Pre- and post-dredge survey and relocation of the American lobster, *Homarus americanus*, population in Portland Harbor, Maine

Final Project Report

(Summary Version Excluding Appendices)

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Executive Summary

Maintenance dredging of Portland Harbor, Portland, Maine scheduled for November, 1998 raised concern over the potential impact of the operations on area lobster populations. A preliminary underwater video survey of the proposed dredge sites conducted in March and April, 1998 revealed that the lobster population in the proposed dredge areas was significant and, in most cases, exceeded the Maine Department of Marine Resources' guideline threshold density of 0.1 lobsters/m^2. As a result, a mitigation plan was developed that included: 1) reduction of the depth to which the harbor would be dredged, 2) omission of the most contaminated sediments, 3) restriction of dredging to the time of year least likely to adversely affect lobsters, 4) sequencing dredging activities in the Harbor to coincide with suspected lobster migration movements, 5) avoidance of densely populated "side slope" areas of the existing channel; and 6) removal and relocation of lobsters from the proposed dredge sites. This report summarizes the efforts and results of the last of these measures.

The relocation effort had three major components: 1) diver observations using video as well as direct assessments of the lobster populations, 2) a trapping effort targeted principally at small, sublegal lobsters known to inhabit the areas, and 3) a tagging effort to assist in determining effectiveness of the relocation effort and subsequent post-dredge recolonization or reoccupation of the dredged areas.

Video surveys of the ten dredge sites within the harbor were conducted on 17 separate dates between July 24, 1998 and November 2, 1999, resulting in 143 separate video segments. These videos and the direct diver observations were used to determine lobster population densities at various times throughout the dredge project from the pre-dredge, or baseline, period through the post-dredge reoccupation phase.

The trapping effort was conducted using 300 standard 36 in. x 21 in. by 13.5 in, 1.5 in. vinyl-clad wire mesh traps with the rear holding section, or "parlor", covered with 1 in. shrimp twine mesh. Traps were deployed and fished at the sites according to the dredge schedule, most sites being fished to within a day or two of dredging. A total of 9,243 trap-hauls were made over 41 haul dates. A total of 34,012 lobsters were removed off of the dredge sites, including 33,248 sub-legal lobsters which were relocated outside of the harbor proper in the general vicinity of Fort Gorges and House Island, mostly within General Anchorage "B" on NOAA/NOS Navigational Chart No. 13292. Catch per effort (C/E) values were calculated daily to monitor effectiveness of the trapping effort and determine whether dredging of the site could proceed. An arbitrary target C/E value 0.5 lobsters/ trap/night-set (l/t/ns) was set as the level to reach before dredging could begin on any site. This threshold was achieved at all but one site prior to initiation of dredging.

Information on lobster carapace length, sex, and claw condition was taken to better understand the population characteristics of the relocated lobsters. Data was collected on 22,889 lobsters, or 67.3%, of the 34,012 caught during the project. Given the size of the data set collected, a database architect was independently hired by MER to design and develop a database to input and manage the data. The data indicate that the majority of the harbor's lobster population is sub-legal in size with a carapace length mode of 58 mm and a mean of 64.4 mm ±0.2, males being slightly larger than females.

A tagging component was included in the relocation effort to allow tracking of relocated lobster movements to ensure adequate distance between the harbor and the relocation sites. If, based on tag returns, it became apparent that a substantial number of lobsters were returning to the harbor shortly after

relocation, an alternative, more distant relocation site was to be used. A total of 4,027 lobsters were tagged between 3 November 1998 and 17 February 1999. Of these 4,027 tagged lobsters, 267 were recaptured during the project period. Only 20 of these recaptures were recorded returning across the main navigational channel towards the Fore River during the dredging period between 12 November 1998 and 8 April 1999. Thirteen (13) of these were recaptured on the eastern edge of the harbor and only 8 were recaptured on dredge sites or well within Portland Harbor. Assuming that each tagged lobster represents ~8.45 lobsters in the total relocated population (34,012/4,027), then ~169 lobsters would have been expected to have returned back towards the Fore River over the course of the dredging project and only ~68 onto dredge sites or well within the harbor proper. Based on the rate and location of recapture, it is reasonable to conclude that the relocation site at General Anchorage "B" was sufficiently distant from the harbor proper to prevent excessive returns during dredging.

Based on the recapture data, most of the lobsters either remained in the general vicinity where they were relocated or moved back in the direction of inner Casco Bay. Only 9 lobsters appeared to be moving in an offshore direction, three of these apparently headed towards the outer islands of the Bay. Several others, although not moving back towards the harbor, appeared to be moving toward other areas within Inner Casco Bay, most in the general vicinity of the outer harbor, some moving northward toward the Upper Bay.

A project effectiveness evaluation was carried out comparing initial population estimates, calculated using the DeLury method (fishery-dependent), with total catch (fishery-dependent), tag recapture data, and the diver video surveys, direct observations, and associated population density values (fishery-independent) over the entire project period. The evaluation was based on data collected from Sites 1, 2, 3, 7, and 8, the latter two contiguous sites combined as a single site. The DeLury estimate of initial population for these sites is 31,780 lobsters. This agrees well with the total catch of 31,676 lobsters. The initial population estimate derived from the dive surveys for these sites was 26,574 lobsters, or 84% of the total catch (95% Conf. Interval: 17,105-36,043). The difference between the dive survey initial population estimate and the catch data may be due to the sampling technique or to lobsters immigrating to the eastern sites from the ship channel. Based on these values, a combined total of 8,247 lobsters may have remained on the dredge sites when dredging began, most on the easternmost sites, 1 and 2.

Finally, following completion of the dredge project in April, 1999, a five-month study was initiated in June, 1999 to monitor reoccupation of the dredged sites by returning lobsters. The study was carried out using the same methodologies used in the preliminary study of Spring 1998 and during the relocation project. Despite low density values in June, 1999, all sites showed an increase in density beginning in July 1999, indicating rapid recolonization of the areas. In the cases of Sites 1 and 2 the July 1999 density actually exceeded the baseline density found in July 1998, prior to dredging and trapping. At Sites 3, 4, 7, and 8, while recolonization was evident, the population density values never quite reached the baseline value, although the baseline value was nearly reached in at least one of the three months of June, July, or August. The November 1999 values for Sites 1 and 2 were the same as the pre-trapping, pre-dredge values for September 1998, suggesting that this may be the normal Fall density. In contrast, the November 1999 population density values for Sites 3, 7, and 8 were similar to those found in November/December 1998, suggesting that, in these areas of normally low population density, the trapping effort had less net effect than in the areas of high density. This being the case, it appears that the greatest benefit/effort of any future effort of this kind would be achieved by focusing on high population density areas.

1.0. Introduction and background

The U.S. Army Corps of Engineers' (USACOE) plan to perform maintenance dredging in Portland Harbor, Portland, Maine in 1998 raised concerns over the possible impact the dredging project might have on the lobster, *Homarus americanus*, population in the Fore River. Responding to this expressed concern, the Maine Department of Environmental Protection (MDEP) contacted MER Assessment Corporation (MER) in early March 1998 with a request for a survey of the bottom at ten (10) of the eleven (11) proposed dredge areas (one small area was considered substantially and sufficiently represented by an adjacent area). The proposed dredge sites are shown in Figure 1.1. on the following page.

A quantitative video survey of the bottom was conducted between March 17 and April 16, 1998. The purpose of the survey was to determine the existence of a winter-resident population of lobsters within the Fore River, and if it existed, whether the density of the population met or exceeded the threshold value of 0.1 lobsters/m^2 historically used by the Maine Department of Marine Resources (MDMR) as an indicator of important lobster habitat.

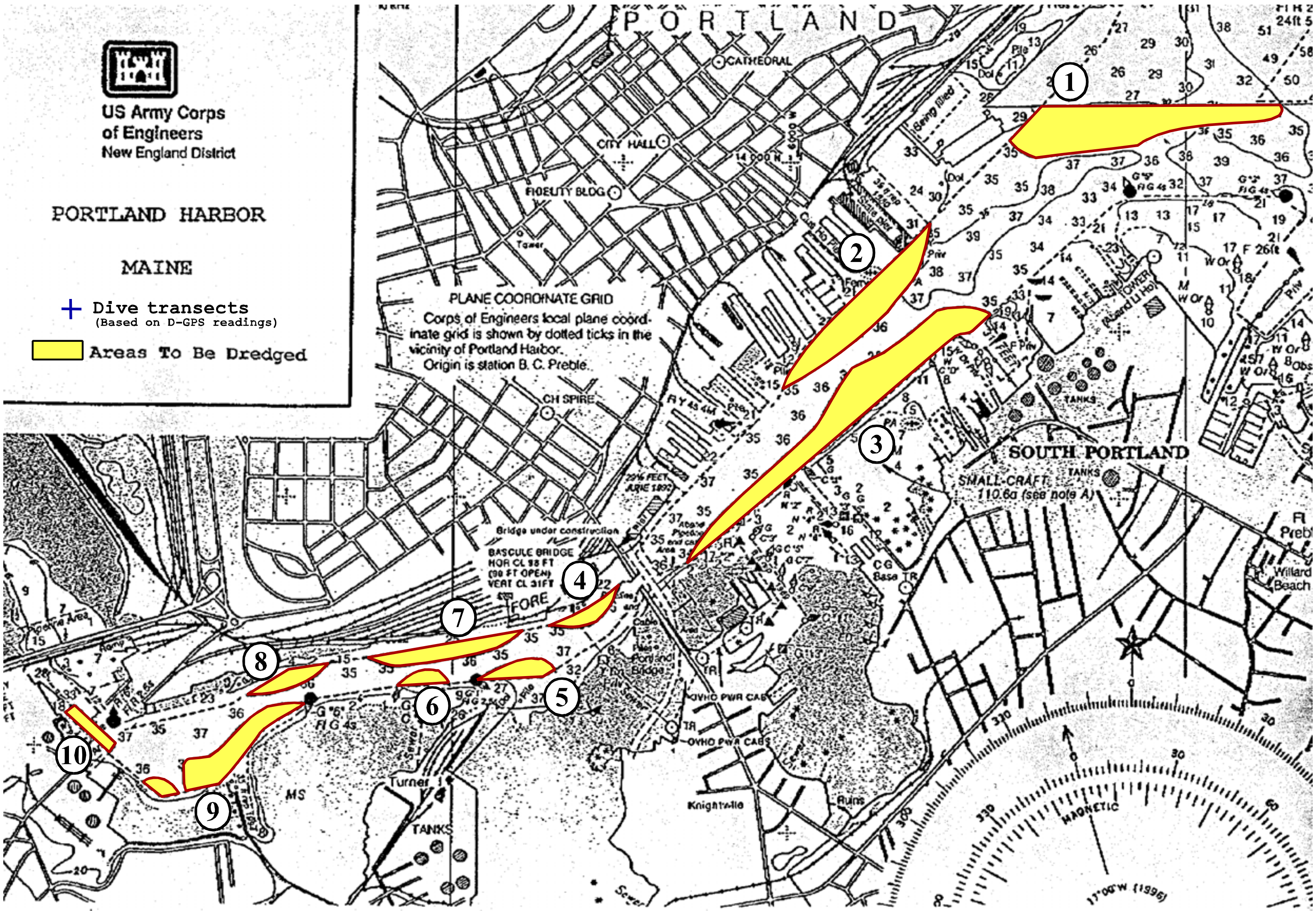
The survey consisted of five major tasks: 1) daylight underwater video surveys of the bottom at all but one of the eleven proposed dredge sites in March and April, 2) nighttime underwater video surveys of selected proposed dredge sites, 3) additional daylight video surveys of areas outside of, but adjacent to, selected proposed dredge sites, 4) a determination of occupancy rates of burrows found in the bottom, and 5) an Early Benthic Stage (EBS) survey using both hand and suction excavation methods.

Details of the methodologies have been previously reported, (Heinig and Cowperthwaite, 1998). Briefly, video surveys at each of the proposed sites were carried out using measured sinking transect lines. The transect lines consisted of 60 meter (-200 ft) ropes marked in 10m alternating black and white sections, with the exception of the first and last 10m which were marked as two 5m sections, the last five of which were marked in alternating 1m black and white increments. Geographic Positioning System (GPS) coordinates were taken at both ends of each transect and used to compare transect location between successive dives at the same location. The Hi8 format video recordings were made with a Sony TR-101 video camera held in an Amphibico housing. Lighting was used throughout the dives provided by dual 50 watt Ikelite Modular Video-Lites. The width of the field of view was calibrated to 1 meter by adjusting the height off of the bottom at which the recording was made. This was accomplished by attaching a short piece of lead line to the camera housing handle and adjusting the length of the line such that it just touched the bottom while a 1 meter section of the measure transect line was viewed through the camera viewfinder. During recording, the diver ensured the trailing lead line was in contact with but not dragging on the bottom.

Based on these recordings, counts were made of visible lobsters as well as suspected lobster burrows. In order to estimate the number of lobsters represented by the burrows, a separate study was conducted to determine occupancy rates for the burrows. Based on the actual lobster counts, a count of burrows observed on the videos, and an occupancy coefficient derived from the burrows occupancy study, estimates were made of the density of lobsters at each proposed site.

The results of the video surveys, combined with the burrows occupancy study results, indicated that the density of lobsters east of the Casco Bay Bridge in March and April, 1998 was 0.13 lobsters/m^2 and 0.24 lobsters/m^2 , respectively. West of the bridge densities for the same periods were 0.03 lobsters/m^2 and 0.04 lobsters/m^2, respectively.

Figure 1.1.
Portland Harbor and proposed dredge Sites 1-11 (NOAA/NOS Chart 13292 Portland Harbor and Vicinity, 31st Ed., July 13/91)



An early benthic stage (# 20 mm carapace length, CL [eye socket to carapace edge measurement]) lobster survey was conducted on April 22 and 24, 1998. The survey was carried out by setting a 0.25 m^2 frame on the bottom over areas of small to intermediate-sized burrows and excavating the entire area within the frame with an airlift, fitted with a 6 mm mesh capture bag attached to the exhaust end of the airlift, to a depth of 20-25 cm (8-10 inches). The surface of the bottom within the frame was suctioned prior to any extensive excavation to ensure capture of any lobsters on the immediate surface. Upon return to the surface, the contents of the bag were immediately examined for small lobsters of all sizes. Hand probing was also used to investigate small burrows in the 40-80 mm diameter range. Sites 1, 2, 3, and 7, having the highest probability of supporting juvenile lobsters, were sampled for the survey.

This survey yielded no small early benthic stage lobsters at any of the sites. Larger juvenile lobsters, with CLs ranging from 28 mm (1 1/4") to 75 mm (2 7/8"), however, were found within the framed area effectively avoiding the suction of the airlift. An attempt was therefore made to determine whether these lobsters were residing in burrows smaller than those investigated in the burrows occupancy study that focused on larger burrows suspected to be occupied by near legal-size lobsters. This investigation of small burrows in the 40-110 mm diameter range revealed that smaller lobsters were, indeed, occupying these burrows and at a rate similar to that found for larger burrows and larger lobsters, *i.e.* 55-70%. These smaller lobsters seemed to be confined to the eastern section of the harbor in the vicinity of Sites 1 and 2. Two dives along the southern side of the channel within Site 3 showed very few burrows, particularly within the 40-110 mm range. At Site 7 burrows were found within this size range, but the majority of burrows were larger, and most of these were occupied, corroborating the earlier findings. No lobsters were found in burrows <60 mm in diameter.

Although the early benthic stage survey failed to show the existence of recent recruits, the results of the video surveys and burrows occupancy study showed clearly that the lobster population density in the Fore River, at least east of the Casco Bay Bridge, exceeded the 0.1 lobsters/m^2 guideline, even in early Spring, therefore indicating the need for mitigation.

Based on the indicated need for mitigation of the potential impacts dredging might have on the resident lobster population, MER was further tasked with the development of a proposed mitigation and compensation plan to be included in the US Army Corps' Environmental Assessment and federal consistency determination for consideration by the State in making its water quality certification decisions.

Charged with development of a mitigation plan, MER sought the collaboration of Normandeau Associates,(NAI) to explore mitigation alternatives, assess their feasibility, and determine likely costs. Following meetings with MDMR and discussions with other state and federal marine resource agencies, including the Massachusetts Division of Marine Fisheries (MDMF), Rhode Island Department of Environmental Management (RIDEM), National Marine Fisheries Service (NMFS), and New Hampshire Fish and Game (NHFG), a variety of options were identified to avoid and minimize adverse effects on the lobster fishery:

1. Reduce the dredge depth;
2. Leave the most contaminated sediments in place;
3. Restrict dredging to the time of year least likely to adversely affect lobsters;
4. Sequence dredging activities in the Harbor to coincide with suspected lobster movements;
5. Avoid dredging the densely populated "side slope" areas of the existing channel; and
6. Relocate lobsters.

The first two options had been previously discussed and recommended by the Portland Harbor Dredge Committee's Technical Advisory Subcommittee (TAS). A request was initially made to have the harbor dredged to a depth of 45 ft. This, however, would have required dredging 100% of the bottom within the federal channel in the harbor since the deepest part of the channel is only 39 ft. deep. The TAS subsequently recommended reducing the depth of dredging to 35 ft., effectively reducing the area requiring dredging to ~29% of the federal channel bottom. Second, during the project environmental impact assessment certain areas of the bottom had been identified as containing significantly to moderately contaminated sediments. It was therefore recommended that those areas having the most significantly contaminated sediments remain undisturbed. Where slightly to moderately contaminated sediments had been found, the EPA recommended that these sites be dredged first and that the uncontaminated sediments from the remainder of sites be used to sequentially cover the contaminated sediments at the disposal site.

The other four recommendations arose from the preliminary survey work performed by MER, the investigative work by MER and NAI, and discussions with representatives of the lobster fishing industry. First, it was originally estimated that the dredging of the harbor might take as much as 10 months to complete. If this ten-month period had been confined to a single year, the dredging operations would have severely conflicted with lobster activity during the summer and fall. Holding to a ten-month dredging window, while avoiding interference with the lobster fishing season would have required the dredging project to have been conducted over a two-year period. Review of fishing industry and MDMR data on catch revealed that the acceptable window for dredging was between November/December and May. A recommendation was therefore made to restrict the dredging period to the six-month period between November 1 and April 30.

Second, discussions with lobster fisherman fishing in the harbor indicated that the annual migration of lobsters out of the harbor begins in the western portion of the harbor (west of the Casco Bay Bridge), following a course along the southern side of the federal channel, the eastern end of the harbor being the last area from which lobsters migrate. The spring immigration, conversely, begins at the eastern end of the harbor and moves westward predominantly along the northern side of the federal channel. As a result, it was recommended that the dredge begin operations in the areas west of the Casco Bay bridge, along the northern side of the channel. Following completion of those areas, the dredge was to move to the westernmost site on the southern side of the federal channel and proceed eastward until all western sites were completed or January 1, whichever came first. The dredge was then to proceed to the easternmost area of the harbor and begin moving westward.

