3.0 RESULTS AND DISCUSSION

3.1 CHARACTERIZATION OF OYSTER BEDS

The following sections present the results of monitoring activities conducted on the Delaware Bay oyster beds near Kelly Island including water quality monitoring, an oyster spat settlement study, and oyster dredge assessment of seed and lease beds.

3.1.1 Water Quality Monitoring

The following sections present and discuss the results of continuous water quality monitoring for physical/chemical parameters including total suspended solids, and the estimation of sedimentation rates for Delaware Bay oyster beds near Kelly Island.

3.1.1.1 Continuous Monitoring with Water Quality Meters

Water quality monitoring was conducted on four Delaware Bay oyster beds near Kelly Island from May to November 2001 (see Figure 2-1). At each bed, parameters of temperature, specific conductivity, salinity, dissolved oxygen (DO), pH, turbidity, and chlorophyll were measured at 30-minute intervals. This continuous record of water quality data was compiled for each oyster bed barring the occasional malfunction of individual probes or brief interruption for probe servicing and replacement. In the sections that follow, water quality data for each parameter are presented on an annual scale with each data point constituting a monthly mean. Additional figures are provided in Appendix A that display the water quality data on a monthly scale with each data point representative of a daily mean.

3.1.1.2 Temperature

Water temperature followed a strong seasonal pattern over the 2001 monitoring period and was very consistent among the four Delaware Bay oyster beds near Kelly Island (Figure 3-1). In May, temperatures at Beck's Rock, Delaware Lower Middle, Drum Bed, and Lease Bed 102 closely averaged about 17°C. With approach of summer, water temperature increased rapidly and by June averaged 24°C. In the ensuing summer months of July and August, temperature increased incrementally and averaged of 25°C and 26°C, respectively. A marked cooling trend was evident by September with temperatures averaging 23°C. Thereafter, in October and November, temperatures decreased quicker with averages 16°C and 12°C, respectively.

3.1.1.3 Specific Conductivity

In general, specific conductivity increased linearly over the 2001 monitoring period and was very consistent among the four Delaware Bay oyster beds near Kelly Island (Figure 3-2). In May, specific conductivity was lowest at Beck's Rock, Delaware Lower Middle, Drum Bed, and

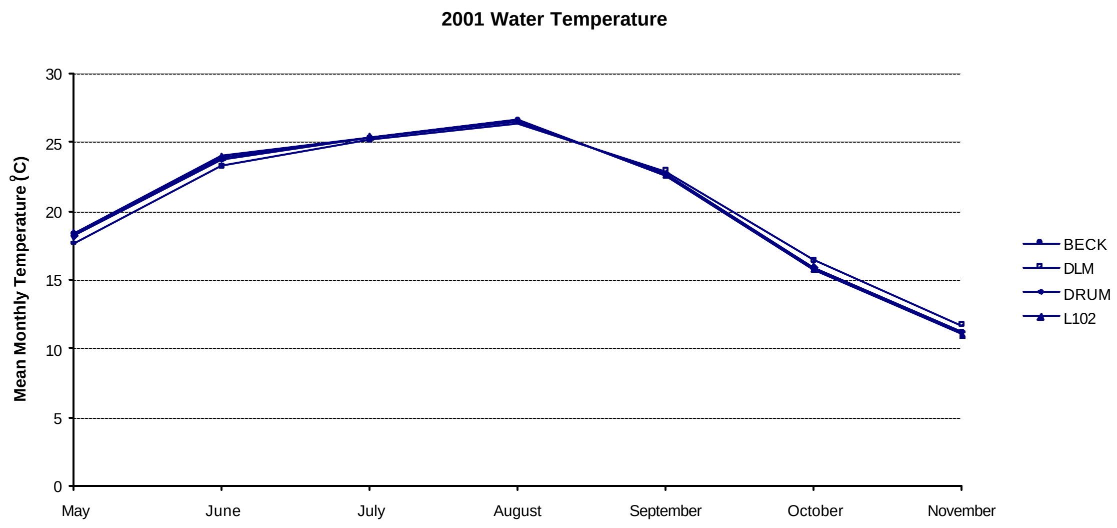


Figure 3-1. Mean monthly water temperature measured during 2001 at Delaware Bay oyster beds, Beck's Rock, Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bead (102).

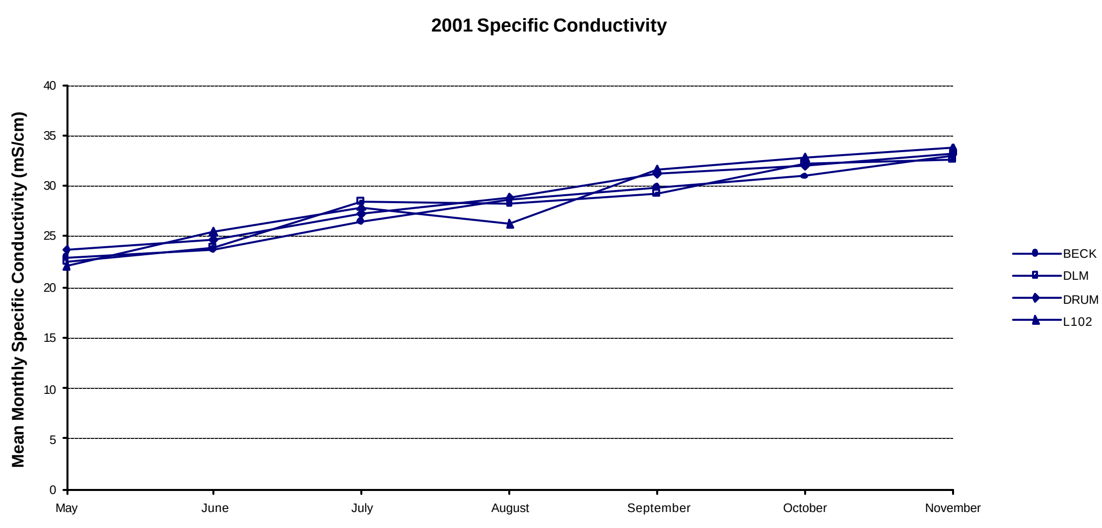


Figure 3-2. Mean monthly specific conductivity measured during 2001 at Delaware Bay oyster beds, Beck's Rock, Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bead (102).

Lease Bed 102 and averaged only 23-mS/cm. Throughout the summer months and continuing into the fall, specific conductivity increased incrementally by about 1.7-mS/cm per month. By November, the average conductivity was highest at approximately 33-mS/cm. The increasing trend of specific conductivity over the monitoring period followed an expected seasonal pattern as springtime freshwater inputs abated with the approach of the dryer summer and fall seasons.

3.1.1.4 Salinity

Salinity closely followed the seasonal pattern evinced by specific conductivity and gradually increased over the 2001 monitoring period (Figure 3-3). In May, salinity was lowest at Beck's Rock, Delaware Lower Middle, Drum Bed, and Lease Bed 102 and averaged only 14-ppt. From June to November, salinity increased incrementally by slightly more than 1-ppt per month, and in the latter month, the average salinity was approximately 21-ppt. By the same reasoning as discussed for specific conductivity, salinity would be expected to increase from the wet spring into and through the dryer summer and fall seasons.

3.1.1.5 Dissolved Oxygen

Dissolved oxygen (DO) followed a distinctive seasonal pattern during the 2001 monitoring period marked by a decrease from spring into summer and recovery in the fall (Figure 3-4). In May and June, concentrations at Beck's Rock, Delaware Lower Middle, Drum Bed, and Lease Bed 102 were steady and averaged 7.5-mg/L. In July and August, average concentrations decreased to a low of about 5-mg/L. From September to November, average concentrations progressively increased and in the latter month reached a high of about 9-mg/L. Overall, DO concentrations were rather consistent among the oyster beds with few exceptions. If at all, the average concentrations at Delaware Lower Middle most often appeared as outliers; in June, the average concentration was greater than all others by 1-mg/L, while in September and October, almost 2-mg/L less. This pattern suggests that a lag effect may be occurring at this oyster bed, which could be related to its location.

3.1.1.6 pH

Average monthly pH was relatively stable over the 2001 monitoring period and generally followed a consistent pattern among the four Delaware Bay oyster beds (Figure 3-5). From May to November, monthly averages at Beck's Rock, Delaware Lower Middle, Drum Bed, and Lease Bed 102 ranged from 7.4 to 8.0. Average measures at Beck's Rock were often lowest, and from June to September, ranged 0.2 to 0.3 units less than all others. The pH at this oyster bed may be influenced by its proximity to freshwater inputs, which generally support a much lower pH than marine influenced waters. Beck's Rock is located closest to the Leipsic River, the principal freshwater source in the vicinity of Kelly Island.

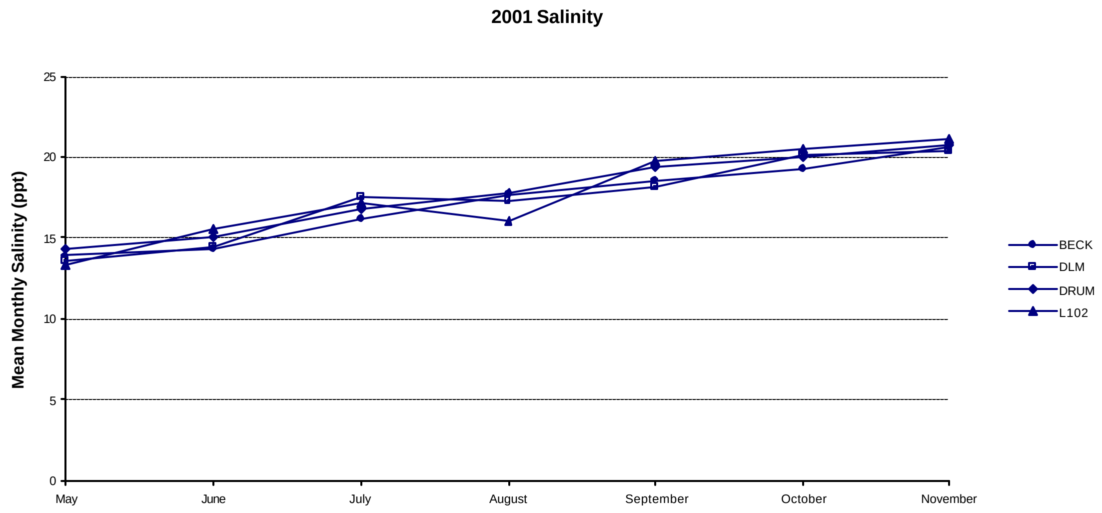


Figure 3-3. Mean monthly salinity measured during 2001 at Delaware Bay oyster beds, Beck's Rock, Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bead (102).

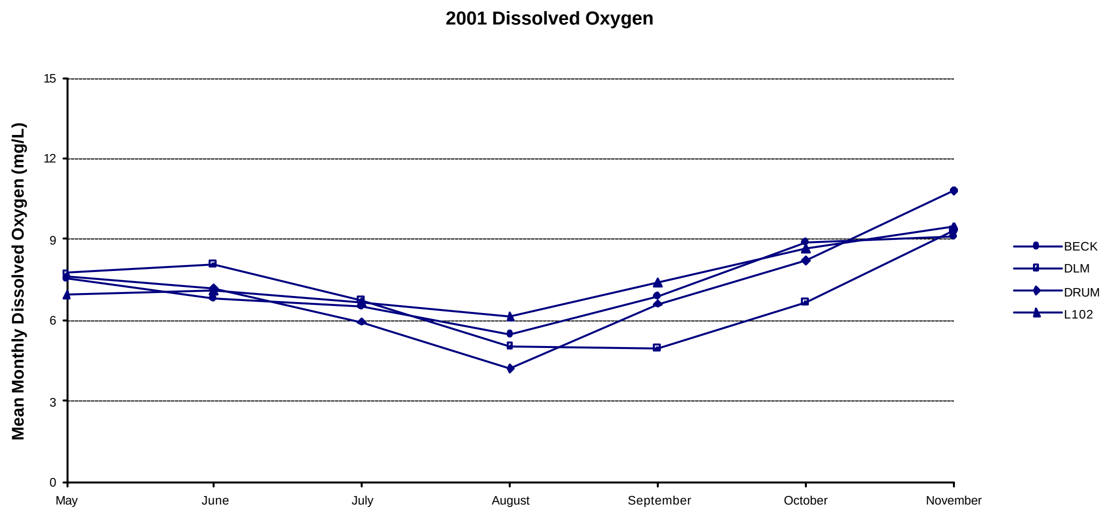


Figure 3-4. Mean monthly dissolved oxygen measured during 2001 at Delaware Bay oyster beds, Beck's Rock, Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bead (102).

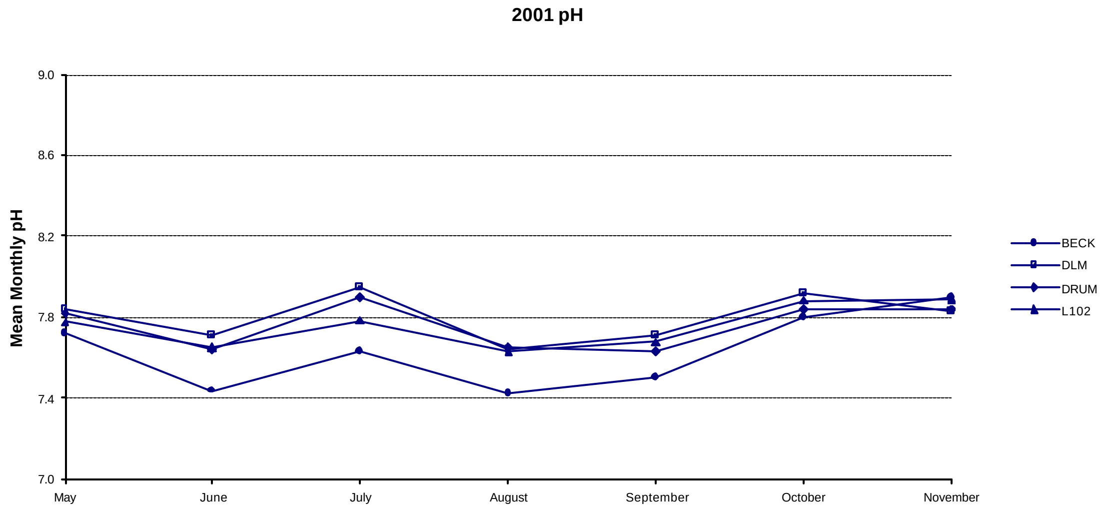


Figure 3-5. Mean monthly ph measured during 2001 at Delaware Bay oyster beds, Beck's Rock, Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bead (102).

