scallops. A glance at this graphic depicts the variability in stock size structure encountered within the zone and further gives an indication of the proportion of seed vs. harvestable scallops overall in the area. Below the box plot are summary statistics of: the number of stations sampled (n) and the mean relative density of all sites sampled within the zone (scallops/ meter^2) ± the standard deviation – again broken down into the size categories described previously. Lastly, the overall size frequency histogram for the entire zone is plotted. Maximum size for *P. magellanicus* approaches 200 mm. The stock size structure did not change greatly between the 2002 and 2003 survey years – so only the 2003 data is plotted in this report. A comparison of mean scallop densities by survey year, zone, and size class is presented in Figure 12.

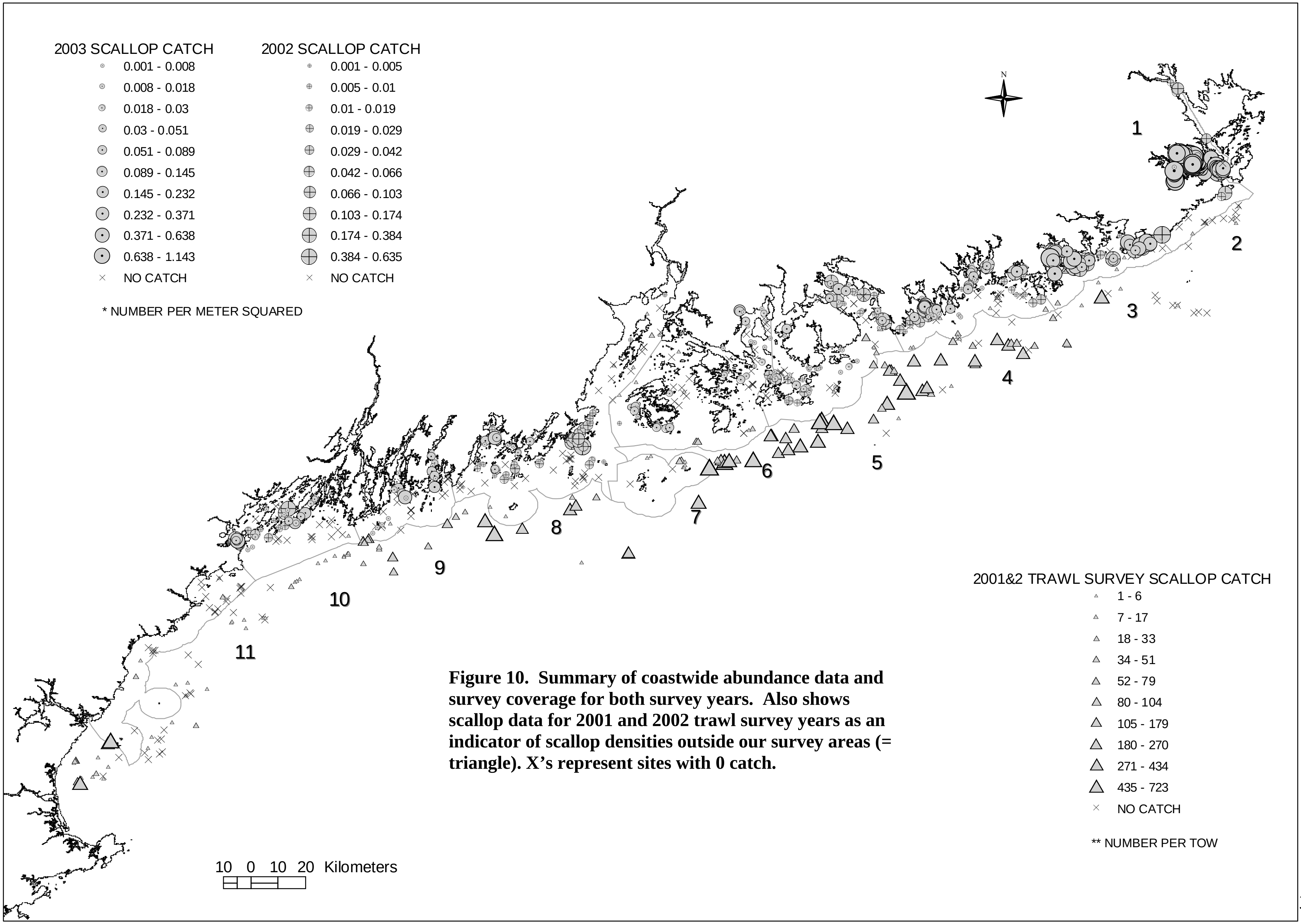
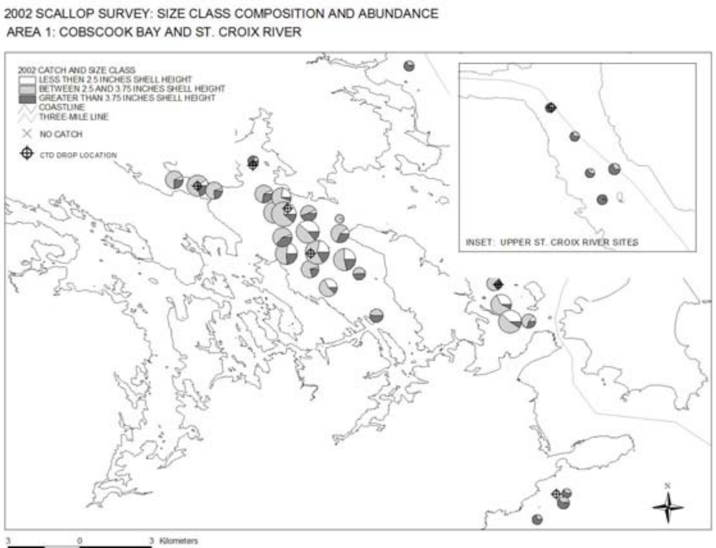
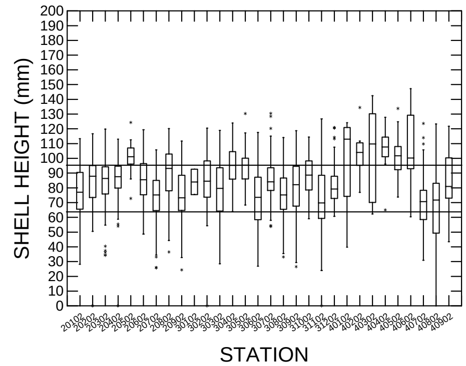


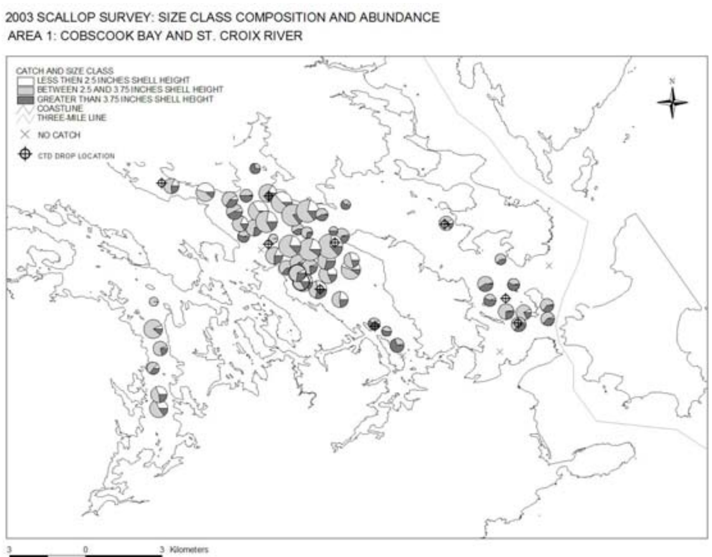
Figure 10. Summary of coastwide abundance data and survey coverage for both survey years. Also shows scallop data for 2001 and 2002 trawl survey years as an indicator of scallop densities outside our survey areas (= triangle). X's represent sites with 0 catch.

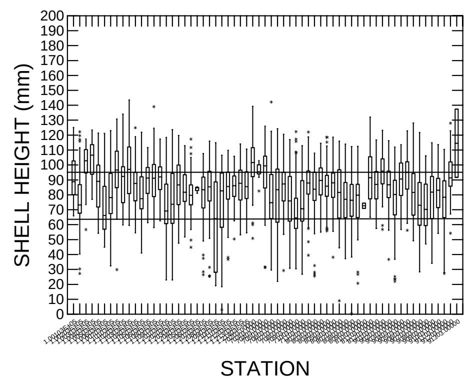
ZONE 1 - COBSCOOK BAY AND ST. CROIX RIVER





n=30
mean rel. density (scallops/m^2) unadjusted=
overall: 0.242 ± 0.199
seed: 0.047 ± 0.062
sublegal: 0.146 ± 0.122
legal: 0.049 ± 0.035





n=68
mean rel. density (scallops/m^2) unadjusted=
overall: 0.307 ± 0.255
seed: 0.057 ± 0.075
sublegal: 0.184 ± 0.167
legal: 0.065 ± 0.255

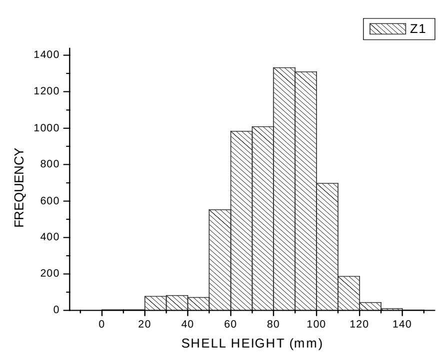
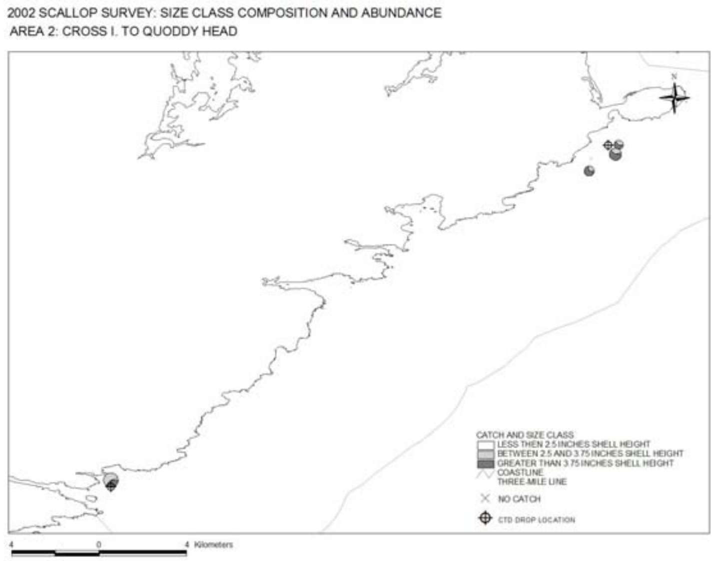
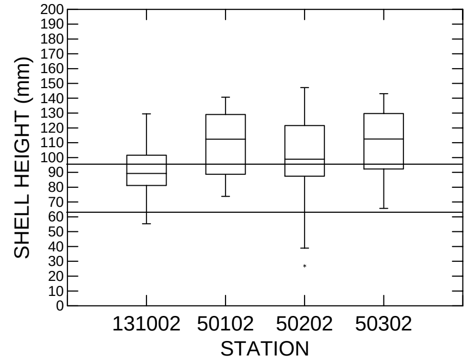


Figure 11a. Sampling intensity during both survey years was high because of the importance of Cobscook Bay as a productive scallop ground. The resource here is characterized by a relatively high overall scallop density and marked by a high proportion of sublegal and seed scallops (up to 85% of the total catch) indicating that recruitment in this area is high and consistent. The lack of larger sized animals likely reflects intense fishing pressure here. Mean scallop density and the location of beds demonstrating the highest scallop abundance did not vary greatly between the 2002 and 2003 survey years. Catch rates were lower in the St. Croix River compared to areas within the Bay. Catch rates and the high seed abundances encountered were very similar to a previous survey of Cobscook (McGowan, 1996).

ZONE 2 - CROSS ISLAND TO QUODDY HEAD

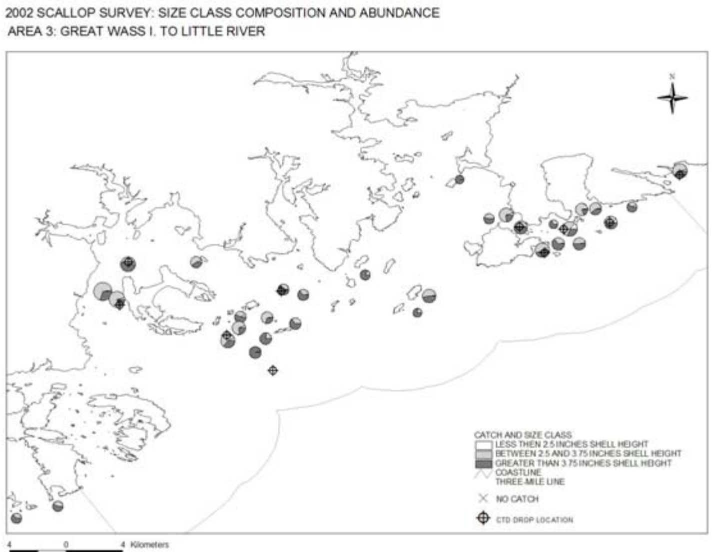


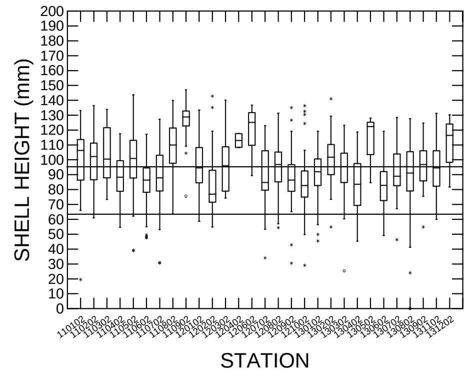


n=5
mean rel. density (scallops/m^2) unadjusted=
overall: 0.051 ± 0.056
seed: 0.002 ± 0.003
sublegal: 0.025 ± 0.034
legal: 0.024 ± 0.020

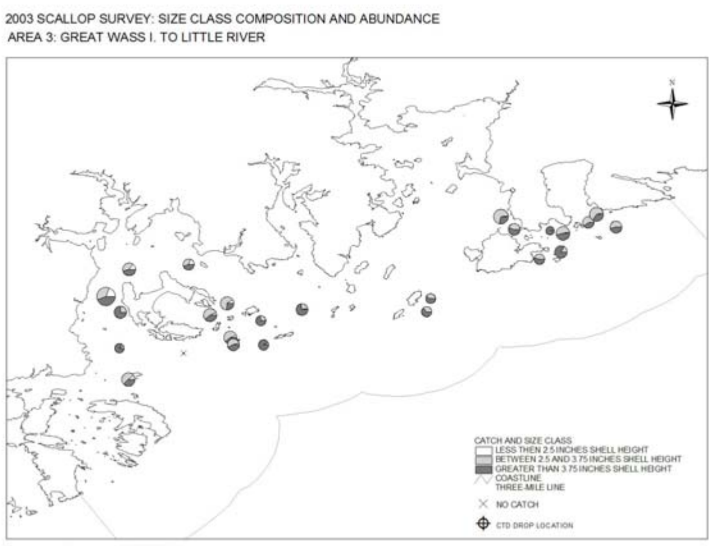
Figure 11b. Lobster gear in Zone 2 made sampling difficult and only five stations were covered in 2002 (none in 2003). Catch rates were lower here across all size categories and consisted mainly of larger scallops. Future sea sampling should target this zone because of the prevalence of traps during the survey timeframe.