Third, the preliminary video surveys had revealed an extensive population of lobsters burrowed into the clay walls of the existing channel throughout the harbor. Consequently, a recommendation was made that the dredge leave the existing channel wall undisturbed.

Finally, in view of the lobster density having been found to exceed the 0.1 lobsters/m^2 guideline during all times of year, it was further recommended that an effort be made to remove as much of the population as possible from the proposed dredge sites prior to dredging.

All six of these recommendations were eventually incorporated as conditions on the U.S. Army Corps of Engineers Water Quality Certificate issued by the MDEP on 18 August 1998 (refer to Appendix I). The full details of the development of the mitigation plan can be found in *A Proposed Lobster Mitigation Plan for the Portland Harbor Maintenance Dredging Project,* MER/NAI, submitted to the Portland Harbor Dredge Committee, Lobster Working Group, July 1998. The following sections of this report deal specifically with the last of the recommendations, the relocation of lobsters.

2.0. Lobster relocation

The lobster relocation project consisted of several components:

1. lobster trapping, removal, and relocation;
2. lobster data collection, including carapace length (CL), sex, claw condition;
3. lobster tagging;
4. video surveys pre-dredge summer baseline, post-trapping/pre-dredge, and post-dredge;
   post-dredge reoccupation of dredge sites;
5. pre-dredge, post-dredge and reoccupation population density estimates; and
6. effectiveness evaluation

2.1. Lobster trapping, removal and relocation

2.1.1. Trap design and construction

The initial design of the traps called for a ventless, standard 36 in. x 21 in. by 13.5 in, 1.5 in. vinyl-clad wire mesh trap with the rear holding section, or “parlor”, covered with 1 in. shrimp twine mesh. Twenty prototypes of the trap design were built in early September 1998 by Anderson-Pierce Traps, 77 Bell Street, Portland, Maine. The prototypes were fished for approximately one month prior to finalizing the design under a Special License 98-63-00 issued by the MDMR on 10 September 1998 (refer to Appendix II).

The final design was substantially similar to the prototypes, with only two exceptions. First, the traps were built as standard vented, rather than ventless, traps to allow optional sale of the traps to commercial fishermen at the end of the project, if desired. Second, due to an anticipated large catch of crabs in the western section of the harbor, a number of the traps were fitted with small doors on the back of the “parlor” to facilitate removal of crabs by simple inversion and shaking of the trap. Photographs and details of the traps are included here as Appendix III.

As initially envisioned, the relocation project anticipated the use of 150 traps. An order was placed with Anderson-Pierce for the construction of these traps on 19 October 1998. The first twelve traps were completed and set out on 22 October at Site 7. The traps were tagged with special light blue trap tags of the “SI” series provided by the MDMR Marine Patrol and were identified on the surface by standard 6"x12" Spongex buoys bearing a red band at the top. Construction and setting of the remaining 130 traps continued from 23 October through 4 November.

An informational meeting was held at the Casco Bay Lines conference room on 26 October to inform all interested parties and participants of the project schedule. At this meeting, the representative of Great Lakes Dredge and Dock Company, the contractor hired by the Corps to carry out the dredge project, informed the participants that, due to the large capacity of the dredge bucket to be used, 22 cu. yards, the Company anticipated completion of the project by end of January 1999, three months ahead of schedule, effectively halving the time allowed to carry out the relocation effort.

In response to the abbreviated schedule, the Portland Dredge Committee agreed to an expansion and acceleration of the relocation effort and approved the purchase of an additional 150 traps, bringing the total to 300. An order for the additional 150 traps was placed with Anderson-Pierce Trap on 29 October and delivery was completed by 20 November.

2.1.2. Trap rigging and fishing

The first 20 traps were rigged as 6-trap trawls, baited, and set out on 22 October at Site 7. The remainder of the initial 150 traps were set on Sites 4-10 between 23 October and 4 November, during which time 3 traps were lost due to vessel traffic, bring the total number fished to 147.

On 5 November, Special License 98-63-00 was amended to include the four commercial fishermen working on the project, in the exempted activities (refer to Appendix II). As compensation for participation in the trapping effort, each participating fisherman was paid $50/hr for his time, vessel, and crew. In addition, all fuel and bait costs associated with the hauling of project traps was covered by the project funds. Finally, each fisherman was allowed to keep and sell all legal-sized lobsters for subsequent sale following collection of size, sex, and condition data.

The first 200+ trap-haul day occurred on 7 November. Between 7 November 1998 and 21 December 1999 traps were hauled on a 2-3 night set (soak). Although the original dredge operations schedule was for uninterrupted dredging from start to finish, Great Lakes was required to move its dredge and barges to Norfolk, Virginia on 16 December, with an anticipated return date of 15 January. As of the date of the dredge's departure all sites west of the Casco Bay bridge had been dredged, as well as a substantial portion of Site 3, just east of the bridge. After reviewing the catch data for the remaining two sites, Site 1 and 2, a decision was made to continue the relocation effort, despite the interruption in dredging operations, albeit at a reduced level of frequency. Beginning on January 11, 1999 the haul schedule was changes to a 6-7 night set.

Great Lakes returned to Portland harbor on or about 7 March 1999 with smaller dredge equipment than had previously been used. Based on the equipment, the area to be completed, and allowing for inclement weather, the dredge completion date was estimated to be in the first week of April. Trapping on Sites 1 and 2 continued through 10 and 17 March, respectively, after which the last of the traps were removed from the water.

2.1.3. Trapping results

The trapping effort is summarized in Table 2.1.3.1. which shows number of trap-hauls/site/date, as well as the aggregated trap-hauls. A total of 9,243 trap-hauls were made over the course of the 41 haul dates. The majority, 3,910 (42.3%), were made at Site 1, the easternmost site in harbor. A total of 2,334 (25.3%) trap hauls were made on Site 2 and 895 (~10%) on Site 3, with the remainder distributed over the areas west of the Casco Bay bridge. This distribution of effort corresponds to the anticipated lobster population at each site based on the observed population density distribution.

Table 2.1.3.2. on page 8 summarizes the catch by site per haul date. Figure 2.1.3.1., on page 9, shows these catch data graphically. Site 1, with 18,849 lobsters caught, represents 55.4% of the total catch out of 42.3% of the trap-hauls. Site 2 is a distant second at 8,035, or 23.6%, and Site 3, with 3,207 lobsters caught, or 9.4%, an even more distant third. Combined, the sites east of the Casco Bay bridge, excluding a temporary site off of Bug Light, yielded 30,091 lobsters, or 88.4% of the total catch. All sites west of the bridge yielded a combined total of 3,091, or ~9% of the total catch, more than half of these having come from Sites 7 and 8 on the Portland side of the channel. This catch distribution is consistent with the population density distribution developed through the preliminary video surveys and burrow occupancy studies of March/April 1998.

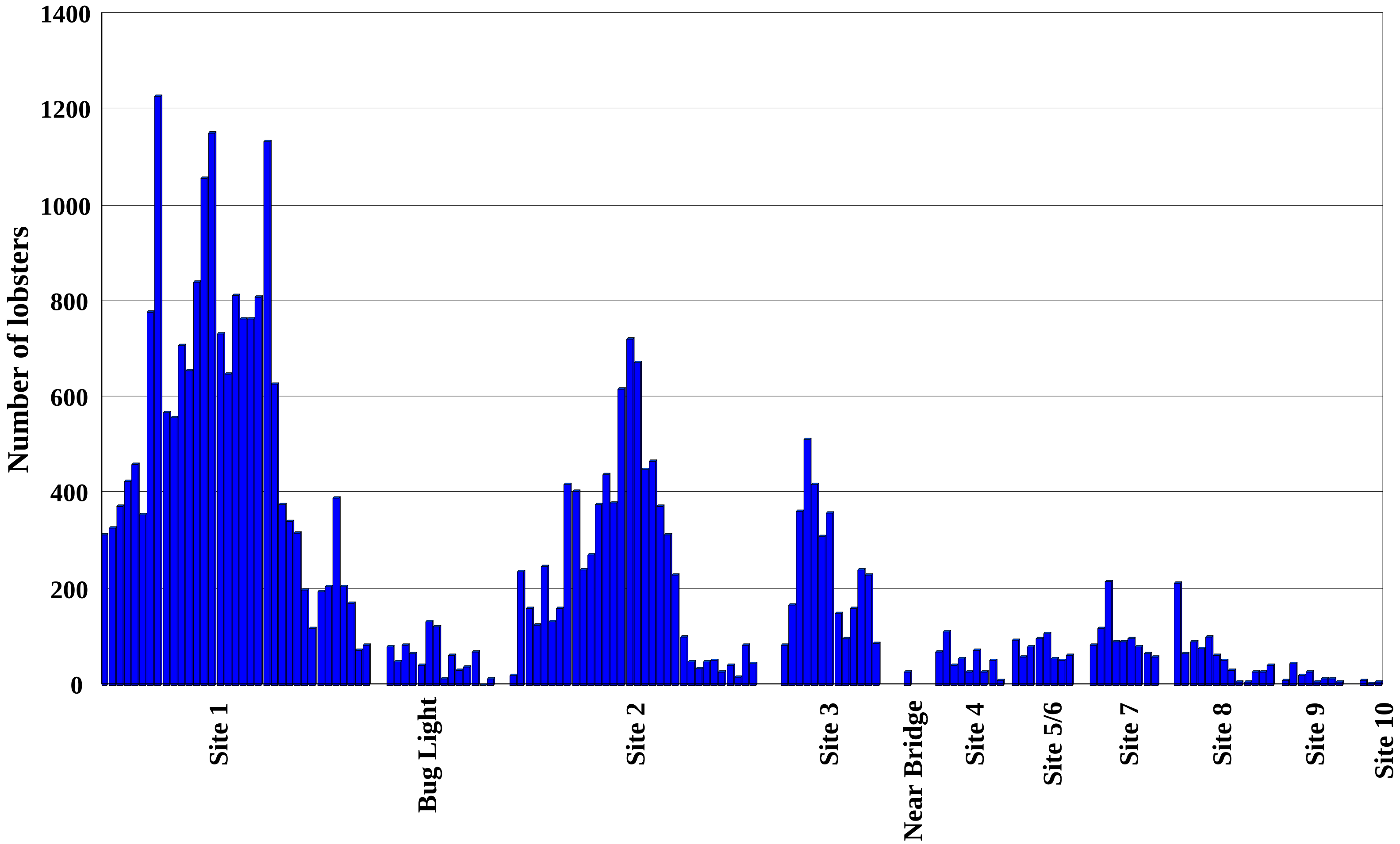
Table 2.1.3.1.
Number of traps hauled (trap-hauls) by site per haul date

Haul Dates	Site 1	Bug Light	Site 2	Site 3	Site 4	Site 5 and	Site 7	Site 8	Site 9	Site 10	Total #	Traps missed/ removed
10/22/98	0	0	0	0	0	0	12	0	0	0	12	
10/26	0	0	0	0	0	0	16	0	0	0	16	
11/03	0	0	0	0	0	0	46	38	0	0	84	
11/04	0	0	0	0	0	31	46	38	32	0	147	
11/05	0	0	0	0	0	31	46	34	0	0	111	
11/07	35	0	0	24	0	31	46	34	31	0	201	
11/09	35	0	0	24	0	31	46	34	31	0	201	
11/12	35	0	0	56	24	31	58	34	31	0	269	
11/14	35	0	12	0	34	31	48	32	31	0	223	
11/16	35	0	46	56	34	31	0	16	39	8	265	
11/18	35	0	46	77	34	31	0	16	39	8	286	
11/20	76	0	46	77	34	0	0	16	32	16	297	3
11/23	76	0	46	85	34	0	0	24	0	32	297	3
11/25	56	0	46	85	34	0	0	24	0	32	277	23
11/27	56	0	48	85	33	0	0	40	0	0	262	38
11/30	64	0	67	104	0	0	12	0	0	0	247	53
12/02	83	0	68	96	0	0	12	0	0	0	259	41
12/04	83	0	68	96	0	0	12	0	0	0	259	41
12/07	137	0	68	30	0	0	12	0	0	0	247	53
12/09	171	0	68	0	0	0	12	0	0	0	251	49
12/11	178	0	80	0	0	0	0	0	0	0	258	42
12/12	178	0	84	0	0	0	0	0	0	0	262	38
12/14	182	0	84	0	0	0	0	0	0	0	266	34
12/16	174	0	84	0	0	0	0	0	0	0	258	42
12/18	138	33	84	0	0	0	0	0	0	0	255	45
12/21	146	33	84	0	0	0	0	0	0	0	263	37
12/28	146	33	84	0	0	0	0	0	0	0	263	37
12/31	146	33	84	0	0	0	0	0	0	0	263	37
01/04/1999	146	33	84	0	0	0	0	0	0	0	263	37
01/07	146	33	84	0	0	0	0	0	0	0	263	37
01/11	146	33	84	0	0	0	0	0	0	0	263	37
01/18	146	33	0	0	0	0	0	0	0	0	179	121
01/25	146	33	64	0	0	0	0	0	0	0	243	57
02/01	146	33	85	0	0	0	0	0	0	0	264	36
02/08	116	33	85	0	0	0	0	0	0	0	234	66
02/15	108	33	85	0	0	0	0	0	0	0	226	74
02/17	144	33	85	0	0	0	0	0	0	0	262	38
02/25	144	0	86	0	0	0	0	0	0	0	230	70
03/01	144	0	84	0	0	0	0	0	0	0	228	72
03/10	78	0	119	0	0	0	0	0	0	0	197	103
03/17	0	0	92	0	0	0	0	0	0	0	92	208
	3,910	**429**	**2,334**	**895**	**261**	**248**	**424**	**380**	**266**	**96**	**9,243**	**Traps hauled**

Table 2.1.3.2.
Catch by site per haul date

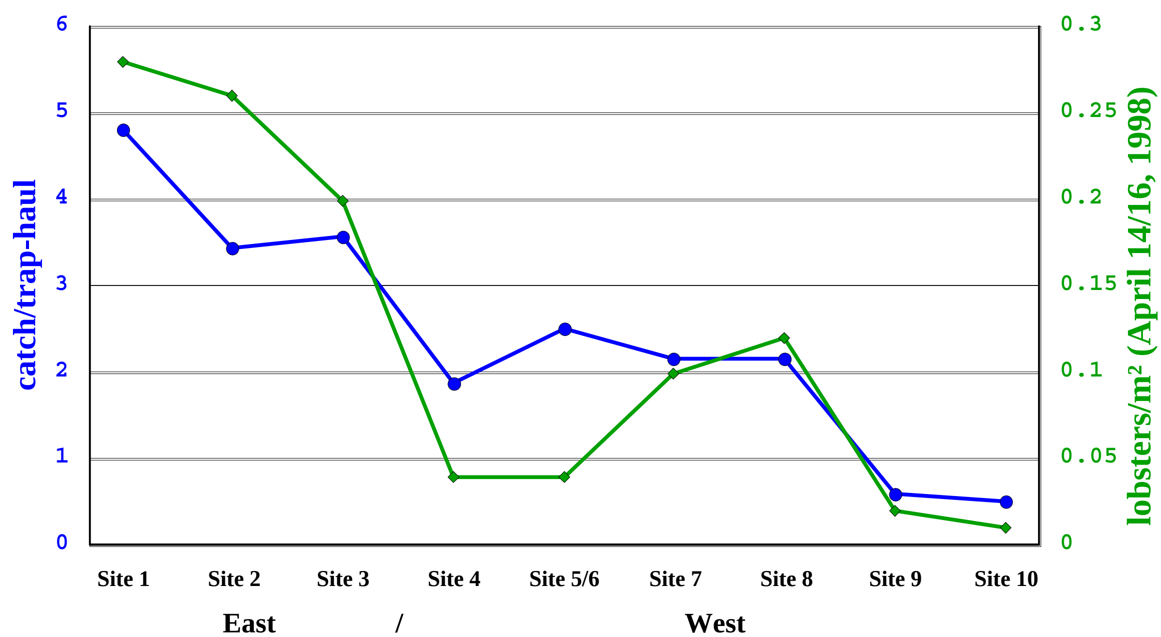
Haul Dates	Site 1	Bug Light	Site 2	Site 3	Bug Light	Site 4	Site 5 and 6	Site 7	Site 8	Site 9	Site 10	Total lobsters
10/22/98	0	0	0	0	0	0	0	84	0	0	0	84
10/26	0	0	0	0	0	0	0	122	0	0	0	122
11/03	0	0	0	0	0	0	0	217	216	0	0	433
11/04	0	0	0	0	0	0	95	92	69	12	0	268
11/05	0	0	0	0	0	0	60	92	91	0	0	243
11/07	315	0	0	85	0	0	82	99	79	47	0	707
11/09	331	0	0	171	0	0	101	81	102	21	0	807
11/12	375	0	0	366	0	70	109	67	65	31	0	1083
11/14	429	0	23	0	0	115	58	62	55	9	12	763
11/16	461	0	240	515	0	45	54	0	32	14	4	1365
11/18	359	0	161	421	0	57	65	0	8	15	7	1093
11/20	781	0	128	311	0	31	0	0	9	9	20	1289
11/23	1232	0	251	361	0	75	0	0	28	0	5	1952
11/25	571	0	134	151	0	30	0	0	28	0	0	914
11/27	559	0	164	101	0	54	0	0	42	0	0	920
11/30	709	0	421	161	0	13	0	0	0	0	0	1304
12/02	658	0	408	241	0	0	0	0	0	0	0	1307
12/04	843	0	241	233	0	0	0	0	0	0	0	1317
12/07	1060	0	275	90	0	0	0	0	0	0	0	1425
12/09	1153	0	380	0	0	0	0	0	0	0	0	1533
12/11	735	0	440	0	0	0	0	0	0	0	0	1175
12/12	650	0	381	0	0	0	0	0	0	0	0	1031
12/14	816	0	620	0	0	0	0	0	0	0	0	1436
12/16	766	0	723	0	0	0	0	0	0	0	0	1489
12/18	765	82	677	0	0	0	0	0	0	0	0	1524
12/21	812	52	453	0	0	0	0	0	0	0	0	1317
12/28	1137	84	471	0	30	0	0	0	0	0	0	1722
12/31	629	68	376	0	0	0	0	0	0	0	0	1073
01/04/99	379	45	316	0	0	0	0	0	0	0	0	740
01/07	343	133	231	0	0	0	0	0	0	0	0	707
01/11	319	124	102	0	0	0	0	0	0	0	0	545
01/18	201	16	0	0	0	0	0	0	0	0	0	217
01/25	122	65	50	0	0	0	0	0	0	0	0	237
02/01	197	32	37	0	0	0	0	0	0	0	0	266
02/08	209	39	50	0	0	0	0	0	0	0	0	298
02/15	392	73	54	0	0	0	0	0	0	0	0	519
02/17	209	3	31	0	0	0	0	0	0	0	0	243
02/25	172	15	45	0	0	0	0	0	0	0	0	232
03/01	76	0	18	0	0	0	0	0	0	0	0	94
03/10	84	0	86	0	0	0	0	0	0	0	0	170
03/17	0	0	48	0	0	0	0	0	0	0	0	48
41	**18,849**	**831**	**8,035**	**3,207**	**30**	**490**	**624**	**916**	**824**	**158**	**48**	**34,012**

Figure 2.1.3.1.
Catch by site per haul date



The correspondence between the geographic decline east to west in both population density, as estimated in April, 1998, and catch per trap haul, based on the relocation effort results, can be best visualized by a comparison of these two parameters as shown in Figure 2.1.3.2., below, Site 1 being the easternmost site and Site 10 the westernmost and the "/" represents the Casco Bay bridge. This close correspondence suggests that video surveys, combined with density assessments, can be useful in predicting catch.