3.1.1.7 Turbidity

Turbidity was generally uniform over the 2001 monitoring period, apart from several spikes that resulted in elevated averages (Figure 3-6). From May to November, monthly averages at Beck's Rock, Delaware Lower Middle, Drum Bed, and Lease Bed 102 clustered around 100-NTU. This pattern was consistent with that observed during the 2000 pre-construction monitoring (Kelley and Sillett 2001). Higher turbidity averages, most notably occurring in September, are most likely artifacts of epifaunal organisms and fouling. The turbidity probe in particular is most sensitive to these factors as it functions by measuring the amount of light that penetrates the water. As the probe lenses become fouled, the value of measurements increase often radically.

3.1.1.8 Chlorophyll

Chlorophyll followed a predictable seasonal pattern over the 2001 monitoring period among the four Delaware Bay oyster beds (Figure 3-7). Concentrations are generally highest in the springtime as algal productivity peaks with the warming water temperature and influx of nutrient from runoff. In May, chlorophyll concentrations at Beck's Rock, Delaware Lower Middle, Drum Bed, and Lease Bed 102 were highest with averages ranging from 40 to 64-µg/L. As the summer progresses, nutrient loads decrease and it is likely that more consumers are available to reduce algae populations. From June onward, chlorophyll concentrations for the most part ranged less than 20-µg/L. In the fall and continuing into winter, chlorophyll concentrations tend to decrease as the water temperature cools and algal productivity wanes. In November, except for a high average concentration at Lease Bed 102 of 28-µg/L, concentrations at the remaining oyster beds were among the lowest of the monitoring period at about 10-µg/L.

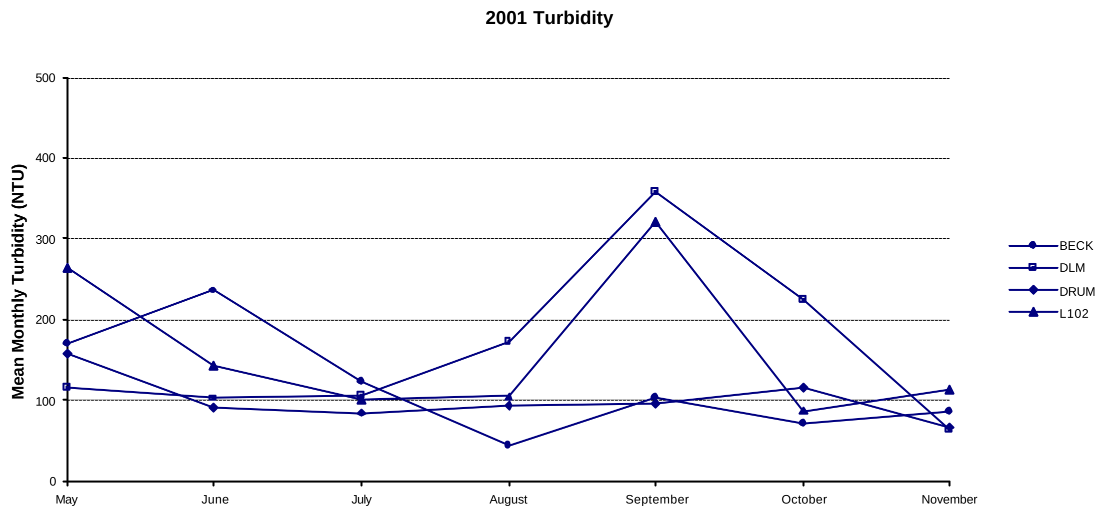


Figure 3-6. Mean monthly turbidity measured during 2001 at Delaware Bay oyster beds, Beck's Rock, Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bead (102).

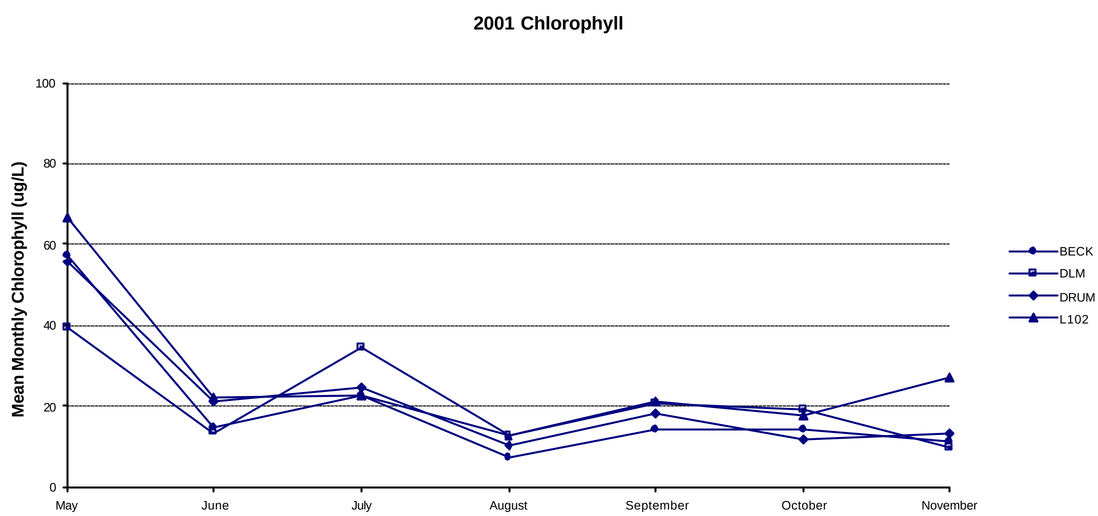


Figure 3-7. Mean monthly chlorophyll measured during 2001 at Delaware Bay oyster beds, Beck's Rock, Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bead (102).

3.1.1.9 Total Suspended Solids

Total suspended solids (TSS) measured at the Delaware Bay oyster beds were somewhat variable over the 2001 monitoring period, but for the most part ranged less than 100-mg/L (Table 3-1; Figure 3-8). A slight trend might be discerned as decreasing from late spring and early summer into the late summer. From June to July, TSS concentrations averaged about 75-mg/L, while from mid-August to September, concentrations were about 50-mg/L. By the end of the monitoring period, TSS concentrations appeared to be increasing. In mid-December, concentrations ranged from 94 to 264-mg/L.

Table 3-1. Total suspended solids concentrations (mg/L) measured at the Delaware Bay oyster beds near Kelly Island during 2001

Date	BECK	DLM	DRUM	L102
31-May	98	86	82	75
14-Jun	34	69	50	107
3-Jul	128	51	50	102
23-Jul	49	106	77	50
31-Jul	66	65	77	53
15-Aug	17	50	36	--
28-Aug	100	60	49	23
19-Sep	32	19	40	77
12-Oct	78	100	45	39
2-Nov	40	30	44	42
12-Dec	133	94	103	264

3.1.1.10 Sedimentation Rates

For the most part, sediment accumulation rates were successfully measured for the four Delaware Bay oyster beds monitored near Kelly Island (Table 3-2). Several of the sediment traps, however, were compromised by fish that took up residence in the sediment cups (principally, oyster toadfish and American eel). As the particulate material that settled in the sediment cups was typically very flocculent, the presence of a fish greatly reduced the amount of sediment that was collected. This occurred most often at Becks Rock, and from August to October, no sediment data were collected at this station. To a lesser extent, this problem also occurred at the remaining three stations. Four replicates were lost at Lease Bed 102 (L102), three at Drum bed (DRUM), and one at Delaware Lower Middle (DLM).

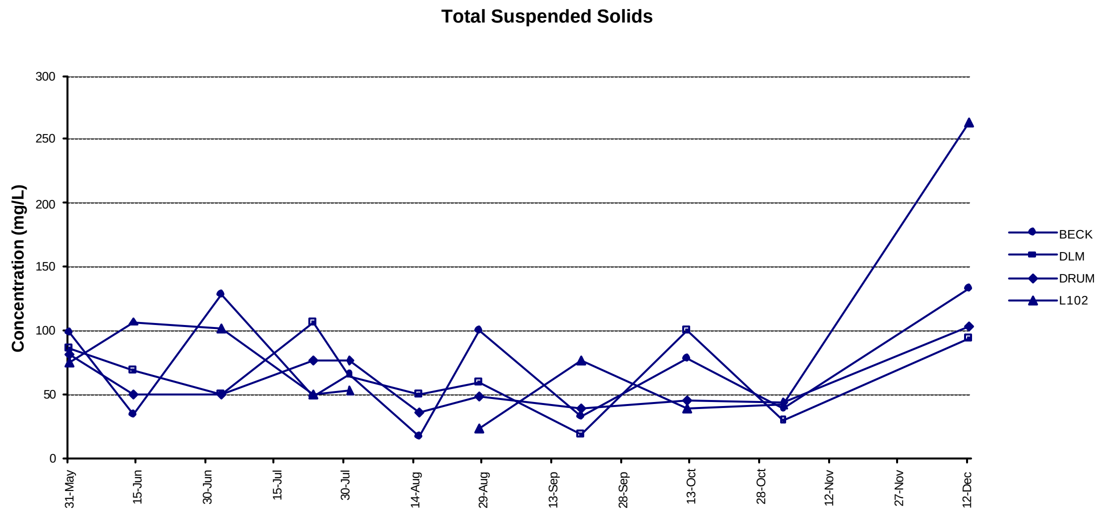


Figure 3-8. Total suspended solids measured during 2001 at Delaware Bay oyster beds, Beck's Rock (BECK), Delaware Lower Middle (DLM), Drum Bed (DRUM), and Lease Bed 102 (L102).

Table 3-2. Sedimentation accumulation rates measured at Delaware Bay oyster beds near Kelly Island during 2001

Station	Deployment Mid-Date	Time (days)	Rep	Sediment (g)	Sediment/Area (g/cm^2)	Sediment Rate (g/cm^2/year)
BECK	9-Jun	10.1	1	352.9	7.78	281.89
			2	348.1	7.67	278.05
	24-Jun	19.0	1	695.3	15.33	293.93
			2	683.1	15.06	288.78
	10-Jul	14.1	1	510.9	11.26	291.77
			2	405.1	8.93	231.35
	24-Jul	13.9	1	843.0	18.58	487.04
			2	684.0	15.08	395.18
	8-Aug	15.0	1	NS	-	-
			2	NS	-	-
	21-Aug	12.9	1	NS	-	-
			2	NS	-	-
	8-Sep	22.2	1	NS	-	-
			2	NS	-	-
	30-Sep	22.9	1	NS	-	-
			2	NS	-	-
	25-Oct	26.0	1	NS	-	-
			2	NS	-	-
	25-Nov	35.0	1	549.2	12.11	126.20
			2	589.6	13.00	135.49
DLM	9-Jun	10.1	1	237.8	5.24	189.69

Table 3-2. Cont'd						
Station	**Deployment Mid-Date**	**Time (days)**	**Rep**	**Sediment (g)**	**Sediment/Area (g/cm^2)**	**Sediment Rate (g/cm^2/year)**
			2	233.0	5.14	185.86
	24-Jun	19.0	1	615.7	13.57	260.97
			2	607.7	13.40	257.58
	10-Jul	14.1	1	497.6	10.97	284.56
			2	492.1	10.85	281.42
	24-Jul	14.0	1	638.0	14.06	366.12
			2	625.5	13.79	358.95
	8-Aug	14.9	1	287.1	6.33	154.82
			2	333.1	7.34	179.63
	21-Aug	13.0	1	584.9	12.89	361.81
			2	609.4	13.43	376.97
	8-Sep	22.1	1	687.3	15.15	250.45
			2	631.5	13.92	230.12
	30-Sep	22.9	1	NS	-	-
			2	667.4	14.71	234.46
	25-Oct	26.0	1	340.4	7.50	105.36
			2	370.0	8.16	114.52
	25-Nov	35.0	1	771.5	17.01	177.21
			2	701.1	15.45	161.04
DRUM	9-Jun	10.1	1	175.6	3.87	140.39
			2	198.7	4.38	158.86
	24-Jun	19.0	1	558.4	12.31	236.79
			2	586.0	12.92	248.49
	10-Jul	14.1	1	467.6	10.31	267.61
			2	253.7	5.59	145.19
	24-Jul	14.0	1	534.8	11.79	307.13
			2	588.1	12.96	337.73
	8-Aug	15.0	1	296.3	6.53	159.44
			2	287.5	6.34	154.70
	21-Aug	13.1	1	740.4	16.32	455.13
			2	707.6	15.60	434.97
	8-Sep	22.0	1	NS	-	-
			2	NS	-	-
	30-Sep	22.9	1	492.2	10.85	172.91
			2	508.4	11.21	178.61
	25-Oct	26.0	1	220.5	4.86	68.20
			2	207.5	4.57	64.18
	25-Nov	35.0	1	NS	-	-
			2	567.5	12.51	130.34
L102	9-Jun	10.0	1	242.2	5.34	194.13
			2	218.2	4.81	174.89
	24-Jun	19.1	1	583.0	12.85	245.12
			2	569.3	12.55	239.36
	10-Jul	13.9	1	314.4	6.93	181.74
			2	315.2	6.95	182.21
	24-Jul	14.1	1	487.4	10.74	277.16
			2	471.7	10.40	268.23
	8-Aug	14.9	1	178.0	3.92	95.81

Table 3-2. Cont'd						
Station	**Deployment Mid-Date**	**Time (days)**	**Rep**	**Sediment (g)**	**Sediment/Area (g/cm^2)**	**Sediment Rate (g/cm^2/year)**
			2	185.3	4.08	99.74
	21-Aug	13.0	1	287.8	6.34	177.98
			2	NS	-	-
	8-Sep	22.0	1	654.1	14.42	238.80
			2	603.3	13.30	220.25
	30-Sep	22.9	1	573.7	12.65	201.37
			2	548.3	12.09	192.45
	25-Oct	26.0	1	NS	-	-
			2	NS	-	-
	25-Nov	35.0	1	791.8	17.45	181.94
			2	NS	-	-

In general, sediment accumulation rates averaged about 250-g/cm^2/year (based on dry weight) among the replicate samples collected at the four oyster bed monitoring stations (Table 3-2; Figure 3-9). Rates were variable over the monitoring period, and much higher earlier from June to August. In those months, mean rates ranged from 100 to 445-g/cm^2/year, while from September to November, they ranged less than 250-g/cm^2/year. Higher rates in late spring and summer may be reflective higher flows from spring runoff coincident with increased agricultural activity.