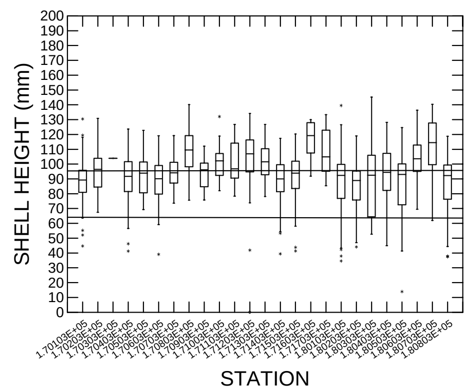
ZONE 3 - GREAT WASS ISLAND TO LITTLE RIVER





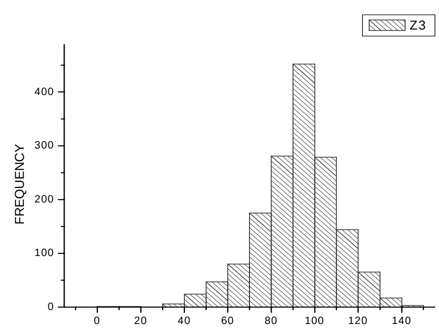
n=29
mean rel. density (scallops/m^2) unadjusted=
overall: 0.070 ± 0.058
seed: 0.003 ± 0.004
sublegal: 0.038 ± 0.041
legal: 0.029 ± 0.019



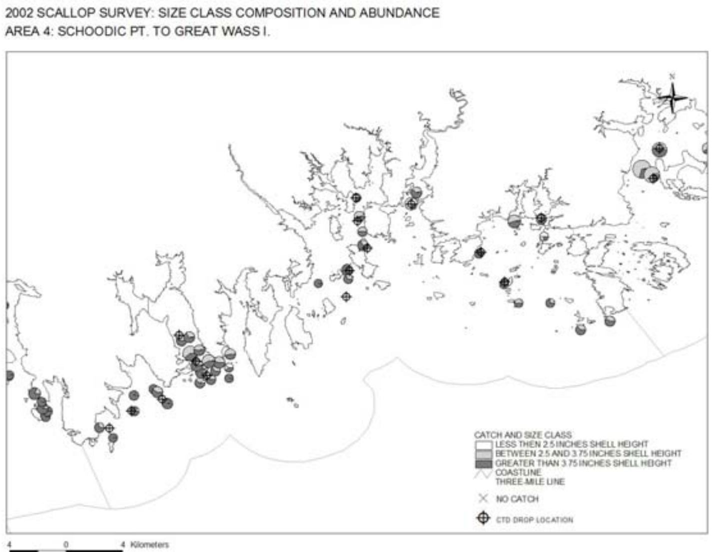


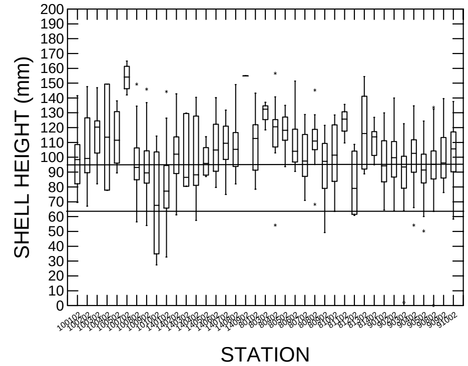
n=25
mean rel. density (scallops/m^2) unadjusted=
overall: 0.111 ± 0.104
seed: 0.008 ± 0.020
sublegal: 0.051 ± 0.051
legal: 0.051 ± 0.044

Figure 11c. Zone 3 exhibited the second highest mean densities of scallops in all size classes. There was a fairly broad range of sizes encountered between sites and within individual tows (ranging from 30-140 mm). The broad size range encountered and presence of seed is an indication of successful past (*i.e.* consistent) recruitment.

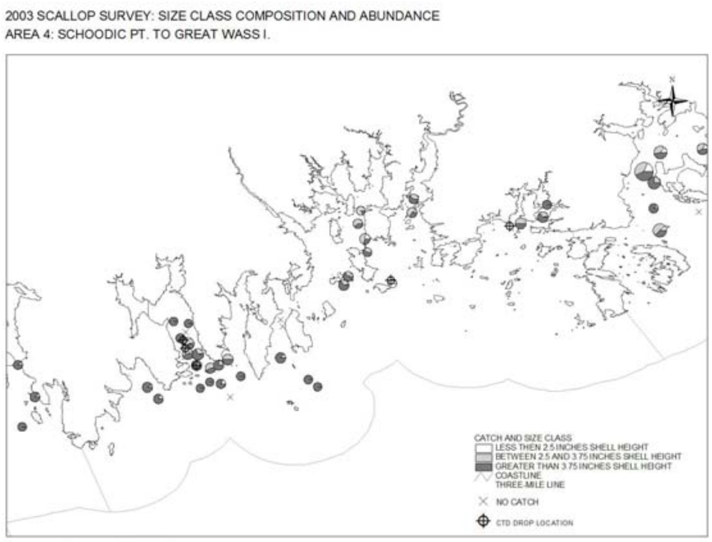


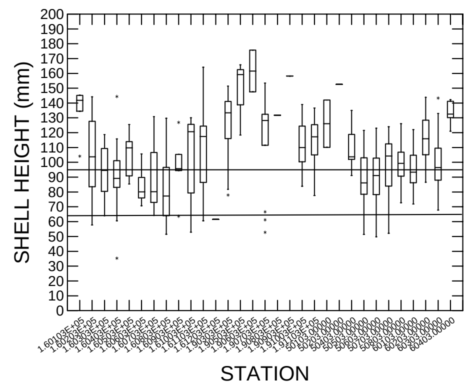
ZONE 4 - SCHOODIC POINT TO GREAT WASS ISLAND





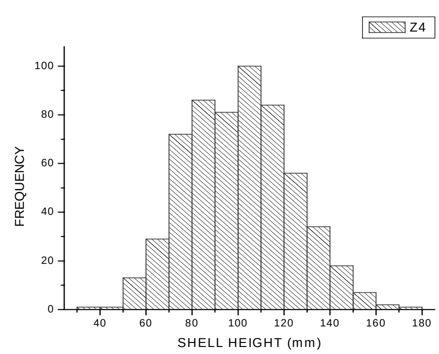
n=39
mean rel. density (scallops/m^2) unadjusted=
overall: 0.026 ± 0.058
seed: 0.001 ± 0.002
sublegal: 0.011 ± 0.016
legal: 0.014 ± 0.011



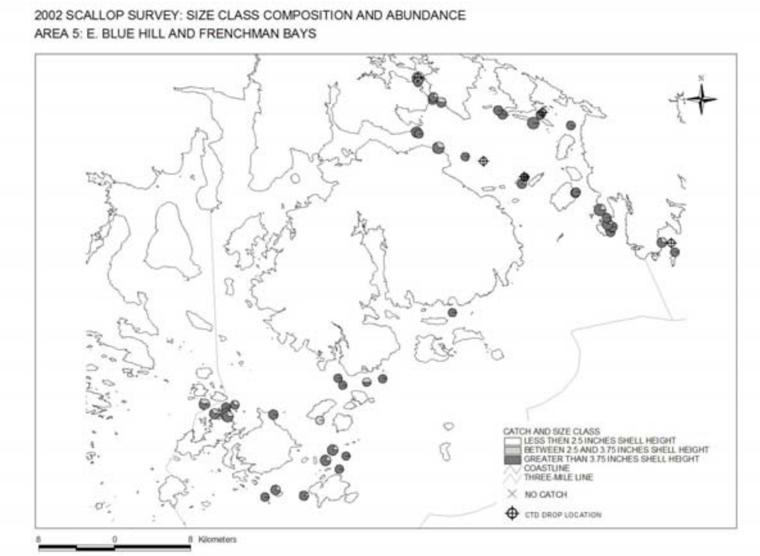


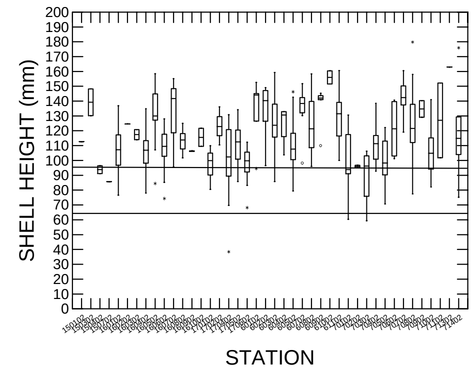
n=40
mean rel. density (scallops/m^2) unadjusted=
overall: 0.024 ± 0.024
seed: 0.001 ± 0.002
sublegal: 0.009 ± 0.013
legal: 0.013 ± 0.013

Figure 11d. Zone 4 was marked by lower catch rates compared to areas 1& 3 farther downeast. Gouldsboro Bay, an historically productive scallop ground contained a broad patch of scallops – but catch levels were lower here than in the past based on fisher information. Overall, there were about 40% sublegal sized scallops in the catch but few areas with significant quantities of small seed.

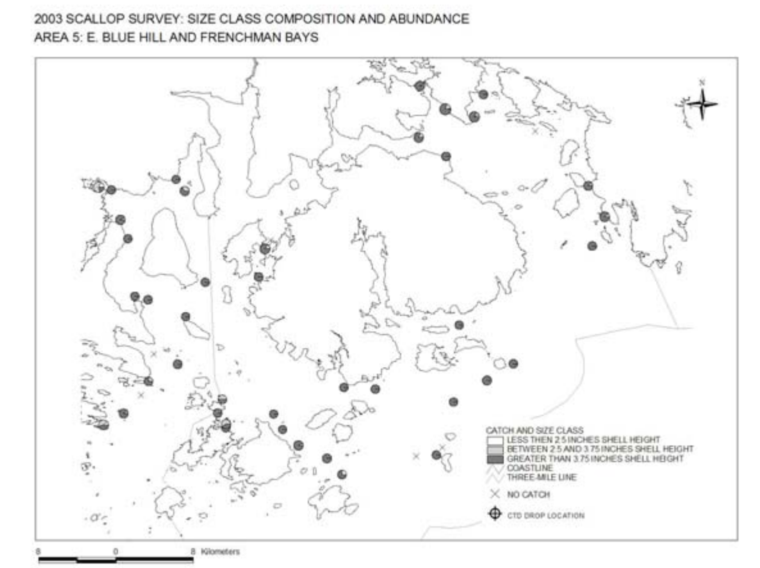


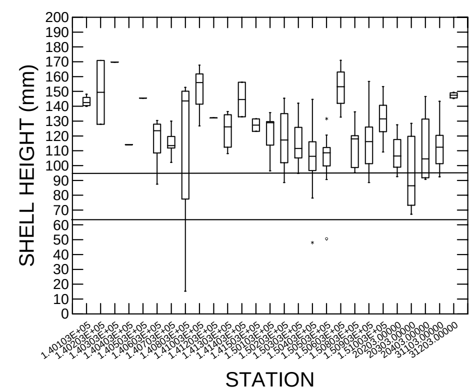
ZONE 5 - EASTERN BLUE HILL BAY AND FRENCHMAN BAY





n=42
mean rel. density (scallops/m^2) unadjusted=
overall: 0.013 ± 0.015
seed: 0.0001 ± 0.0004
sublegal: 0.002 ± 0.005
legal: 0.011 ± 0.012





n=31
mean rel. density (scallops/m^2) unadjusted=
overall: 0.011 ± 0.014
seed: 0.0002 ± 0.0006
sublegal: 0.002 ± 0.003
legal: 0.011 ± 0.014

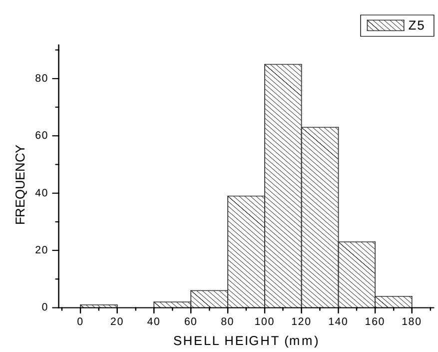
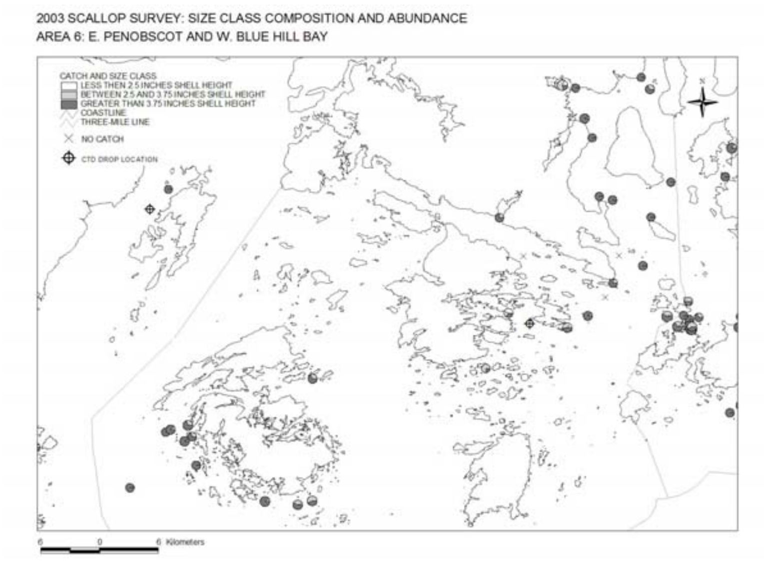
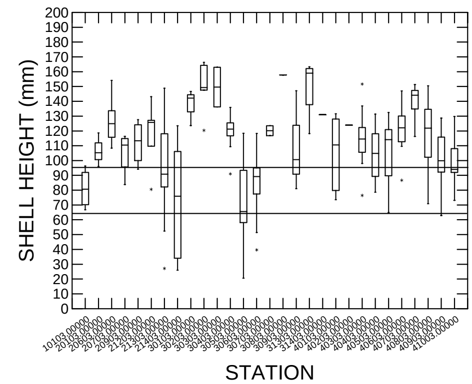


Figure 11e. Zone 5 had the lowest mean scallop density (0.011 scallops/ m^2) and the catch was comprised mostly of larger, older animals.

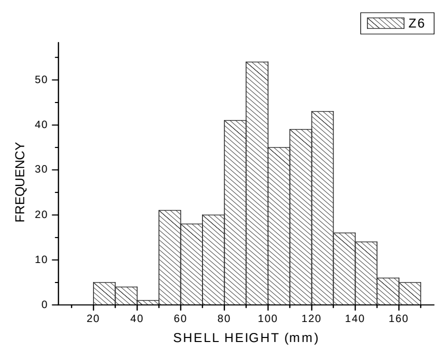
Zone 6 - Eastern Penobscot Bay and Western Blue Hill Bay



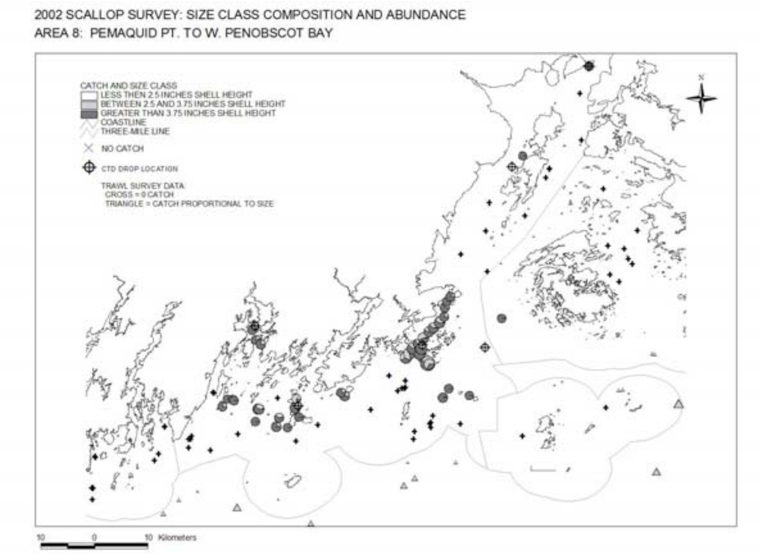


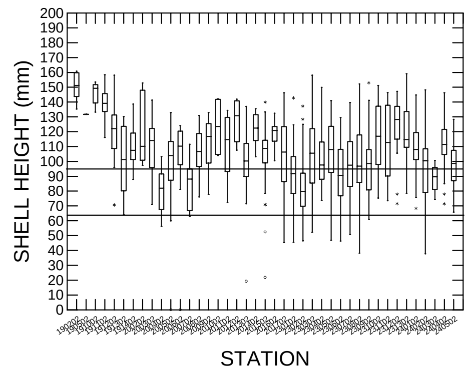
2003 data; n=33
mean rel. density (scallops/m^2) unadjusted=
overall: 0.013 ± 0.014
seed: 0.001 ± 0.005
sublegal: 0.004 ± 0.007
legal: 0.008 ± 0.006

Figure 11f. __2002 (5 sites) and 2003 (33 sites) combined.__ Similar to zone 5, zone 6 had a low mean scallop density (0.013 scallops/ m^2 overall) but several sites did show scattered patches of sublegals and seed.