Figure 2.1.3.2.
Comparison of geographic population density distribution, as of April 14/16, 1998 and catch/trap haul during the relocation project



Initially, the effectiveness of the relocation effort was to be evaluated in the basis of population density reduction as determined from post-trapping/pre-dredge burrow densities as calculated from video recordings and simultaneous burrow occupancy estimates as previously described. However, due to the accelerated schedule of the dredging operation and the consequent expansion of the trapping effort, it became clear that insufficient time would be available to complete video surveys and burrow occupancy determinations at all sites. We therefore decide to rely more heavily, in some cases exclusively, on catch per effort values (C/E), an index previously used by others in similar efforts (Sterl and Schick, 1976).

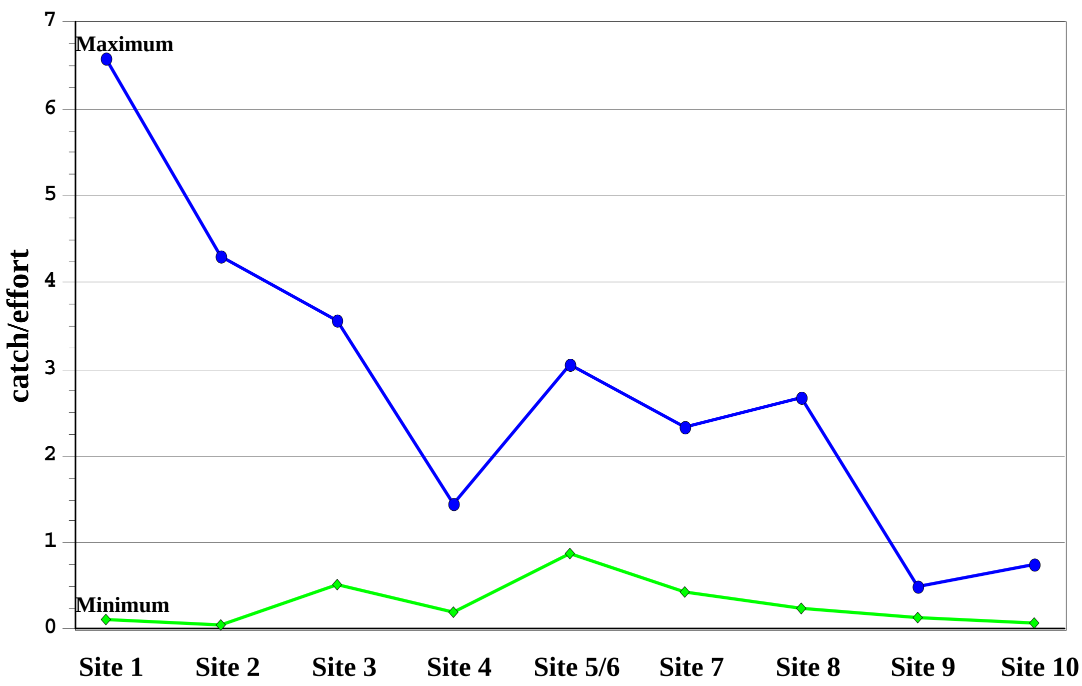
Due to the variable number of traps fished at each site and trap hauling frequency, the catch/effort was normalized as lobsters caught/trap/night-set (l/t/ns) for each site and haul date. The individual site data and indices values are included here as Appendix IV. Table 2.1.3.3. on the following page shows the maximum and minimum C/E values for each site. Figure 2.1.3.3. shows the same data in graphic form.

Table 2.1.3.3.
Maximum and minimum catch per effort for each dredge site

	Catch/effort (l/t/ns)		
	Maximum	**Minimum**	**Min. Date**
Site 1	6.59	0.12	03-10-99
Site 2	4.30	0.05	03-01-99
Site 3	3.56	0.52	11-30-98
Site 4	1.46	0.20	11-30-98
Site 5/6	3.06	0.87	11-16-98
Site 7	2.33 [1]	0.43	11-14-98
Site 8	2.68 [1]	0.25	11-20-98
Site 9	0.51	0.14	11-20-98
Site 10	0.75	0.08	11-25-98

[1] **Actual maximum value for 11/03/98 disregarded due to inclusion of off-site catch**

Figure 2.1.3.3.
Maximum and minimum catch per effort for each dredge site



An arbitrary target of 0.5 l/t/ns was set as the level to reach before dredging began on any site. The dredge operators requested that every effort be made to avoid having to stop the dredge once it began operations, even if this would require repeated relocation of the dredge. The intensity of the trapping effort was therefore adjusted to achieve these two goals. C/E calculations were made daily based on catch at each site. The results of the previous day's calculations were communicated to the dredge operators at 7:00 AM each morning and the dredge operations directed accordingly.

The date shown in Table 2.1.3.3. is the date on which the minimum C/E was reached. In most cases this date represents the last day of trapping on the site, that is, the day before the dredge began operations on the site. As the minimum C/Es show, the target of 0.5 l/t/ns was achieved, or very nearly achieved, at all but Site 5/6 where the minimum was 0.87 on 11/16/98. A review of the full data, however, shows that only 54 lobsters were caught on Site 5/6 that day, the smallest number for all haul dates (refer to Appendix IV).

It is important to note that achievement of the minimum C/E at a site is independent of time, *i.e.* minimum C/E was achieved at certain sites while others were still at near maximum. This suggests that the decline in C/E and achievement of the minimum was more a function of the trapping effort than simply migration. Figure 2.1.3.4., on the following page, shows the catch/effort values for each haul date at each site (Bug Light and "Near Bridge" were late add-ons and are included only for comparison). The visual presentation of the data shows clearly that there was a very significant reduction in C/E at all sites during the trapping effort. Again, while the declining trend in C/E is similar at all sites, the trapping periods are separate in time, *i.e.* the first trapping date at Site 1 was the last trapping date at Site 7. Furthermore, the data suggests that the variations in night-set, or soak time, has little effect on C/E, within the first 2-4 night sets further suggesting that trap saturation was not a factor for night-sets below five (see Appendix IV, Site 1 on 12/21-12/28 and 2/25-03/01). This supports previous conclusions regarding saturation effect on sub-legal lobsters in vent-disabled traps (Watson, 1999). However, if the traps set more than 5 nights, the fishing efficiency of the traps appears to decline (see 2.6.3. Trapping effort).

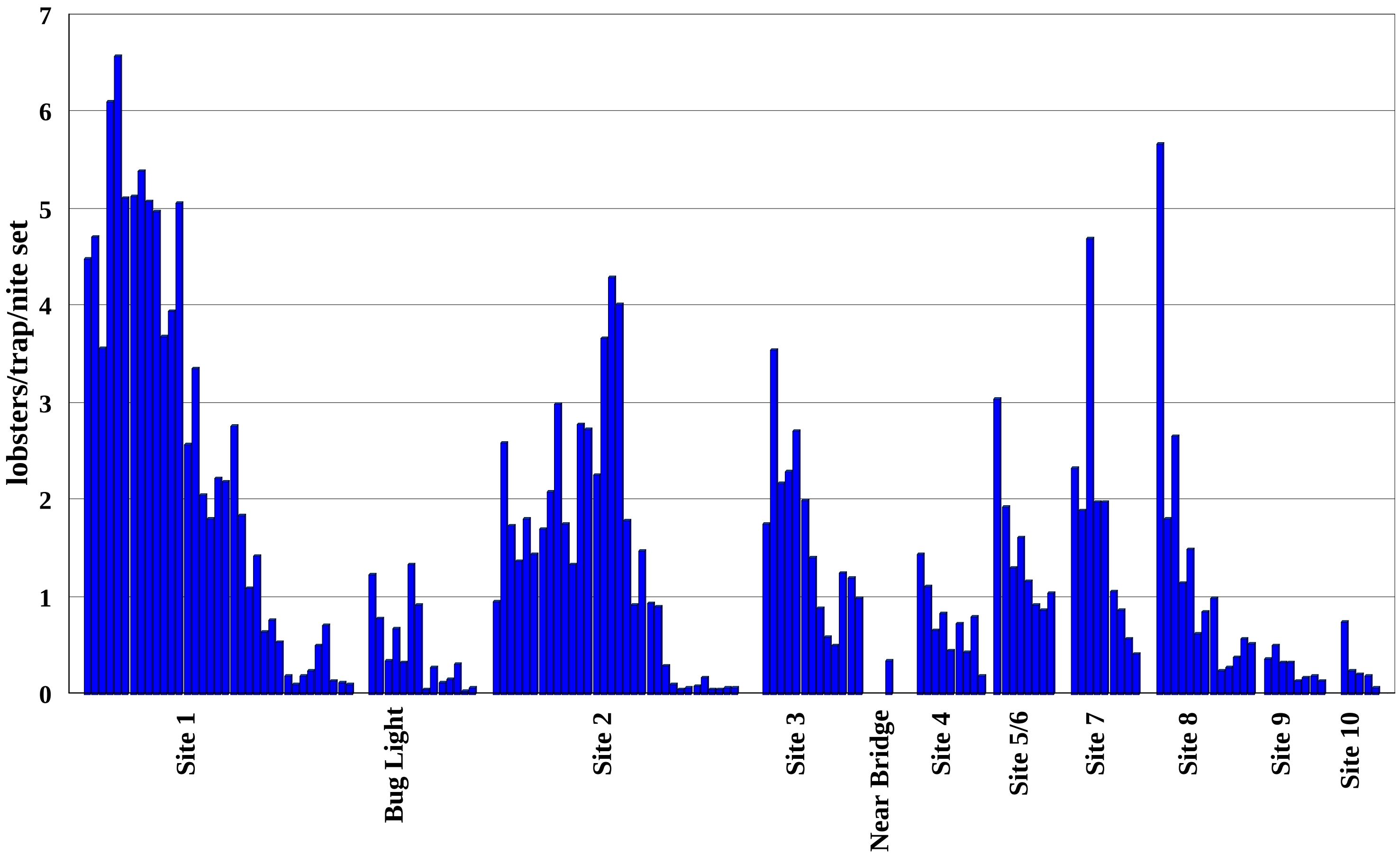
Based on these results, it seems reasonable to conclude that the trapping effort was successful in removing a large portion of the lobster population from each site before the initiation of dredge operations. Additional discussion on effectiveness evaluation is presented in Section 6.0.

2.1.4. Removal and relocation

All lobsters, both legal-size and sub-legal-size, caught on a site were retained aboard the vessel and landed at the New Meadows Lobster pound on Portland Pier. After landing, lobsters from each site were maintained separately for weighing, counting, measuring and possible tagging (see Section 2.2., Lobster data collection, following). At the end of each haul day the lobsters were transferred to the MDMR patrol vessel *Vigilant* for transport to the relocation site.

Although the specific relocation, or "drop", site varied from day to day, most relocation sites were located within the quarantine area, General Anchorage "B" on NOAA/NOS Navigational Chart No. 13292, 31st Ed., July 13/91) between Fort Gorges and House Island, with some lots relocated along the channel north of Fort Gorges. This area was selected based on the similarity of the substrate and depth to that from which the lobsters were taken. Furthermore, this site was within relatively close proximity of Portland Harbor proper, yet separated from it by the main navigational channel. The idea, as will be discussed further in Section 2.3., was to find a relocation site close enough to the harbor to allow lobsters to return in the Spring while at the same time being sufficiently distant to prevent lobsters from immediately returning back into the harbor before the dredge project was completed. Alternative relocation site options had been identified, but as will be discussed later, the tagging results indicated that the Fort Gorges to House Island site was acceptable (refer to Section 2.3.).

Figure 2.1.3.4.
Catch/effort by site per haul date



2.2. Lobster data collection

Responding to concerns expressed by the MDMR Marine Patrol over the number of sub-legal lobsters being handled in the project, on each haul date all lobsters, both legal- and sub-legal size, caught from each site were landed at one specific location, the New Meadows Lobster Company's commercial wharf and pound, Portland Pier. All lobsters originating from each site being kept strictly separate.

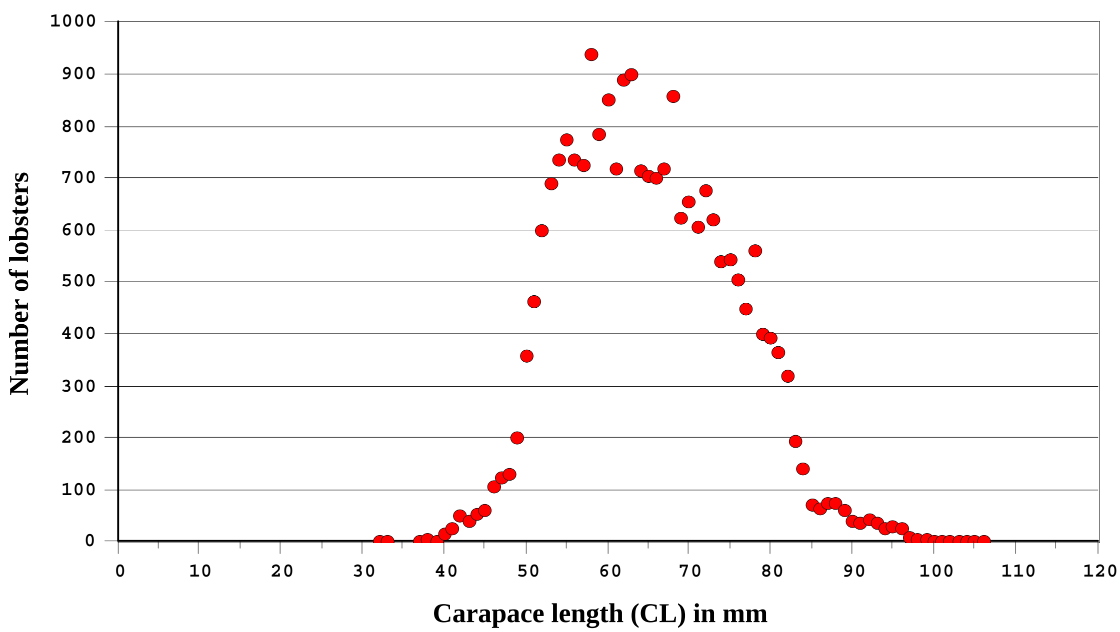
In order to better understand and describe the lobster population, several parameters were measured and observations made daily on the catch from each site: count and weight of legal-size lobsters, count and weight of sub-legal size lobsters, sex, carapace length (CL), and claw condition. When possible, the last three parameters were taken on *all* lobsters caught. However, when the catch was excessively large, observations and measurements were taken on as large a subset of the total population as possible.

Immediately following landing, legal-size lobsters were counted, weighed (total), and measurements and observations made. These lobsters were then returned to the respective fisherman for subsequent sale. Following this, measurements and observations were made of all or a representative portion of the sub-legal size population. A further subset of these lobsters was also tagged for tracking (see Section 2.3 Lobster tagging). After measurement, the lobsters were placed in floating plastic crates and held in wet-storage tanks until late afternoon when all lobsters were transferred to the MDMR patrol vessel *Vigilant* for transport to the relocation site.

Given the size of the data set collected, a database architect, Sean Creagan, was independently hired by MER to design and develop a database in which to input and manage the data. The resulting database, Lobster Trak© Ver. 1.3, Sean Creagan 1999, operates in Microsoft Access® and allows data comparisons and queries to be made in a variety of ways. Additional analyses remain to be done on these data, however, the most important results are discussed here.

Data was collected on 22,889 lobsters, or 67.3%, of the 34,012 caught during the project. Figure 2.2.1., below, shows the carapace length-frequency distribution of the population.

Figure 2.2.1.
Carapace length-frequency distribution for total population of lobsters caught



The distribution is nearly normal with a mode of 58 mm and the mean of 64.37 mm ±0.18. Based on the catch counts, of the 34,012 lobster caught, 764 were of legal size ($83 mm CL) 33,248 were of sub-legal size (#82 mm CL), representing 2.2% and 97.8% of the population, respectively. Although these values accurately describe the population of lobsters removed from the sites and relocated outside of the Fore River, they may not accurately describe the entire population for two reasons.

First, according to Dr. Winsor Watson III, professor and lobster researcher at the University of New Hampshire's Center for Marine Biology, substantial evidence exists that shows territorial behavior on the part of larger lobsters in traps (pers. comm.). Once a large, *i.e.* legal-size, lobster enters a trap, the behavior exhibited by the lobster appears territorial, other large lobsters being discouraged from entering. This appears to apply to the "kitchen" as well as the "parlor" sections of the trap. If a lobster larger than the first does enter the trap, the smaller of the two usually leaves. As a result, at any given time a standard trap will usually contain no more than one lobster. This is further supported by the rather consistent industry-wide standard "one lobster per trap" haul. Sub-legal-sized lobsters may enter the trap, but the number is maintained low since smaller lobsters can exit the "kitchen" through the heads or the "parlor" through the vents, and the ratio of sub-legals to legals remains small.

Interestingly, the territorial behavior of larger lobsters appears to apply for vent-disabled traps as well. However, in vent-disabled traps, although larger lobsters continue to be territorial with respect to other large lobsters, thus keeping the number of legal lobsters at one, the number of sub-legal-sized lobsters increases several-fold since these are no longer able to leave through the vents. Therefore, the ratio of sub-legal-sized to legal-sized lobsters increases dramatically. The increase in the ratio is not, however, necessarily representative of the population size distribution, but may instead simply be an artefact of territorial behavior amongst larger lobsters.

The traps used in the project were highly modified to catch and retain small lobsters, although not exclusively. Not only were the vents disabled, the entire "parlor" was wrapped in 1" shrimp-mesh to retain lobsters as small as 32 mm CL. As a result of this and the territoriality of larger lobsters, it is not surprising that the ratio of sub-legals to legals caught by these highly modified traps is nearly 50:1.