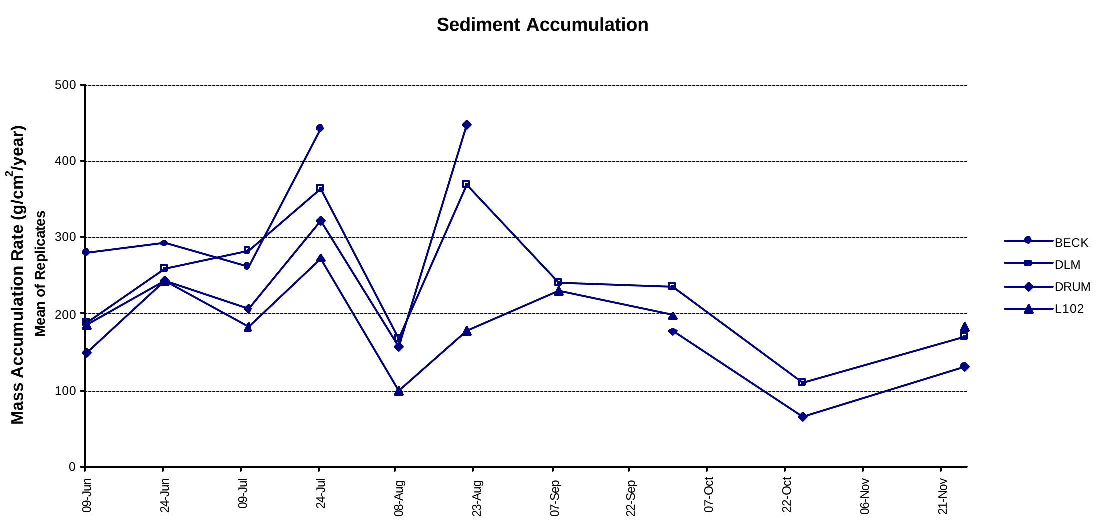


Figure 3-9. Mean sediment accumulation rates for Delaware Bay oyster beds near Kelly Island during 2001

Much of the particulate material that was deposited into the collection cups was most likely in flux within the lower water column of the Delaware Bay. With intense tidal currents and wind action, sediments alternate between resuspension and depositional cycles. In the case of the sediment traps, as the particulate material encounters the attenuated flow present at the opening to a sediment cup, it is deposited from the water column. Thus, estimates of sedimentation rates at best grossly overestimate net sedimentation.

By comparison, the accumulation rates of the four Delaware Bay oyster beds were much higher than those measured in the Delaware River approximately 25-miles upstream. In the spring of 2001 spanning April and May, Versar conducted a similar study in the vicinity of Pea Patch Island (Llanso and Kelley 2001). Accumulation rates in that study ranged from 70 to 134-g/cm^2/year, and at times three times less than those of the current study. The sediment traps for this study were deployed alongside of the Bulkhead Shoal Channel in 6 to 8 feet of water.

3.1.2 Spat Settlement Rates

Oyster spawning most likely began sometime before the deployment of the spat settlement trays. Spat were present on settlement trays recovered from the initial deployment spanning 3 to 15 July (Table 3-3; Figure 3-10). Water temperature is regarded as an important factor influencing oyster spawning. In a study of Gulf Coast oysters, spawning was initiated only after water temperature reached 25ºC (Kennedy, et al 1996). The water temperature at the Delaware Bay oyster beds reached 25ºC during mid-June (Appendix figure A-1), therefore it is likely that oyster spawning began a couple of weeks prior to spat settlement trays were deployed. At the other end of the season, spawning appeared to end by mid-September. No spat were identified on settlement trays deployed from 19 September to 12 October.

Table 3-3. Settlement rates of oyster spat (spat/100-cm2/day) at the Delaware Bay seed and lease oyster beds near Kelly Island during 2001

Date Deployed	Soak Days	Lease Beds					Seed Beds				
		LB-01	LB-02	LB-05	LB-08	LB-102	DLM	Drum	Martin's Rock	Ridge	Silver
3-Jul	14	0.349	0.297	0.130	0	0.044	0.061	0.039	0.077	0	0
17-Jul	14	0.026	0	0.017	0	0	0	0	0	0	0
31-Jul	15	0.419	0.045	0.041	0	0.020	0.088	0.089	0.123	0.048	0.019
15-Aug	13	0.043	0.019	0	0	0	0.036	0	0	0	0.009
28-Aug	22	0.191	0.073	0.023	0.013	0	0.056	0.105	0.105	0.013	0.058
19-Sep	23	0	0	0	0	0	0	0	0	0	0
12-Oct	21	0	0	0	0	0	0	0	0	0	0

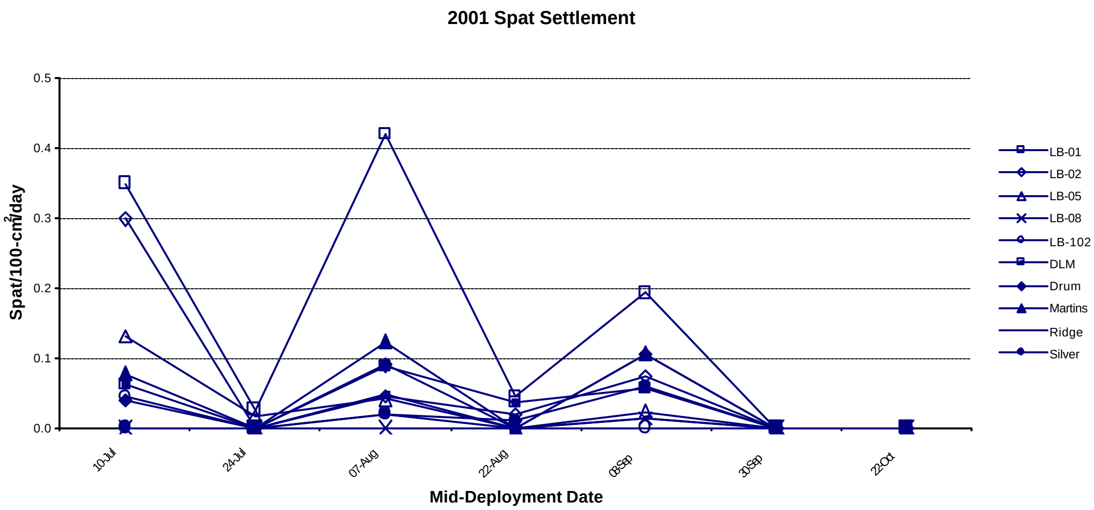


Figure 3-10. Spat settlement rates calculated for Delaware Bay oyster beds off Kelly Island during 2001

Spat settlement rates were variable over the monitoring period from July to October suggesting that the oysters in the Delaware Bay near Kelly Island might be attuned to a monthly cycle (Figure 3-10). In particular, from July through mid-September, settlement rate peaks ranging as high as 0.42-spat/100-cm^2/day were followed intervals of reduced spat-set with at most 0.05-spat/100-cm^2/day. As the spat trays were generally deployed for two weeks at a time, the interval between peaks was approximately one month. In every case, the interval in which the settlement rate peaked coincided with a full moon (5 July, 4 August, and 2 September). As oysters typically spend 15-days as larvae following fertilization, than spawning would more directly coincide with the phase of the new moon. As this behavior has not been reported previously, further field studies involving the manipulation of settlement tray deployment times would be recommended to confirm this pattern.

Spat settlement rates for most Delaware Bay oyster beds generally ranged less than 0.1-spat/100-cm^2/day, however at some lease beds, rates were often much higher (Figure 3-10). Lease Bed 01 always maintained the highest rate of settlement, and over the three peaking intervals, ranged from 0.2 to 0.4-spat/100-cm^2/day. Lease Bed 02 was more productive than most in early July at 0.3-spat/100-cm^2/day, but thereafter performed as the others. In contrast, Lease Bed 08 was the poorest of all in terms of productivity. Settlement was recorded at this bed only in early September, and that at the very low rate of 0.01-spat/100-cm^2/day. Among the seedbeds, settlement rates at Martin's Rock and Drum Bed were often highest. Settlement rates at these two were the only seed beds to exceed 0.1-spat/100-cm^2/day, Martin's Rock in August and both of them in September.

3.1.3 Characterization of Oyster Beds

Delaware oyster seedbeds and nine beds near Kelly Island were surveyed by oyster dredge during early summer and fall during 2001. In the sections that follow, we present an overview of the oyster beds by season describing the composition and size of oyster in each bed, indications of recent mortality as evidenced by boxes or empty shells that remain articulated, recent mortality due to predation as evidenced by boxes with drill holes in them, and the presence of the significant predators, the oyster drill. A follow-up survey is planned for spring 2002. The results of this survey will be reported as soon as the data are available.

3.1.3.1 Early Summer

The seedbeds near Kelly Island were mainly composed of live oysters during the early summer dredge survey (Table 3-4). Among the nine beds surveyed, the percent shell comprising material recovered by the dredge was low and ranged from 7 to 31 percent. Mean numbers of live oysters per bushel of dredge material ranged from 312 to 589 and correlated negatively with the mean oyster size. Silver Bed East, with the highest number of oysters at 589 per bushel material, on average, had the smallest oysters at 54-mm. Delaware Lower Middle with the largest mean oyster size at 66-mm averaged 415 oysters per bushel of material. Live oysters categorized by size showed that a preponderance of the oysters from the seedbeds were in the small class, and market size oysters made up a quarter or less of the total. Spats were less abundant in most cases and may have been undercounted; among the categories, they were the least easily identifiable. Boxes, or articulated oyster shells indicating recent mortality, were comparable among the seedbeds ranging from 43 to 84 per bushel material. The means of box size were similar to that for live oysters suggesting that mortality was spread evenly in the population. By oversight, boxes were not measured at Drum Bed and Silver Bed. Indicators of predation were observed on only three of the nine seedbed sampling areas. From Martin's Rock and Ridge Bed East and West, boxes with drill holes comprised 20% or less of all boxes. The oyster drills may have been selectively predating on smaller oyster as the mean sizes of these boxes averaged close to 30-mm. Oyster drills were present in low incidence but only on those beds for which boxes with oyster drill holes were recorded.

The lease beds near Kelly Island had substantially fewer oysters than the seedbeds during the early summer dredge survey (Table 3-5). For the most part, oyster shell comprised more than half of the material collected, and at several beds, the recovery was entirely shell. The beds on the western portion of the study area were most depauperate; Lease Bed 08 averaged only 8 live oysters, Lease Beds 09 and 16 had none, and Lease Bed 10 had no recoverable material present. Of the eastern beds, average numbers of live oysters ranged from 13 to 204 per bushel of material. Like the seedbeds, the average size of oysters for most lease beds was relatively small averaging about 65-mm. Lease Bed 02 East had a mean size of 83-mm but only 13 oysters were collected, 7 of which in the market category. The number of boxes relative to live oysters was often substantial ranging from 15% to outnumbering them. The sizes of boxes were comparable to that of live oysters indicating a general mortality. It should noted that shell material recovered from Lease Beds 08, 09, and 16 had little to no boxes indicating that the beds have been barren for awhile. The incidence of boxes with drill holes was significant only at Lease Bed 05, accounting approximately 25% of the boxes. The sizes of the boxes with drill holes at these sites were small relative to the population with means around 35-mm. Reflective of boxes with drill holes, oyster drills, for the most part, were found only at Lease Bed 05.

Table 3-4. Characteristics of Delaware Bay oyster seedbeds near Kelly Island during early summer 2001. Results are reported as the mean of three replicate dredge-tows at each bed.

Oyster Bed	Delaware Lower Middle	Drum	Martin's Rock	Ridge West	Ridge Center	Ridge East	Silver West	Silver Center	Silver East
Percent shell	15	31	24	10	7	10	13	22	7
Live oysters	415	367	312	344	326	329	529	398	589
Mean size (mm)	66.0	55.7	61.8	64.7	64.3	61.7	54.1	54.8	53.7
Spat	28	64	26	28	24	35	28	37	46
Small	287	266	223	248	232	207	477	342	510
Market	99	37	63	64	70	87	24	20	33
Boxes	43	54	45	78	84	84	48	49	47
Mean size (mm)	64.0	NM	51.6	51.9	51.7	53.9	NM	NM	NM
Boxes w/ drill hole	0	0	9	11	3	0	0	0	0
Mean size (mm)	-	-	26.5	33.2	29.1	-	-	-	-
Oyster Drills	0	0	2	3	3	1	0	0	0

Table 3-5. Characteristics of Delaware Bay oyster lease beds near Kelly Island during early summer 2001. Results are reported as the mean of three replicate dredge-tows at each bed.

Oyster Bed	LB-01	LB-02 West	LB-02 East	LB-05 West	LB-05 East	LB-08	LB-09	LB-10	LB-16
Percent shell	43	75	86	62	83	99	100	-	100
Live oysters	204	48	13	32	16	8	0	0	0
Mean size (mm)	55.7	69.1	82.6	67.7	68.1	59.2	-	-	-
Spat	5	3	1	3	2	1	0	0	0
Small	139	29	5	12	7	6	0	0	0
Market	60	17	7	17	7	1	0	0	0
Boxes	32	15	13	30	18	1	0	0	0
Mean size (mm)	46.5	56.7	62.0	50.7	47.5	51.0	-	-	-
Boxes w/ drill hole	1	1	1	7	5	0	0	0	0
Mean size (mm)	26.0	63.0	50.5	32.8	36.6	-	-	-	-
Oyster Drills	0	0	0	1	4	0	1	0	0

3.1.3.2 Fall Survey

The seedbeds of Kelly Island comprised mostly live oyster during the fall survey (Table 3-6). Mean percent shell among the beds ranged from 3 to 43 per bushel of material. The mean number of live oysters was somewhat lower than observed in the early summer and ranged from 119 to 456 per bushel of dredge material. The mean size of oysters remained small and ranged from 50 to 76-mm. The latter measure is close to the cutoff for market size and was the mean for the Delaware Lower Middle. Most notably among the counts by category was the reduction in number of spats and smalls. The former ranged less than 20 per bushel of material for all beds but one. The latter was less by a hundred for most beds except for Silver Bed Center which increased slightly. The number of boxes was comparable to the earlier survey ranging from 43 to 82 per bushel of material, as were the sizes of the boxes ranging from 56 to 78-mm which were reflective of the population mean for live oysters. The numbers of boxes with drill holes ranged less than 15 percent of the total number of boxes and were observed only at Martin's Rock and throughout the Ridge Bed. The mean size of these boxes was less than that for live oysters indicating higher predation on smaller, younger oysters. Coincident with boxes with drill holes, oyster drill were only found on those beds and ranged from 1 to 5.