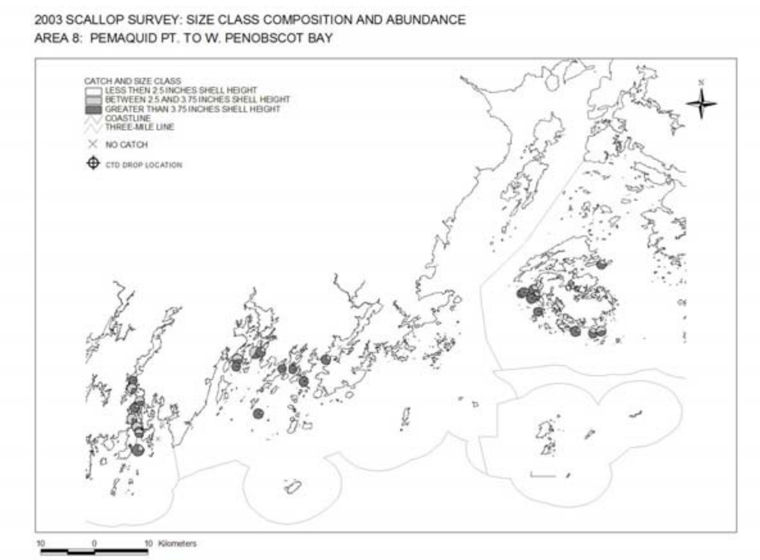


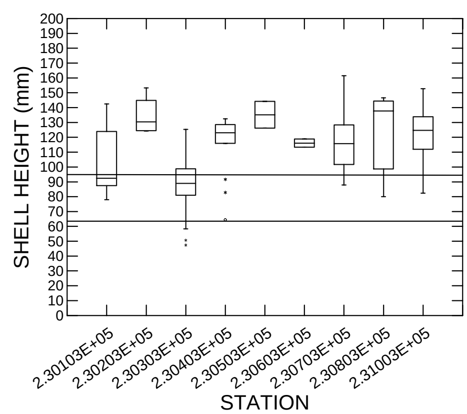
Zone 8 - Pemaquid Point to Western Penobscot Bay





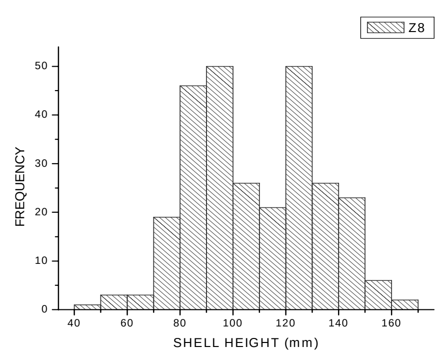
n=41
mean rel. density (scallops/m^2) unadjusted=
overall: 0.018 ± 0.022
seed: 0.0004 ± 0.0012
sublegal: 0.007 ± 0.010
legal: 0.011 ± 0.012



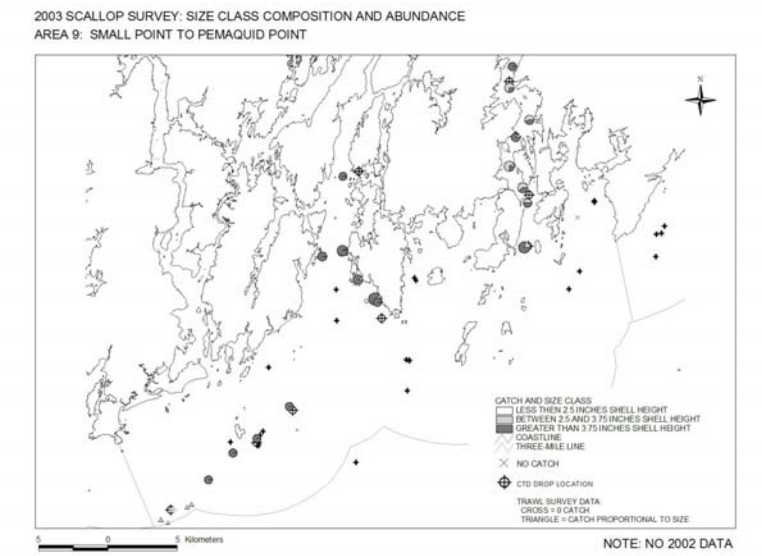


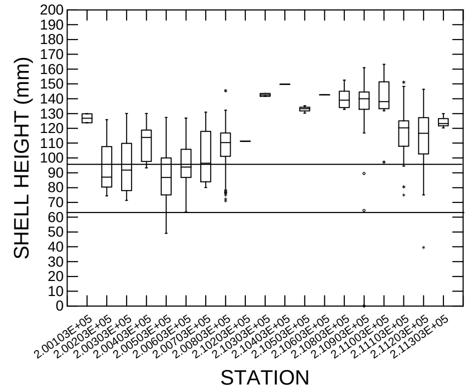
n= 10
mean rel. density (scallops/m^2) unadjusted=
overall: 0.025 ± 0.032
seed: 0.0007 ± 0.0021
sublegal: 0.010 ± 0.020
legal: 0.014 ± 0.012

Figure 11g. Mean scallop density for this region was moderate. The size frequency distribution for the zone in 2003 was bimodal (80 to 100 mm and 120-130 mm). The smaller size classes were found up the Medomak River while sites further from shore into Muscongus Bay were comprised of larger scallops. In 2002, we conducted more intense sampling of Mussel Ridge Channel, near Spruce Head – which showed a lot of variability in scallop size composition. Trawl survey data show some scallop concentrations just outside the three-mile line.



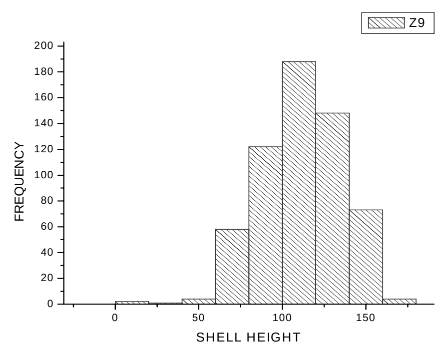
ZONE 9 - SMALL POINT TO PEMAQUID POINT



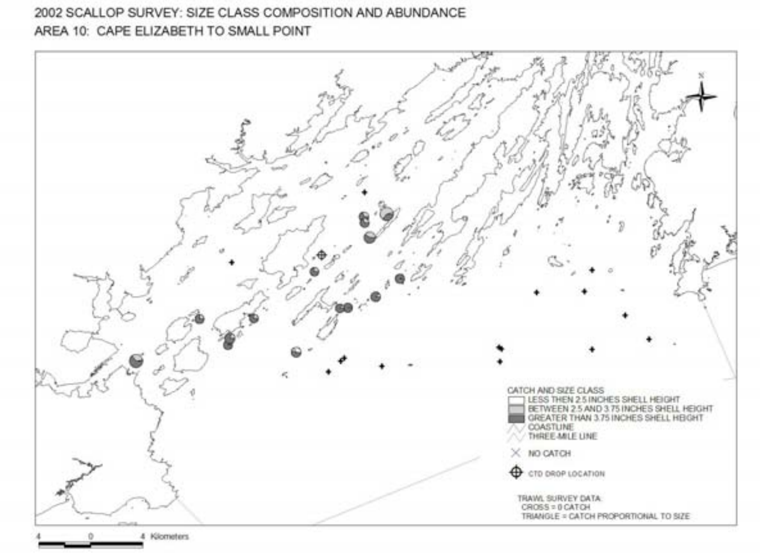


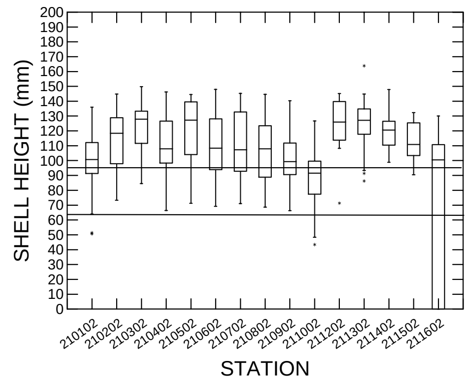
2003 only; n=41
mean rel. density (scallops/m^2) unadjusted=
overall: 0.031 ± 0.029
seed: 0.0024 ± 0.0068
sublegal: 0.013 ± 0.008
legal: 0.019 ± 0.025

Figure 11h. Zone 9 was sampled only during the 2003 survey year, due in part to gear conflict through November. Sites in the Damariscotta River had a smaller mean size and higher proportion of sublegal scallops compared to the Sheepscot River and further offshore sites. Mean scallop density was moderate (0.031 scallops/ m^2).

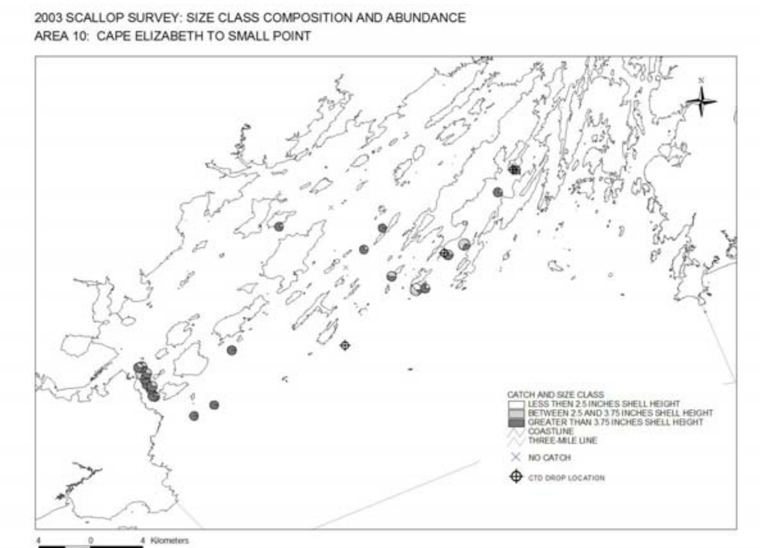


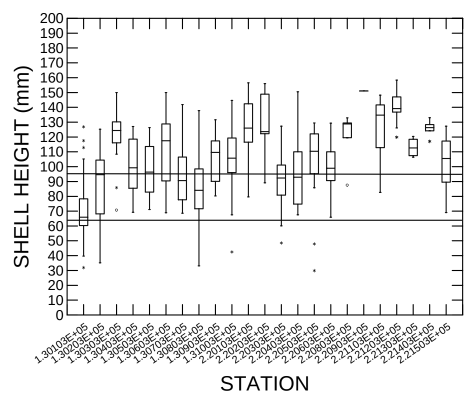
ZONE 10 - CAPE ELIZABETH TO SMALL POINT





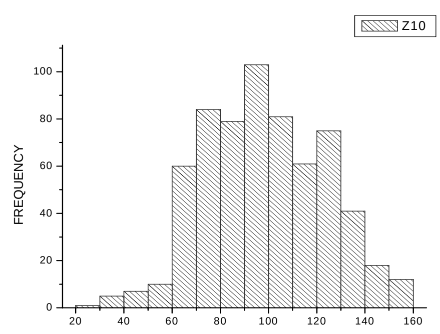
n= 15
mean rel. density (scallops/m^2) unadjusted=
overall: 0.023 ± 0.029
seed: 0.0007 ± 0.0016
sublegal: 0.008 ± 0.012
legal: 0.014 ± 0.015





n= 25
mean rel. density (scallops/m^2) unadjusted=
overall: 0.031 ± 0.040
seed: 0.0024 ± 0.0068
sublegal: 0.013 ± 0.008
legal: 0.015 ± 0.014

Figure 11i. Scallop distribution in Casco Bay and Harpswell Sound was patchy and the density was moderate (0.023 and 0.031 scallops/ m^2 in 2002 and 2003 respectively).



AREA 11 - KITTERY TO CAPE ELIZABETH

TRAWL SURVEY DATA ONLY

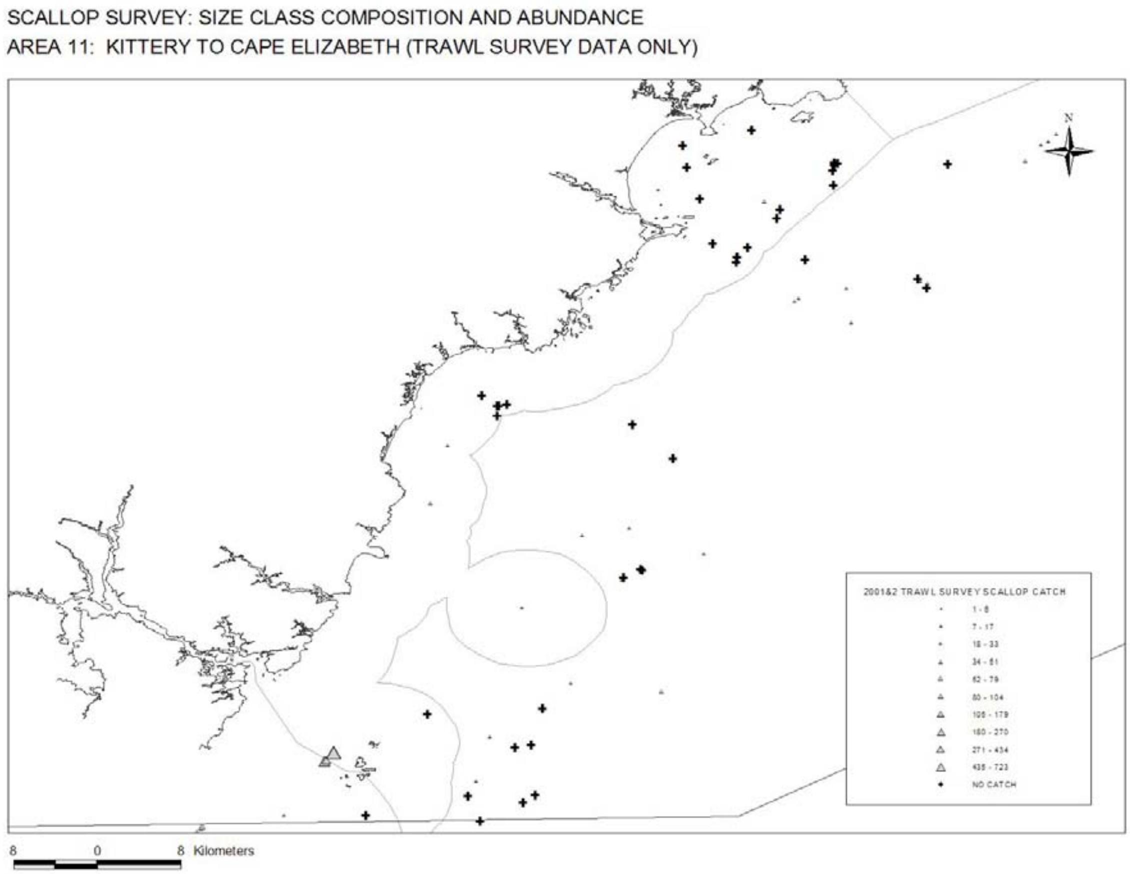


Figure 11j. Survey coverage did not extend to Zone 11, but trawl survey data shows only a small concentration of scallops near the New Hampshire border. There are also known scattered patches, not shown, in Saco Bay and near Boon Island.