Second, commercial lobster fishing with standard traps continued concurrently with the project at most sites, but extensively at Sites 1, 2, and 3 where most of the lobsters were caught. Since the commercial fishing gear specifically targets legal-size lobsters by allowing smaller lobsters to escape through the vents, this gear was selectively removing larger lobsters from the population while leaving the sub-legal size population behind.

There is no doubt that a large population of sub-legal lobsters resides in Portland Harbor, however, given the two potentially confounding factors discussed above, the degree of disproportion between legal and sub-legal lobsters may not be as great as suggested by a simple superficial review of the data.

Regarding sex ratio, of the 22,889 lobsters sexed, 13,091 were males and 9,798 were females, yielding a males:females ratio of 1.3:1. On average, males were slightly larger than females, with mean carapace lengths of 65.8 mm and 63.7 mm, respectively.

No statistical analyses have yet been done on claw condition. However, as with length-frequency and sex, these data will be available for further analysis after the conclusion of this project.

2.3. Lobster tagging

Despite general agreement on the part of fishermen that relocation would be a worthwhile effort, concern was expressed over the proper location of the relocation site. The lobsters clearly needed to be relocated sufficiently far away to reduce the possibility of their simply returning within a very short period of time. On the other hand, the fishermen did not wish to see the lobsters relocated so far away that they would never return to the harbor. With these concerns in mind, several potential sites were identified, the Fort Gorges to House Island site, ~0.5 nautical mile away, being the first choice. However, given the close proximity of this site to the harbor, combined with the need to ensure that the lobsters would not immediately return to the harbor, some means of tracking recently relocated lobsters needed to be employed. A tagging component was therefore added to the relocation effort to allow tracking of relocated lobster movements. If, based on tag returns, it became apparent that a substantial number of lobsters were returning to the harbor shortly after relocation, an alternative, more distant relocation site would be used.

2.3.1. Tags and tagging procedure

Five thousand (5,000) ~2 mm polyolefin tubing "shrink tags" attached to flexible monofilament thread ~4 mm in total length with stainless steel sphyrion anchors were obtained for the project (Floy Tag and Manufacturing, Inc., Seattle, WA, Model No. FTLS-97). Based on the anticipated catch from each section of the harbor, estimated from the preliminary video surveys, the 5,000 tags were divided into groups of five colors corresponding to specific sites of origin: 500 green sequenced MER1000-MER1499 for Sites 5, 6, 9, and 10; 500 blue MER1500-MER1999 for Sites 4, 7, and 8; 1,000 yellow MER2000-2999 for Site 3; 1,500 orange MER3000-4499 for Site 2; and 1,500 red MER4500-MER6000 for Site 1. In addition to the sequence number, each tag bore the toll-free reporting phone number.

The tags were inserted on the left posterior side in muscle tissue between the carapace and the first segment of the tail to ensure tag survival through at least one molt. The sphyrion anchors were inserted through a small scalpel cut made in the tissue using an inoculation needle fixed to a plunger-type ball-point pen, adapted with a fine wire that traveled through the bore of the needle which would release the sphyrion anchor from the end of the needle when the plunger was depressed. Tagged lobsters were placed into wet-storage tanks immediately following insertion of the tag to avoid excessive loss of fluid.

To determine tagging-related mortality, three studies were carried out over the course of the project. In two of the studies, tagged and untagged (control) lobsters were segregated by placing the lobsters in individual lengths of 3" PVC pipe. The pipe lengths were placed into a wire lobster trap such that the ends of the pipe rested against each side of the trap, effectively trapping the lobster in the pipe. In one of the studies, lobsters were not segregated and allowed to roam freely within the trap. In each case, the trap was maintained submerged and checked every few days for mortalities. Tables 2.3.1.1.(a)-(c), on the following pages, summarize the data of these studies.

As a result of the mortalities among tagged lobsters in the 25 November 1998 trial, the tag insertion location was moved further to the left of the midline to avoid puncturing the pericardial cavity, an error assumed to have contributed to the mortalities based on postmortem dissections. Based on the results of the subsequent trials, it is reasonable to conclude that tagging had little, if any, effect on mortality.

Table 2.3.1.1.(a)
25 November 1998 tagging-related mortality study results

Set up 11/25/98
19 lobsters in a wire trap, segregated from each other
9 tagged, 10 untagged
Tagger: Hugh

Tag No.	Cl (mm)	Sex	Claws	Comments	Mortalities	Release Date
4795	78	f	2			12/21/1998
4796	75	f	2	h		12/21/1998
4797	74	m	2	h	12/09/1998	**tagged mort**
4798	76	m	2			12/21/1998
4799	75	f	2	h		12/21/1998
4800	72	m	2	h		12/21/1998
4801	70	m	2	h		12/21/1998
4802	75	m	2			12/21/1998
4803	67	m	2		12/11/1998	**tagged mort**
	71	f	2	h		12/21/1998
	77	m	2	h		12/21/1998
	67	m	2	h		12/21/1998
	73	m	2		12/14/1998	**control mort**
	75	f	rr			12/21/1998
	67	m	2	h		12/21/1998
	77	f	lrr			12/21/1998
	68	m	2	h		12/21/1998
	77	m	lr	h		12/21/1998
	65	f	2	h		12/21/1998

Checked trap	
11/27	all alive
11/30	all alive
12/09	Tag mort
12/11	Tag mort
12/14	control mort

Study concluded on 12/21/98

Table 2.3.1.1.(b)
14 January 1999 tagging-related mortality study results

Set up 1/14/99
37 lobsters in a wire trap, lobsters not segregated from each other
14 tagged, 23 untagged
Taggers: Brian Tarbox/students

Tag No.	Cl (mm)	Sex	Claws	Comments	Mortalities	Release Date
3765	78	m	2	h, l abnormal		01/25/1999
3766	73	m	2			01/25/1999
3767	68	m	2	h, r abnormal		01/25/1999
3768	68	m	2	h		01/25/1999
3769	69	f	2	h, r abnormal		01/25/1999
3770	65	m	2			01/25/1999
3771	64	m	2	h		01/25/1999
3772	72	m	2		**01/25/1999**	**tagged mort**
3773	69	f	lr			01/25/1999
3774	78	m	2			01/25/1999
3775	65	f	2	r abnormal		01/25/1999
3776	67	m	2	l damaged		01/25/1999
3777	66	m	2	r damaged		01/25/1999
3778	67	m	2	h		01/25/1999
	52	m	2			01/25/1999
	62	f	2	h		01/25/1999
	64	m	rr	h		01/25/1999
	58	f	rr			01/25/1999
	63	m	2			01/25/1999
	60	m	2			01/25/1999
	58	f	2	h		01/25/1999
	54	f	2			01/25/1999
	58	m	lr			01/25/1999
	45	m	2			01/25/1999
	58	f	2	r damaged		01/25/1999
	57	m	2			01/25/1999
	60	f	2			01/25/1999
	61	m	2	h		01/25/1999
	60	f	1	h, r abnormal		01/25/1999
	64	m	2	h		01/25/1999
	60	f	2			01/25/1999
	52	m	rr			01/25/1999
	63	m	2			01/25/1999
	55	f	2			01/25/1999
	58	m	lr			01/25/1999
	49	m	2			01/25/1999
	48	m	2			01/25/1999
	60	f	2	h		01/25/1999
	49	m	2			01/25/1999
	55	f	2	h		01/25/1999
	52	m	2			01/25/1999

Checked Car

Study concluded on 1/25/99

01/18	all alive
01/25	tag mort

Table 2.3.1.1.(c)
15 February 1999 tagging-related mortality study results

Set up 2/15/99
19 lobsters in a wire car, segregated from each other
9 tagged, 10 not tagged
Tagger: Brian Tarbox

Tag No.	Cl (mm)	Sex	Claws	Comments	Mortalities	Release Date
3806	75	m	1	h		03/10/1999
3807	71	m	1	h		03/10/1999
3808	68	f	2	rr		03/10/1999
3809	73	f	2	h, rr		03/10/1999
3810	77	f	1			03/10/1999
3811	78	f	2	h, r damaged		03/10/1999
3812	70	m	2			03/10/1999
3813	65	f	2	h		03/10/1999
3814	70	m	2			03/10/1999
	58	f	2		**03/10/1999**	**control mort**
	72	m	2	h		03/10/1999
	79	m	2	h		03/10/1999
	77	f	2			03/10/1999
	71	m	1	h		03/10/1999
	61	m	2			03/10/1999
	66	f	2	h		03/10/1999
	63	f	2	lr		03/10/1999
	70	f	2	h		03/10/1999
	71	f	2			03/10/1999

Checked Car		
02/23	all alive	Study concluded study on 3/10/99; lobsters released at House Island
02/25	all alive	
03/10	one mort	

2.3.2. Results

A total of 4,027 lobsters were tagged between 3 November 1998 and 17 February 1999. Table 2.3.2.1., below, summarizes the number of tags of each color (area) used, the number of recaptures by color, and the percent of recaptures.

Table 2.3.2.1.
Distribution of tags and recaptures

No. of tags used	Site #	No. recaptured	% of recaptures
353	**5, 6, 9, 10**	27	7.6
553	**4, 7, 8**	49	8.9
671	**3**	36	5.4
784	**2**	53	6.8
1,666	**1**	102	6.1
4,027		**267**	**6.6**

Of the 267 returns, only 20 were recorded returning across the main navigational channel towards the Fore River during the dredging period between 12 November 1998 and 8 April 1999. Thirteen (13) of these were recaptured on the eastern edge of the harbor and only 8 were recaptured on dredge sites or well within Portland Harbor. Assuming that each tagged lobster represents ~8.45 lobsters in the total relocated population (34,012/4,027), then ~169 lobsters would been expected to have returned back towards the Fore River over the course of the dredging project and only ~68 onto dredge sites or well within the harbor proper.

Based on the rate and location of recapture, it is reasonable to conclude that the relocation site at General Anchorage "B" was sufficiently distant from the harbor proper to prevent excessive returns during dredging. Other possible contributing factors to the lack of return movement were the decreasing seawater temperature over the relocation period and shortening day length during the early part of the project, both of which would likely have discouraged migration towards shore.

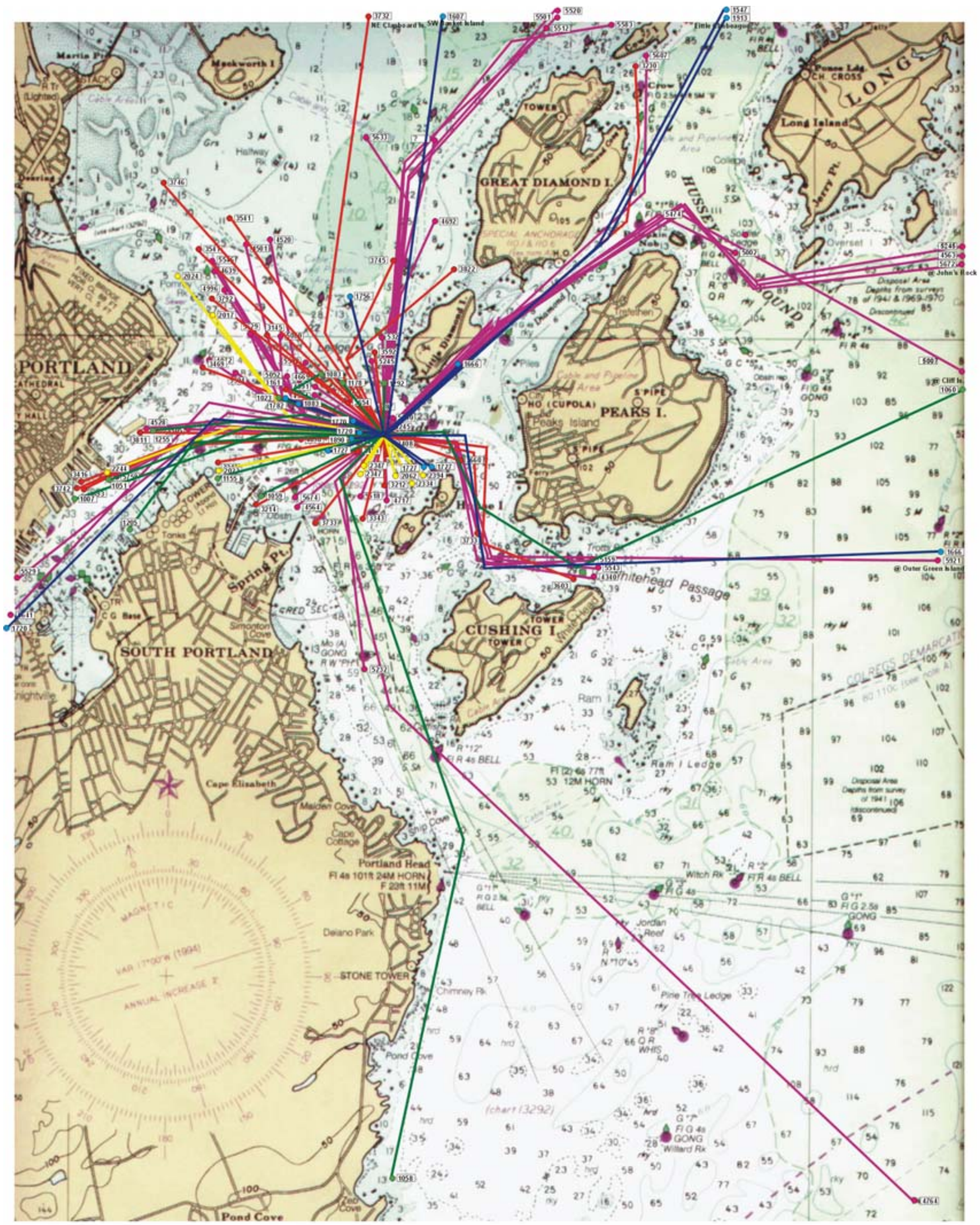
The continuation of the lobster project beyond the completion of the dredge project in early April has allowed continued tracking of tagged lobster movements. An additional 246 recaptures were reported between 13 April and 23 September 1999. Detailed information on tag recaptures is included here in Appendix V.

The 6.6% recapture rate is low compared to other similar studies. Several factors may have contributed to this low rate recapture. First, since all of the lobsters tagged were of sub-legal size, most of these lobsters would not be retained by commercial vented traps, particular following the vent size increase from 1 7/8" to 1 15/16" in 1999. As a result, it is unlikely that commercial fishermen would encounter a large number of tagged lobsters unless a lobster had shed and attained a size close to the legal limit. This suggestion is supported by the fact that most recaptures reported by commercial fishermen, other than those fishing the modified traps as part of the study, were at or near legal size. Indeed, the vast majority of small recaptures were caught by the project's modified traps. Furthermore, many of recaptures were reported by dealers who had received the lobsters from Casco Bay-area fishermen. Even if tagged sub-legal lobsters had been hauled aboard, little attention may have been given to these since obvious "shorts" are quickly tossed overboard.

Every effort was made to advertise the tagging project and facilitate reporting of tag returns, including advertisements in commercial fishing newspapers, distribution of flyers and posters, and the setting up a toll-free reporting line, the number for which was embossed on each tag. However, despite the general awareness of the project and the wide use of cellular phones on the water by commercial fishermen, few were willing to stop to make a call while hauling gear. As a result, several reports have been received of fishermen accumulating numerous tags "on the dash" but never reporting them; one report estimated between 35-40 unreported tags on a single vessel. In view of the ineffectiveness of telephone reporting, an alternative marine radio reporting option was established. Although this option did improve the rate of reporting, overall reporting remained low. Consequently, the *actual* rate of recapture may have been significantly better than that represented by the *reports* of recaptures.

Even when tag recaptures were reported, the reports usually included very limited information, often only the tag color, number, and a general location description. Figure 2.3.2.1., on the following page, shows the assumed "straight-line" movement of recaptured tagged lobsters where recapture location was provided. The lines are drawn based on a simplified single, central relocation point of departure and the recapture location.

Figure 2.3.2.1.
“Straight-line” movement of recaptured tagged lobsters based on recapture location



Track lines represent shortest distance between point of release and point of recapture and do not presume to represent actual path.

As this figure shows, most of the lobsters either remained in the general vicinity where they were relocated or moved back in the direction of inner Casco Bay. Only 9 lobsters appeared to be moving in an offshore direction, three of these apparently headed towards the outer islands of the Bay. Several others, although not moving back towards the harbor, appear to be moving toward other areas within Inner Casco Bay, most in the general vicinity of the outer harbor, some moving northward toward the Upper Bay. Nevertheless, at least a portion of the relocated population could be expected to return to the Fore River fishery. Additional graphics showing movements of lobsters according to tag color, *i.e.* area of origin are included here as Appendix VI.

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2.4. Video surveys

Video surveys were carried out in July and September, 1998 to provide baseline views of pre-dredge conditions. When time permitted, post-trapping/pre-dredge surveys were also made to help in assessing the effectiveness of the trapping effort. Again, when time allowed, post-dredge surveys were conducted once dredging was completed in an area. Finally, video surveys were made in June, July, August, and November 1999 to assess reoccupation of the dredge sites.

The methodology used was the same as that described in Heinig and Cowperthwaite, (1998) and briefly summarized in Section 1. Between July 1998 and November, 1999 143 videos were taken. In most cases, three video transects were made at each site to increase coverage of the bottom. GPS coordinates were used to relocate transects on successive dives at each site to ensure consistency of location from one date to another. Video transect lines were positioned perpendicular to the shore at the larger sites (Sites 1, 2, and 3). At the smaller, narrower sites, (Sites 4, 7, and 8) the video transect lines were positioned parallel to the shore with the exception of one transect at Site 7.

Copies of all video recordings made during the project are being submitted along with this report as a set of nine (9) 120 minute VHS tapes. A complete list of all videos, dates, times, and graphic identification code is included here in Appendix VII. The videos were reviewed principally to count the lobsters within the 60 m^2 transect to support and document diver observations. Additional observations were made of other organisms, the number of burrows that were present, and any other feature of interest. Graphic representations of these observations were made using CorelDraw 9© and are also included in Appendix VII.

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2.5. Population density estimates

Lobster density estimates were made during the various phases of the project, *i.e.* baseline, pre-dredge, post-dredge, and reoccupation. The baseline values represent the normal, pre-trapping condition. The pre-dredge values represent population estimates as the lobsters were being removed, up to the day before (post-trapping), or shortly before, dredge operations began on the site. Post-dredge values represent estimates from immediately to a few weeks after dredging was completed. Reoccupation estimates were made to observe the rate and extent of return of the lobsters to the dredged sites.