Table 3-6. Characteristics of Delaware Bay oyster seedbeds near Kelly Island during fall 2001. Results are reported as the mean of three replicate dredge-tows at each bed.

Oyster Bed	Delaware Lower Middle	Drum	Martin's Rock	Ridge West	Ridge Center	Ridge East	Silver West	Silver Center	Silver East
Percent shell	3	43	18	30	17	20	28	15	12
Live oysters	308	215	241	119	203	165	286	456	357
Mean size (mm)	75.7	56.6	66.6	73.0	71.7	68.1	49.8	53.5	54.5
Spat	18	34	18	6	14	14	19	7	8
Small	171	141	143	59	102	93	239	388	290
Market	118	40	79	54	87	58	28	61	59
Boxes	43	46	66	66	72	80	51	82	74
Mean size (mm)	78.1	64.1	65.1	62.4	64.8	60.2	56.1	57.9	60.3
Boxes w/ drill hole	0	0	6	10	6	11	0	0	0
Mean size (mm)	-	-	26.0	39.9	42.6	35.6	-	-	-
Oyster Drills	0	0	1	5	2	3	0	0	0

The lease beds of Kelly Island for the most part had few live oysters during the fall survey (Table 3-7). Bushels of material from most beds were comprised of 90% or more of shell material and less than 20 live oysters with one exception. Lease Bed 01 had 43% shell and 212 live oysters per bushel of material. As observed from the early summer survey, the lease beds of the western portion of the study area had little to no oyster viability. Lease Bed 08, which had been sampled in the summer, was not sampleable due to sedimentation. Conversely, Lease Bed 10, which was not sampleable during summer, yielded two oysters. Lease Beds 09 and 16 yielded shell material, but no live oysters. The size of oysters was relatively small and most were less than 76-mm or the market cutoff. Only the mean from Lease Bed 02 West was greater at 87-mm. Although most of the oysters at Lease Bed 01 were in the small category, the number of spat was very high and comparable to that of the seedbeds. Oyster size by category of the remaining beds was largely divided evenly between smalls and markets. The number of boxes per dredge material was relatively high given the low number of live oysters at most beds. Even at Lease Bed 01, the number of boxes was one-fifth the number of live oysters. As before, the size of boxes was similar to that of live oysters reflecting even mortality in the beds. The number of boxes with drill holes was about 25% of the total number of boxes for most beds. The sizes of these again indicated heavier predation on the smaller oysters. Oyster drills were found at most sites and high count for both seasonal surveys was recorded at Lease Bed 05 East at 9.

Table 3-7. Characteristics of Delaware Bay oyster lease beds near Kelly Island during fall 2001. Results are reported as the mean of three replicate dredge-tows at each bed.

Oyster Bed	LB-01	LB-02 West	LB-02 East	LB-05 West	LB-05 East	LB-08	LB-09	LB-10	LB-16
Percent shell	43	97	98	88	87	-	100	100	100
Live oysters	212	16	5	19	16	0	0	2	0
Mean size (mm)	48.8	87.4	68.8	74.5	73.7	-	-	33.6	-
Spat	65	0	1	2	1	0	0	1	0
Small	93	8	2	9	6	0	0	1	0
Market	54	8	2	9	10	0	0	0	0
Boxes	42	7	3	11	24	0	0	0	0
Mean size (mm)	48.4	69.0	55.3	48.1	63.3	-	-	-	-
Boxes w/ drill hole	8	1	<1	3	5	-	-	-	-
Mean size (mm)	22.4	32.0	58.0	19.9	32.9	-	-	-	-
Oyster Drills	1	1	1	4	9	0	1	2	0

3.1.3.3 Spring Survey 2002

This survey was conducted during April 2002 to evaluate the potential effects of the December 2001 harvest permitted by DNREC on the oyster seed beds (Table 3-8). This effort did not suggest that the winter harvest dramatically reduced the abundance of live oysters as the numbers observed in the spring of 2000 survey were not consistently lower than the fall 2001 survey (Table 3-6). Lease bed oyster abundance in the spring 2002 survey (Table 3-9) was similar to earlier surveys.

3.2 CHARACTERIZATION OF FISHERIES

The fisheries of Kelly Island were characterized principally by four trawling and seining surveys conducted seasonally during 2001. In addition, the horseshoe crab fishery was further investigated by an adult spawning horseshoe crab survey conducted in spring, and a juvenile survey conducted in late summer.

Table 3-8. Characteristics of Delaware Bay oyster seedbeds near Kelly Island during spring 2002. Results are reported as the mean of three replicate dredge-tows at each bed.

Oyster Bed	Delaware Lower Middle	Drum	Martin's Rock	Ridge West	Ridge Center	Ridge East	Silver West	Silver Center	Silver East
Live Oysters	164	366	151	170	184	141	329	311	354
Spat	2	14	4	1	1	0	4	4	9
Small	42	183	35	26	32	15	190	173	206
Market	21	70	49	44	51	31	34	33	39
Mean Size (mm)	65	58	80	81	81	82	54	56	57
% shell	36	9	30	31	22	37	24	21	14
Boxes	25	49	34	36	48	35	33	35	54
Mean Box Size	66	62	83	75	77	81	54	62	59
Boxes w/ drill holes	<1	0	<1	<1	2	<1	0	0	0
Mean Size (mm)	7	-	15	6	37	6	-	-	-
Oyster drills	1	1	0	5	2	5	0	0	0

Table 3-9. Characteristics of Delaware Bay oyster lease beds near Kelly Island during spring 2002. Results are reported as the mean of three replicate dredge-tows at each bed.

Oyster Bed	LB-01	LB-02 West	LB-02 East	LB-05 West	LB-05 East	LB-08	LB-09	LB-10	LB-16
Live Oysters	157	40	36	56	6	1	0	0	2
Spat	30	1	0	1	0	0	0	0	0
Small	23	2	0	1	0	0	0	0	0
Market	12	1	0	1	0	0	0	0	0
Mean Size (mm)	51	45	76	79	99	8	0	0	10
% shell	51	40	70	70	90	100	100	100	100
Boxes	14	11	7	15	3	0	0	0	0
Mean Box Size	54	40	68	69	53	0	0	0	0
Boxes w/ drill holes	0	<1	<1	0	0	0	0	0	0
Mean Size (mm)	-	6	11	-	-	-	-	-	-
Oyster drills	0	0	0	0	0	0	0	0	0

3.2.1 Seasonal Trawling and Seining

In the following sections, the results of the trawling and seining surveys are presented by season. Information on species collected is reported in summary tables. Because of the low number of individuals collected for many species, the count reported in the summary tables is the sum of the three replicate trawls or seine-hauls conducted at each station. The results of trawling and seining for each replicate are reported in Appendix B.

3.2.1.1 Spring Trawling

Sixteen species of fish were collected by trawl during the spring season of sampling, as well as horseshoe crab and blue crab (Table 3-10). The most common fish species included spotted hake, striped cusk-eel, and hogchoker. Spotted hake were taken at all sampling locations, but were most abundant at the south reference location where a total of 46 fish were collected. All of the fish were mostly medium in size with average lengths among trawls ranging from 162 to 187-mm; maximum adult spotted hake size is about 400-mm. Striped cusk-eel was represented at all of the sampling locations but appeared to be more common along the lower nearshore of Kelly Island. Total counts were higher at KI South, KI Central, and Reference South ranging from 19 to 38. Between the Mahon River, KI North, and North Reference, counts ranged 15 or less. The sizes of cusk-eels indicated a community composition of sub-adults to adults with trawl averages ranging from 123 to 202-mm. Hogchokers were represented at all sampling locations but were much more common in the Mahon River and at the north reference area. Total counts of 192 and 299 were four times greater than at other sampling locations. The sizes of hogchokers reflected life stages ranging from juvenile to adult with total lengths ranging from 37 to 195-mm. Several species of fish were common to only a few sampling locations around Kelly Island. American eels were only abundant in the Mahon River with a total count of 22. Oyster toadfish were only collected in trawls conducted at KI north and the north reference area. Most of the remaining fish species were present in limited abundance with an individual collected in one replicate but absent from the others. Bay anchovies were present in low numbers at most sampling locations but occasionally a markedly higher count was recorded. A single replicate trawl at the north reference area netted 21 fish out of a total of 25 for that sampling location.

Horseshoe crabs were more abundant at the south reference location than at any other area (Table 3-10). This was consistent with the better suitability of the nearby Port Mahon beach as a spawning area for the adult crabs. As was observed during the spawning survey conducted at Kelly Island, horseshoe crabs were present in a ratio of 2 males to one female; all of the individuals were adults. Blue crabs were well-represented at all sampling locations except for the north reference area. For the most part, there was an equal mix of males and females and sizes indicated that the crabs were principally juveniles.

Table 3-10. Fish and other species collected by trawl off Kelly Island and reference areas during spring 2001

Species		Ref South	Mahon River	KI South	KI Central	KI North	Ref North
American eel	Count	**3**	**22**	**0**	**0**	**1**	**0**
(Anguilla rostrata)	Mean Length	268.7	214.5	-	-	274.0	-
	Minimum Length	202	152	-	-	-	-
	Maximum Length	232	504	-	-	-	-
Bay anchovy	Count	**3**	**6**	**1**	**0**	**4**	**25**
(Anchoa mitchilli)	Mean Length	113.3	65.8	76.0	-	70.8	77.2
	Minimum Length	87	50	-	-	61	56
	Maximum Length	183	73	-	-	74	96
Atlantic menhaden	Count	**0**	**1**	**0**	**0**	**0**	**0**
(Brevoortia tyrannus)	Length	-	39	-	-	-	-
Alosid sp.	Count	**0**	**0**	**0**	**0**	**1**	**4**
(Alosid)	Mean Length	-	-	-	-	50	38
	Minimu m Length	-	-	-	-	-	35
	Maximum Length	-	-	-	-	-	42
Oyster toadfish	Count	**0**	**0**	**0**	**0**	**3**	**8**
(Opsanus tau)	Mean Length	-	-	-	-	114.7	114.4
	Minimum Length	-	-	-	-	110	64
	Maximum Length	-	-	-	-	130	186
Spotted hake	Count	**45**	**10**	**14**	**23**	**14**	**18**
(Urophycis regius)	Mean Length	167.3	162.5	174.3	171.2	185.5	186.8
	Minimum Length	20	145	140	120	170	159
	Maximum Length	219	194	202	199	235	223
Striped cusk-eel	Count	**19**	**9**	**38**	**22**	**15**	**5**
(Ophidion	Mean Length	144.5	137.0	123.7	124.7	187.7	202.0
marginatum)	Minimum Length	65	105	82	72	99	106
	Maximum Length	211	195	210	229	222	249
Northern pipefish		**1**	**0**	**1**	**0**	**1**	**1**
(Syngnathus fuscus)		147	-	154	-	199	158
Northern searobin	Count	**1**	**0**	**0**	**0**	**1**	**4**
(Prionotus carolinus)	Mean Length	58	-	-	-	55	89.25
	Minimum Length	-	-	-	-	0	71
	Maximum Length	-	-	-	-	0	104
Weakfish	Count	**3**	**4**	**3**	**0**	**1**	**0**
(Cynoscion)	Mean Length	226.3	199.8	202.0	-	189.0	-
	Minimum Length	199	190	195	-	-	-
	Maximum Length	270	212	200	-	-	-
Spot *(Leiostomus*	Count	**0**	**1**	**0**	**0**	**0**	**0**
xanthurus)	Length	-	34	-	-	-	-
Striped bass	Count	**0**	**1**	**0**	**0**	**0**	**0**
(Morone saxatilus)	Length	-	125	-	-	-	-
Black sea bass	Count	**0**	**0**	**0**	**0**	**1**	**3**
(Centropristis striata)	Mean Length	-	-	-	-	111.0	111.3
	Minimum Length	-	-	-	-	-	99
	Maximum Length	-	-	-	-	-	120

Table 3-10. Cont'd							
Species		**Ref South**	**Mahon River**	**KI South**	**KI Central**	**KI North**	**Ref North**
Hogchoker	Count	**34**	**192**	**32**	**9**	**44**	**299**
(Trinectes maculates)	Mean Length	78.5	99.5	67.8	73.0	70.1	81.9
	Minimum Length	48	48	37	49	40	40
	Maximum Length	147	195	170	93	145	185
Winter flounder	Count	**2**	**0**	**0**	**0**	**0**	**0**
(Pleuronectes	Mean Length	39	-	-	-	-	-
americanus)	Minimum Length	36	-	-	-	-	-
	Maximum Length	42	-	-	-	-	-
Windowpane	Count	**0**	**0**	**1**	**0**	**0**	**0**
(Scophthalmus aquosus)	Length	-	-	105	-	-	-
Horseshoe crab – all	Count	**16**	**2**	**0**	**0**	**2**	**3**
(Limulus	Mean Length	217.3	205.0	-	-	212.5	257.0
polyphemus)	Minimum Length	175	200	-	-	195	190
	Maximum Length	269	210	-	-	230	296
Male	Count	**11**	**1**	**0**	**0**	**1**	**1**
	Mean Length	206.4	200.0	-	-	195.0	190.0
	Minimum Length	182	-	-	-	-	-
	Maximum Length	225	-	-	-	-	-
Female	Count	**5**	**1**	**0**	**0**	**1**	**2**
	Mean Length	241.2	210.0	-	-	230.0	290.5
	Minimum Length	175	-	-	-	-	285
	Maximum Length	269	-	-	-	-	296
Blue crab – all	Count	**119**	**58**	**50**	**62**	**30**	**3**
(Callinectes sapidus)	Mean Length	81.6	76.4	84.9	83.6	77.1	59.0
	Minimum Length	36	32	45	35	35	35
	Maximum Length	150	156	140	162	125	70
Male	Count	**44**	**41**	**20**	**29**	**17**	**1**
	Mean Length	82.1	75.5	81.6	77.9	73.4	35.0
	Minimum Length	37	32	45	35	35	-
	Maximum Length	150	156	140	159	115	-
Female	Count	**75**	**17**	**23**	**33**	**13**	**2**
	Mean Length	81.5	78.8	87.6	88.7	81.9	71.0
	Minimum Length	36	47	54	45	50	70
	Maximum Length	105	113	115	162	125	72

3.2.1.2 Spring Seining

Eleven species of fish as well as horseshoe and blue crabs were collected by seine during the spring survey of inshore habitats around Kelly Island (Table 3-11). Five of the fish species were different from those collected by trawl. These included three common forage fish species, striped killifish, mummichog, and Atlantic silverside, and two potential predators, white perch and striped bass. In general, the total catch from spring seining was very low. Many fish species were represented by only 1 or 2 individuals in each replicate seine-haul.