Overall catch rates

A summary of relative mean scallop densities, by zone and size class, is shown in Figures 12a and b. Catch frequencies, standardized to scallops • m^{-2}, for all survey sites broken down into designated size classes are shown in Figure 13 (2003 data presented). Relative densities, unadjusted for drag efficiency ranged for the most part from 0 to 0.3 scallops • m^{-2} but are highly skewed towards the minimum density. The exception to this was in Cobscook Bay where a significant number of sites had densities greater than 0.4 – with a maximum of 1.2 scallops/ m^2. The most productive areas seemed to be centered downeast, falling off sharply at zone 5 around MDI. This resource abundance distribution correlates with fishing activity by county encountered in the port sampling program. Even though the survey specifically targeted known scallop concentrations, most beds were of moderate to low density with relatively few sites (mainly in zones 1 and 3) in the higher density categories. Compared to sea scallop densities reported in the literature (Table 8), the maximum densities observed in this study fall in the lower ranges cited. Beyond zones 1 and 3, seed occurrence was patchy or sparse.

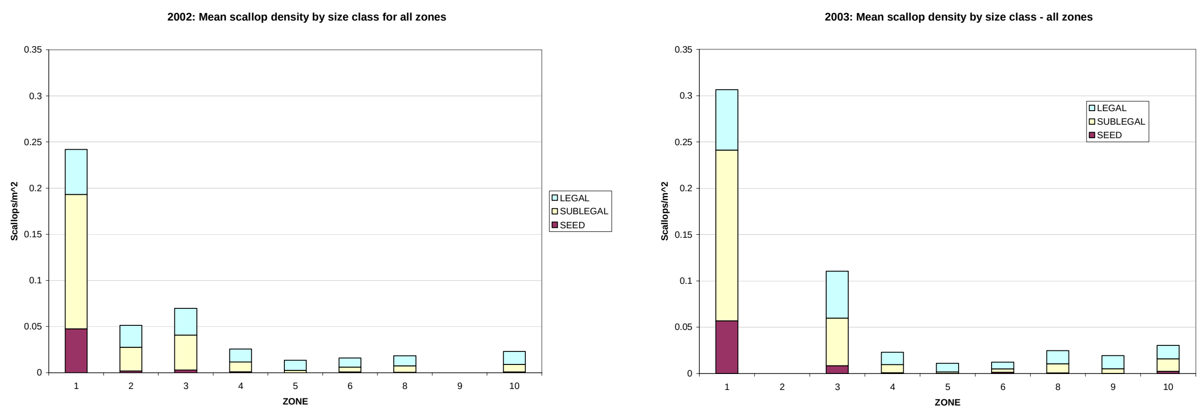


Figure 12. Mean relative scallop density by size class and zone for the 2002 (left) and 2003 (right) survey year.

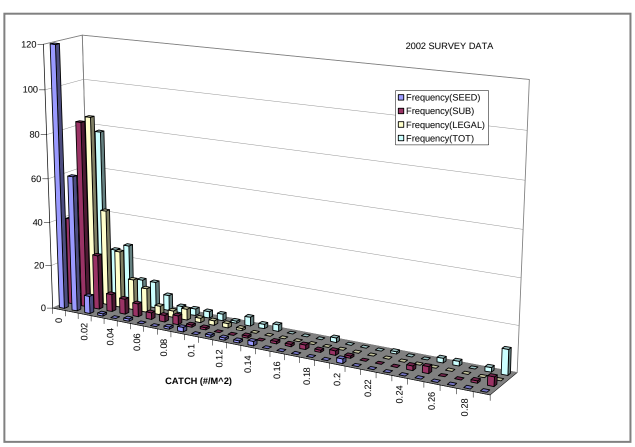


Figure 13. Catch rate frequencies by size class and overall for all sites (2003 data shown).

Table 8. Sea scallop densities encountered in other studies compared to max imum survey result densities.

Density (scallops • m^{-2})	Type	Location	Reference
6.3	maximum density	Inshore Digby, NS grounds	Dickie, 1955
0.6-1.2		Intermediate beds, Digby, NS grounds	Dickie, 1955
1.2-2.0		Offshore Digby, NS beds	Dickie, 1955
4-7	dense bed	Northumberland Straight	Caddy, 1975
2-4		North George's Bank	Caddy, 1975
1.7-123	spat densities	George's Bank	Larsen and Lee, 1978
4-5	recruits	George's Bank	in Caddy, 1975
0.5	"older" scallops	George's Bank	in Caddy, 1975
0.19-0.86		Newfoundland	MacDonald and Thompson, 1986
0.98		Fippennies Ledge, Gulf of Maine	Langdon and Robinson, 1987
0.025 - 0.89	>3.5 inch scallop	George's Bank	NMFS survey
0.18 - 1.14	max scallop densities*	Inshore, Gulf of Maine	This study
0.22	max density >3.5 inch scallop*	Inshore, Gulf of Maine	This study
0.36	mean high abundance fishing ground*	Cobscook Bay, Maine	This study

* unadjusted for gear efficiency

Stratified random survey for Cobscook Bay

The 2003 survey for Cobscook Bay, which had a greater sampling intensity than the 2002 survey, is presented in this section. Figure 11a (Zone 1, above) provides a review of sample site locations.

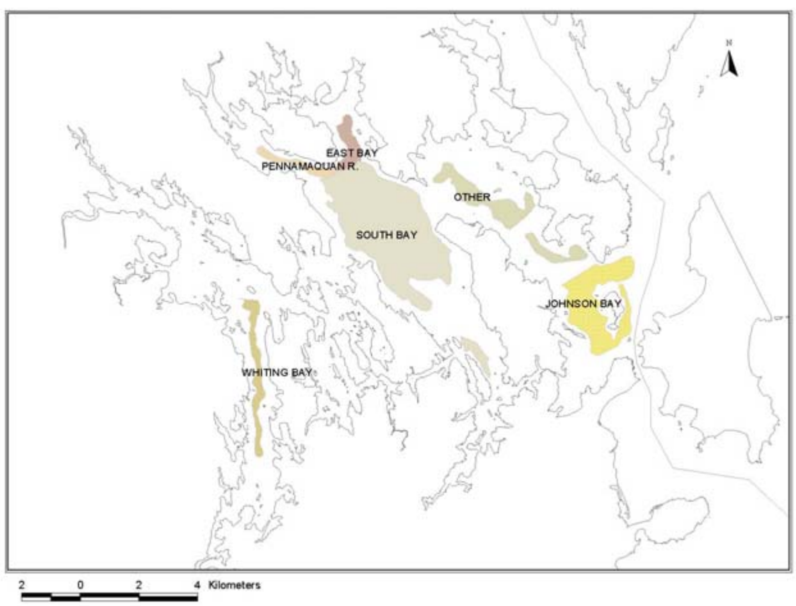
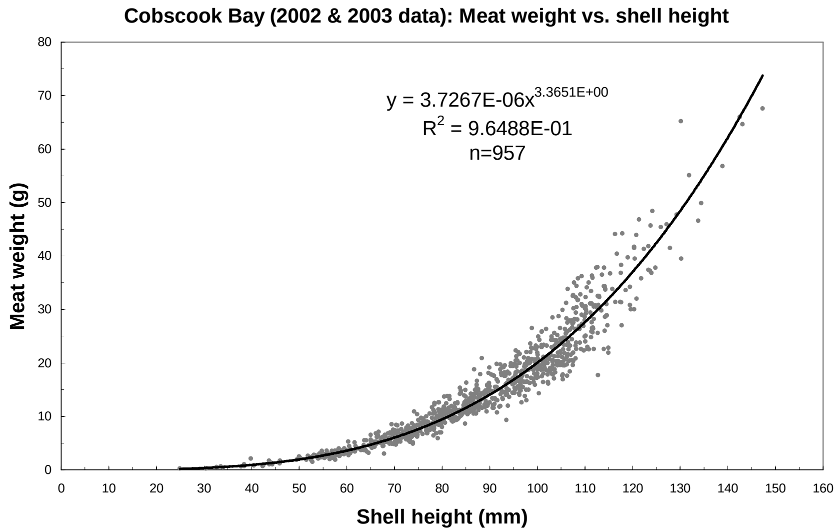


Figure 14. Cobscook Bay -stratified random survey. Six designated stratums.

The designated strata included Whiting Bay, South Bay, the Pennamaquan River, East Bay, Johnson Bay, and an area that was not a primary fishing ground (designated as 'other'; Figure 14). Unlike for the coastwide survey, catch rate frequencies for this zone were not highly skewed. Because of this, bootstrap estimates were not necessary and the statistical analysis followed after Cochran (1977).

Abundance estimates are presented in Table 9. The highest mean densities were in South Bay and the Pennamaquan River, but because of South Bay's much greater area, most of the Cobscook Bay resource is situated in this stratum. A total abundance estimate of 6.07 million scallops (±0.56 million standard error) was calculated. Of these, only 1.34 million were greater than 3 ¾ inches in shell height.



The following meat weight to shell height relationship was calculated from survey data and applied to the shell height data from each tow (Figure 15):

$W = .0000037\ H^{3.365}$ where W is the meat weight in grams and H, the shell height in mm (R^2 = 0.96)

Figure 15. Meat weight as a function of shell height for Cobscook Bay scallops.

From these calculated meat weights, we estimated total harvestable biomass (meats from scallops greater than 3 ¾ inch shell height) as 62,271 pounds. Upper and lower 90% confidence bounds were within 11% of the biomass estimate at 55,571 – 68,971 pounds. A preliminary drag efficiency estimate (Table 10) was applied to the estimate to arrive at a total of 82,198 total pounds (73,354 to 91,042 90% confidence interval; see Table 11). With the current 135 pound trip limit for the Cobscook Bay area in effect, this amounts to a total of 609 trips available if all harvestable scallops were caught - assuming that the maximum pound limit could be caught throughout the season .

Drag efficiency, the number of scallops in the tow path that enter the dredge, was calculated from dragger/ diver comparative transects where we assumed that the diver counts represented a "true" measure of abundance. Estimates, 68% for scallops greater than 3 3/4" inch shell height or 54.9% overall, were higher than some reported in the literature – but in line with others (e.g. efficiency estimates for the NMFS survey dredge are estimated between 38-63%, NMFS, 2004). The particular bottom type at the study site, and typical of much of Cobscook Bay, was sandy-gravel, which likely served to increase gear efficiency – in comparison to the rocky bottom characteristic of some other Maine coastal scallop grounds. A more comprehensive study of dredge efficiency, and selectivity, is needed to estimate real scallop abundance in other survey areas.

Table 9. Survey summary statistics for Cobscook Bay (2003) by stratum and overall. Mean +/-(standard error).

STRATA	**TOTAL**		SOUTH BAY		EAST BAY		PENNAMAQUAN R.		WHITING BAY		JOHNSON BAY		OTHER	
AREA (hectares)	2158		1182		92		64		135		401		284	
N (# sites)	65		42		2		3		6		9		3	
W_h *	1		0.55		0.04		0.03		0.06		0.19		0.13	
DENSITY** (scallops • m^{-2})	*mean*	*s.e.*	*mean*	*s.e.*	*mean*	*s.e.*	*mean*	*s.e.*	*mean*	*s.e.*	*mean*	*s.e.*	*mean*	*s.e.*
seed			0.075	(0.013)	0.001	(0.001)	0.098	(0.063)	0.052	(0.024)	0.006	(0.002)	0.006	(0.005)
sublegal			0.228	(0.028)	0.035	(0.025)	0.177	(0.022)	0.175	(0.062)	0.105	(0.024)	0.061	(0.044)
harvestable			0.077	(0.006)	0.045	(0.018)	0.071	(0.014)	0.046	(0.011)	0.058	(0.009)	0.019	(0.005)
all sizes			0.379	(0.043)	0.081	(0.045)	0.346	(0.077)	0.272	(0.083)	0.170	(0.032)	0.086	(0.054)
ABUNDANCE**														
seed	1059259	(157723)	881869	(147891)	1371	(1371)	63167	(40614)	69437	(32502)	25864	(7593)	17550	(15468)
sublegal	3670515	(380359)	2693919	(334913)	31791	(23052)	113954	(14246)	234826	(83119)	422913	(96140)	173112	(124980)
harvestable	1343313	(87668)	906148	(74171)	41028	(16558)	45607	(8873)	62233	(14763)	233708	(37390)	54589	(14682)
all sizes	6073087	(556809)	4481936	(503616)	74190	(40981)	222728	(49570)	366496	(111892)	682486	(126682)	245251	(153957)
HARVSESTABLE BIOMASS (kg)														
uncorrected**	28246	(1819)	18516	(1545)	897	(293)	985	(168)	1299	(306)	5209	(779)	1340	(324)

* Stratum weight
** uncorrected for drag efficiency

Table 10. Preliminary dredge efficiency estimate for Cobscook Bay.

Mean abundance (scallops • m-2)	OVERALL	SEED < 2.5 inches	SUBLEGAL 2.5-3.75 inches	HARVESTABLE >3.75 inches
Dive transect method	0.640	0.250	0.270	0.120
Drag sweep	0.352	0.038	0.233	0.082
Estimated efficiency	54.9%	15.3%	18.4%	68.0%

Table 11. Preliminary harvestable biomass estimate with 90% confidence interval. Upper and lower bounds are within 10.8% of the mean.

HARVESTABLE BIOMASS *(lbs of meats)*	Mean	Lower 90% bound	Upper 90% bound
uncorrected	62271	68971	55571
*corrected**	82198	91042	73354
*Available boat trips***	609	674	543

* preliminary drag efficiency estimarte = 68%
** Daily catch is limited to 135 lbs in Cobscook Bay

Meat yield

Not uncharacteristic for this species, wide variability in the shell height/ meat weight relationship was evident between sites. For example, sites within Cobscook Bay showed a much greater increase in meat yield for a scallop of a given size compared to nearby sites just outside Quoddy Head (Figure 16).

An exponent parameter of three or greater in the shell height to meat yield relationship has been cited as an indicator of “good” growing conditions. Relationships calculated over the course of our study show a range of values from “average” (overall relationship- $y=0.00002x^{2.913}$) to excellent (e.g. Cobscook – $y=0.000004x^{3.326}$) to poor (e.g Quoddy Head – $y=0.00009x^{2.581}$).

Mean meat yield relationships did vary by zone, but not in a consistent manner. An exploratory analysis using multiple regressions showed only a minute increase (less than 1% in adjusted R^2 values) when zone was included as a categorical variable (not shown). Contrary to past studies pointing to the influence of depth on meat yield, including depth alone or in addition to zone also showed a negligible (<1%) increase in explained variance. This may underscore the patchy nature of the inshore Gulf of Maine, at the scale of the survey, where other factors such as inputs of phytoplankton from river systems or oceanographic factors affecting temperatures and food supply may underlie site to site differences in meat growth and condition rather than depth per se. Another explanation is that comparatively few very deep sites were sampled on the survey. With the large tidal currents present over many productive scallop grounds, the water column may often be well mixed from shallow to moderate depths. The area specific information on meat yield recorded during the survey will help to explore these more intricate factors.