At least one estimate was made at each site during the baseline and pre-dredge phases. Multiple estimates were calculated for Sites 1, 2, and 3 due to the extended trapping period at these sites. However, due to the accelerated schedule of the project, post-dredge diver observations and video recordings could be made only at Site 7 (November 23, 1998) and Site 1, and between Sites 1 and 2 (April 28, 1999). During the reoccupation study phase periodic estimates were made at Sites 1, 2, and 3, east of the Casco Bay bridge, and Sites 4, 7, and 8 west of the bridge. Sites 5, 6, 9, and 10 were not studied due to the very low abundance found at these sites on previous dives.

Prior to July 1998 the video surveys and burrow occupancy studies were conducted separately. The burrow occupancy rate was determined from random sampling of burrows along the video transect and the resulting occupancy rate applied to the number of burrows observed on the video recording. Beginning with the Summer 1998 dive series, the video recording and probing of burrows were conducted simultaneously with the diver attempting to probe all likely lobster burrows and maintaining a tally of numbers of burrows and lobsters. The diver, however, was unable to probe all burrows. We therefore estimated by three methods, first by the direct diver observations, second by video observations, and third, a combination of the two.

Tables 2.5.1. (a) through (c), beginning on the following page, presents the diver and video observations and the respective density estimates for all transects for the period July 24, 1998 through November 2, 1999. The Observed Density under Diver Observations is calculated simply as:

$$\mathbf{d_d = l_d/t}$$

where $\mathbf{d_d}$ is the density, $\mathbf{l_d}$ the number of diver lobsters observed within a 1- meter wide field of view, and t the length of the transect in meters over which the observations were made. The Observed Density under Video Observations ($\mathbf{d_v}$) is calculated using the same equation, with the exception that $\mathbf{l_v}$ is the number of lobsters seen during the review of the video. As the tables show, these two estimates correspond very closely. Occasionally the diver missed lobsters hidden in burrows, thus the video count is higher. On other occasions the diver will find a lobster in a burrow that is not recorded on the video tape, accounting for a higher diver count. Overall, however, the correspondence is remarkably good. However, as just mentioned, the diver was not able to probe all burrows and must therefore select those burrows most likely to be lobster burrows, thus possibly leading to an underestimation of the true population density. An alternative is to use the approach used in the preliminary study for this project where the occupancy rate determined from the diver observations is applied to the burrow count as determined from the video tape review. This is calculated as:

$$\mathbf{d_{dv} = ((l_d/b_d)\ b_v)/t}$$

where $\mathbf{d_{dv}}$ is density, $\mathbf{l_d}$ the diver observed lobsters, $\mathbf{b_d}$ the number of burrows probed by the diver, $\mathbf{b_v}$ the number of burrows observed on the video, and **t** the length of the video transect.

Table 2.5.1.(a)
Baseline and pre-dredge population density estimates

July 24, 1998 - Baseline Site (transect) Daylight	Diver Observations No. lob. (l_d)	No. burr. (b_d)	Meters (t)	Obs. Density (d_d)	Video Observations No. lob. (l_v)	No. burr. (b_v)	Meters (t)	Obs. Density (d_v)	Est. density (d_{dv})
1a	11	23	120	0.09	11	203	120	0.09	0.81
1b	12	23	120	0.10	11	98	120	0.09	0.43
2	3	14	120	0.03	3	107	120	0.03	0.19
7	1	5	60	0.02	1	29	60	0.02	0.10
8	2	8	60	0.03	2	24	60	0.03	0.10
Night Dives									
1	24	30	120	0.20	26	56	120	0.22	0.37
BB site (no dredge)	6	# on wall (?)	60	0.10	6	11	60	0.10	?
September 12, 1998 Baseline									
1a	20	36	120	0.17	18	141	120	0.15	0.65
1b	13	27	120	0.11	13	79	120	0.11	0.32
2a	5	19	120	0.04	5	86	120	0.04	0.19
2b	12	27	120	0.10	12	201	120	0.10	0.74
3a	4	9	60	0.07	4	34	60	0.07	0.25
3b	10	23	120	0.08	10	91	120	0.08	0.33
4	4	1	60	0.07	5	1	60	0.08	0.07
7	2	6	60	0.03	1	11	60	0.02	0.06
8	1	3	60	0.02	2	2	60	0.03	0.01
September 18, 1998 Baseline									
3c	6	16	120	0.05	6	59	120	0.05	0.18
5	4	7	60	0.07	3	12	60	0.05	0.11
6	0	7	60	0.00	0	14	60	0.00	0.00
9a	0	1	60	0.00	0	1	60	0.00	0.00
9b	1	7	120	0.01	1	15	120	0.01	0.02
10	0	3	60	0.00	0	3	60	0.00	0.00
September 28, 1998 Baseline									
5	0	3	60	0.00	0	3	60	0.00	0.00
6	1	7	60	0.02	1	9	60	0.02	0.02
10	1	2	60	0.02	1	2	60	0.02	0.02
October 19, 1998 Pre-dredge									
7	2	13	60	0.03	2	40	60	0.03	0.10

Table 2.5.1.(b)
Pre-dredge population density estimates

November 14, 1998 Site (transect)	No. lob. (l_d)	No. burr. (b_d)	Meters (t)	Obs. Density (d_d)	No. lob. (l_v)	No. burr. (b_v)	Meters (t)	Obs. Density (d_v)	Est. density (d_{dv})
7 1/4	0	12	60	0.00	0	28	60	0.00	0.00
7 2/4	0	4	60	0.00	0	4	60	0.00	0.00
7 3/4	0	7	60	0.00	0	10	60	0.00	0.00
7 4/4	0	11	60	0.00	0	12	60	0.00	0.00
November 18, 1998									
6	0	0	60	0.00	0	0	60	0.00	0.00
5	0	1	60	0.00	0	1	60	0.00	0.00
November 23, 1998									
7 1/1 Post-dredge	0	0	60	0.00	0	0	60	0.00	0.00
9 1/3	0	0	60	0.00	0	0	60	0.00	0.00
9 2/3	0	4	60	0.00	0	5	60	0.00	0.00
9 3/3	0	1	60	0.00	0	1	60	0.00	0.00
November 25, 1998									
8 1/3	1	*7*	60	0.02	1	20	60	0.02	0.05
8 2/3	0	*12*	60	0.00	0	32	60	0.00	0.00
8 3/3	0	14	60	0.00	0	19	60	0.00	0.00
10 1/3	0	0	60	0.00	0	0	60	0.00	0.00
10 1/3	0	0	60	0.00	0	0	60	0.00	0.00
10 1/3	0	0	60	0.00	0	0	60	0.00	0.00
November 30, 1998									
House Is. ½	7	13	60	0.12	6	63	60	0.10	0.57
House Is. 2/2	3	17	60	0.05	2	56	60	0.03	0.16
3 ½	0	8	60	0.00	0	25	60	0.00	0.00
3 2/2	0	15	60	0.00	0	56	60	0.00	0.00
December 4, 1998									
1 E ½	11	27	60	0.18	11	22	60	0.18	0.15
1 E 2/2	12	27	60	0.20	12	41	60	0.20	0.30
December 7, 1998									
3 1/3	0	8	60	0.00	0	48	60	0.00	0.00
3 2/3	1	5	60	0.02	1	30	60	0.02	0.10
3 3/3	0	2	60	0.00	0	12	60	0.00	0.00

Table 2.5.1.(b) (Cont.)
Pre-dredge population density estimates

December 23,1998 Site (transect)	**No. lob.** (l_d)	**No. burr.** (b_d)	**Meters** (t)	**Obs. Density** (d_d)	**No. lob.** (l_v)	**No. burr.** (b_v)	**Meters** (t)	**Obs. Density** (d_v)	**Est. density** (d_{dv})
1 and 2 1/4	12	38	60	0.20	11	103	60	0.18	0.54
1 and 2 2/4	2	8	60	0.03	2	35	60	0.03	0.15
1 and 2 3/4	7	17	60	0.12	7	79	60	0.12	0.54
1 and 2 4/4	14	20	60	0.23	14	70	60	0.23	0.82
1 1/5	9	25	60	0.15	8	57	60	0.13	0.34
1 2/5	7	17	60	0.12	6	68	60	0.10	0.47
1 3/5	8	11	60	0.13	8	54	60	0.13	0.65
1 4/5	3	11	60	0.05	2	54	60	0.03	0.25
1 5/5	10	29	60	0.17	7	56	60	0.12	0.32
February 10, 1999									
1 and 2 1/4	7	27	60	0.12	4	52	60	0.07	0.22
1 and 2 2/4	0	2	60	0.00	0	31	60	0.00	0.00
1 and 2 3/4	1	9	60	0.02	1	40	60	0.02	0.07
1 and 2 4/4	6	32	60	0.10	1	69	60	0.02	0.22
1 1/5	8	17	60	0.13	3	52	60	0.05	0.41
1 2/5	3	11	60	0.05	2	22	60	0.03	0.10
1 3/5	1	4	60	0.02	1	15	60	0.02	0.06
1 4/5	3	11	60	0.05	2	11	60	0.03	0.05
1 5/5	10	29	60	0.17	4	28	60	0.07	0.16
February 16, 1999									
2 ½	0	3	60	0.00	0	34	60	0.00	0.00
2 2/2	1	6	60	0.02	1	59	60	0.02	0.16
April 28, 1999 - POST-DREDGE									
1 and 2 1/3	1	2	60	0.02	1	14	60	0.02	0.12
1 and 2 2/3	0	0	60	0.00	0	6	60	0.00	0.00
1 and 2 3/3	0	0	60	0.00	0	3	60	0.00	0.00
1 1/3	4	5	60	0.07	2	20	60	0.03	0.27
1 2/3	7	8	60	0.12	7	8	60	0.12	0.12
1 3/3	1	4	60	0.02	1	23	60	0.02	0.10

Table 2.5.1.(c)
Post-dredge and reoccupation population density estimates

June 14, 1999 Reoccupation Site (transect)	No. lob. (l_d)	No. burr. (b_d)	Meters (t)	Obs. Density (d_d)	No. lob. (l_v)	No. burr. (b_v)	Meters (t)	Obs. Density (d_v)	Est. density (d_{dv})
1 1/3	15	16	60	0.25	14	9	60	0.23	0.14
1 2/3	9	16	60	0.15	9	19	60	0.15	0.18
1 3/3	3	3	60	0.05	3	34	60	0.05	0.57
2 1/3	2	2	60	0.03	1	6	60	0.02	0.10
2 2/3	3	3	60	0.05	3	8	60	0.05	0.13
2 3/3	6	6	60	0.10	6	12	60	0.10	0.20
3 1/3	3	26	60	0.05	3	5	60	0.05	0.01
3 2/3	1	1	60	0.02	1	0	60	0.02	0.00
3 3/3	2	2	60	0.03	2	3	60	0.03	0.05
4 ½	2	2	60	0.03	1	1	60	0.02	0.02
4 2/2	1	0	60	0.02	1	0	60	0.02	0.00
8 ½	1	2	60	0.02	0	2	60	0.00	0.02
8 2/2	2	4	60	0.03	2	11	60	0.03	0.09
7	1	1	60	0.02	1	2	60	0.02	0.03
July 21, 1999 Reoccupation									
1 1/3	14	20	60	0.23	13	13	60	0.22	0.15
1 2/3	14	22	60	0.23	13	28	60	0.22	0.30
1 3/3	9	13	60	0.15	10	6	60	0.17	0.07
2 1/3	8	11	60	0.13	8	25	60	0.13	0.30
2 2/3	4	6	60	0.07	4	12	60	0.07	0.13
2 3/3	5	10	60	0.08	3	5	60	0.05	0.04
3 1/3	4	7	60	0.07	3	9	60	0.05	0.09
3 2/3	3	7	60	0.05	2	6	60	0.03	0.04
3 3/3	1	4	60	0.02	2	10	60	0.03	0.04
4 ½	0	0	60	0.00	0	0	60	0.00	0.00
4 2/2	3	3	60	0.05	4	8	60	0.07	0.13
8 ½	1	1	60	0.02	1	0	60	0.02	0.00
8 2/2	2	5	60	0.03	3	16	60	0.05	0.11
7	0	1	60	0.00	0	1	60	0.00	0.00

Table 2.5.1.(c) (Cont.)
Post-dredge and reoccupation population density estimates

August 20, 1999

Site (transect)	No. lob. (l_d)	No. burr. (b_d)	Meters (t)	Obs. Density (d_d)	No. lob. (l_v)	No. burr. (b_v)	Meters (t)	Obs. Density (d_v)	Est. density (d_{dv})
1 1/3	5	11	60	0.08	0	8	60	0.00	0.06
1 2/3	14	20	60	0.23	6	12	60	0.10	0.14
1 3/3	12	15	60	0.20	2	16	60	0.03	0.21
2 1/3	5	8	60	0.08	0	5	60	0.00	0.05
2 2/3	2	9	60	0.03	1	3	60	0.02	0.01
2 3/3	5	7	60	0.08	2	8	60	0.03	0.10
3 1/3	3	9	60	0.05	0	3	60	0.00	0.02
3 2/3	0	3	60	0.00	0	1	60	0.00	0.00
3 3/3	3	5	60	0.05	2	4	60	0.03	0.04
4 ½	4	3	60	0.07	3	3	60	0.05	0.07
4 2/2	2	3	60	0.03	2	0	60	0.03	0.00
8 ½	3	7	60	0.05	0	3	60	0.00	0.02
8 2/2	0	1	60	0.00	2	5	60	0.03	0.00
7	2	3	60	0.03	2	5	60	0.03	0.06
November 2, 1999									
1 1/3	3	10	60	0.05	2	23	60	0.03	0.12
1 2/3	9	12	60	0.15	6	24	60	0.10	0.30
1 3/3	13	16	60	0.22	7	26	60	0.12	0.35
2 1/3	10	15	60	0.17	6	32	60	0.10	0.36
2 2/3	3	6	60	0.05	2	10	60	0.03	0.08
2 3/3	0	1	60	0.00	0	8	60	0.00	0.00
3 1/3	1	2	60	0.02	0	5	60	0.00	0.04
3 2/3	0	2	60	0.00	0	1	60	0.00	0.00
3 3/3	0	1	60	0.00	0	3	60	0.00	0.00
4 ½	N/D	N/D	N/D	----	N/D	N/D	N/D	----	----
4 2/2	N/D	N/D	N/D	----	N/D	N/D	N/D	----	----
8 ½	1	4	60	0.02	2	13	60	0.03	0.05
8 2/2	0	1	60	0.00	0	6	60	0.00	0.00
7	0	4	60	0.00	0	3	60	0.00	0.00

The correspondence between the diver observed density (**d_d**) and the video/diver estimated density **(d_{dv})** is not very good, particularly where numerous burrows are encountered. There are two principal reasons for the discrepancy. The first is the fact that lobster burrows in soft sediment, such as those in the Fore River, tend to be U-shaped, having both an entrance and an exit. Without being able to determine with certainty if two adjacent burrows are connected, counting each burrow as representing an individual lobster could yield a doubled density estimate. Second, the reviewer of the video must subjectively discriminate between lobster burrows and other type of burrows, *i.e.* small hake (*Merluccius* sp. or *Urophycis* sp.), wrymouth eel, etc. Previous work in Portland Harbor indicates that lobsters in the harbor are not found in burrows <60 mm in diameter (Heinig and Cowperthwaite, 1998). However, size alone is an inadequate criterion upon which to base such discrimination since lobsters are often seen being removed from relatively small burrows. Other burrow characteristics, such as oval shape and mounding at the entrance, can be used, but detection of these subtle characteristics requires considerable experience. We believe this technique has applicability in conducting these types of surveys, but interpretation of the video images needs refinement.

In view of the tendency towards overestimation using the video/diver estimated density values, the diver observed density was selected as the most appropriate value to use. However, for the reasons already mentioned, this may result in an underestimate of the true density.

Table 2.5.2., below, summarizes the diver observed density results for the transect dives for each site on each date.

Table 2.5.2.
Summary densities (lobsters/m^2) for each site by date based on diver observed density

Month	Site	Max	Min	Mean	Std. Dev.
Jul 98	**1**	0.20	0.09	0.13	0.050
	2	0.03	0.03	0.03	0.000
	7	0.02	0.02	0.02	0.000
	8	0.03	0.03	0.03	0.000
Sep 98	**1**	0.17	0.11	0.14	0.030
	2	0.10	0.04	0.07	0.030
	3	0.08	0.05	0.07	0.012
	4	0.07	0.07	0.07	0.000
	5	0.07	0.00	0.04	0.035
	6	0.02	0.00	0.01	0.010
	7	0.03	0.03	0.03	0.000
	8	0.02	0.02	0.02	0.000
	9	0.01	0.00	0.01	0.005
	10	0.02	0.00	0.01	0.010
Oct 98	**7**	0.03	0.03	0.03	0.000
Nov 98	**5**	0.00	0.00	0.00	0.000
	6	0.00	0.00	0.00	0.000
	7	0.00	0.00	0.00	0.000
	8	0.02	0.00	0.01	0.009
	9	0.00	0.00	0.00	0.000
	10	0.00	0.00	0.00	0.000

(Continued on following page)

Table 2.5.2. (Cont)
Summary densities (lobsters/m^2) for each site by date based on diver observed density

Month	Site	Max	Min	Mean	Std. Dev.
Dec 98	**1**	0.20	0.05	0.14	0.046
	1/2	0.23	0.03	0.15	0.078
	3	0.02	0.00	0.01	0.009
Feb 99	**1**	0.17	0.02	0.08	0.056
	1/2	0.12	0.00	0.06	0.051
	2	0.02	0.00	0.01	0.010
Apr 99	**1**	0.12	0.02	0.07	0.041
	1/2	0.02	0.00	0.01	0.009
Jun 99	**1**	0.25	0.05	0.15	0.082
	2	0.10	0.03	0.06	0.029
	3	0.05	0.02	0.03	0.012
	4	0.03	0.02	0.03	0.005
	7	0.02	0.02	0.02	0.000
	8	0.03	0.02	0.03	0.005
Jul 99	**1**	0.23	0.15	0.20	0.038
	2	0.13	0.07	0.09	0.026
	3	0.07	0.02	0.05	0.021
	4	0.05	0.00	0.03	0.025
	7	0.00	0.00	0.00	0.000
	8	0.02	0.00	0.01	0.010
Aug 99	**1**	0.23	0.08	0.17	0.065
	2	0.08	0.03	0.06	0.024
	3	0.05	0.00	0.03	0.024
	4	0.07	0.03	0.05	0.020
	7	0.03	0.03	0.03	0.000
	8	0.05	0.00	0.03	0.025
Nov 99	**1**	0.22	0.05	0.14	0.070
	2	0.17	0.00	0.07	0.071
	3	0.02	0.00	0.01	0.009
	4	-----	-----	-----	-----
	7	0.00	0.00	0.00	0.000
	8	0.02	0.00	0.01	0.010

The population density values for Sites 1, 2, 3, 4, 7, and 8 are presented graphically in Figures 2.5.1 through 2.5.6., beginning on the following page.