Table 3-11. Fish and other species collected by seine along Kelly Island and reference areas during spring 2001

Species		Ref South	KI South	KI Central	KI North	Ref North
American eel *(Anguilla rostrata)*	Count	**3**	**0**	**2**	**0**	**0**
	Mean Length	445.0	-	377.0	-	-
	Minimum Length	-	-	324	-	-
	Maximum Length	-	-	430	-	-
Bay anchovy *(Anchoa mitchilli)*	Count	**0**	**0**	**0**	**1**	**1**
	Length	-	-	-	NM	50.0
Atlantic menhaden *(Brevoortia tyrannus)*	Count	**0**	**0**	**1**	**0**	**0**
	Length	-	-	52.0	-	-
Spotted hake *(Urophycis regius)*	Count	**0**	**0**	**0**	**1**	**0**
	Length	-	-	-	195.0	-
Striped killifish *(Fundulus majalis)*	Count	**2**	**0**	**1**	**1**	**0**
	Mean Length	83.0	-	106.0	111.0	-
	Minimum Length	81	-	-	-	-
	Maximum Length	85	-	-	-	-
Mummichog *(Fundulus heteroclitus)*	Count	**0**	**0**	**0**	**1**	**0**
	Length	-	-	-	65.0	-
Atlantic silverside *(Menidia menidia)*	Count	**1**	**7**	**1**	**0**	**0**
	Mean Length	95.0	94.4	92.0	-	-
	Minimum Length	-	80	-	-	-
	Maximum Length	-	105	-	-	-
White perch *(Morone Americana)*	Count	**6**	**1**	**0**	**4**	**0**
	Mean Length	236.8	269.0	-	193.8	-
	Minimum Length	210	-	-	125	-
	Maximum Length	305	-	-	225	-
Striped bass *(Morone saxatilus)*	Count	**0**	**0**	**0**	**2**	**0**
	Mean Length	-	-	-	389.0	-
	Minimum Length	-	-	-	375	-
	Maximum Length	-	-	-	403	-
Hogchoker *(Trinectes maculates)*	Count	**1**	**0**	**1**	**1**	**2**
	Mean Length	120.0	-	176.0	178.0	140.5
	Minimum Length	-	-	-	-	130
	Maximum Length	-	-	-	-	151
Winter flounder *(Pleuronectes americanus)*	Count	**0**	**0**	**0**	**0**	**1**
	Length	-	-	-	-	50.0
Horseshoe crab - all *(Limulus polyphemus)*	Count	**53**	**0**	**3**	**20**	**13**
	Mean Length	210.4	-	223.3	216.5	204.0
	Minimum Length	119	-	210	180	115
	Maximum Length	287	-	260	290	279
Male	Count	**37**	**0**	**2**	**16**	**11**
	Mean Length	199.8	-	205.0	204.7	192.9
	Minimum Length	119	-	200	180	115
	Maximum Length	231	-	210	230	225
Female	Count	**6**	**0**	**1**	**4**	**2**
	Mean Length	266.5	-	260.0	263.8	265.0
	Minimum Length	242	-	-	245	251
	Maximum Length	287	-	-	290	279

Table 3-11. Cont'd						
Species		**Ref South**	**KI South**	**KI Central**	**KI North**	**Ref North**
Blue crab – all *(Callinectes sapidus)*	Count	**2**	**2**	**6**	**6**	**19**
	Mean Length	60.5	63.5	64.7	40.0	55.3
	Minimum Length	60	51	49	36	20
	Maximum Length	61	76	68	61	87
Male	Count	**2**	**2**	**2**	**3**	**11**
	Mean Length	60.5	63.5	71.5	47.0	52.1
	Minimum Length	60	51	53	36	20
	Maximum Length	61	76	90	50	87
Female	Count	**0**	**0**	**4**	**2**	**8**
	Mean Length	-	-	61.3	49.5	59.6
	Minimum Length	-	-	49	38	44
	Maximum Length	-	-	68	61	72
Diamondback terrapin *(Malaclemys terrapin)*	Count	**0**	**2**	**2**	**0**	**0**
	Mean Length	-	126.0	149.0	-	-
	Minimum Length	-	115	116	-	-
	Maximum Length	-	137	182	-	-

Horseshoe crabs were most abundant at the south reference area (Table 3-11). In total, as many as 35 crabs were collected in a single seine-haul. This was most likely attributable to the reference area being coincident with Port Mahon beach, a documented horseshoe crab spawning area. All of the crabs collected were of adult size, and throughout, males repeatedly outnumbered females. Counts of blue crabs were much fewer than those resulting from trawling. Sizes of the crabs were comparable, however, and all were juveniles.

Diamondback terrapins were occasionally collected along the inshore of Kelly Island (Table 3-11). A pair was collected at Kelly Island south and central sampling locations. In both cases, the terrapins were taken only in the first seine-haul, suggesting that they may have avoided ensuing replicate seine-hauls. The heads of swimming terrapins were commonly seen offshore while we were working with the seine, further leading us to believe that they learned to avoid successive capture. The lengths of the terrapins were consistent with those given for adults of the species (Conant 1975). In all likelihood, the individuals that we observed along the Kelly Island shorefront were assembling for breeding and subsequent nesting; these activities usually take place in May and June (Carr 1952).

3.2.1.3 Summer Trawling

Fifteen species of fish were collected during the summer trawl survey at the six sampling locations around Kelly Island (Table 3-12). The most commonly occurring species included bay anchovy, weakfish, and hogchoker. Bay anchovies were collected at all sampling locations with the exception of the north reference area. The highest number of anchovies was collected in the Mahon River at 407, however, this a schooling species and tends to be patchily encountered. Sizes of anchovies were very uniform with average length among trawls ranging from 42 to 54-

mm. Weakfish was the most abundant fish species collected during summer sampling. More than 700 fish were collected at the sampling locations, Mahon River, KI Central, KI North, and north reference areas. The nearshore habitats of Kelly Island as well as the Mahon River appear to provide nursery grounds for this species. Most of the fish collected were juveniles with mean lengths among trawls ranging from 65 to 86-mm. Hogchokers were present at all sampling locations but most common in the Mahon River. At this sampling location, the total count of 80 hogchokers was almost twice that of any other location. Sizes of hogchokers were comparable to those observed in the spring with mean lengths among trawls ranging from 83 to105. These sizes are indicative of the sub-adult to adult composition of the fish community. The oyster toadfish was only found in the northern portion of the sampling range. As observed during spring sampling, toadfish were collected only from KI North and the north reference area. These areas are located close to the oyster beds offshore of Kelly Island which may explain the presence of toadfish. The striped cusk-eel was present at a much reduced abundance with respect to the spring survey. Recurring counts were in evidence only in the north part of the sampling range including Central and North Kelly Island, the north reference area. All of the remaining fish species were present in very low abundance and represented by only a few individuals at each sampling location.

Horseshoe crabs were present at only four of the sampling locations and in low abundance during the summer survey (Table 3-12). The marked decrease in abundance from spring was consistent with this species spawning behavior. A lesser degree of spawning during summer was apparent, however, and all of the individuals collected were of adults. Blue crabs were common to most sampling locations. The highest counts, however, were recorded from the lower part of the sampling range with 118 at KI south, 58 at KI Central, and 56 from the Mahon River. For the most part, the blue crabs appeared to be larger than in the spring and average lengths among trawls ranged from 88 to 113-mm. In all cases, total counts of male blue crabs outnumbered those of females.

Table 3-12. Fish and other species collected by trawl off Kelly Island and reference areas during summer 2001

Species		Ref South	Mahon River	KI South	KI Central	KI North	Ref North
American eel	Count	**0**	**0**	**1**	**0**	**0**	**0**
(Anguilla rostrata)	Length	-	-	NM	-	-	-
Bay anchovy	Count	**81**	**407**	**138**	**29**	**12**	**0**
(Anchoa mitchilli)	Mean Length	54.4	46.4	43.5	48.3	42.1	-
	Minimum Length	34	33	32	39	34	-
	Maximum Length	105	60	59	75	55	-
Oyster toadfish	Count	**0**	**0**	**0**	**0**	**7**	**4**
(Opsanus tau)	Mean Length	-	-	-	-	120.4	164.8
	Minimum Length	-	-	-	-	90	122
	Maximum Length	-	-	-	-	144	202

Table 3-12. Cont'd							
Species		**Ref South**	**Mahon River**	**KI South**	**KI Central**	**KI North**	**Ref North**
Striped cusk-eel *(Ophidion marginatum)*	Count	**0**	**0**	**1**	**8**	**5**	**4**
	Mean Length	-	-	166.0	161.0	183.2	194.0
	Minimum Length	-	-	-	103	152	174
	Maximum Length	-	-	-	192	196	202
Northern pipefish *(Syngnathus fuscus)*	Count	**0**	**0**	**0**	**1**	**0**	**0**
	Length	-	-	-	115.0	-	-
Northern searobin *(Prionotus carolinus)*	Count	**0**	**0**	**1**	**0**	**0**	**0**
	Length	-	-	74.0	-	-	-
Black drum *(Pogonias cromis)*	Count	**0**	**2**	**0**	**0**	**0**	**0**
	Length	-	103.5	-	-	-	-
	Minimum Length	-	92	-	-	-	-
	Maximum Length	-	115	-	-	-	-
Weakfish *(Cynoscion)*	Count	**119**	**1176**	**231**	**842**	**702**	**752**
	Mean Length	75.0	79.6	85.8	72.7	68.2	64.2
	Minimum Length	24	45	39	43	38	37
	Maximum Length	141	150	199	154	165	90
Spot *(Leiostomus xanthurus)*	Count	**0**	**1**	**0**	**0**	**0**	**0**
	Length	-	120.0	-	-	-	-
Bluefish *(Pomatomus saltatrix)*	Count	**1**	**0**	**1**	**0**	**0**	**0**
	Length	158.0	-	111.0	-	-	-
Striped burrfish *(Chilomycterus schoepfi)*	Count	**0**	**0**	**1**	**0**	**0**	**0**
	Length	-	-	30.0	-	-	-
Northern puffer *(Sphoeroides maculates)*	Count	**0**	**0**	**0**	**0**	**1**	**0**
	Length	-	-	-	-	89.0	-
Hogchoker *(Trinectes maculates)*	Count	**48**	**80**	**21**	**13**	**10**	**27**
	Mean Length	83.4	101.7	95.1	87.8	105.4	105.4
	Minimum Length	56	64	61	64	73	75
	Maximum Length	153	165	126	123	169	144
Winter flounder *(Pleuronectes americanus)*	Count	**0**	**2**	**0**	**1**	**0**	**0**
	Mean Length	-	55.0	-	68.0	-	-
	Minimum Length	-	53	-	-	-	-
	Maximum Length	-	57	-	-	-	-
Summer flounder *(Paralichthys dentatus)*	Count	**0**	**1**	**0**	**0**	**0**	**2**
	Length	-	325.0	-	-	-	252.5
	Minimum Length	-	-	-	-	-	152
	Maximum Length	-	-	-	-	-	353
Horseshoe crab – all *(Limulus polyphemus)*	Count	**0**	**0**	**3**	**2**	**6**	**1**
	Mean Length	-	-	210.3	246.5	231.3	240.0
	Minimum Length	-	-	186	226	201	-
	Maximum Length	-	-	250	267	269	-
Male	Count	**0**	**0**	**2**	**1**	**3**	**0**
	Mean Length	-	-	190.5	226.0	207.3	-
	Minimum Length	-	-	186	-	209	-
	Maximum Length	-	-	195	-	212	-

Table 3-12. Cont'd							
Species		**Ref South**	**Mahon River**	**KI South**	**KI Central**	**KI North**	**Ref North**
Female	Count	**0**	**0**	**1**	**1**	**3**	**1**
	Mean Length	-	-	250.0	267.0	255.3	240.0
	Minimum Length	-	-	-	-	266	-
	Maximum Length	-	-	-	-	269	-
Blue crab – all *(Callinectes sapidus)*	Count	**39**	**56**	**118**	**58**	**29**	**24**
	Mean Length	88.0	103.4	100.1	108.2	113.3	113.6
	Minimum Length	39	60	39	64	88	58
	Maximum Length	160	150	163	156	146	149
Male	Count	**23**	**21**	**51**	**38**	**21**	**13**
	Mean Length	99.8	104.0	102.6	111.3	115.2	121.2
	Minimum Length	42	60	39	72	88	76
	Maximum Length	160	150	163	156	146	149
Female	Count	**16**	**14**	**24**	**20**	**8**	**11**
	Mean Length	71.0	107.5	96.3	102.5	108.4	104.6
	Minimum Length	39	70	60	64	98	58
	Maximum Length	100	135	162	151	117	144

3.2.1.4 Summer Seining

Eleven species of fish as well as horseshoe crab, blue crab, and diamondback terrapins were collected by seine along Kelly Island (Table 3-13). The most abundant fish species was the weakfish and was collected at all sampling locations. In contrast to the trawl results, higher total counts of weakfish were recorded from the southern portion of the study area including 229 from the south reference and 95 from KI South. Total counts from the three northern stations ranged from 14 to 50. All of the weakfish collected were juveniles, and as this species breeds as early as April, many were probably young-of-the-year. The mean sizes among sampling locations were very uniform and ranged only from 74 to 81-mm. All of the other fish species collected were present in low abundance, but included newly collected species, northern stargazer and black drum.

Horseshoe crabs were present at most sampling locations, but in much reduced numbers as compared to spring sampling (Table 3-13). Counts were still highest at the south reference area with a total of 14, while those at the remaining locations ranged 5 or less. All of the crabs collected were adults, and males continued to outnumber females. The abundance of blue crabs was markedly lower than during spring sampling. A highest total count of 13 was recorded from KI South while counts at other stations were largely incidental.