It is also important in the context of calculating biomass, as in the Cobscook Bay example above. A small increase in shell height causes a much greater percentage increase in meat weight (Table 12 below) so converting scallop densities and size data to meat biomass should rely on the shell height to meat weight relationship for that specific area/ bed. Use of an inaccurate relationship for this data conversion can result in large errors and biases in the biomass estimate. There is also a known seasonal effect on meat yield, with meat condition improving after spawning in late August until gonad development commences again in the Spring. Seasonality in this trend should be better documented – perhaps through repeated sea sampling in several areas throughout the season.

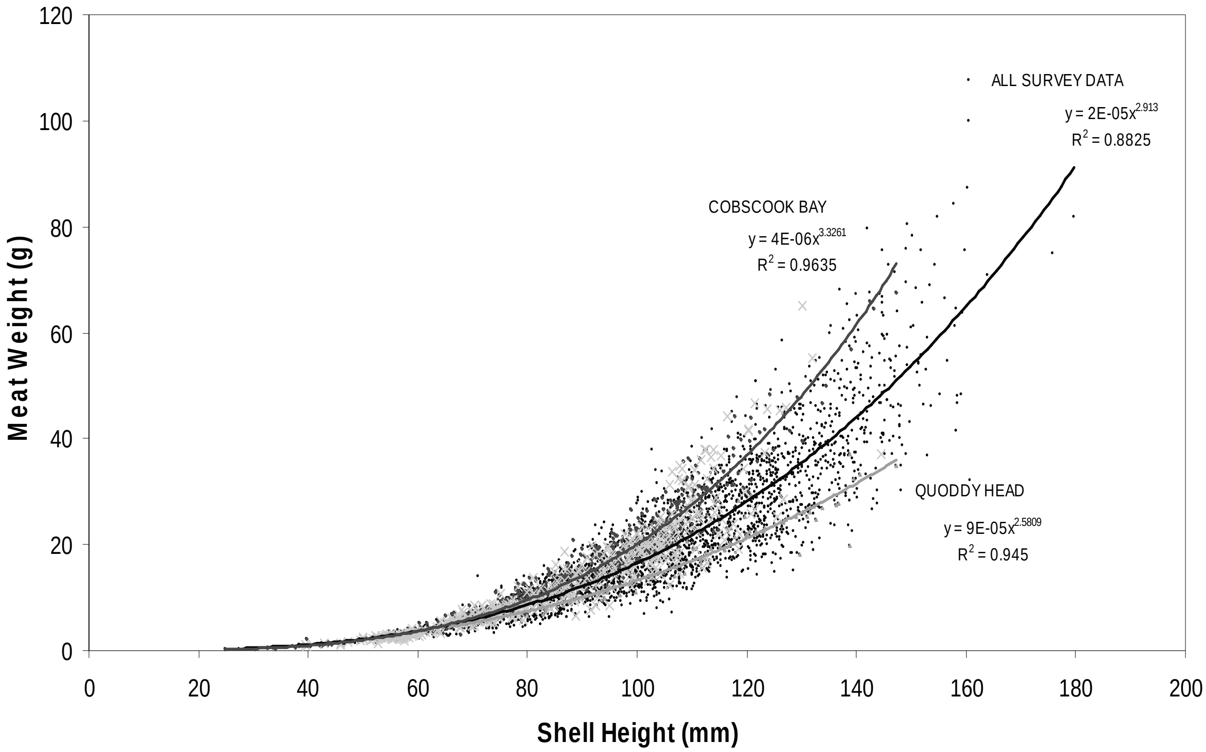


Figure 16. Overall meat weight/ shell height relationship (all data combined) showing significant variability. Cobscook Bay allometric equation compared to nearby offshore Quoddy Head showing a striking difference in meat yield obtained.

Table 12. The impact of small increases in shell height on meat yield: Cobscook Bay example.

SHELL HEIGHT (INCHES)	MEAT WEIGHT (G)	COUNT PER LB	% INCREASE MEAT YIELD
3.00	8.1	56	
3.25	10.6	43	31.4%
3.50	13.6	33	28.7%
3.75	17.1	27	25.4%
4.00	21.1	21	23.5%
5.00	44.5	10	
6.00	82.7	5	

Bycatch/ Associated fauna/ Bottom type

The digital photo taken of each haul sometimes provided a very clear visual reference to the dominant organism or bottom type (Figure 17, below). From top to bottom and left to right: 1) mud bottom, 2) typical "good" scallop catch, 3) rocky bottom, 4) urchin tow, 5) sea stars, 6) mussel tow, 7) sea cucumbers, 8) sand dollars.

Data collected over the course of the survey on bycatch and bottom type can help to:

- *Map resources related to other drag fisheries*. In addition to qualitative information on the occurrence of mussels and sea urchins, we also recorded numbers and size distribution of sea cucumbers – another drag fishery in Maine for which there is little information (Figure 18). The presence of ocean quahogs were also noted for the same reason. Although the survey gear is not appropriate for determining relative densities of this later species – a few in the catch may indicate a substantial bed within the sediment.

- *Document potential interactions with other fisheries*, such as the incidence of lobster or sea urchins in the catch and observations on potential damage and incidental mortality.

- *Provide information on the occurrence of rarer species* that may be of interest for other Gulf of Maine studies (Table 14) as well as nuisance species and bivalve predators such as sea stars and green crabs.

- *Provide data to analyze associations with other fauna and bottom types* in order to gain insights on the "preferred environment" of sea scallops and the community ecology associated with beds. Although scallops display no "obvious" sediment preference, higher densities do tend to occur on mixed gravel, hard bottoms, and sand more than on mud bottoms (Caddy, 1972).

-In relation to enhancement, this data may help determine suitable seeding areas – sites with a low scallop abundance but good yield and importantly – low numbers of predators such as starfish.

Table 13 is a list of bycatch species in order of their relative occurrence over all survey sites from highest to lowest. The percent frequency of these sites that fell in each qualitative abundance ranking is also presented. This subjective rank designation was species specific. For example a haul of 6-7 lobsters would be noted as "very abundant" for this bycatch species, whereas 6-10 mussels, sea urchins, or sand dollars in the catch would be classified as "common".

Not listed in Table 13 are juvenile red hake (*Urophycis chuss*). These were extremely numerous at some sites but could not be quantified systematically because they were discovered usually only when shucking out meats. In tows where they were common, sometimes 50% of the scallops shucked housed a hake within the shell.

Other occasional species encountered included: Skate, unidentified cockles and arcs, horseshoe crab (*Limulus polyphemus*), Surf clam (*Spisula solidissima*), jingle shell (*Anomia* sp.), Slipper shell (*Crepidula fornicata*). The latter two species were most commonly found as epifauna on the shells. Some of the rarer species encountered are listed in Table 14.

Figure 17. Haul photos showingvery apparant dominant organism/ bottom type of some tows. A typical scallop catch is shown in the top right photo.

Table 13. Bycatch summary.

BYCATCH IN ORDER OF ABUNDANCE - 2003 SURVEY DATA

COMMON NAME	SCIENTIFIC NAME	% OCCURRENCE OVER ALL SITES	ABUNDANCE RATING AT SITES WHERE FOUND				
			PRESENT	RARE	COMMON	ABUNDANT	V. ABUNDANT
SEA CUCUMBER	*Cucumaria frondosa*	78.7%	35.0%	23.0%	16.0%	10.0%	16.0%
ROCK CRAB	*Cancer irroratus*	75.4%	21.2%	39.7%	28.8%	10.3%	0.0%
NORTHERN STAR	*Asterias rubens*	54.9%	16.4%	40.3%	27.6%	11.9%	3.7%
JONAH CRAB	*Cancer borealis*	43.0%	28.6%	25.7%	36.2%	9.5%	0.0%
HORSE MUSSEL	*Modiolus modiolus*	35.2%	23.3%	33.7%	20.9%	12.8%	9.3%
GREEN SEA URCHIN	*Stronglyocentrotus droebachiensis*	30.7%	24.0%	24.0%	21.3%	18.7%	12.0%
LOBSTER	*Homarus americanus*	30.3%	55.4%	31.1%	9.5%	4.1%	0.0%
HERMIT CRAB	*Diogenidae/ Paguridae spp.*	29.1%	47.9%	38.0%	8.5%	5.6%	0.0%
TEN RIDGED WHELK	*Neptunea decemcostata*	29.1%	29.6%	43.7%	19.7%	5.6%	1.4%
GREEN CRAB	*Carcinus maenus*	17.6%	48.8%	39.5%	4.7%	4.7%	2.3%
SMOOTH SUNSTAR	*Solaster endeca*	15.2%	32.4%	56.8%	10.8%	0.0%	0.0%
LONGHORN SCULPIN	*Myoxocephalus octodecemspinosis*	14.8%	83.3%	13.9%	2.8%	0.0%	0.0%
SPRING SUNSTAR	*Crossaster papposus*	14.3%	54.3%	37.1%	5.7%	2.9%	0.0%
WAVED WHELK	*Buccinum undata*	14.3%	60.0%	22.9%	8.6%	8.6%	0.0%
BLUE MUSSEL	*Mytilus edulis*	13.9%	20.6%	23.5%	23.5%	17.6%	14.7%
BLOOD STAR	*Henrica sanguinolenta*	13.5%	72.7%	18.2%	3.0%	6.1%	0.0%
FLOUNDER	*species not identified*	11.9%	82.8%	13.8%	0.0%	3.4%	0.0%
ANENOME UNKNOWN	*species not identified*	11.1%	59.3%	29.6%	3.7%	7.4%	0.0%
SPONGE UNKNOWN	*species not identified*	10.2%	48.0%	28.0%	12.0%	12.0%	0.0%
SPONGE-FIG	*fig-like*	9.4%	52.2%	4.3%	21.7%	8.7%	13.0%
SAND DOLLAR	*Echinarachnius parma*	9.0%	22.7%	27.3%	9.1%	13.6%	27.3%
SEA RAVEN	*Hemitripterus americanus*	9.0%	86.4%	13.6%	0.0%	0.0%	0.0%
SPONGE-FINGER	*finger-like*	8.6%	61.9%	14.3%	19.0%	0.0%	4.8%
MOON SNAIL	*Lunatia heros*	8.2%	75.0%	25.0%	0.0%	0.0%	0.0%
SPIDER CRAB	*Mjidae spp.*	7.8%	78.9%	15.8%	0.0%	5.3%	0.0%
STALKED SEA SQUIRT	*Boltenia ovifera*	6.1%	13.3%	73.3%	6.7%	6.7%	0.0%
STIMPSONS WHELK	*Colus stimpsoni*	5.7%	78.6%	21.4%	0.0%	0.0%	0.0%
COMMON SEASTAR	*Asterias forbesi*	4.5%	0.0%	45.5%	27.3%	27.3%	0.0%
SHORTHORN SCULPIN	*Myoxocephalus scorpius*	4.1%	100.0%	0.0%	0.0%	0.0%	0.0%
WAVED ASTARTE	*Astarte undata*	2.9%	14.3%	14.3%	57.1%	14.3%	0.0%
OCEAN QUAHOG	*Arctic islandica*	2.9%	71.4%	14.3%	14.3%	0.0%	0.0%
NORTHERN CARDITA	*Venercardia borealis*	2.0%	80.0%	0.0%	20.0%	0.0%	0.0%
FISH UNKNOWN	*species not identified*	2.0%	60.0%	40.0%	0.0%	0.0%	0.0%
WINTER FLOUNDER	*Pseudopleuronectes americanus*	1.6%	100.0%	0.0%	0.0%	0.0%	0.0%
BRITTLE STAR	*Class Ophioridae -small*	1.6%	75.0%	25.0%	0.0%	0.0%	0.0%
CRAB UNKNOWN	*species not identified*	1.6%	50.0%	25.0%	25.0%	0.0%	0.0%
SPONGE-ENCRUST	*encrusting*	1.6%	75.0%	0.0%	25.0%	0.0%	0.0%
SPONGE-BRANCH	*branching*	1.2%	33.3%	33.3%	33.3%	0.0%	0.0%
GASTROPOD UNKNOWN	*species not identified*	0.8%	100.0%	0.0%	0.0%	0.0%	0.0%
MONKFISH	*Lophius americanus*	0.4%	100.0%	0.0%	0.0%	0.0%	0.0%
OCEAN POUT	*Macrozoarces americanus*	0.4%	100.0%	0.0%	0.0%	0.0%	0.0%
SPONGE-BALL	*ball-like*	0.4%	100.0%	0.0%	0.0%	0.0%	0.0%
WOLF EELPOUT	*Lyncenchelys verrillii*	0.4%	100.0%	0.0%	0.0%	0.0%	0.0%

Table 14. Rarely encountered species.

RARE SPECIES LIST

COMMON NAME	SCIENTIFIC NAME	NOTES
Rat-tail sea cucumber	*Caudina arenata*	Found in St. Croix River
Scarlet psolus	*Psolas fabricii*	Found in Frenchman Bay by "Porcupines"
False quahog	*Pitar morrhuana*	
Mud star	*Ctenodiscus crispatus*	identification uncertain
Pale sea cucumber	*Pentamera(=cucumaria) calcigera*	identification uncertain
Pink synapta	*Epitomapta (=Leptosynapta) roseola*	
Cup and saucer striata	*Crucibulum striatum*	
Gould's pandora spoon	*Pandora gouldiana*	
Cleft clam	*Thracia conradi*	
Sea mouse	*Aphrodita bastata*	
Atlantic seasnail	*Liparis atlanticus*	
Stalked jellyfish	unidentified species	Found in St. Croix River
Razor clam	*Ensis directus*	Often present as shells but hard to catch live in drag