Figure 2.5.1.
Site 1 lobster population density by date based on diver observed density

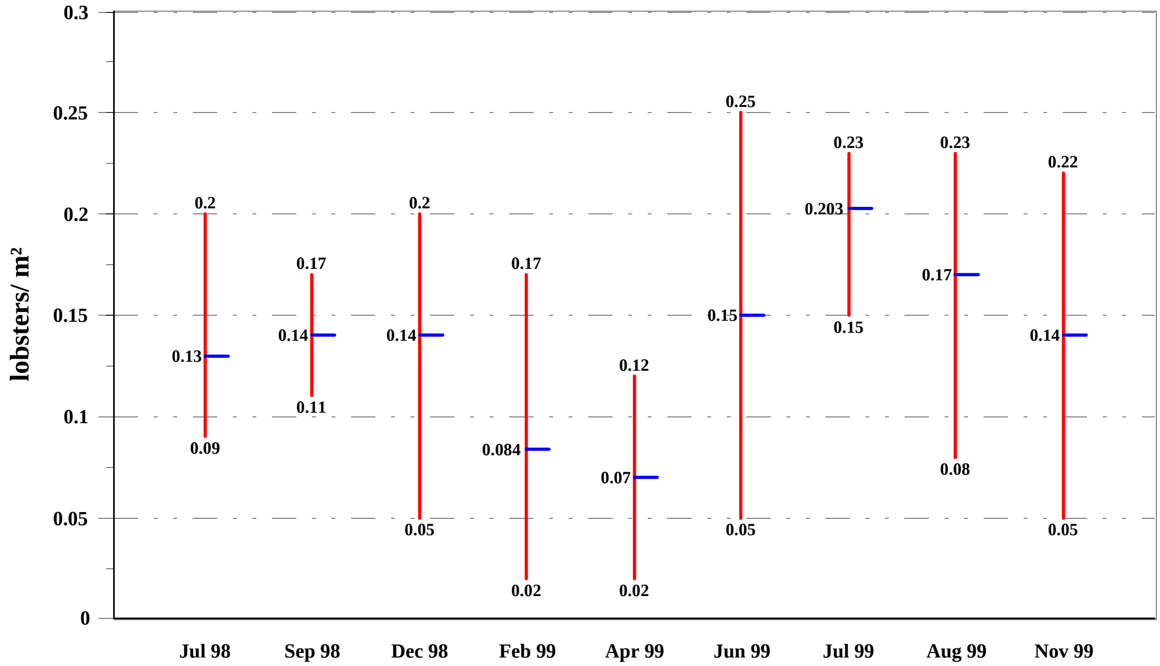
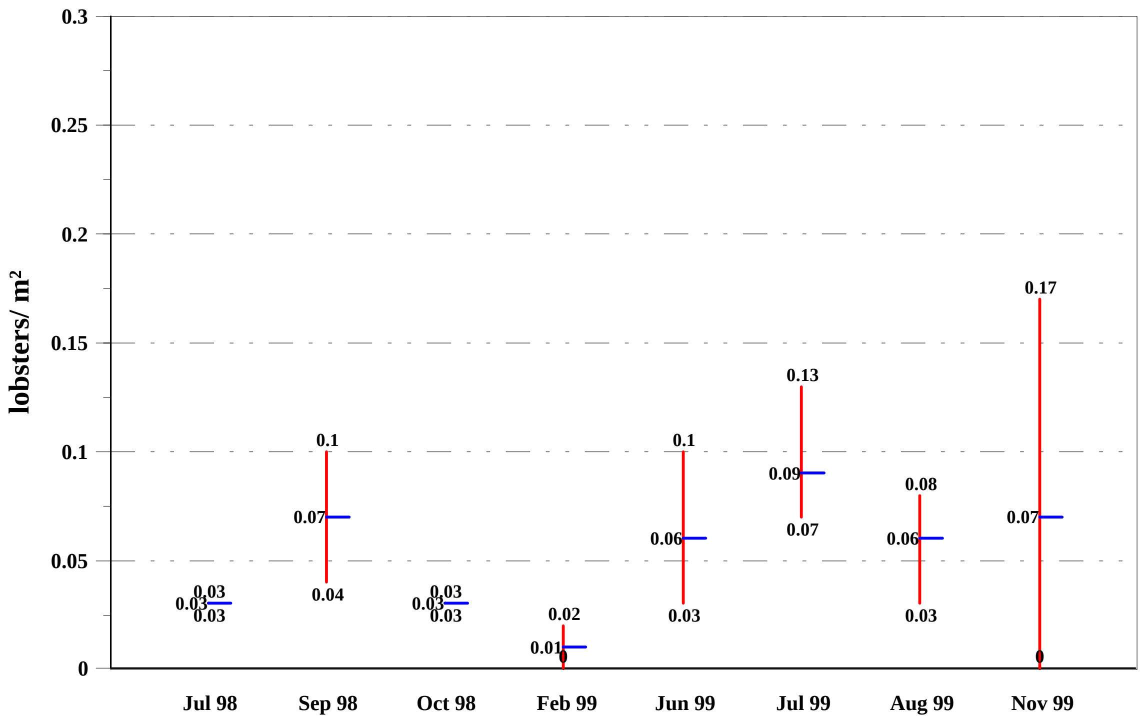


Figure 2.5.2.



Site 2 lobster population density by date based on diver observed density

Figure 2.5.3.
Site 3 lobster population density by date based on diver observed density

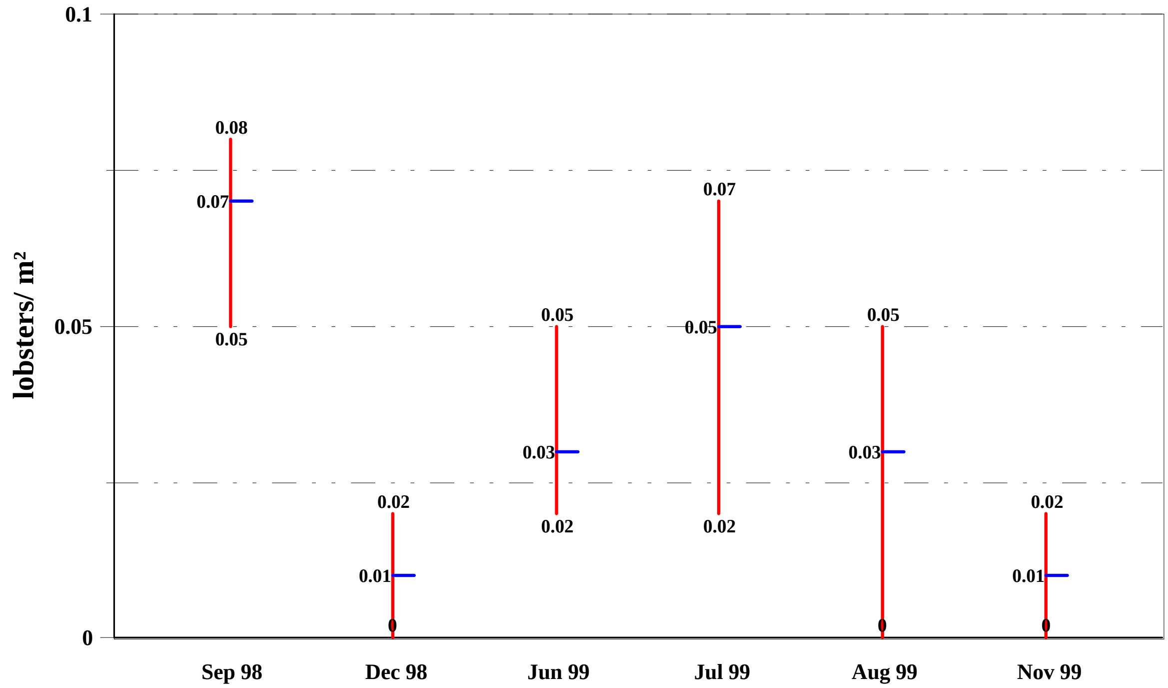


Figure 2.5.4.
Site 4 lobster population density by date based on diver observed density

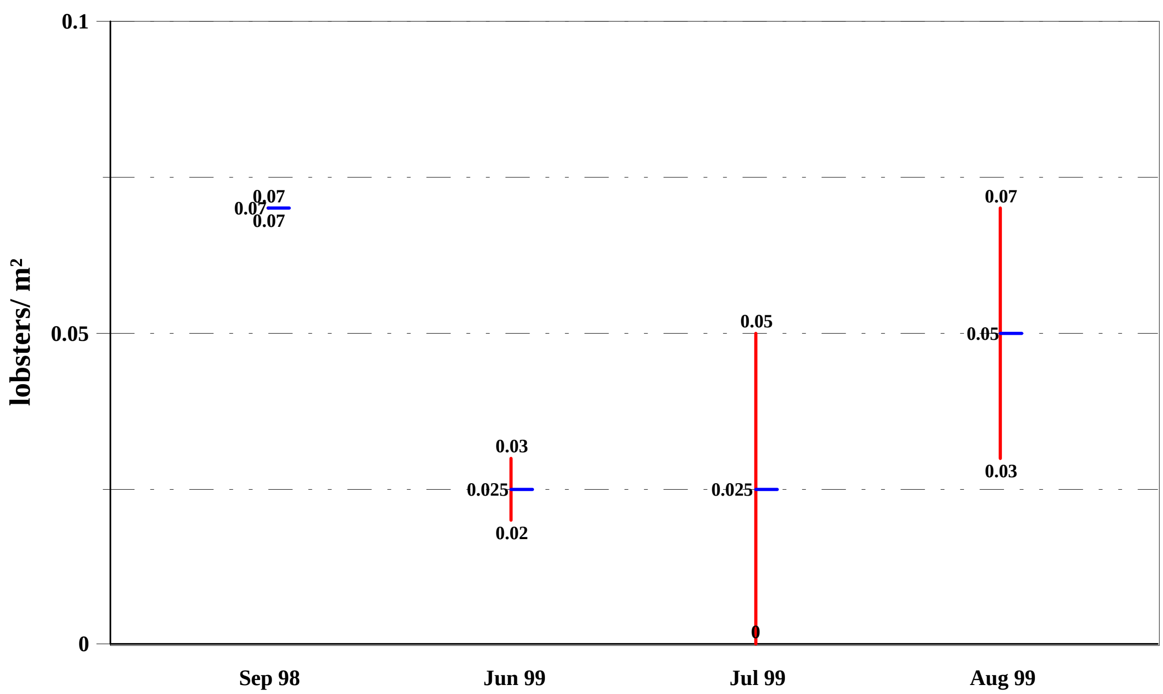


Figure 2.5.5.
Site 7 lobster population density by date based on diver observed density

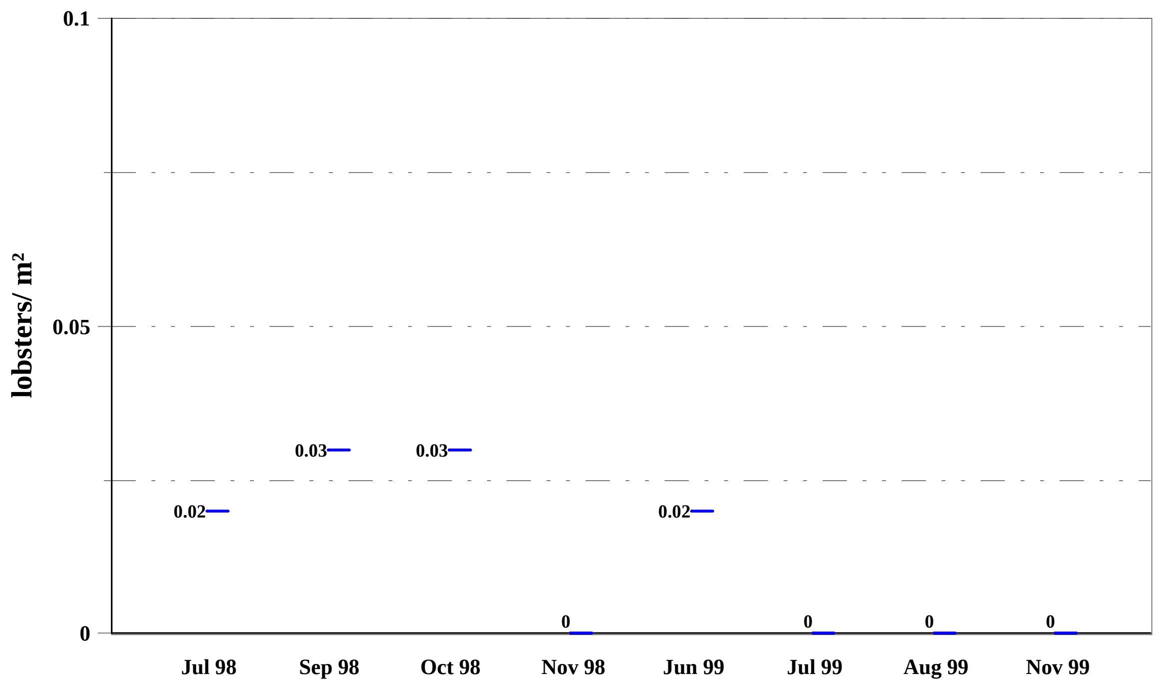
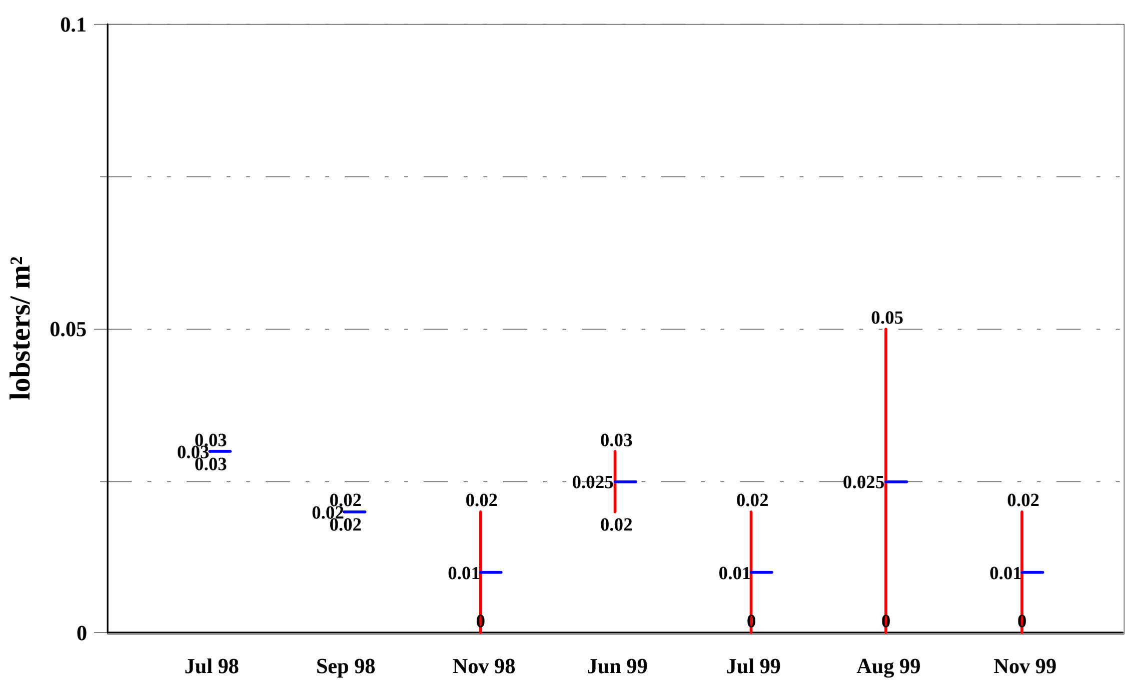


Figure 2.5.6.
Site 8 lobster population density by date based on diver observed density



As the trend in mean values shows, lobster densities were reduced to significantly low levels at each site just before dredging occurred (November '98 for Sites 7 and 8; December '98 for Site 3;

February ‘99 for Sites 1 and 2). All sites show an increase in density beginning in July 1999. In the cases of Sites 1 and 2 the July 1999 density exceeds the baseline density found in July 1998, prior to dredging and trapping. At Sites 3, 4, 7, and 8, although recolonization is evident, the population density values never reach the baseline value; at many sites, however, the baseline value is nearly reached in at least one of the three months of June, July, and August.

Interestingly, the November 1999 values for Sites 1 and 2 are the same as the pre-trapping, pre-dredge values for September 1998, suggesting that this may be the normal Fall density. If so, it seems reasonable to assume that the further decrease in population density during the period October 1998 through February 1999 at Sites 1 and 2, respectively, are the direct result of the trapping/relocation effort, particularly since the 1999 density values are based on observations two months later in the year than in 1998. In contrast, the November 1999 population density values for Sites 3, 7, and 8 are the same as those found in November/December 1998, suggesting that in these areas of normally low population density, the trapping effort had less net effect than in the areas of high density (Sites 1 and 2). If this is the case, it would indicate that the greatest benefit/effort of any future effort(s) of this kind would be achieved in high population density areas.

More detailed analyses and evaluation of these results are provided in Section 2.6. Effectiveness evaluation, immediately following.

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2.6. Effectiveness evaluation

In order to determine the efficacy of the trapping effort, it was necessary to estimate the initial population (N_0) and the population left after the completion of trapping but prior to dredging (pre-dredge). We used diver surveys to estimate these populations (see Section 2.6.2. Baseline Densities, below).

Since the trapped lobsters were moved off site, the catch per unit effort declined during the course of the trapping as a function of the cumulative effort. Regressing the natural logarithm of C/E against cumulative effort gives an estimate of the initial population size (N_0) and catchability (q) (see Section 2.6.3. Trapping Data, following).

The diver surveys can also be used to estimate the initial number of lobsters and the relative magnitude of the required trapping effort. As soon as enough trapping effort has occurred to reduce the C/E, the regression technique can be used to forecast the amount of effort required to complete the trapping by calculating the X axis intercept of the regression line. This will give an estimate of the cumulative effort required to trap the entire population on a given site. The regression estimate of $N_{0,}$ having been calculated independently, can also be used to validate the diver estimate of N_0 which tends to underestimate the population.

2.6.1. Area of dredged bottom

The area of the dredged bottom was taken from a chart (scale1”=200’) provided by the U.S. Army Corps of Engineers. The chart was overlain with five square to the inch graph paper and the number of squares of dredged bottom at each site was counted. The number of squares was then multiplied by 149 m^2 per square to estimate the total area of each site. Observations of the dredge and the barge which towed the leveling bar indicate that the calculated areas probably underestimate the total area impacted. The areas of each site are given in Table 2.6.1.1. along with the proportion of the total area included in each site.