A single diamondback terrapin was collected by seine at KI North (Table 3-13). Although this catch may appear incidental, additional terrapins were observed swimming in the nearshore waters during subsequent seine sampling.

Table 3-13. Fish and other species collected by seine along Kelly Island and reference areas during summer 2001

Species		Ref South	KI South	KI Central	KI North	Ref North
American eel *(Anguilla rostrata)*	Count	**6**	**1**	**0**	**0**	**2**
	Mean Length	437.5	485.0	-	-	435.0
	Minimum Length	375	-	-	-	358
	Maximum Length	520	-	-	-	512
Atlantic menhaden *(Brevoortia tyrannus)*	Count	**0**	**2**	**0**	**0**	**0**
	Mean Length	-	56.5	-	-	-
	Minimum Length	-	55	-	-	-
	Maximum Length	-	58	-	-	-
Atlantic silverside *(Menidia menidia)*	Count	**0**	**0**	**0**	**0**	**3**
	Mean Length	-	-	-	-	62.3
	Minimum Length	-	-	-	-	54
	Maximum Length	-	-	-	-	78
Northern stargazer *(Astroscopus guttatus)*	Count	**0**	**1**	**0**	**0**	**0**
	Length	-	70.0	-	-	-
Black drum *(Pogonias cromis)*	Count	**1**	**0**	**0**	**1**	**3**
	Mean Length	98.0	-	-	113.0	97.3
	Minimum Length	-	-	-	-	84
	Maximum Length	-	-	-	-	106
Weakfish *(Cynoscion)*	Count	**229**	**95**	**36**	**14**	**50**
	Mean Length	79.0	78.2	74.4	80.6	73.8
	Minimum Length	48	53	55	47	16
	Maximum Length	135	115	99	102	118
White perch *(Morone Americana)*	Count	**0**	**1**	**1**	**4**	**0**
	Mean Length	-	290.0	230.0	245.5	-
	Minimum Length	-	-	-	221	-
	Maximum Length	-	-	-	274	-
Striped bass *(Morone saxatilus)*	Count	**2**	**1**	**2**	**1**	**0**
	Mean Length	277.5	255.0	209.0	262.0	-
	Minimum Length	275	-	209	-	-
	Maximum Length	280	-	209	-	-
Hogchoker *(Trinectes maculates)*	Count	**0**	**1**	**0**	**2**	**0**
	Mean Length	-	110.0	-	140.5	-
	Minimum Length	-	-	-	129	-
	Maximum Length	-	-	-	152	-
Winter flounder *(Pleu-ronectes americanus)*	Count	**0**	**1**	**0**	**0**	**0**
	Length	-	54.0	-	-	-
Summer flounder *(Paralichthys dentatus)*	Count	**0**	**1**	**0**	**0**	**0**
	Length	-	159.0	-	-	-
Horseshoe crab – all *(Limulus polyphemus)*	Count	**14**	**5**	**4**	**0**	**2**
	Mean Length	201.5	208.0	222.8	-	226.5
	Minimum Length	180	189	210	-	219
	Maximum Length	250	227	238	-	234
Male	Count	**12**	**4**	**4**	**0**	**2**
	Mean Length	194.9	203.3	222.8	-	226.5
	Minimum Length	180	189	210	-	219
	Maximum Length	210	224	238	-	234

Table 3-13. Cont'd						
Species		**Ref South**	**KI South**	**KI Central**	**KI North**	**Ref North**
Female	Count	**2**	**1**	**0**	**0**	**0**
	Mean Length	241.0	227.0	-	-	-
	Minimum Length	232	-	-	-	-
	Maximum Length	250	-	-	-	-
Blue crab – all *(Callinectes sapidus)*	Count	**5**	**13**	**0**	**0**	**6**
	Mean Length	102.0	91.1	-	-	84.2
	Minimum Length	68	64	-	-	60
	Maximum Length	145	116	-	-	102
Male	Count	**4**	**9**	**0**	**0**	**4**
	Mean Length	91.3	94.4	-	-	91.5
	Minimum Length	68	74	-	-	60
	Maximum Length	140	116	-	-	102
Female	Count	**1**	**4**	**0**	**0**	**2**
	Mean Length	145.0	83.5	-	-	69.5
	Minimum Length	-	64	-	-	64
	Maximum Length	-	99	-	-	75
Diamondback terrapin *(Malaclemys terrapin)*	Count	**0**	**0**	**0**	**1**	**0**
	Length	-	-	-	118.0	-

3.2.1.5 Fall Trawling

Eighteen species of fish as well as horseshoe crabs and blue crabs were collected by trawl during fall sampling at Kelly Island (Table 3-14). The most commonly collected species included bay anchovy, black drum, Atlantic croaker, white perch, and hogchoker. Bay anchovies were most common in the Mahon River and KI North with counts of 105 and 114, respectively. This species was largely incidental at the remaining sampling locations. The mean sizes of anchovies were generally uniform with average total lengths among trawls ranging from 50 to 72-mm. Black drum was most abundant in the Mahon River with a total count of 18. This species was present at all of the remaining sampling locations, but counts ranged 9 or less. Throughout, the mean sizes of black drum were relatively uniform, and lengths among trawls ranged from 167 to 198-mm. At this length, black drum are often referred to as "puppy drum"; this species can reach lengths up to 1.7-m. Overwhelmingly, Atlantic croaker was the most abundant fish encountered during fall sampling. Trawl counts commonly exceeded 1,000 fish at many sampling locations. Nearshore Kelly Island and the Mahon River appear to offer excellent habitat for juvenile croakers. Most of the fish present were young-of-the-year and mean lengths among trawls ranged from 29 to 47-mm. White perch were collected at all sampling locations but present only in moderate abundance. The highest total counts were recorded from the south and north reference areas at 57 and 26, respectively. Counts along Kelly Island and the Mahon River totaled 10 or less. Most of the white perch present were of adult size with means ranging from 185 to 213-mm. At this size, the perch are most likely feeding on the schools of juvenile Atlantic croaker that abound in the nearshore habitats. Hogchokers were most abundant in the

Mahon River with a high total count of 47. Total counts at the remaining sampling locations ranged 6 or less. The size distribution of hogchokers reflected a mix of juvenile and adult fish. Mean lengths among sampling locations ranged from 89 to 123-mm. Several fish species appeared to be more common relative to specific sampling locations. As noted in other seasons, the oyster toadfish was more abundant in the north part of the sampling range, and likewise during fall sampling, was only encountered in the north reference area. Striped cusk-eel was regularly collected from the south reference to KI Central as well as the Mahon River, but was largely absent from the north part of the sampling range. The northern pipefish, northern searobin, and smallmouth flounder were almost exclusively collected in the Mahon River. Weakfish were collected at all of the sampling locations, but at a much reduced abundance than observed in the summer. Black sea bass was a newly collected species and was found exclusively at the north reference area.

Horseshoe crab abundance continued to taper off with the fall survey (Table 3-14). A total of 5 male crabs were collected between KI South and the north reference area. In contrast, blue crab abundance increased markedly, especially in the southern part of the sampling range. Total counts ranged greater than 100 crabs for the south reference area, KI South and the Mahon River. Total counts at the remaining stations ranged from 9 to 65. The size distribution of crabs indicated a mainly juvenile composition. Average lengths among trawls ranged from 57 to 70-mm. Although males outnumbered females at most monitoring locations, both sexes were well represented, throughout.

Table 3-14. Fish and other species collected by trawl off Kelly Island and reference areas during fall 2001

Species		Ref South	Mahon River	KI South	KI Central	KI North	Ref North
Clearnose skate	Count	**1**	**0**	**0**	**0**	**0**	**0**
(Raja eglanteria)	Length	580.0	-	-	-	-	-
American eel	Count	**0**	**5**	**1**	**0**	**0**	**1**
(Anguilla rostrata)	Mean Length	-	251.0	402.0	-	-	390.0
	Minimum Length	-	180	-	-	-	-
	Maximum Length	-	460	-	-	-	-
Bay anchovy	Count	**5**	**105**	**3**	**10**	**114**	**11**
(Anchoa mitchilli)	Mean Length	61.0	60.2	50.3	61.6	71.6	66.6
	Minimum Length	56	33	47	54	45	47
	Maximum Length	71	83	55	80	95	87
Atlantic menhaden	Count	**0**	**1**	**0**	**0**	**0**	**0**
(Brevoortia tyrannus)	Length	-	116.0	-	-	-	-
Alosid sp.	Count	**0**	**1**	**0**	**0**	**0**	**0**
(Alosid)	Length	-	82.0	-	-	-	-
Oyster toadfish	Count	**0**	**0**	**0**	**0**	**0**	**42**
(Opsanus tau)	Mean Length	-	-	-	-	-	160.2
	Minimum Length	-	-	-	-	-	115
	Maximum Length	-	-	-	-	-	280

Table 3-14. Cont'd							
Species		**Ref South**	**Mahon River**	**KI South**	**KI Central**	**KI North**	**Ref North**
Striped cusk-eel *(Ophidion marginatum)*	Count	**6**	**20**	**9**	**5**	**1**	**0**
	Mean Length	165.7	159.4	194.8	157.0	155.0	-
	Minimum Length	145	145	166	144	-	-
	Maximum Length	166	186	232	184	-	-
Northern pipefish *(Syngnathus fuscus)*	Count	**0**	**5**	**0**	**0**	**0**	**1**
	Mean Length	-	169.6	-	-	-	220.0
	Minimum Length	-	129	-	-	-	-
	Maximum Length	-	192	-	-	-	-
Northern searobin *(Prionotus carolinus)*	Count	**1**	**5**	**0**	**0**	**0**	**0**
	Mean Length	57.0	58.0	-	-	-	-
	Minimum Length	-	42	-	-	-	-
	Maximum Length	-	71	-	-	-	-
Black drum *(Pogonias cromis)*	Count	**9**	**18**	**3**	**6**	**6**	**2**
	Mean Length	198.3	166.9	180.3	174.8	182.7	176.0
	Minimum Length	174	117	165	130	161	158
	Maximum Length	230	204	190	217	205	194
Atlantic croaker *(Micropogonias undulates)*	Count	**1752**	**3660**	**4077**	**2316**	**1885**	**4468**
	Mean Length	33.9	47.4	36.8	37.0	28.7	30.9
	Minimum Length	20	17	19	20	17	19
	Maximum Length	89	76	85	275	61	77
Weakfish *(Cynoscion)*	Count	**4**	**6**	**5**	**7**	**4**	**0**
	Mean Length	116.8	122.2	113.4	132.0	162.3	-
	Minimum Length	115	87	87	115	97	-
	Maximum Length	124	157	127	149	233	-
Silver perch *(Bairdiella chrysoura)*	Count	**2**	**0**	**1**	**0**	**0**	**0**
	Mean Length	135.0	-	136.0	-	-	-
	Minimum Length	135	-	-	-	-	-
	Maximum Length	135	-	-	-	-	-
White perch *(Morone Americana)*	Count	**57**	**9**	**10**	**10**	**4**	**26**
	Mean Length	200.6	198.4	193.9	185.2	190.5	212.7
	Minimum Length	142	165	177	165	176	179
	Maximum Length	262	225	232	211	231	261
Striped bass *(Morone saxatilus)*	Count	**2**	**0**	**0**	**3**	**2**	**1**
	Mean Length	250.5	-	-	191.0	231.5	255.0
	Minimum Length	235	-	-	142	227	-
	Maximum Length	266	-	-	236	236	-
Black sea bass *(Centropristis striata)*	Count	**0**	**0**	**0**	**0**	**0**	**8**
	Mean Length	-	-	-	-	-	204.3
	Minimum Length	-	-	-	-	-	178
	Maximum Length	-	-	-	-	-	284
Hogchoker *(Trinectes maculates)*	Count	**2**	**47**	**3**	**5**	**5**	**6**
	Mean Length	108.0	88.8	108.3	122.4	123.0	115.0
	Minimum Length	0	27	91	99	87	95
	Maximum Length	0	166	133	148	156	130

Table 3-14. Cont'd

Species		Ref South	Mahon River	KI South	KI Central	KI North	Ref North
Smallmouth flounder *(Etropus microstomus)*	Count	**0**	**18**	**0**	**0**	**0**	**0**
	Mean Length	-	66.2	-	-	-	-
	Minimum Length	-	45	-	-	-	-
	Maximum Length	-	82	-	-	-	-
Horseshoe crab – female *(Limulus polyphemus)*	Count	**0**	**0**	**3**	**0**	**0**	**2**
	Mean Length	-	-	157.7	-	-	177.0
	Minimum Length	-	-	115	-	-	170
	Maximum Length	-	-	121	-	-	184
Blue crab – all *(Callinectes sapidus)*	Count	**142**	**113**	**150**	**65**	**10**	**9**
	Mean Length	63.5	56.8	64.5	68.8	69.5	60.0
	Minimum Length	31	15	30	41	45	39
	Maximum Length	95	130	92	95	90	88
Male	Count	**74**	**66**	**90**	**38**	**4**	**7**
	Mean Length	62.8	57.2	63.1	68.5	65.0	57.3
	Minimum Length	38	15	40	41	55	39
	Maximum Length	93	130	90	95	84	74
Female	Count	**68**	**47**	**60**	**27**	**6**	**2**
	Mean Length	64.2	56.3	66.6	69.1	72.5	69.5
	Minimum Length	31	30	30	50	45	51
	Maximum Length	95	122	92	93	90	88

3.2.1.6 Fall Seining

Eleven species of fish and blue crabs were collected by seine along Kelly Island inshore habitats (Table 3-15). None of the fish species were particularly abundant, and many were represented by only a single fish. While Atlantic croaker was very abundant in the fall trawling, surprisingly few were collected in the near shore habitat suggesting that deeper waters are their primary habitat. Bay anchovies had high total counts of 26 and 44 at KI Central and the south reference, respectively, but were absent from all other sampling locations. Atlantic silverside and Atlantic croaker were regularly collected at the southern reference location but was incidental to absent for the remaining areas.

As observed from trawling, blue crabs were more abundant in the southern portion of the sampling range (Table 3-15). The highest total count of 99 crabs was recorded at the south reference area. In contrast to the trawl data however, higher counts were recorded at the north reference area with a total of 27. All of the crabs were juveniles and mean size among sampling locations ranged from 40 to 57-mm. Total counts of males and females were relatively even.