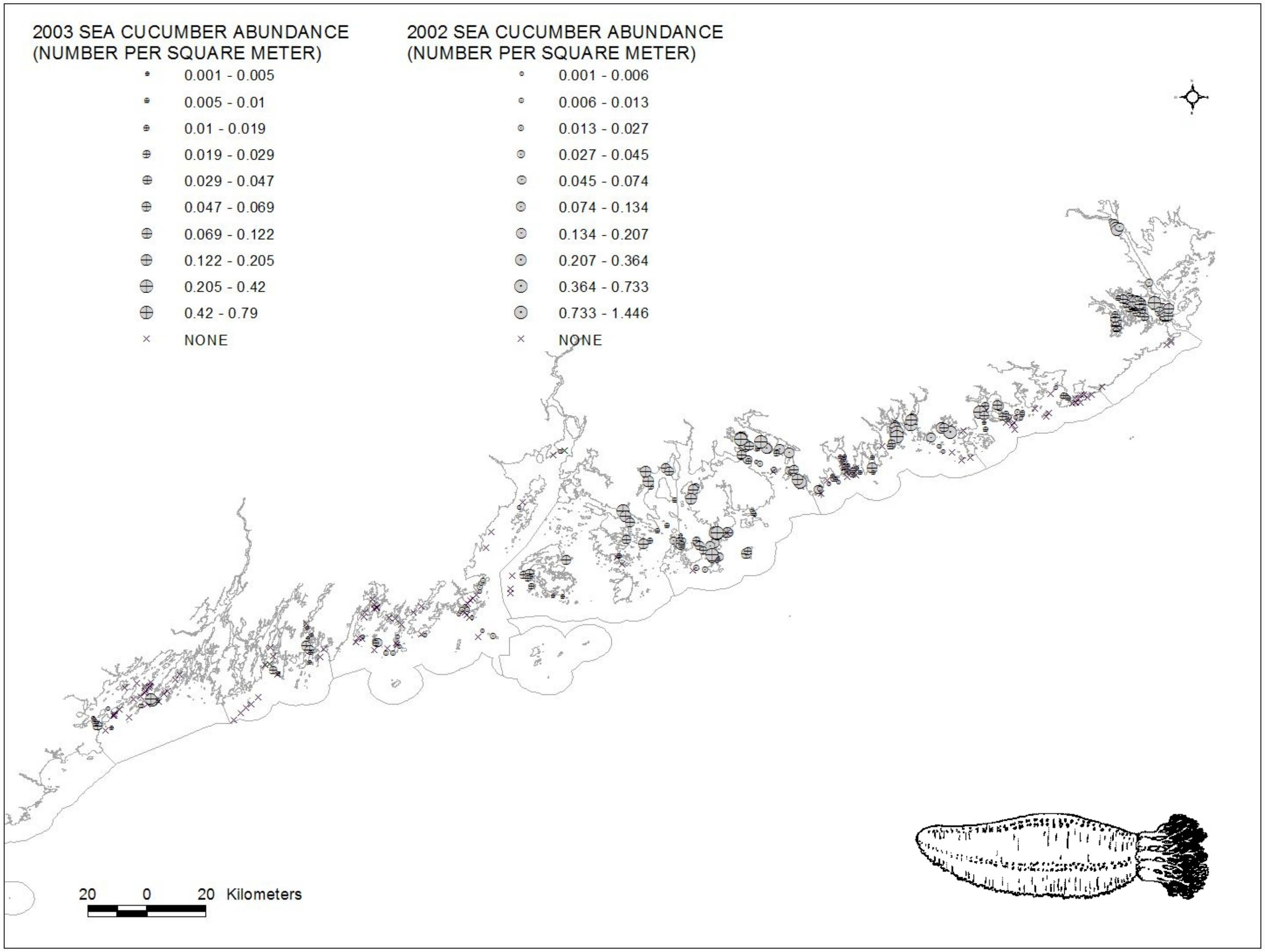
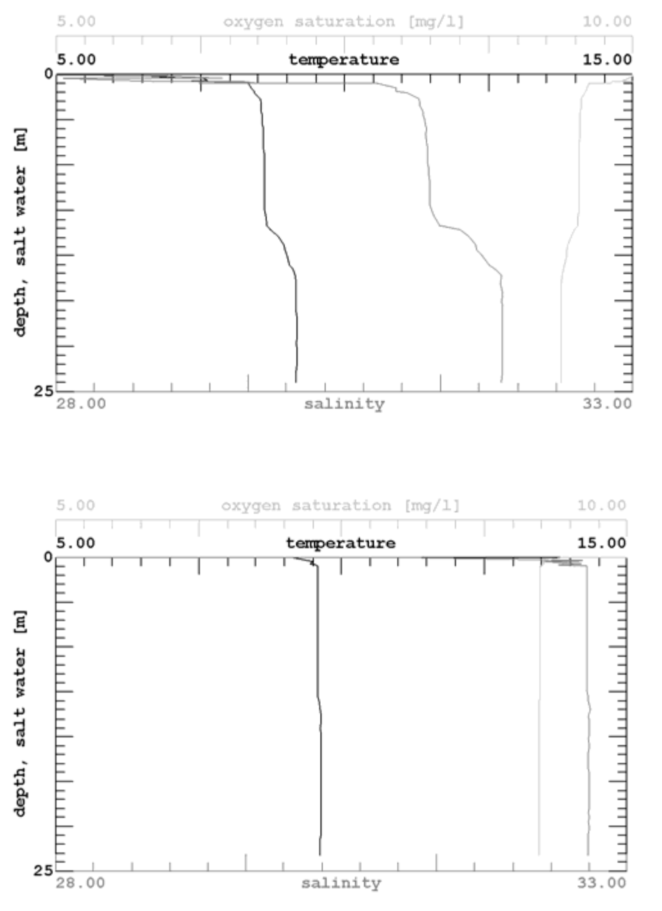


Figure 18. Distribution map and relative abundance of sea cucumber (*Cucumaria frondosa*) determined from survey data.

CTD and Environmental data

A total of 72 CTD drops were conducted within various regions of each zone to provide a snapshot profile of salinity, temperature, and oxygen saturation values (locations shown in Figure 10a-i). These give an indication of bottom water temperatures encountered during the time period of the survey and an indication of oceanographic effects such as the "salt wedge" characteristic of estuarine environments (Figure 19, top, compared to bottom graph showing a well mixed water column). Bottom water temperatures between the end of October to December 1st in both years ranged from 10 degrees at end of October to 6 degrees at the end of November. Coldest bottom water temperatures were in March (from a few sites sampled during the scallop season due to lobster gear interference in the fall) at 1.2-1.6 degrees Celsius.



Above: CTD

Right top: St. Croix River profile

Right bottom: Johnson Bay profile

Figure 19. CTD instrument and selected profiles.

Survey – Conclusions

General abundance trends: The resource appeared to be healthiest in zones 1 and 3. The high occurrence of seed in zone 1 (Cobscook Bay) should elicit concerns over incidental mortality. The lack of larger scallops within this zone also may mean that this area may be impacted greatly by the recent raising of the legal minimum shell size to four inches – until the resource catches up in size. Zone 4 had intermediate densities of scallops, but the resource was down compared to anecdotal past accounts of scallop catch in this area. Zones 5 and 6 (Mount Desert Island and Stonington) were marked by poor resource abundance compared to past reports by fishermen (this incidentally may lend credence to enhancement effort taking place in this area). The resource in zones 7-10 was more variable and patchy in terms of density and seed occurrence. Zone 11 was not sampled by our survey, but trawl survey data indicate only small, occasional patches of scallops. Overall, the catch frequencies show that measured against potential scallop densities encountered in our region, there is much room for improvement of the resource.

Biomass estimate: We were able to calculate a biomass estimate for one scallop producing area (Cobscook Bay) with a reasonable level of confidence (ca. 11% of the mean with 90% confidence). It would still be difficult to produce a state-wide resource estimate, although the distribution map from this work should help to refine suitable strata.

Meat yield: Not unexpectedly, the meat yield to shell size relationship was highly variable and appeared to be site specific. Broad variables of area, latitude, and depth, did not help to explain additional variability in this relationship.

Additional work can be done with the data set – including exploratory analyses with bycatch and environmental data. The time series generated with additional survey years will add to the value of this baseline data. A scallop survey handbook, detailing methods, was written to help train future survey hands.

Survey – Future work

The DMR plans to continue annual surveys of scallops – funded by a recently enacted license surcharge and in consultation with an industry advisory group formed. Two separate areas of the coast – west and east of Penobscot Bay will be surveyed in alternate years. Additional work is needed to provide for a more general drag efficiency/ selectivity estimate. Age and growth analyses also need additional time to be completed.

<u>Examination of alternative methodologies</u>

In August 2005, we did a preliminary experiment to try to gauge the potential for a drop camera approach to surveying. The advantage to a drop camera is that: 1) no correction for dredge efficiency is necessary, and 2) the drop set-up avoids the inevitable gear conflict issues that arise when towing a drag - enabling sampling even in areas with high densities of lobster traps. A 50 m x 50 m area containing a good density of scallops was identified. Industry divers collaborating on the project covered the entire bottom area in order to obtain a true estimate of the number of scallops within the area (104 scallops = 0.0416 scallops • m^{-2}). In addition, several hundred paired empty scallop shells were painted white and released over the area. Next, (16) 25-meter band transects (2 meters in width) were swum by divers – counting the number of natural and painted scallops encountered. Lastly, a camera was attached to 0.5 meter-square frame and 240 drops performed. Only 5 scallops were recorded over these 240 drops – but this turns out to be similar to the known scallop density for the area (5/120 m^2 = 0.042 scallops • m^{-2}). The estimate of scallop density derived from the drop camera work shows that there is potential in this method – however, it also demonstrates several drawbacks – mainly, that only a very small fraction of the drops conducted even contained scallops. A typical survey tow would cover over 1000 square meters of bottom –more than 10 times the coverage of 240 camera drops. The camera is also more sensitive to on-bottom turbulence and visibility problems and requires additional post-survey processing time analyzing videotape to measure scallops. The camera might best be reserved for only sites where lobster gear poses a problem. Plans are also being made to try a larger drop camera (designed by CMAST researcher Kevin Stokesbury).

ENHANCEMENT

Enhancement - Methods

<u>Approach</u>

There has been much recent research into scallop culture and applied ecology, and scallop enhancement is a proven concept in several countries (Robinson, 1993). Japan (see Figure 20), China, and New Zealand have all successfully adopted this technology to promote a profitable fishery/ aquaculture endeavor. With government support, several Atlantic provinces in Canada (e.g. Quebec, New Brunswick) have also made great strides with this different form of a fishery. The technology, development, and socio-economic and governance structures in each of these places is very different however and development of this technology in Maine will also need to evolve to fit our own state's working waterfront. Maine currently has many scallop licenses that are unused or underused. These represent a sizable labor pool that could work towards enhancing the resource.

In 1999, a Maine delegation traveled to Japan to see first hand how our state might adapt spat collection and seeding technology developed there to our industry (Beal et al., 1999). This spawned several industry initiatives that began to push scallop enhancement from a concept into practice. Discussion was stimulated and enhancement as a stock building tool, as well as a method to answer broader questions about scallop biology in the Gulf of Maine, was encouraged in the form of a set of coastal research priorities for sea scallops (Alden and Perkins, 2001), and in an economic analysis of Maine's fishery (Gardiner and Pinfold, 2001). A number of groups began separate projects but shared their experiences. Participating groups included: Cobscook Bay Resource Center, Beals Island Regional Shellfish Hatchery, Stonington Fisheries Alliance and Wild Scallop Stock Enhancement Program, the Northwest Atlantic Marine Alliance, Maine Sea Grant, as well as the Department of Marine Resources. There was also communication beyond Maine-based groups to projects going on in the Atlantic Provinces and other New England states.

While one avenue the delegation to Japan explored was private aquaculture (Mike Hastings, personal communication), the effort evolved into an enhancement strategy centered on spat collection and direct bottom seeding that seemed to fit best with the realities of a low-cost, part-time volunteer effort. This grass-roots endeavor was begun by full time fishermen – and they still had to make a living. Participants were encouraged by some initial success in collecting scallops. Our work in this project was to play a supporting role by: helping to expand spat collection trials through outreach efforts, easing out-of-pocket costs of fishermen involved by providing collection gear (through NEC funding); documenting the effort by collecting data on spat densities, size, and competing organisms within deployed collectors; and by providing diver surveys for possible re-seeding sites and follow-up diver monitoring after sites have been seeded - as a gauge of success.

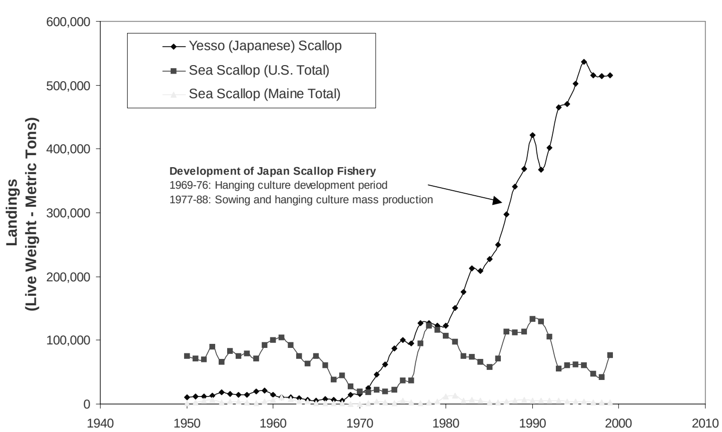


Figure 20. Japanese scallop production climbs due to aquaculture technology. Compared to U.S. and GOM sea scallop landings.

Enhancement – Data and Results

Gear distribution

Through this NEC grant, the DMR purchased approximately 150 rolls of netron and over 9,000 spat bags. Gear was distributed in July to September each year through the various project coordinators (Marsden Brewer, Craig Pendleton, Dana Morse) and at 4-5 outreach meetings scheduled in various coastal communities each year (see Figure 22 for locations). Fishermen involved supplied their own line, buoys, and markers –as well as labor. Nearly 100 project participants over three years worked under special licenses allowing gear placement and transport of seed scallops. Many others contributed time in spat bag preparation, seeding, and data collection. Fishermen were the prime force in the effort but- students, environmental groups, and friends and family members helped on several occasions.

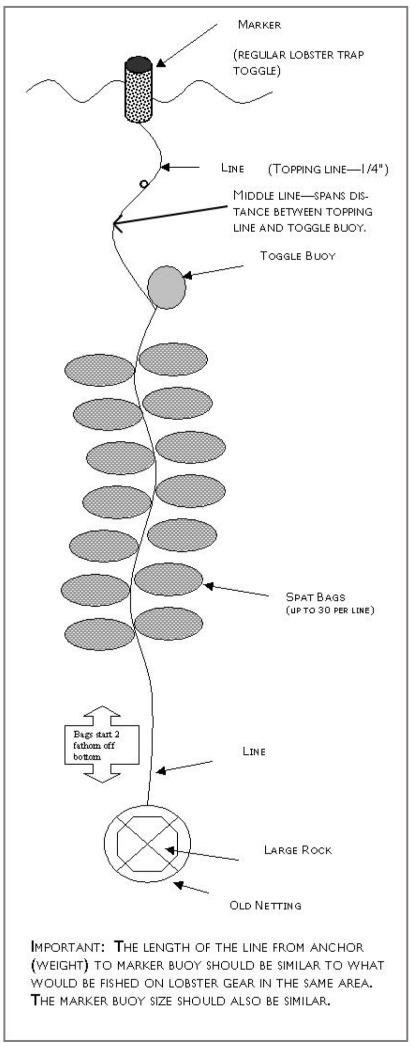


Figure 21. Spat bag deployment diagram.

Spat bag preparation and deployment

A leaflet was prepared outlining how best to rig spat bag lines and providing background information on the project (appended and figure 21) and project coordinators, DMR, and Sea Grant staff traveled to many of the gear distribution points to demonstrate the technique and relate their own observations in person. Some fishermen deployed bags independently, but large "bag rigging" events were also held in both Stonington and Saco where many recruits helped to speed things along (see photo gallery A). Typically, someone trying collection for the first time would take away 30-100 bags to deploy while participants with experience could deploy up to 900 bags from a typical lobster boat. Spat bags were generally set in early September each year to coincide with settlement of larval scallops – approximately 35-40 days after adults spawn in mid August. We estimate that approximately 2750 bags were set in 2000, 5500 in2001, and a slightly reduced number in 2002. In 2003, fewer bags were set while options for enhancement were being reconsidered. Figure 22 gives an overview of locations where enhancement activities occurred. Spat collection primarily centered around Stonington followed by Saco Bay, with some trials in Cobscook Bay and the Damariscotta River – and scattered other sites.