Table 2.6.1.1.
Estimated area of selected dredge sites

Site	Area (m^2)	% of Total Area
1	86,271	28.24
2	51,107	16.73
3	124,266	40.67
7-8	43,806	14.36
Total	305,450	100.00

The largest proportion (93.5%) of lobsters came from Sites 1, 2, 3, and 7/8. Because of this, we did not calculate population estimates or do post-dredge monitoring for Sites 4, 5, 6, 9 and 10. Sites 7 and 8 are treated as one site as they are contiguous.

2.6.2. Baseline density

The baseline density of lobsters was estimated by swimming diver transects of each site. These estimates are shown in Table 2.6.2.1., below. The diver videotaped each transect line and inspected each lobster burrow within a one meter width along the transect line to determine if a lobster was present. During the cold months, lobsters tend to stay well inside the burrows and it was necessary to poke a hand in the length of the burrow to determine if a lobster was present. As mentioned earlier, burrows in soft sediments tend to be U-shaped with both an entrance and an exit. Consequently, this technique of probing burrows probably underestimates the number of lobsters present as many lobsters were seen to exit the burrow by the second entrance as the diver poked his hand into the first entrance. These exiting lobsters were hard to see in the silt stirred up by the diver and some were probably missed.

The video camera was fitted with a length of lead core line which, when just touching the bottom, kept the camera at such a height that the view screen framed a width of one meter. The ends of the transect lines were graduated in one meter lengths so that the camera's view and the lead core line could be calibrated. By counting the number of lobsters observed within this one meter wide transect and dividing by the length of the transect, a value for the density of lobsters/m^2 was calculated. The mean density for each site could then be calculated.

In order to reduce the variance of the density estimate, the mean densities for all sites were pooled in a stratified sampling design. The mean density and variance (s^2) of each site was weighted according to its proportion of the total area of all sites (Meyer, 1975).

The pooled mean density of lobsters was 0.087 lobsters/m^2 with a pooled variance of 0.00025 (refer to Table 2.6.2.1., below). The 95% confidence interval about the mean was: $0.056 < u < 0.118$. Multiplying the mean density by the total area gives an estimated initial population (N_0) for Sites 1, 2, 3 and 7/8 of 26,574 with a 95% confidence interval of 17,105-36,043. Given that the site area figures are probably underestimated and the diver density figures are also underestimated, the value for N_0 in the dredged areas is also underestimated. This estimate of N_0 is a fishery independent value as no trapping data was used in the calculations.

Table 2.6.2.1.
Estimated baseline lobster densities

Site	Date	Mean lobsters/m^2	s^2	No. of transects
1	09/12/98	0.140	0.009	2
2	09/12/98	0.070	0.009	2
3	09/12-18/98	0.080	0.00028	3
7-8	09/18/98	0.025	0.00002	2

Pooled, weighted mean density: 0.087 lobsters/m^2
Pooled, weighted mean variance: 0.00025
95% confidence interval of mean density: $0.056 < u < 0.118$

2.6.3. Trapping data

During the relocation effort, catch was recorded by date and site. A standardized value for C/E was calculated by dividing the number of lobsters trapped on a site by the quantity of the number of traps hauled on that site times the number of nights since the last haul. Whenever possible, the number of nights between hauls was kept constant (three nights) however winter conditions and the movement of the dredge sometimes prevented this. The number of traps hauled on each site changed as the dredge moved to new sites and traps were moved. Variations in the number of nights between hauls and the number of traps on an individual site may change the fishing efficiency of the traps. This will in turn effect the estimate of q or catchability of the lobsters computed in the regression analysis. Longer sets may reduce the fishing efficiency as bait becomes depleted and traps become crowded. Table 2.6.3.1., on the following page, shows a summary of the catch and C/E values for each site by date. Most of the traps were hauled on two and three night sets but there were some seven and eight night sets in February and March of 1999 on Sites 1 and 2. The data in Table 2.6.3.1. for February 17, 1999 clearly shows the effect of fishing long sets on the fishing efficiency of the traps. The two night set on Sites 1 and 2 shows a higher value for C/E than the seven night sets before and after it.

Catch per effort values are plotted by date for each site in Fig. 2.6.3.1. on page 40. Catch per effort on Site 1 declined from a maximum of 6.59 lobsters per trap per night set on November 16, 1998 with 35 traps hauled to 0.12 lobsters per trap per night set on March 10, 1999 with 78 traps hauled. With the exception of Site 3, C/E values had declined close to 0.5 lobsters per trap per night or less before trapping was discontinued. Site 3 was abandoned early due to movements of the dredge and the traps were concentrated on the easternmost end of the site for the last three dates. The eastern end of the site had the highest density of lobsters thus accounting for the high values of C/E for the last three dates of trapping.

Each site seemed to trap independently of the other sites. West of the bridge, on November 14, 1998, Site 7 yielded a C/E of 0.43 lobsters per trap per night set with a cumulative total of 682 trap nights of effort while Site 8, which is contiguous to Site 7, yielded a C/E of 0.86 with a cumulative total effort of 412 trap nights. East of the bridge, on December 7, 1998, Site 1 yielded a C/E of 2.58 with 1,994 trap nights, Site 2 showed a C/E of 1.35 with 1,303 trap nights and Site 3 showed a C/E of 1.00 with 2,177 trap nights. If adjacent sites trapped independently of one another, it seems likely that the bulk of lobsters caught on each site came from that site. If it can be assumed that there is no significant immigration to or emigration from each site during the course of the trapping period, then the pre-dredge population (N_0) for each site can be estimated by plotting the natural logarithm of C/E during each trapping interval against cumulative effort to the middle of the time interval (Ricker, 1975).

The regression equation becomes:

$$\mathbf{Ln\ c/e = a + q\ k}, \text{ where:}$$

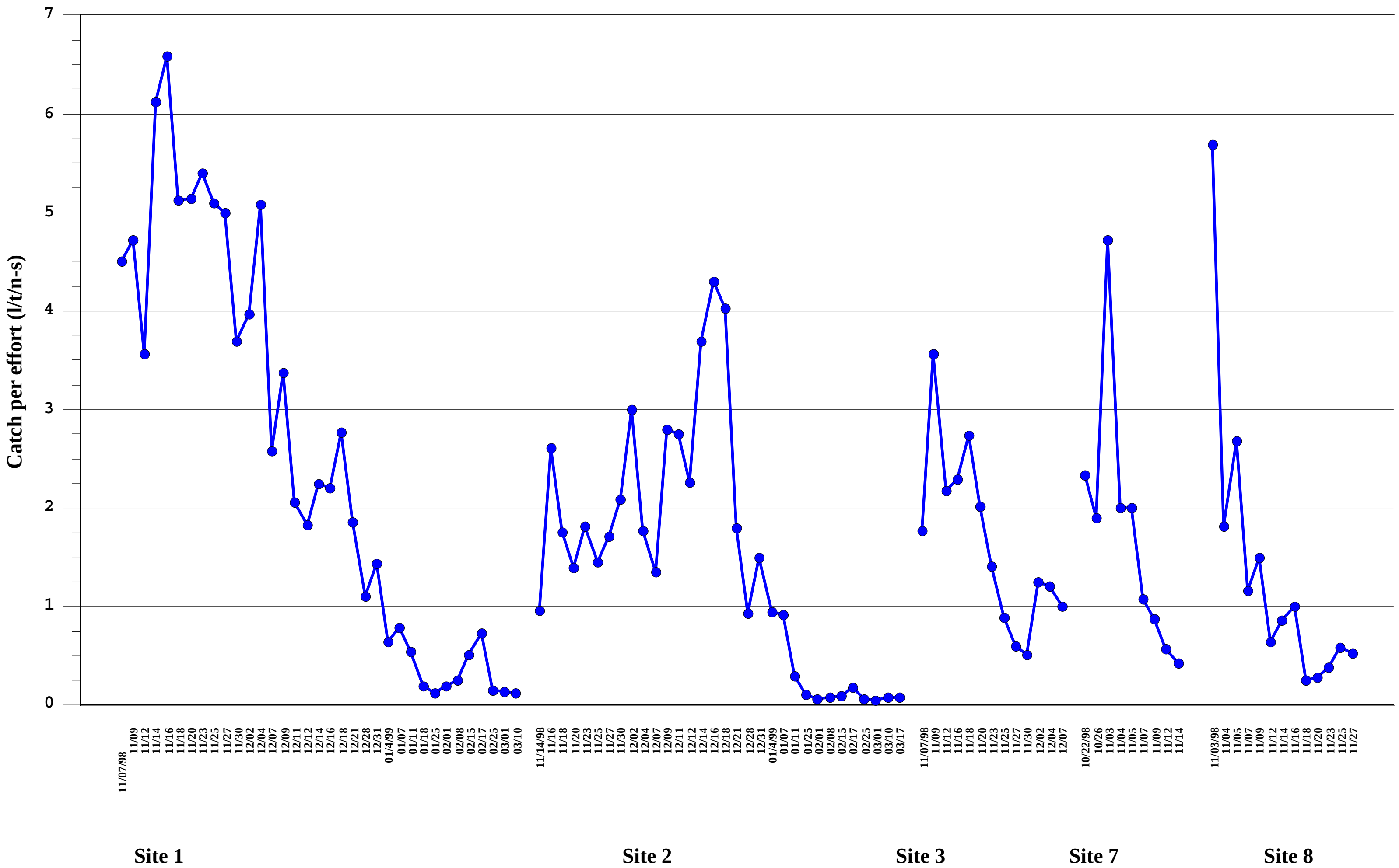
c/e = catch/unit effort for each time interval,
a = Y intercept of regression line,
q = slope of the regression line and is an estimate of the catchability of the lobsters,
k = Cumulative effort to the middle of each time interval, and
$N_0 = (\text{antilog}_e \bullet a)/q$

This technique is known as the DeLury method .

Table 2.6.3.1.
Catch and C/E by site per haul date

Haul date	Site 1 Traps	Site 1 n-s	Site 1 Lob.	Site 1 C/E	Site 2 Traps	Site 2 n-s	Site 2 Lob.	Site 2 C/E	Site 3 Traps	Site 3 n-s	Site 3 Lob.	Site 3 C/E	Site 7 Traps	Site 7 n-s	Site 7 Lob.	Site 7 C/E	Site 8 Traps	Site 8 n-s	Site 8 Lob.	Site 8 C/E
10/22/98	----	----	----	-----	----	----	----	-----	----	----	----	-----	12	3	84	2.33	-----	-----	-----	-----
10/26	----	----	----	-----	----	----	----	-----	----	----	----	-----	416	4	122	1.91	-----	-----	-----	-----
11/03	----	----	----	-----	----	----	----	-----	----	----	----	-----	146	1	217	4.72	38	1	216	5.68
11/04	----	----	----	-----	----	----	----	-----	----	----	----	-----	146	1	92	2.00	38	1	69	1.82
11/05	----	----	----	-----	----	----	----	-----	----	----	----	-----	146	1	92	2.00	34	1	91	2.68
11/07	35	2	315	4.50	----	----	----	-----	24	2	85	1.77	246	2	99	1.08	34	2	79	1.16
11/09	35	2	331	4.73	----	----	----	-----	24	2	171	3.56	246	2	81	0.88	34	2	102	1.50
11/12	35	3	375	3.57	----	----	----	-----	56	3	366	2.18	258	2	67	0.58	34	3	65	0.64
11/14	35	2	429	6.13	12	2	23	0.96	-----	-----	-----	-----	348	3	62	0.43	32	2	55	0.86
11/16	35	2	461	6.59	46	2	240	2.61	56	4	515	2.30	-----	-----	-----	-----	16	2	32	1.00
11/18	35	2	359	5.13	46	2	161	1.75	77	2	421	2.73	-----	-----	-----	-----	16	2	8	0.25
11/20	76	2	781	5.14	46	2	128	1.39	77	2	311	2.02	-----	-----	-----	-----	16	2	9	0.28
11/23	76	3	1232	5.40	46	3	251	1.82	85	3	361	1.42	-----	-----	-----	-----	24	3	28	0.39
11/25	56	2	571	5.10	46	2	134	1.46	85	2	151	0.89	-----	-----	-----	-----	24	2	28	0.58
11/27	56	2	559	4.99	48	2	164	1.71	85	2	101	0.59	-----	-----	-----	-----	40	2	42	0.53
11/30	64	3	709	3.69	67	3	421	2.09	104	3	161	0.52	-----	-----	-----	-----	-----	-----	-----	-----
12/02	83	2	658	3.96	68	2	408	3.00	96	2	241	1.26	-----	-----	-----	-----	-----	-----	-----	-----
12/04	83	2	843	5.08	68	2	241	1.77	96	2	233	1.21	-----	-----	-----	-----	-----	-----	-----	-----
12/07	137	3	1060	2.58	68	3	275	1.35	30	3	90	1.00	-----	-----	-----	-----	-----	-----	-----	-----
12/09	171	2	1153	3.37	68	2	380	2.79	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/11	178	2	735	2.06	80	2	440	2.75	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/12	178	2	650	1.83	84	2	381	2.27	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/14	182	2	816	2.24	84	2	620	3.69	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/16	174	2	766	2.20	84	2	723	4.30	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/18	138	2	765	2.77	84	2	677	4.03	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/21	146	3	812	1.85	84	3	453	1.80	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/28	146	7	1137	1.11	72	7	471	0.93	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12/31	146	3	629	1.44	84	3	376	1.49	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
01/04/99	146	4	379	0.65	84	4	316	0.94	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
01/07	146	3	343	0.78	84	3	231	0.92	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
01/11	146	4	319	0.55	84	4	102	0.30	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
01/18	146	7	201	0.20	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
01/25	146	7	122	0.12	85	7	50	0.11	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
02/01	146	7	197	0.19	85	7	37	0.06	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
02/08	116	7	209	0.26	85	7	50	0.08	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
02/15	108	7	392	0.52	85	7	54	0.09	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
02/17	144	2	209	0.73	85	2	31	0.18	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
02/25	144	8	172	0.15	86	8	45	0.07	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
03/01	144	4	76	0.13	84	4	18	0.05	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
03/10	78	9	84	0.12	119	9	86	0.08	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
03/17	-----	-----	-----	-----	92	7	48	0.07	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Fig. 2.6.3.1.
Catch per effort values by date by site



The results of the DeLury analysis for each site are given in Table 2.6.3.2. The combined estimated N_0 for Sites 1, 2, 3, 7 and 8 is 31,780 lobsters. This is a fishery dependent estimate as it is derived from the trapping data.

Table 2.6.3.2.
DeLury estimates of N_0 by site

	Regression C_0			
Site	**a**	**b**	**Correlation C_0**	**N_0**
1	1.61617370	0.00027327	-0.93	19,085
2	1.16858081	0.00049754	-0.87	6,467
3	0.90942726	0.00056285	-0.71	4,411
7	1.20589697	0.00338132	-0.89	988
8	1.04590510	0.00343314	-0.83	829
			Total N_0 :	**31,780**

Systematic errors that introduce bias in the DeLury estimate include recruitment, natural mortality, immigration, emigration and variations in catchability. Since the trapping took place in late Fall and Winter, it is unlikely that many lobsters were recruited to these sites. The instantaneous rate of natural mortality (m) for lobsters is estimated to be 0.10 which is equivalent to a ten percent loss per year due to natural causes (Clark, 1998). As most of this mortality is associated with molting (J. Idoine, NMFS, pers comm), and molting was not observed during the trapping period, it is unlikely that natural mortality biased the DeLury estimate of N_0. As noted above, variations in the number of nights between trap hauls may affect the fishing efficiency of the traps and hence the estimate of catchability. According to Ricker, however, "less serious but of widespread occurrence, is day-to-day or other short-term variation in catchability. Usually this merely increases the scatter of points along the line of graphs…".

As mentioned earlier, in order to detect immigration or return of relocated lobsters to the dredge sites, 4,027 lobsters were tagged with color coded and serial numbered sphyrion tags. Several controlled experiments with tagged and untagged lobsters showed no significant increase in short term (up to two weeks) mortality in the tagged lobsters. Twenty tagged lobsters were recaptured on or near the dredged areas amounting to 0.49% of the tagged population. If tagged and untagged lobsters returned at the same rate then the total number of lobsters returning to Sites 1, 2, 3, and 7/8 during the trapping process would be 0.49% of the total catch for these sites or 155 lobsters as shown in Table 2.6.3.3., on next page. Therefore, immigration from relocated lobsters returning from the East or harbor mouth appears to be minimal. Since trapping started from the western end of the harbor and moved east, it does not seem likely that immigration came from the west. The trapped sites were bordered by shallow water on the shoreward sides and the shipping channel in the center of the harbor. Several dive surveys of the shallow inshore areas showed few or no lobsters (Heinig and Cowperthwaite, 1998). There may have been some lobsters immigrating to the dredged areas from the ship channel.

If a significant emigration from the sites occurred during the trapping period, this would lead to a systematic overestimate of the catchability (q) and an underestimate of N_0. Since the DeLury estimate of N_0 was higher than the density estimate, migration doesn't seem to have affected the estimate.

Table 2.6.3.3.
Comparison of density and DeLury estimates of N_0 with catch statistics

Site	Density estimate of N_0	DeLury estimate of N_0	Catch	% of Total catch
1	n/a	19,085	18,849	59.5
2	n/a	6,467	8,035	25.4
3	n/a	4,411	3,207	10.1
7	n/a	988	916	2.9
8	n/a	829	824	2.6
Total :	**26,574**	**31,780**	**31,831**	
		recaptures:	**-155**	
		Total lobsters removed:	**31,676**	

Note: Confidence intervals (95%) 13,440-39,708

2.6.4. Catch data

The total number of lobsters trapped and moved by site is given in the next to last column of each site in Table 2.6.3.3. The number of lobsters estimated to have returned to the sites during the trapping period, and thus caught twice, is deducted from the catch figures giving a total catch of 31,676 lobsters removed from Sites 1, 2, 3 and 7/8. Note that although Site 1 comprised 28.24% of the total area, it yielded 59.5% of the catch. In general, catch increased as the trapping moved from west to east or towards the mouth of the harbor.

2.6.4.1. Comparison of estimates of initial population (N_0) with total catch

The DeLury estimate of N_0 for Sites 1, 2, 3, and 7/8 was 31,780 lobsters (Table 2.6.3.1.). This agrees well with the total catch of 31,676, although there was a significant number of lobsters left on Site 1 (see next section). Since both the DeLury estimate and the total catch are derived from trapping data, it is advisable to use a fishery independent estimate of N_0 to reinforce this data. The estimate of N_0 derived from the dive surveys for these sites was 26,574 (95% C.I.: 17,105-36,043). This is 84% of the total catch. The difference between the dive survey estimate of N_0 and the catch data may be due to the sampling technique (see Section 2.6.5. Summary of Population Estimates) or to lobsters immigrating to the eastern sites from the ship channel, or in the case of Site 1, from beneath the BIW drydock..