Table 3-15. Fish and other species collected by seine along Kelly Island and reference areas during fall 2001

Species		Ref South	KI South	KI Central	KI North	Ref North
American eel *(Anguilla rostrata)*	Count	**0**	**0**	**0**	**1**	**0**
	Length	-	-	-	620.0	-
Bay anchovy *(Anchoa mitchilli)*	Count	**44**	**0**	**26**	**0**	**0**
	Mean Length	57.4	-	54.8	-	-
	Minimum Length	31	-	28	-	-
	Maximum Length	90	-	78	-	-
Striped killifish *(Fundulus majalis)*	Count	**0**	**1**	**0**	**0**	**6**
	Mean Length	-	68.0	-	-	76.0
	Minimum Length	-	-	-	-	15
	Maximum Length	-	-	-	-	102
Mummichog *(Fundulus heteroclitus)*	Count	**1**	**0**	**0**	**0**	**0**
	Length	36.0	-	-	-	-
Atlantic silverside *(Menidia menidia)*	Count	**23**	**2**	**1**	**0**	**2**
	Mean Length	79.7	83.5	86.0	-	91.0
	Minimum Length	56	67	-	-	83
	Maximum Length	95	100	-	-	99
Northern pipefish *(Menidia menidia)*	Count	**1**	**0**	**0**	**0**	**0**
	Length	128.0	-	-	-	-
Northern searobin *(Prionotus carolinus)*	Count	**1**	**0**	**0**	**0**	**0**
	Length	54.0	-	-	-	-
Atlantic croaker *(Micropogonias undulates)*	Count	**28**	**0**	**0**	**0**	**0**
	Mean Length	41.1	-	-	-	-
	Minimum Length	22	-	-	-	-
	Maximum Length	71	-	-	-	-
Weakfish *(Cynoscion)*	Count	**0**	**0**	**1**	**0**	**0**
	Length	-	-	30.0	-	-
White perch *(Morone Americana)*	Count	**0**	**1**	**1**	**1**	**0**
	Length	-	127.0	335.0	194.0	-
Striped bass *(Morone saxatilus)*	Count	**0**	**0**	**0**	**0**	**2**
	Mean Length	-	-	-	-	178.5
	Minimum Length	-	-	-	-	116
	Maximum Length	-	-	-	-	241
Blue crab – all *(Callinectes sapidus)*	Count	**99**	**7**	**5**	**1**	**27**
	Mean Length	57.2	51.7	63.8	40.0	50.9
	Minimum Length	21	36	49	-	30
	Maximum Length	91	59	82	-	85
Male	Count	**34**	**3**	**2**	**1**	**17**
	Mean Length	57.5	50.7	50.5	40.0	54.6
	Minimum Length	21	36	49	-	33
	Maximum Length	91	59	52	-	85
Female	Count	**35**	**4**	**3**	**0**	**10**
	Mean Length	55.0	52.5	72.7	-	44.6
	Minimum Length	30	40	62	-	30
	Maximum Length	71	58	82	-	67

3.2.1.7 Winter Trawling

Fourteen species of fish and blue crabs were collected by trawl during a winter survey of Kelly Island nearshore habitats (Table 3-16). The most commonly collected species included Atlantic croaker and white perch. Atlantic croaker were most abundant along the Kelly Island shorefront. Total counts from KI South, KI Central, and KI North ranged from 1,456 to 2,280. Counts from the reference areas and Mahon River were markedly lower ranging from 128 to 328. All of the croakers collected were juveniles and most likely young-of-the-year. Mean sizes among sampling locations ranged from 29 to 37-mm. White perch were also more abundant at the Kelly Island sampling locations. Total counts at KI South, KI Central, and KI North ranged from 52 to 100. Counts at the remaining stations were typically half as much. Size measures of perch indicated the presence of juvenile and adult fish. Minimum and maximum lengths among sampling locations averaged 56 and 215-mm, respectively. Several other species were collected with low abundance but were more common to the Kelly Island shorefront. Spotted hake, black drum, and striped bass all had total counts ranging 10 or less, but in general tended to be more abundant at KI South, KI Central, and KI North. Of the remaining species, most occurred in low abundance and were represented by only one or two fish.

Table 3-16. Fish and other species collected by trawl off Kelly Island and reference areas during winter 2001

Species		Ref South	Mahon River	KI South	KI Central	KI North	Ref North
American eel	Count	**0**	**0**	**0**	**0**	**1**	**0**
(Anguilla rostrata)	Length	-	-	-	-	210.0	-
Bay anchovy	Count	**1**	**0**	**0**	**0**	**0**	**0**
(Anchoa mitchilli)	Length	42.0	-	-	-	-	-
Gizzard shad	Count	**0**	**1**	**0**	**0**	**0**	**1**
(Dorosoma cepedianum	Length	-	124.0	-	-	-	155.0
Oyster toadfish	Count	**0**	**0**	**0**	**1**	**0**	**0**
(Opsanus tau	Length	-	-	-	66.0	-	-
Spotted hake	Count	**2**	**0**	**3**	**2**	**8**	**0**
(Urophycis regius)	Mean Length	58.5	-	88.0	79.0	76.6	-
	Minimum Length	55	-	75	76	68	-
	Maximum Length	62	-	104	82	90	-
Striped cusk-eel	Count	**0**	**0**	**0**	**1**	**0**	**0**
(Ophidion marginatum)	Length	-	-	-	80.0	-	-
Atlantic silverside	Count	**7**	**0**	**2**	**0**	**0**	**0**
(Menidia menidia)	Mean Length	76.9	-	97.5	-	-	-
	Minimum Length	58	-	96	-	-	-
	Maximum Length	113	-	99	-	-	-
Black drum	Count	**0**	**2**	**2**	**5**	**10**	**0**
(Pogonias cromis)	Mean Length	-	154.5	180.0	170.8	164.3	-
	Minimum Length	-	0	0	130	142	-
	Maximum Length	-	0	0	175	187	-

Table 3-16. Cont'd

Species		Ref South	Mahon River	KI South	KI Central	KI North	Ref North
Atlantic croaker	Count	**165**	**128**	**1525**	**2280**	**1456**	**328**
(Micropogonias	Mean Length	29.1	30.8	32.3	37.0	35.4	28.9
undulates)	Minimum Length	19	20	18	20	20	13
	Maximum Length	55	91	58	102	89	40
White perch	Count	**21**	**24**	**100**	**52**	**67**	**34**
(Morone	Mean Length	122.0	163.5	152.0	150.0	112.7	90.5
Americana)	Minimum Length	63	57	80	65	42	29
	Maximum Length	168	221	245	220	254	184
Striped bass	Count	**0**	**2**	**4**	**9**	**2**	**1**
(Morone saxatilus)	Mean Length	-	146.5	170.5	162.3	154.0	142.0
	Minimum Length	-	128	137	109	150	-
	Maximum Length	-	165	205	254	158	-
Hogchoker	Count	**0**	**31**	**0**	**0**	**0**	**0**
(Trinectes	Mean Length	-	51.8	-	-	-	-
maculates)	Minimum Length	-	38	-	-	-	-
	Maximum Length	-	96	-	-	-	-
Windowpane	Count	**0**	**0**	**1**	**0**	**0**	**1**
(Scophthalmus aquosus)	Length	-	-	72.0	-	-	50.0
Smallmouth	Count	**1**	**5**	**0**	**0**	**0**	**0**
flounder	Mean Length	100.0	84.2	-	-	-	-
(Etropus	Minimum Length	-	66	-	-	-	-
microstomus)	Maximum Length	-	118	-	-	-	-
Blue crab – all	Count	**0**	**13**	**3**	**2**	**2**	**2**
(Callinectes	Mean Length	-	50.8	34.0	79.0	65.5	54.5
sapidus)	Minimum Length	-	30	34	79	52	36
	Maximum Length	-	110	34	79	79	73
Male	Count	**0**	**10**	**0**	**0**	**2**	**1**
	Mean Length	-	53.3	-	-	65.5	36.0
	Minimum Length	-	30	-	-	52	-
	Maximum Length	-	110	-	-	79	-
Female	Count	**0**	**3**	**1**	**1**	**0**	**1**
	Mean Length	-	42.7	34.0	31.0	-	73.0
	Minimum Length	-	30	-	-	-	-
	Maximum Length	-	53	-	-	-	-

Blue crabs were collected in much less abundance than in the previous fall survey (Table 3-16). No horseshoe crabs were collected. The highest total count was from the Mahon River with a total of 13. Total counts at all other sampling locations ranged 3 or less. Size measurements indicated primarily small to medium juveniles. Mean carapace widths among sampling locations ranged from 34 to 73-mm. Overall, males were twice as many as females, but with such low counts the difference is most likely irrelevant.

3.2.1.8 Winter Seining

Five species of fish were collected by seine along Kelly Island during the winter survey (Table 3-17). Most species occurred in very low abundance with only one or two fish taken at each sampling location. Atlantic silverside was the most abundant fish. Curiously, the highest total counts were recorded from the south and north reference locations at 7 and 19, respectively. The highest count along the Kelly Island shorefront was only 2.

Table 3-17. Fish collected by seine along Kelly Island and reference areas during winter 2001

Species		Ref South	KI South	KI Central	KI North	Ref North
Gizzard shad *(Dorosoma cepedianum)*	Count	**0**	**0**	**0**	**2**	**0**
	Mean Length	-	-	-	111.5	-
	Minimum Length	-	-	-	77	-
	Maximum Length	-	-	-	146	-
Striped killifish *(Fundulus majalis)*	Count	**1**	**0**	**0**	**1**	**3**
	Mean Length	81.0	-	-	89.0	89.0
	Minimum Length	-	-	-	-	65
	Maximum Length	-	-	-	-	103
Atlantic silverside *(Menidia menidia)*	Count	**7**	**2**	**0**	**2**	**19**
	Mean Length	92.6	108.5	-	82.0	91.7
	Minimum Length	71	108	-	73	70
	Maximum Length	110	109	-	91	196
Striped mullet *(Mugil cephalus)*	Count	**0**	**1**	**0**	**0**	**1**
	Length	-	215.0	-	-	194.0
White perch *(Morone Americana)*	Count	**2**	**2**	**2**	**1**	**0**
	Mean Length	124.0	217.5	162.0	213.0	-
	Minimum Length	105	201	135	-	-
	Maximum Length	143	234	189	-	-

3.2.2 Horseshoe Crab Spawning Survey

Spawning adult horseshoe crabs were more abundant at the Port Mahon Beach than at Kelly Island (Table 3-18). On the peak spawning date, coinciding with the full moon of 5 June, roughly twice as many crabs were counted at the Port Mahon beach. Counts for the northern transect at Port Mahon would likely have been higher were it not for a malfunctioning counter that necessitated repeating the count. The reported count for this transect was initiated about an hour after the optimal start time. Total counts along the Kelly Island shoreline were very similar between the north and south transects at 618 and 600, respectively. The shoreline habitat of Kelly Island at the time of spawning was a mix of the higher salt marsh hummock broken up by eroding cuts in between. Spawning crabs occupied positions on any suitable substrate where the females could dig in. The spawning habitat of the Port Mahon beach was much more favorable with a wide swath of uninterrupted sandy beach. The northern transect, however, had many more obstructions in the lower intertidal zone, which may account for the lower numbers at that beach. The ratio of sexes was very similar between the two beaches with about 2 to 3 males to a female.

Table 3-18 Counts of horseshoe crabs at Kelly Island and Port Mahon during the 2001 spawning survey

Beach	Date	South Transect		North Transect	
		Male	Female	Male	Female
Kelly Island	22 May	Thunderstorm precluded beach survey			
Port Mahon		431	154	115	50
Kelly Island	5 June	400	200	399	219
Port Mahon		989	403	487*	161*

* Counts reported are from a second pass of the beach; on the initial pass, the mechanical counter for males malfuctioned. The count for females on the initial pass was 281.

Port Mahon beach was also surveyed on an earlier date of lesser spawning activity that coincided with the new moon of 22 May. Counts from this survey were approximately half those of the full moon survey. At that time, a survey of the Kelly Island shoreline was precluded by severe thunderstorms in the area; Kelly Island is reachable only by boat.

A program to monitor horseshoe crab spawning in the Delaware Bay has been developed by a multi-agency panel and is currently managed by the USGS, Biological Resources Division. In 2001, the program surveyed horseshoe crab spawning activity at twelve beaches on the Delaware bayshore. The beaches were surveyed up to 12 times including 3, 5, and 7 June, which coincide with our survey of Kelly Island and Port Mahon. The survey protocol differed from our methods principally in that crabs were counted within 1-m^2 quadrants located systematically defined segments with random placement within a segment. The results of this survey were reported as an Index of Spawning Activity (ISA), which in effect was the number of females counted within a survey quadrant. Comparing our female crab densities counted over 50-m^2 transects, Kelly Island and Port Mahon appear to represent high quality horseshoe crab spawning habitat (Figure 3-11). The highest density of females from the USGS monitoring program was 4.5 from Kitts Hummock only slightly greater than that for Kelly Island and about 1 female/m^2 less than Port Mahon. Several factors may be acting to distort this picture. Survey methods of the USGS monitoring program take into account a much broader area (up to 1-km of beach) and most likely have more habitat heterogeneity. Also, their survey parties were issued a quadrant frame, which probably enabled a more precise count rather than our method of estimating a 1-m width over the length of our transects. Clearly, the counts we made at Kelly Island and Port Mahon suggest that the area may be important for horseshoe crab spawning. We recommend that the survey be conducted in 2002 following methods similar to that of the Bay-wide monitoring program.