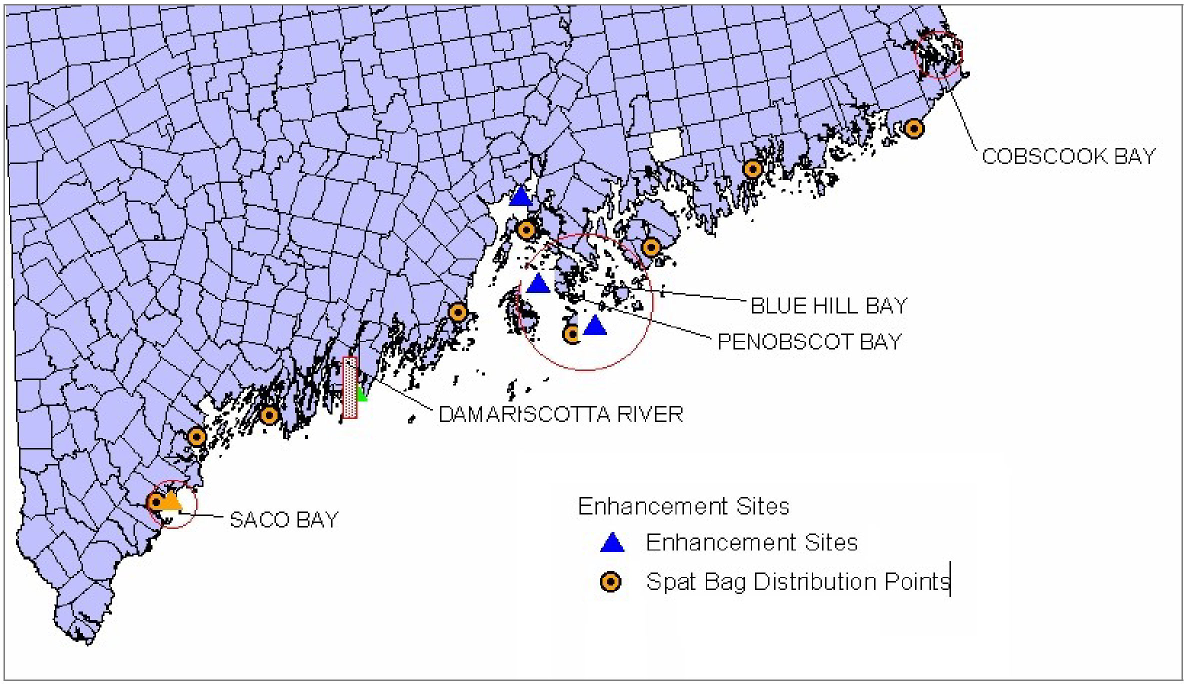


Figure 22. Enhancement program location overview depicting enhancement sites, towns where outreach meetings and spat collection gear were distributed and primary spat collection areas (Penobscot and Blue Hill Bays, Saco Bay, Damariscotta River, and Cobscook Bay, with scattered other sites.

Overwintering

In many of the most productive collection sites, gear had to be hauled and moved to an overwintering site prior to shrimp and scalloping seasons or damage would occur due to dragging or weather. Bags were kept moist and covered from wind during transportation to keep losses to a minimum as seed was still small enough at this point to escape the mesh bag enclosing the netron.

Collection assessment

When possible, in the spring or summer, data on deployment location and depth, collection success (based on a sample count extrapolated to the total sample volume of culled scallops), relative abundance of competing fouling organisms, and scallop size was reported or assessed on a monitoring trip. Common organisms found in bags were mussels (*Mytilus edulis*), rock borer clams (*Hiatella arctica*), sea stars (*Asterias* sp.), and jingle shells (*Anomia* sp.). Densities of scallops and competing organisms varied greatly depending on the deployment area. The preponderance of bags were set in waters around Stonington followed by Saco Bay, but each year new sites were sampled (Figure 23). With regards to the heaviest concentration of collectors centered in waters south of Deer Isle: In 2000, total returns were somewhat modest but several "hot spots" were revealed and in 2001 collectors were concentrated at these sites – yielding the best "catch" to date with some collectors containing over 10,000 scallops. Bag counts in Saco Bay were generally less, ranging from 600-1000 animals – although sometimes more. Mussel sets were also problematic there during some years. Interestingly, collectors deployed in 2001 in Cobscook Bay, an area known for consistently good recruitment success, did not reveal high returns. This disconnect between collector success and natural recruitment in the same area has also been noted before in the literature (Halvorson et al., 1999). In 2002, settlement dropped off slightly, with counts per bag ranging from 287 to 3431, while in 2003 settlement seemed to drop significantly to approximately 2/3 of the prior densities recovered (Marsden Brewer, personal communication). In 2003, a federal permit was obtained in order to deploy collectors farther offshore in federal waters to compare with inshore sites near Isle au Haut. Collection success for bag densities in this comparative trial were not very different however – with 2,212 (+/- 639 SD) and 2,019 (+/- 697 SD) scallops per bag for state water and offshore collectors respectively.

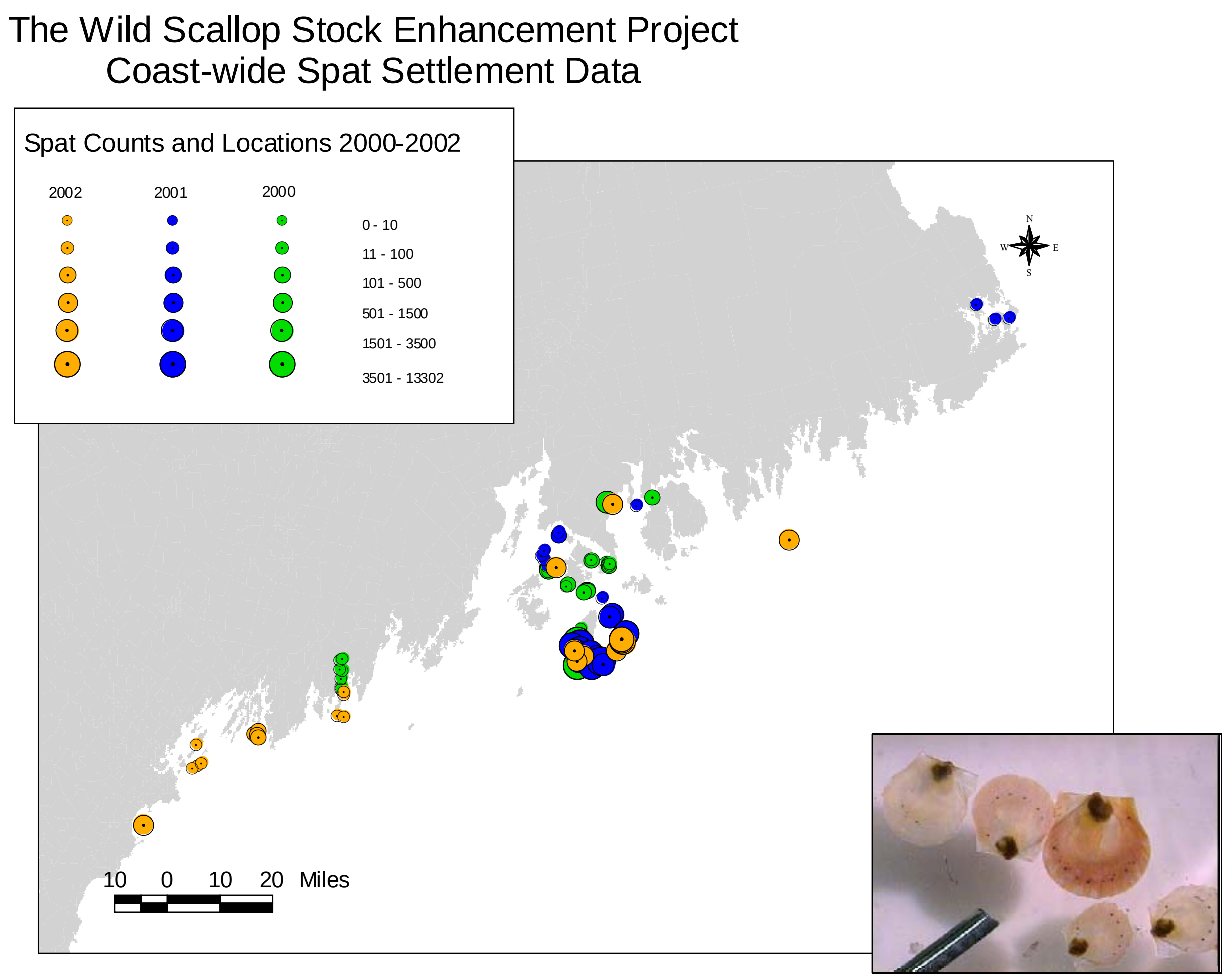


Figure 23. Scallop settlement data and collector locations. 2000-2002.

Re-seeding

Sites for re-seeding were selected by individual fishermen or with the aid of pre-seeding dive surveys performed by the DMR dive team to assess for suitable bottom type and limited numbers of predators. Three sites per year were selected for follow-up monitoring – and approximately 10% of the spat caught was distributed between these sites, but about 20 sites total were seeded based on fisher knowledge. These sites were not generally disclosed in an effort to keep draggers from towing the area prior to growing to legal size. Seeding would usually occur in the summer – when scallops had grown to a "reasonable" size (dime to quarter size) but before bags became too fouled with competing organisms causing stunted growth of scallops. An estimated 8-9 million scallops have been seeded at 20-25 sites to date (2000-2003).

Evaluation of efforts – tagging and post seeding monitoring

At the selected sites, between 100 and 1000 animals were tagged by gluing shellfish tags (Floy Tag Co., WA) to seed using Loctite Prism 459 adhesive. Follow-up dives were conducted as time allowed to look for tag returns and to assess dispersal and survival. An overview of seeding site locations is shown in Figure 21.

Saco Bay release: In the summer of 2001, DMR divers conducted ten videotaped transects in areas indicated by local fishermen as having suitable scallop bottom. Desirable characteristics included the presence of some naturally occurring scallops of different size ranges, a relatively hard bottom (sand, pebble), and low abundance of predators. Dr. Steven Zeeman of the University of New England also recorded temperature, salinity, dissolved oxygen, light attenuation and fluorescence data with a CTD at several sites. The video and associated charted locations were viewed by fishermen who had deployed spat bags during the prior season to aid their decision on where to plant seed.

On July 26, 2001, One thousand seed, four hundred of which were tagged, were placed by divers at a designated control site marked out in a 9m x 9m grid with PVC stakes. A cage of scallops was also deployed on site to provide growth measurements and a temperature logger attached. A follow-up dive two days after the seeding event showed scallops fairly evenly distributed throughout the control grid. Divers went back to the site one week after the seeding, but an offshore storm the night before had created enough wave action to stir up the bottom and make visibility extremely poor. On a return trip two weeks after seeding, divers failed to find any scallops. Although the site was greater than 30' deep, storm action likely contributed to the animals' emigration. Caged scallops retrieved on October 31, grew an average of 13 mm over a 97 day period, while bottom temperature varied considerably between 8.7 and 14.7 degrees.

Cape Jellison seeding: The Stonington scallop project seeded approximately 10% (340830 scallops +/- 49297 s.d. based on spat bag counts) of their seed accompanied by DMR scientists Dan Schick and Scott Feindel and Sea Grant extension agent Dana Morse on July 22, 2001 at a site off Cape Jellison in Upper Penobscot Bay. This site was chosen as a place where scallops were historically abundant but recently absent. A drop camera deployed at the site revealed a muddy bottom. A follow-up site survey, on September 4, 2001, consisting of four diver transects showed that seeded scallops were still present and seemed to be able to stay on top of the silty bottom. Several tagged scallops were found (Figure 23) and few predators were seen. Mean seed densities were approximately 0.5 scallops per meter along the transect line. On another diver survey on October 30, 2001 fewer scallops were found (2-3 per 100 m transect line). On a final site visit over one year later on August 27, 2002 no scallops were recovered. One explanation may be that scallops moved to deeper waters farther from shore over the winter.

Figure 24. Underwater video frame of a tagged released scallop found at the Cape Jellison seeding site one and a half months after planting.

Christmas Cove seeding: A third seeding took place in Christmas Cove on October 22, 2001. This batch of scallops was caught at the mouth of the Damariscotta River and was held prior to release in a flow-through tank at a lobster co-op in South Bristol. Approximately 3000 scallops (500 tagged) were released at a relatively shallow, sandy site bordered on 3 sides by land and "contained" on the last side by an area of mud. It was hoped that this site characteristic might discourage scallops from migrating much beyond the seeded area. Additionally, it was thought that scallops seeded in the fall might experience less predation due to slightly lower water temperatures. Unfortunately, the follow-up dive only four days later indicated a high abundance of crabs and heavy predation. Four tagged scallops were found – three of them dead and one showing chips around the valve margins.

Isle au Haut seeding: On July 7, 2002 approximately 200,000 scallops were seeded in an area with a sandy/ shell hash bottom with several rock outcroppings east of Isle au Haut. A follow up dive on August 28 showed promising signs with numerous seed found over the area – an encouraging finding. No adult scallops were found. However, since the abundance of natural set was not established prior to the seeding in this case it is uncertain if all the seed encountered were from collectors.

Deer Isle Thoroughfare seeding: On July 22, 2002 a smaller seeding (approximately 50-75,000 animals) took place in the Deer isle Thoroughfare. Because of boat traffic in this channel, it is not dragged as often as other areas –providing added protection for the seed. Dispersal is limited by land on either side. Bottom type varied from firm to soft mud and shell hash/sand depending on depth and location along the channel. In addition to direct seeding from collectors deployed the previous September, which averaged 28 mm in shell height, approximately 1000 larger scallops that were held in cages from the previous year, measuring 50 mm in average size, were seeded. Four hundred of the larger scallops were tagged and 300 of smaller ones. Sixteen tagged scallops were found on a post-seeding dive survey over one month later(August 28, 2002) with a higher return rate for larger scallops – which seemed to be less mobile.

Scott and Pickering Islands, Penobscot Bay seeding: On July 27, 2003, approximately 200,000 scallops were seeded in an area near Scott and Pickering Islands in Penobscot Bay. No follow-up dive monitoring has been done at this site to date.

Additional, unmonitored seedings took place in Saco Bay as well. Saco Bay seedings were carried out through NAMA while the others were coordinated by Marsden Brewer.

Enhancement – Conclusions and Future work

As enhancement work continues to progress, it should provide insights into the biological/ oceanographic underpinnings affecting the entire resource. Perhaps of even greater value is how it can serve as a rallying concept to spark collaboration between fishermen and scientists.

<u>Reliable seed supply</u>

Great strides have been made towards the first step in stock enhancement – a reliable seed supply, in this case, through spat collection. It has been shown that scallops can be collected in suitable numbers at certain places along the coast – although the search continues for additional sites. Existing sites are subject to annual variations in the numbers of spat collected. Some preliminary work with gonadal somatic indices (GSI) was done at several sites through BIRSH. This type of work should be expanded and become part of the “science” contribution to future efforts. More detailed work should be done on spat collection timing – specifically on how to avoid settlement from competing organisms and maximize scallop collection.

<u>Efficacy</u>

Expectations at the outset of the enhancement effort among the general fishing community varied from “leave things alone” to “it can’t hurt” to high expectations for success. Those that got involved seemed to

be innately curious about this little seen aspect of the fishery – that of the early life history stages of larval and juvenile scallops - and this phenomenon alone provided for positive exchanges of information between fishermen and researchers based on their experiences.
Results indicated by the monitored seeding events were also varied and success limited and checkered. It is obvious that survival and recovery rates are highly site and time dependent – and this was not unexpected. It is wise in some sense to seed several sites so to spread the risk of any one particular site showing poor returns, but success may also be linked to the scale of seeding. Seeding in the millions, on the scale of successful programs elsewhere, could be needed to overcome initial mortality from predation and losses from emigration. There is a need for some more encouraging recovery rates (other programs cite 30% as a cost-effective cut off point; Cliche and Giguere, 1998) – but more importantly, the generation (or recovery) of a persistent bed, however small, would be a positive step towards encouraging those involved with the project. In this sense, future work may need to include a more comprehensive and scaled-up seeding experiment with a massive tagging effort. However, results were not altogether discouraging since at the better sites, scallops did persist for at least months. Some of the more promising sites were seeded towards the end of the project as well – and have not been re-visited yet. It is also important to bear in mind that based on other experiences the development time for successful enhancement is on the order of ten years or more. The need for a successful demonstration project should supercede issues concerning future resource allocation of restocked beds – although this aspect will also need to be addressed at some point.