2.6.4.2. Pre-dredge estimates of lobster densities

Trapping continued on each site until dredging was due to begin. Diver transects were conducted on all sites except Site 2 after the conclusion of trapping and just before the onset of dredging. Visibility was poor due to dredging on adjacent sites and precluded diving on Site 2.

The results of the pre-dredge dive transects are given in Table 2.6.4.2.1. Transects on Sites 4, 5, 6, 9 and 10, not included in this analysis, showed one lobster each on Sites 6 and 10. Of the four sites selected for continuous monitoring, only Site 1 showed a significant number of lobsters remaining prior to dredging. The C/E value on the last day of trapping on Site 1 was 0.12 lobsters per trap per night set. This was higher than all the other sites except Site 3 which had a value of 1.00. As explained above (Section 2.6.3. Trapping Data), the high value of Site 3 was due to a concentration of trapping effort on the extreme east end of the site during the last three dates of fishing.

Table 2.6.4.2.1.
Pre-dredge lobster count and density for selected sites and haul dates

Site	Date	Transect #	Mean # Lobsters Observed/m^2	SD
1	02/10/99	5	0.050	0.040
2	------	--	----	----
3	11/30/99	2	0.000	0.000
7-8	11/14/99	4	0.000	0.000

Given the higher C/E value on Site 1, we would expect to see a higher density of lobsters in the pre-dredge dive surveys. Table 2.6.4.2.2., below, shows that the mean number of lobsters/m^2 on Site 1 was 0.07 compared to 0.006 on Site 3 and 0.003 on Sites 7/8.

Table 2.6.4.2.2.
Comparison of lobster density estimates for selected sites just prior to dredging with baseline density

Site	Pre-dredge density (lobsters/m^2)	SD	Baseline density (lobsters/m^2)
1	0.070	0.020	0.140
2	------	--	0.070
3	0.006	0.009	0.080
7-8	0.003	0.007	0.025

Comparing pre-dredge and baseline densities, there was a reduction in density of 50% on Site 1, 93.5% on Site 3 and 88% on Sites 7/8. The mean pre-dredge densities for Sites 1, 3, and 7/8 were pooled and weighted according to each site's proportion of the total area. The pooled mean was 0.027 with a standard deviation of 0.01. This gives a 95% confidence interval about the mean of $0.007<u<0.047$. Multiplying the pooled mean by the total area for all monitored sites gives an estimate of 8,247 lobsters left on the monitored sites prior to dredging. Multiplying the mean number of lobsters/m^2 on Site 1 by the area of that site gives an estimate of 6,039 lobsters left on that site prior to dredging or 73% of the total pre-dredge estimate. Both the C/E values and the pre-dredge densities show that the bulk of the lobsters left on the sites prior to dredging were on Site 1.

2.6.5. Summary of population estimates

The baseline estimates of lobster populations on the sites prior to trapping were less than the number trapped on the sites. This may have been due to lobsters migrating into the sites from the ship channel or to sampling error. The diver probably missed some lobsters as he probed the burrows leading to an underestimate of lobster density. Lobsters are not uniformly distributed over the bottom but appear in aggregations probably related to minor features on the bottom and sediment type. This type of distribution increases the standard deviation of the mean density and, when scaled up over large areas, results in broad confidence intervals. We pooled and weighted the density data to reduce the magnitude of the standard deviation. When time and budgets allow, we recommend increasing the length and number of transects to increase the precision of the density estimates.

We observed baseline densities of 0.025-0.14 lobsters/m^2 during daylight surveys conducted in September, 1998. This compares to values of 0.000-0.009 lobsters/m^2 in a November, 1987 daylight surveys and 0.06-0.13 lobsters/m^2 in a September, 1988 nighttime dive study conducted by Normandeau Associates (1988). The Normandeau studies were conducted by divers starting at the shore and swimming out 700 feet, or ~216 meters towards the channel. The paucity of lobsters observed in the Normandeau study was probably due to the fact that most of the transects were in shallow inshore waters. Cooper, Clifford and Newell (1975) conducted diver surveys of lobster habitat off Cape Newagen in 1967. They reported lobster densities of 0.07 to 0.19 lobsters/m^2 which agrees well with the densities we found in Portland Harbor.

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Although the DeLury estimate of N_0 compares well with the total catch (31,780 vs 31,676), if we add the number of lobsters estimated to remain on the sites after trapping (8,247) to the total catch we get a total of 39,923 which is 8,143 more lobsters than the DeLury estimate. The bulk of these lobsters were on Site 1 where the estimate of lobsters left after trapping (6,039) added to the catch gives 24,888 lobsters compared to the DeLury estimate for this site of 19,085.

The total effort expended on Site 1 was 15,072 trap nights. This was sufficient to remove 18,849 lobsters or 1.25 lobsters per trap night. If there were 6,039 lobsters left on the site as previously estimated, and catchability remained roughly constant, it would require 4,831 additional trap nights to remove the rest of the lobsters from this site. Fishing 100 traps on a three night set would require 16 haul dates to expend this much effort.

In summary, diver surveys are a useful way to determine the baseline densities of lobsters but will probably underestimate the true value, at least in soft sediments. Using our values for the standard deviation of mean densities, the proper sample size (number and length of transects) can be determined. When lobsters are removed from the sites, the DeLury estimate can be used to validate the diver surveys although more information on lobster movements adjacent to the sites would be useful. If the lobster trapping occurred at a time of year when there was a significant commercial fishery, the cumulative effort would have to be adjusted to reflect the commercial catch. In our case, most of the legal size lobsters had been caught by the time we started trapping and the commercial fishery should not have significantly affected our effort values.

2.6.6. Reoccupation

After the completion of dredging, Sites 1, 2, 3 and 7/8 were monitored using dive surveys. In addition, traps were fished on Sites 1, 2, 3 from April through November, 1999. The dive data was used to calculate densities as during the pre-dredge phase of the project. Because lobsters were not removed from the sites during the trapping operation, a DeLury estimate could not be calculated. Instead, C/E values were used as an index of abundance.

2.6.6.1. Trapping

Site 1 was fished two days in April, 1999 with 23 traps arranged on one trawl. Sites 1, 2 and 3 were fished on three days in June, July, August, September and October-November, 1999. Each site was fished with a 24-trap trawl. The sites were divided into west, mid and east sections and the respective subdivisions were all fished on the same date, *i.e.* all east sections on the same date. Traps were hauled on three night sets except for four night sets on 7/19, 8/23 and 9/20. All lobsters were counted and measured on-site and sublegals were released at the point of capture. The fishermen kept all legal lobsters. The traps were then moved to the next subdivision of the site for the next trapping interval. In this way, all three subdivisions of all three sites were trapped in each month. The values for C/E for all three subdivisions were used to calculate the mean C/E for each site on each month.

The catch data for each site is given in Table 2.6.6.1.1. The proportion of legal lobsters in the catch varied from 0.6 to 8.3 percent of the total catch. This may underestimate the actual proportion of legal lobsters in the population as larger lobsters exhibit territorial behavior in traps which may prevent more large ones from entering. Small lobsters do not exhibit this behavior (Watson , 1999). The proportion of legals was greatest in July which would be just after the early summer molt.

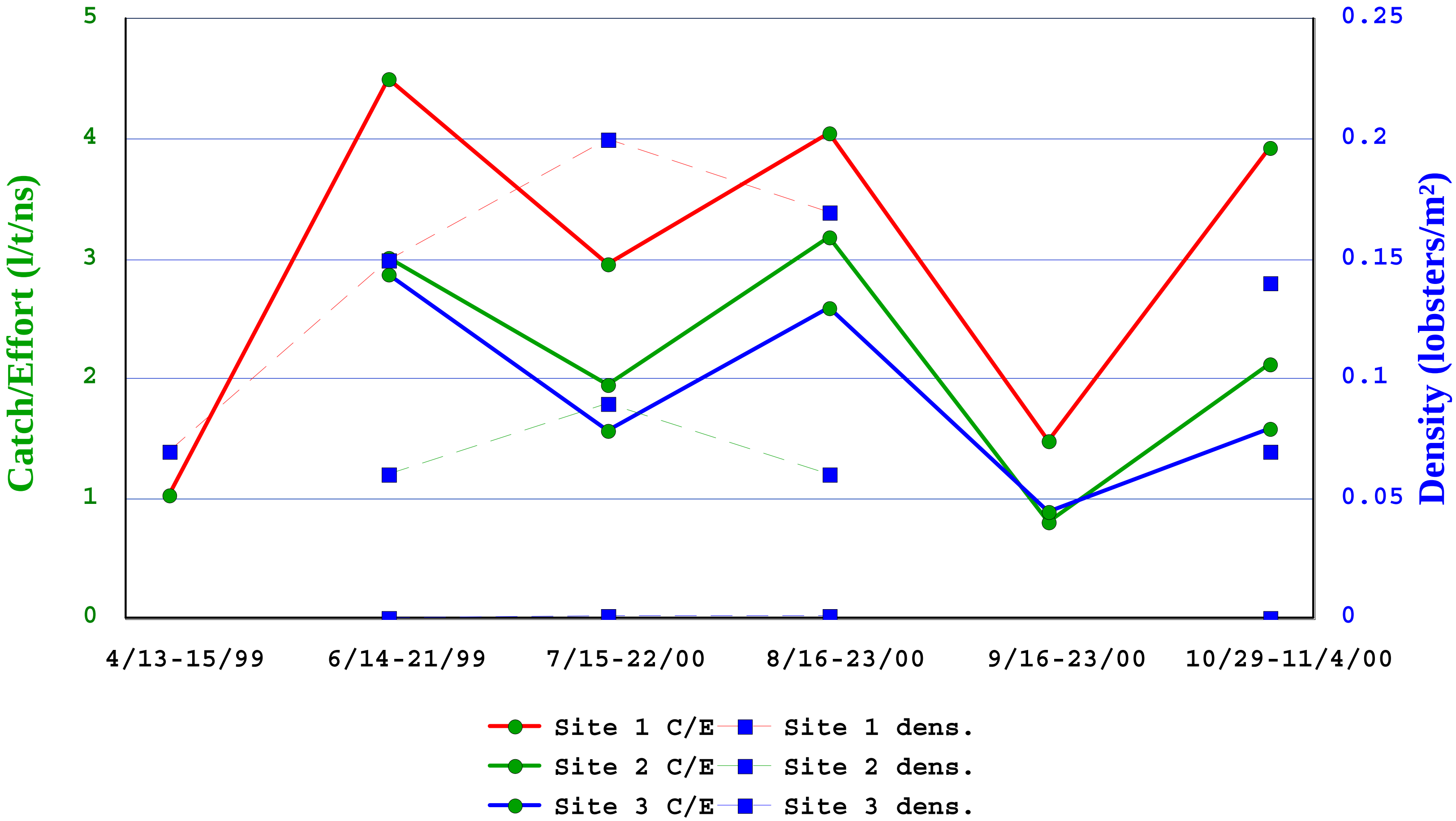
Values for mean C/E for each site at each trapping period are plotted in Figure 2.6.6.1.1. Catch per unit effort on Site 1 increased from 1.03 lobsters per trap per night set in April to 4.51 in June indicating that lobsters were able to recolonize this site (Table 2.6.6.1.1.). The data for percent legal lobsters shows that most of the lobsters immigrating to this site were sublegals (Table 2.6.6.1.1.).

Table 2.6.6.1.1.

Trapping data

Date	0 # sublegal	SD	0 # legal	SD	% legal	Mean C/E	SD
Site 1							
4/13-15/99	57.5	3.5	0.5	0.5	0.9	1.03	0.13
6/14-21/99	323.0	78.4	2.0	1.6	0.6	4.51	1.10
7/15-22/99	220.3	54.3	12.7	5.7	5.3	2.96	0.78
8/16-23/99	317.3	6.0	8.0	2.2	2.4	4.06	0.60
9/16-23/99	109.7	55.4	4.7	1.2	4.1	1.49	0.83
10/29-11/4/99	274.3	76.8	8.7	3.8	3.1	3.93	1.04
Site 2							
6/14-21/99	213.7	64.2	3.7	0.5	1.7	3.02	0.80
7/15-22/99	141.0	30.5	10.7	1.2	7.0	1.95	0.56
8/16-23/99	240.7	50.4	8.0	1.4	3.2	3.19	0.85
9/16-23/99	58.0	11.4	5.3	0.5	8.3	0.8	0.15
10/29-11/4/99	147.7	21.4	5.7	3.3	3.7	2.13	0.34
Site 3							
6/14-21/99	201.0	9.2	5.7	0.5	2.7	2.87	0.13
7/13-22/99	118.7	2.5	5.0	0.8	4.0	1.57	0.18
8/16-23/99	204.3	41.3	4.3	4.0	2.1	2.59	0.25
9/16-23/99	67.3	11.3	1.7	1.2	2.5	0.90	0.26
10/29-11/4/99	108.0	9.9	5.3	3.4	4.7	1.58	0.15

Figure 2.6.6.1.1.
Values for mean C/E for each site at each trapping period



Catch per unit effort values dropped at all sites in July just after the molt. As Table 2.6.6.1.1. shows, this is due to a reduction in the sublegal portion of the catch. By August, the sublegal portion of the catch had returned to June levels. The sharp drop in C/E in September was probably due to a hurricane which struck September 16, 1999. Jury, Watson and Howell (1995) reported similar observations during the passage of Hurricane Bob along the Maine-New Hampshire coast in 1991. Although the wave action in Portland Harbor was minimal, there was a considerable fresh water event on this date. Catch per unit effort recovered in October.

It is difficult to compare the C/E values of the reoccupation trapping with those of the pre-dredge trapping since lobsters were being removed from the sites during the pre-dredge trapping. If we choose the first three trapping dates of the pre-dredge trapping and assume that not enough lobsters had been removed to significantly effect the catch per unit effort at that point, we can compare the mean of these three dates which fell in early to mid November,1998 with the reoccupation trapping period of October 29-November 4, 1999**.** Table 2.6.6.1.2. gives the results of this comparison. There is no significant difference (alpha $_{2\,(0.05)}$) between the mean C/E values on Sites 1 and 2 for 1998 and 1999. The mean C/E on Site 3 however was significantly less (alpha $_{2(0.05)}$) in October- November 1999 than for the same time interval in 1998.

Table 2.6.6.1.2.
Comparison of mean C/E from baseline and reoccupation trapping

	Baseline			Reoccupation		
Site	**Date**	**Mean C/E**	**sd**	**Date**	**Mean C/E**	**sd**
1	11/7-12/98	4.27	0.5	10/29-11/4/99	3.93	1.04
H_0: u_1=u_2 t=1.03 $t_{0.05\,(2)(4)}$=2.776 accept H_0						
2	11/14-18/98	1.77	0.67	10/29-11/4/99	2.13	0.34
H_0: u_1=u_2 t=1.71 $t_{0.05(2)(4)}$ = 2.776 accept H_0						
3	11/7-12/98	2.50	0.76	10/29-11/4/99	1.58	0.15
H_0; u_1 = u_2t= 4.18 $t_{0.05\,(2)(4)}$ = 2.776 reject H_0						

2.6.6.2. Dive surveys

Table 2.6.6.2.1. gives the mean and standard deviation of the number of lobsters/m^2 on Sites 1, 2, 3 and 7/8 as determined by dive surveys. The April 28, 1999 dive on Site 1 yielded an estimated density of 0.07 lobsters/m^2 which was the lowest density reported for this site. The diver reported that the bottom morphology consisted of angular outcrops of bare clay exposed by the dredging and no benthic infauna. Concern was expressed as to whether a lack of food organisms would prevent lobsters from recolonizing this bottom. By the June 4 dive, however, the estimated density had slightly more than doubled to 0.15 lobsters/m^2 and the bottom had been colonized by a variety of annelid worms, burrowing amphipods and mud shrimp. The lobsters tended to burrow at the tops and bases of the clay outcrops.

Table 2.6.6.2.1.
Reoccupation estimates of lobster density

	Site 1		Site 2		Site 3		Site 7/8	
Date	**0 # /m^2**	**SD**	**0 # /m^2**	**SD**	**0 # /m^2**	**SD**	**0 # /m^2**	**SD**
4/28/99	0.07	0.04	-----	-----	-----	-----	-----	-----
6/14/99	0.15	0.08	0.06	0.03	0.03	0.01	0.02	0.005
7/21/99	0.20	0.04	0.09	0.03	0.05	0.02	0.02	0.01
8/20/99	0.17	0.06	0.06	0.02	0.03	0.02	0.03	0.02
11/2/99	0.14	0.07	0.07	0.07	0.01	0.01	0.01	0.01

Lobster densities on Sites 1 and 2 returned to levels observed at the start of the project. Densities on Sites 3 and 7/8, however, remained consistently lower. Table 2.6.6.2.2. shows the baseline densities observed on September 12-18, 1998 as compared to reoccupation densities observed November 2, 1999. The densities on Sites 1 and 2 are the same for both dates suggesting rapid recolonization of these sites; the densities on Sites 3 and 7/8 are much lower in 1999. This agrees with the trapping data for Sites 3 and suggests that lobsters did not return to the westernmost sites in the numbers that were seen there before dredging. This conclusion is reinforced by conversations with some of the fishermen fishing those areas (Peter Pray and Dan Harriman , pers. comm.).

Table 2.6.6.2.2.
Comparison of baseline and reoccupation lobster densities

	Baseline Densities 9/12-18/98		Reoccupation Densities 11/2/99	
Site	**Mean #/m^2**	**SD**	**Mean #/m^2**	**SD**
1	0.14	0.09	0.14	0.07
2	0.07	0.09	0.07	0.07
3	0.08	0.02	0.01	0.01
7-8	0.025	0.004	0.01	0.01

2.6.6.3. Conclusions

The trapping effort proved to be an effective means of removing most of the lobsters prior to dredging, thus mitigating the potential impact. More effort was needed on Site 1 where the estimated densities were highest. In future efforts of this type, once enough lobsters have been removed to reduce the C/E, the application of the DeLury technique might be useful in estimating the effort required to remove the bulk of the remaining lobsters. Although the estimated dive densities worked well as a relative index of abundance, longer transects are required to reduce the variance.

Lobsters and other benthic organisms readily recolonized Sites 1 and 2, but the westernmost sites showed relatively little recovery by the end of the project period. Although there is no obvious reason for this anomaly, it may simply be natural variation. Personal observations in other parts of Casco Bay indicate that lobster abundance seems to be shifting away from shoal waters, perhaps explaining in part the slow reoccupation of the westernmost areas.

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