Alternative enhancement strategies

The recovery rates of the Deer Island Thoroughfare seeding provide some support for intermediate culture – growing scallops in containment for one more season prior to re-seeding. Naidu (1991) suggests that releasing seed scallops harvested from collectors directly on to bottom usually results in catastrophic mortalities and other studies have found greatly increased survival with larger scallops (Robinson, 1993). Making the leap to this form of enhancement without the government financial backing that has supported related ventures may be a stretch though and runs somewhat counter to the low-cost, volunteer supported effort that has evolved to date.

Other forms of enhancement beyond intermediate culture that could be explored include the direct release of hatchery or "remote set" scallop spat, "natural release" of scallop spat caught but not contained within a bag, limiting dispersion through underwater fencing, spawning sanctuaries (a potential beneficial by-product of lease based or transient gear aquaculture), and predator removal.

Sustaining the effort

There has been a drop off in enhancement activity in 2004 while results to date and other avenues are considered. In February 2005, a Maine scallop enhancement conference was held to talk over past experiences and to invite representatives from initiatives in Canada and other New England states to share their experiences. Among the participants there was a general consensus that enhancement should continue to be pursued in some form, but next steps are still being considered.

If technical problems are solved, efficacy may come down to a question of cost-effectiveness. This problem leads to a broader question of how to sustain and develop this effort with or without some form of incentive. Past work has been based on curiosity and altruism – a desire to give back to the fishery. However, the time required for scaled up spat collection and seeding is not incidental. Some more tangible incentive may be necessary to sustain the effort while technical hurdles are addressed.

There is a contingent of project participants that are interested in grow-out of scallops to market size (a more intensive form of aquaculture). This is one way of providing incentive and compensation to participants involved in spat collection while continuing enhancement of public beds on a voluntary basis. It is relatively easy to catch tens of thousands of scallops, given suitable collection areas, but logistically, only a fraction of these can be grown out. Thus, a significant proportion of collected spat could still be put towards seeding public beds. Grow-out to market size should increase regional knowledge on spat collection and culture and may also be a more direct way of realizing increased economic gains from the scallop resource. As fishermen relying on a public resource, there is concern over privatization of ocean sites in the form of leases. Some are advocating using transient gear to grow scallops similar in concept to lobster pots- where clusters of gear could be relocated periodically and not tied to a particular leased bottom space. This would avoid the (actual or perceived) loss of fishable bottom that fishermen often associate with lease-based aquaculture- and constitute a form of aquaculture that may better co-exist with traditional fishing practices. This is not a new concept (Rheault and Rice, 1994) but has not yet been put into practice commercially and there is no regulatory precedent for it in state. Limited purpose aquaculture licenses (LPA's) where very small areas are granted for grow-out of shellfish for the period of a year come the closest to this idea. The benefit is a fast-tracked licensing process compared to a lease, which is subject to an extensive public hearing process, and therefore a way to try culture without a great expenditure of up-front capital. There is, however, no consensus on this topic and currently scallops can not be cultured on an LPA lease site.

Additionally, there are significant regulatory and economic hurdles that would have to be overcome to bring this sort of endeavor to fruition. One example is a paralytic shellfish poisoning (PSP) concern in whole scallops, a high-end niche market that would likely have to be tapped to realize profits. This concern would have to be addressed through site considerations and affordable testing procedures. While this is not a direct part of this NEC project, it bears mentioning as an example of one of the socio-economic issues that the DMR and local communities will have to address as enhancement efforts evolve. Short of a clear demonstration of efficacy that would encourage continued volunteer efforts, other avenues beyond private/ public grow-out and enhancement efforts could include taxation on the catch and surcharges and piecemeal approaches through continued grant funded studies to work out technical and cost problems.

Enhancement of some form may yet be important in the rehabilitation of specific scallop beds, but the mixed success to date also points to the importance of sound management to protect the bulk of the fishery and concomitantly to the reasons for the monitoring aspects of this project. Still -much remains to be investigated and given experiences elsewhere, it is likely that technical problems could be overcome. If this is true – matters of economic incentive and cost efficiency may be paramount. In this regard, the state needs to continue to work towards issues previously mentioned – the whole scallop issue, how scallops might fit into current aquaculture regulations with regards to LPAs, transient gear aquaculture etc. Either a public, private, or joint venture could break the current impasse in enhancement activity by providing a needed definitive success story or by demonstrating significant progress in overcoming technical and cost restraints. It is possible that even seedings done to date (the majority of which were not monitored) may have indeed bolstered populations in certain areas. Industry members that have been working tirelessly on this for over five years have added greatly to knowledge in this area.

PARTNERSHIPS

Despite the fact that there was no named industry collaborator in our initial proposal, it should be evident that fishermen-scientist partnerships formed the core of this project. In both the monitoring and enhancement aspects of our work there was a direct link between researchers and industry members – both one on one and in group collaboration. Shared knowledge between the two groups was vital to carrying out the work and will most certainly continue. Marsden Brewer and Wallace Gray in particular were driving forces behind the project. During the course of this project, informal public meetings were held in many coastal towns to discuss this work and broader possibilities for a revitalized scallop industry. By the end of the project, a scallop advisory committee was formed to guide future DMR research efforts for this resource – including a continuation of the monitoring programs begun and provision for a yearly survey.

A great many people lent combined decades worth of knowledge about Maine's scallop resource. Gary Hatch (F/V Shearwater, Rockland, ME) helped to plan the western portion of the scallop survey and served as boat captain for that leg in 2001. Gary, Wallace Gray, Tim Harper (Southwest Harbor, ME), John Higgins (Bristol, ME), Marsden Brewer, Vic Nordhal (NMFS), and Terry Stockwell (DMR) helped in various capacities to design, deliver, rig, and tune the survey drags. Erik Waterman (F/V Sea Ryder, Spruce Head, ME) served as an auxiliary boat captain for areas of Penobscot Bay. Many fisherman provided comments on the survey at numerous meetings. Detailed information was provided by Bruce McInnis (Eastport, ME) , Kristan Porter (Cutler, ME), and Ernie Burgess (Chebeague, ME). Wally Gray Jr. served as an enthusiastic deckhand throughout most of the survey and thanks go to him and the others who served as crew for this work as well as DMR staff Glenn Nutting, Andrew Gowan, Jesse Symonds and the DMR dive team who assisted many field aspects of the project. Marsden Brewer, Richard Taylor, Craig Pendleton and staff from the Northwest Atlantic Marine Alliance (NAMA), Steve Zeeman from the University of New England, and Erin Fisher and Brian Beale from the University of Maine were important collaborators in the enhancement aspects of the program.

COLLABORATION WITH OTHER PROJECTS

This project was not formally a part of any other research activity, but we did make an effort to contribute to other studies through our work. For example, additional live scallop samples were taken for the DMR's water quality division during the fishery independent survey to look for the potential occurrence of amnesiac shellfish poisoning (ASP). Meat samples were also provided for a separate study on putative genetic differences of Gulf of Maine scallops being conducted by Erin Fisher, a doctoral student at the University of Maine's School of Marine Sciences. Survey methodologies developed in this project were used to study the catch-characteristics of light-weight scallop drags in another DMR project, and to map scallop densities near Portland Harbor where a proposed pipe laying project was planned.

IMPACTS ON END USERS

This work had direct and indirect impacts on stakeholders in the scallop industry. Prior and during the project, local fisher groups such as the Cobscook Bay Fisherman's Association held their own meetings and initiated legislation to protect scallop resources in their area. New regulations drew on some of the data produced by this project – including minimum meat counts in Cobscook Bay. The passage of an increased shell height for scallops to four inches was also sponsored by several industry members and was in part due to the realized importance of larval supply and recruitment fostered by the enhancement program.

Results have been presented to the NMFS scallop PDT and are being entered into, and will be made available to the public through, the DMRs MARVIN database – in addition to figures and tables submitted to the NEC.

PRESENTATIONS

S. Feindel, *Developing a coastal Maine sea scallop enhancement program*, National Shellfisheries Association (NSA) meeting, Mystic, CT, April 16, 2002. Abstract reprinted in *J. Shellfish Res*.

S. Feindel, *Maine Wild Scallop Stock Enhancement Project*, New England Fish and Wildlife conference, Portland, ME, May, 2002.

S. Feindel, Maine Fisherman's Forum, Scallop roundtable, Rockland, ME, February 28, 2002
Scott Feindel, Maine Fisherman's Forum, Scallop roundtable, Rockland, ME, March 3, 2005

S. Feindel, *Maine's scallop fishery – monitoring and enhancement.* Cobscook Fisherman's Forum, Eastport, ME, February, 2002

S. Feindel, *Coastal Maine scallop survey*. Cobscook Fisherman's Forum, Eastport, ME, February, 2003

S. Feindel, *2003 Sea scallop survey – Cobscook results.* Cobscook Fisherman's Forum, Eastport, ME, February, 2004 (travel prevented by a winter storm – not presented in person).

Fisher, E.C., Rawson, P.D. and S. Feindel. 2003. Genetic assessment of sea scallop, *Placopecten magellanicus* (Gmelin, 1791), stock structure in the southern Gulf of Maine. Poster presented at the 14th International Pectinid Workshop, St. Petersburg, FL (appended).

STUDENT PARTICIPATION

Erin Fisher-Owen, PhD. Candidate at the University of Maine was involved in this research through her work on scallop genetics in the Gulf of Maine. Prior to her becoming a student at U. Maine, she was also involved with the enhancement work through the Stonington Fisheries Alliance.

Many other students were involved in the enhancement aspects of this project – mainly through outreach efforts of Marsden Brewer, Craig Pendleton, and Dana Morse.

PUBLISHED REPORTS AND PAPERS

<u>Published abstracts</u>

S. Feindel, *Developing a coastal Maine sea scallop enhancement program*, National Shellfisheries Association (NSA) meeting, Mystic, CT, April 16, 2002. Abstract reprinted in *J. Shellfish Res*.

Fisher, E.C., Rawson, P.D. and S. Feindel. 2003. Genetic assessment of sea scallop, *Placopecten magellanicus* (Gmelin, 1791), stock structure in the southern Gulf of Maine. Poster presented at the 14th International Pectinid Workshop, St. Petersburg, FL (appended).

We plan to submit additional articles for publication based on this work in the future.

<u>Articles</u>

Anonymous. Sea Scallops: Setting research priorities. Originally published in Commercial Fisheries News, September 2001. posted at: http://www.fishresearch.org/Articles/2001/09/Scallops.asp

Associated Press. Fishermen give scallop industry a hand. Portland Press Herald, July 17,2002; posted at: http://www.seascallop.com/MaineScallopSpat.jpg

Brewer, M., Wild scallop enhancement project, monthly updates originally published in Fisherman's Voice. Found at: http://www.seascallop.com/MarsdenReports.html

Hewitt, R. Scallop restoration plan a success. Bangor Daily News. July 22, 2000.

Maine Sea Grant. Sea Scallop Stock Enhancement. http://www.seagrant.umaine.edu/extension/fisheries/morespat.htm

Porter, A.. Scallop restoration effort is a fishermen's act of faith. *Ellsworth American*. December 12, 2001.

Porter, A. Scallop effort makes progress. *Ellsworth American*. May 9, 2002.

Seaver, R. Bring on the Scallops. A wild scallop stock enhancement project in Saco Bay is fostering new relationships and exciting potential. NAMA Collaborations newsletter. September, 2002. posted at: http://www.namanet.org/collaborations/collab_sep_02.pdf

Springuel, N. Enhancement: Giving scallops a helping hand. Part 1 of 2. Originally published in Commercial Fisheries News, September 2001. Posted at: http://www.fishresearch.org/Articles/2001/09/Scallop_Spat.asp

Springuel, N. Scallop enhancement: Management implications. Part 2 of 2. Originally published in Commercial Fisheries News, October 2001. posted at: http://www.fishresearch.org/Articles/2001/10/102601_scallops.asp

IMAGES

A photo gallery of enhancement and survey and sea sampling experiences is appended.

REFERENCES

Alden, R. and D. Perkins. 2001. Coastal Fishery Research Priorities: Sea Scallops. Gulf of Maine Aquarium. http://www.maine.gov/dmr/research/sea_scallops.htm.

Beal, B.F., M.M. Hastings, L. Taylor, T. Pottle, S. Rappaport, D. Morse, K. Porter, S. Inches, W. Hopkins, and J. Trenholm. 1999. The culture of Japanese Scallops (*Patinopecten yessoensis*). Report of the Maine Delegation to the Aomori Prefecture, Japan. May 14-21, 1999. Maine Aquaculture Innovation Center, Orono, ME.

Brewer, M., Wild scallop stock enhancement project coordinator. Stonington, ME

Caddy, J.F. 1989. A perspective on the population dynamics and assessment of scallop fisheries, with special reference to the sea scallop, Placopecten magellanicus (Gmelin). Chapter 25 In: *Marine Invertebrate Fisheries: Their Assessment and Management.* J.F. Caddy (ed.). Jouhn Wiley and Sons. New York. p. 559-589.

Cliché, G. and M. Giguere. 1998. Final report of the research program on scallop culture and restocking (REPERE), 1990-1997. Can. Ind. Rept. Fish. Aquat. Sci. No. 247. 86 p.

Cochran, W.G. 1977. Sampling techniques, 3rd ed. John Wiley, New York

Gardiner Pinfold Consulting Economists Ltd. January 2001. Development Potential of the Maine Scallop Industry. Halifax, Nova Scotia, Canada.

Halvorson, H.O., C. Goudey, R. Johnson, D. Leavitt, R. Smolowitz, and R. Taylor. 1999. Sea Scallop Aquaculture: 1999 Blueprint, Background, Discussion, and Policy Recommendations, NRAC Publ. No. 99-001, 45 p.

Hastings, M. Past director of Maine Aquaculture Innovation Center, Orono, ME.

Hilborn, R. and C. J. Walters. 1992. *Quantitative Fisheries Stock Assessment: Choice, Dynamics, and Uncertainty.* Chapman and Hall. New York. 570 pp.

Kelley, J.T., W.A. Barnhardt, D.F. Belknap, S.M. Dickson, and A.R. Kelley. 1998. The seafloor revealed. The geology of the Northwestern Gulf of Maine inner continental shelf. Open-File 96-6 Maine Geological Survey Natural Resources Information and Mapping Center. Department of Conservation. Robert G. Marvinney, State Geologist. 22 State House Station, Augusta, ME 04333.

McGowan, J. 1996. Cobscook Bay sea scallop survey. DMR report.

Naidu, K.S. Sea Scallop, *Placopecten magellanicus*. 1991. In: *Scallops: Biology, Ecology, and Aquaculture*, Developments in Aquaculture and Fisheries Science, 21. (S. Shumway, Ed.). Elsevier, New York.

NMFS, 2004. 39th Northeast Regional Stock Assessment Workshop. Northeast Fisheries Science Center Reference Doc. 04-10a & 04-10b. 238 pp.

Posgay, J.A. 1957. The range of the sea scallop. The Nautilus 71:55-57.

Rheault, R. and M.A. Rice. 1994. Transient gear shellfish aquaculture. *World Aquaculture.* 13 p.

Robinson, S.M.C. 1993. The potential for aquaculture technology to enhance wild scallop production in Atlantic Canada. *World Aquaculture* 24(2): 61-67.

Wallace, D. 2000. The Molluscan Fisheries of Maine.

Welch, W. 1950. Growth and spawning characteristics of the sea scallop, Placopecten magellanicus (Gmelin) in Maine waters. Masters Thesis submitted to the University of Maine, Orono. 95 pp.