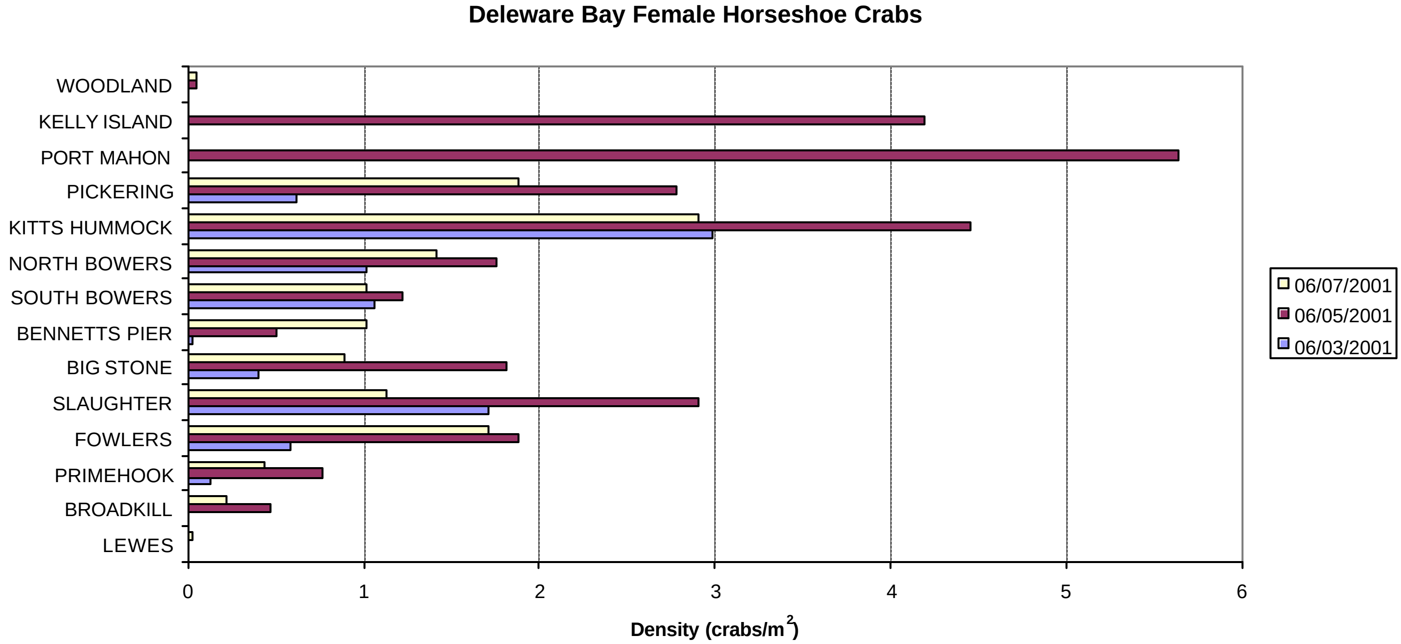


Figure 3-11. Density of spawning female horseshoe crabs at Delaware Bay beaches during June 2001. Kelly Island and Port Mahon data are from the present study. All other data are from the USGS surveys.

3.2.3 Late Summer Juvenile Horseshoe Crab Survey

Juvenile horseshoe crabs were successfully collected at only one of the five beaches surveyed. A total of 11 crabs were collected at the south reference area approximately 0.5-miles downbay from Kelly Island (Table 3-19). This area is also immediately downbay of the Port Mahon spawning beach. Crabs were collected in low numbers in each tow. The highest number was 3 from the second replicate tow at the 100-ft distance. Crabs were only collected at distances of 100 to 300-ft from the mean high water mark. Sizes of juvenile crabs measured as carapace width ranged from 6 to 14-mm. Data from DNREC's 16-foot trawl survey conducted between 1992 and 1999 indicated that mean catches of juvenile horseshoe crabs was between 8.13 and 0.29 per 10-minute haul in the Kelly Island area (Stewart Michaels, personal communication March 2002). In addition, the USGS data indicated that much higher mean catches occur between the Murderkill and Mispillion Rivers where catches ranged up to 20 juveniles per haul.

3.3 CHARACTERIZATION OF SEDIMENTS

Bottom sediments off Kelly Island were characterized by Sediment Profile Imagery (SPI) and a benthic assessment. Images and benthic samples were collected along transects radiating from Kelly Island toward the navigation channel (Figure 2-4). Images were taken at distances of 750, 1500, 2000, 2500, 3000, 3500, 4000, 5000, 7000, and 9000 feet from Kelly Island. Benthic samples were collected at 2000, 3000, and 4000 feet from Kelly Island.

Table 3-19. Summary of juvenile horseshoe crab survey of Delaware Bay Beaches conducted during September, 2001

Beach	Transect	50-ft	100-ft	200-ft	300-ft	Total
Kelly Island	1	0/0	0/0	0/0	0/0	0
	2	0/0	0/0	0/0	0/0	0
Reference North	3	0/0	0/0	0/0	0/0	0
	4	0/0	0/0	0/0	0/0	0
Reference South	5	0/0	0/**1**	**1**/0	**2**/0	**4**
	6	0/0	0/**3**	0/**2**	**2**/0	**7**
Kitts Hummock	7	0/0	0/0	0/0	0/0	0
	8	0/0	0/0	0/0	0/0	0
Broadkill Beach	9	0/0	0/0	0/0	0/0	0
	10	0/0	0/0	0/0	0/0	0

3.3.1 Sediment Profile Imagery

July and October SPI images are stored in CD-ROM format (Appendix C). All images have been processed to highlight the apparent color RPD layer and other sediment layers. The width of all images is approximately 15 cm. Tick-marks on the side of the images are 1 cm with every fifth cm from the bottom of the faceplate marked in white.

3.3.1.1 Sediments

Sediment grain size at most stations were consistent between the July and October sampling suggesting that little change in sediment characteristics occurred as a result of fall storm events. Of the 50 stations sampled 46 had the same sediment grain size in July and October (Figures 3-12 and 3-13). Stations with different sediments were KM-06, KS-07, and RN-09 that became finer in October, and RN-06 that became coarser in October. Sediments ranged from medium-sand to clay with one station being a shell bed (Table 3-20).

Silty-clay (modal Phi 8 to 6) was the most widely distributed surficial sediment type occurring at 57 % of the 96 station-date combinations. The second was silty-fine-sands (modal Phi 6 to 5) and fine-sandy-silts (modal Phi 5 to 4) that occurred at 20 % of the station-date combinations (Table 3-21). Finest sediments were clayey-silts (modal Phi >8 to 7) occurring at 8 % of the station-dates. There were also three stations that appeared to have clay (modal Phi >8) underlying silty sediments (RN-01, RN-04, and KN-01). Coarsest sediments were fine-sands (modal Phi 4 to 2) to medium-sands (modal Phi 2 to 1) occurring at 13 % of the station-dates. Oyster shell, whole shell to coarse shell hash, was the only substrate observed at Station KM-10 in both July and October.

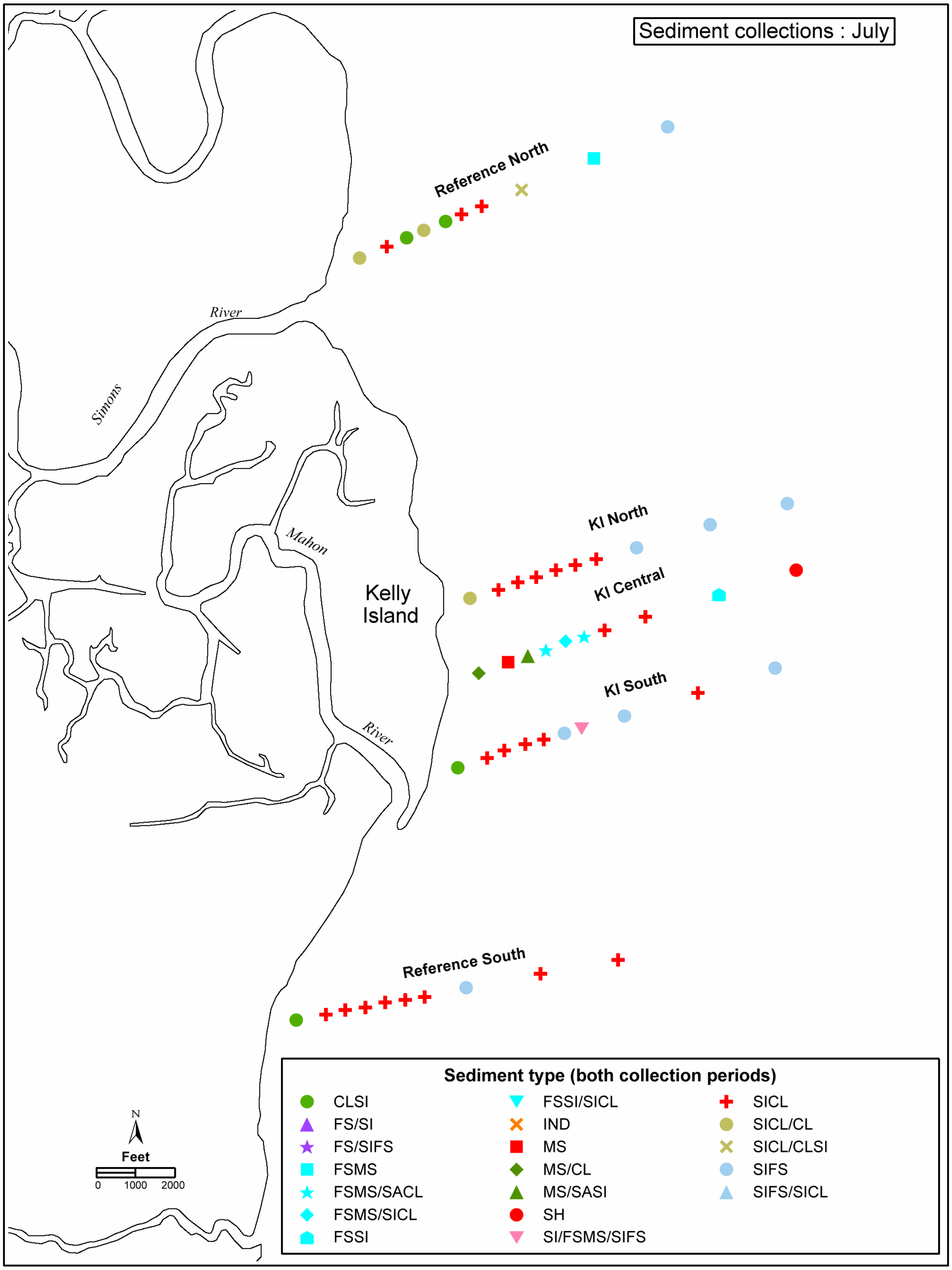


Figure 3-12. Sediment types along transects off Kelly Island during July 2001

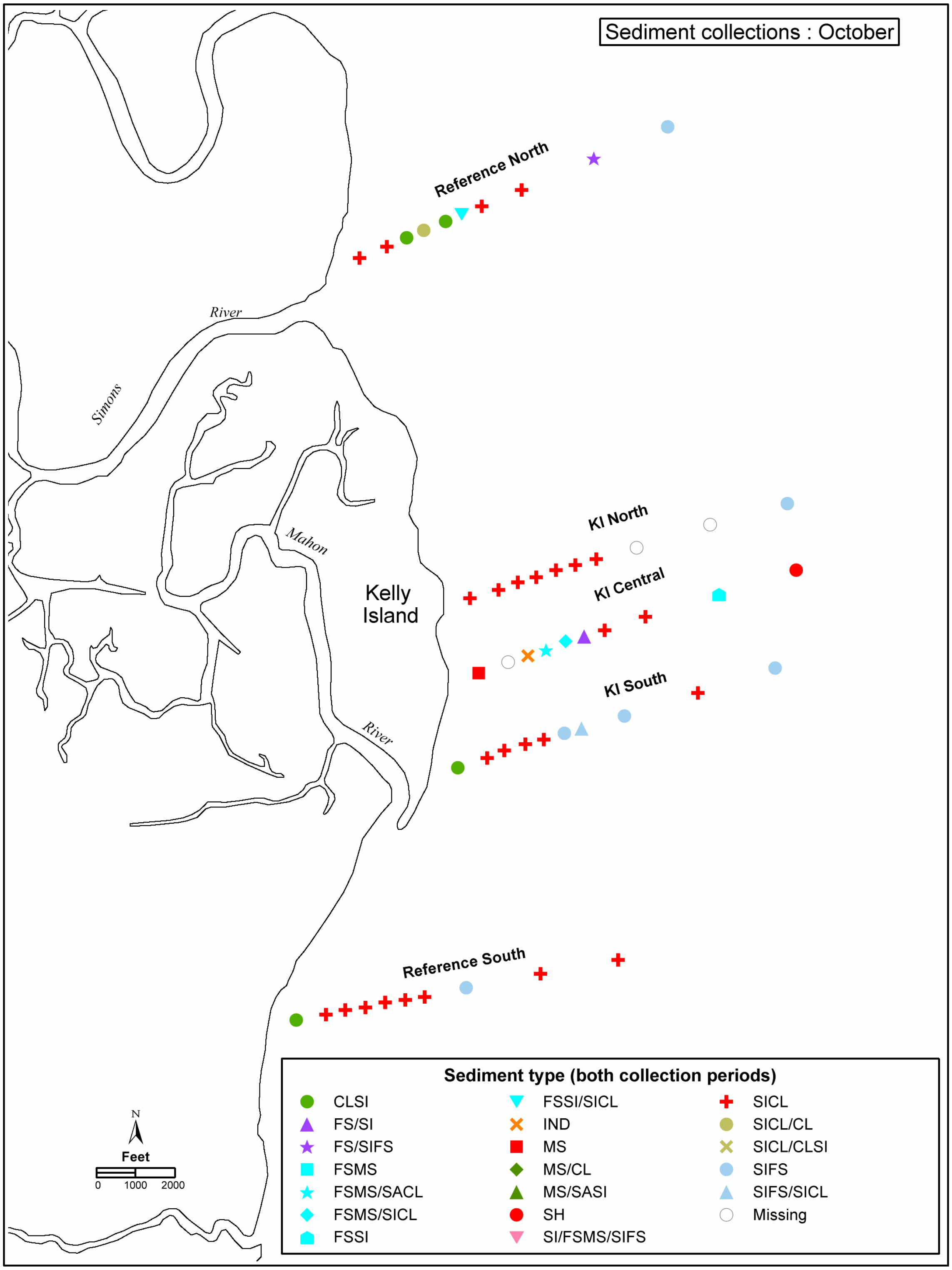


Figure 3-13. Sediment types along transects of Kelly Island during October 2001

Table 3-20. Kelly Island sediment profile image data, July and October 2001

Station	Date	Penetration (cm)	Surface Relief (cm)	RPD (cm)	Shell Hash	Bedforms	Detritus	Recent Deposition	Grain Size	Floc Thickness: Floc	Floc Thickness: (cm)	Sediment Layering: Grain Size	Sediment Layering: Color	Sediment Layering: Layer Detail	Sediment Layering: 1st Layer Thickness (cm)	Sediment Layering: 2nd Layer Thickness (cm)	Tubes	Infauna	Burrows	Voids: Oxic	Voids: Anaerobic	Voids: Gas	Comments
KM-01	Jul	5.4	1.0	1.7	+	+	-	-	MS/CL	-		+	-	sandy over clayey	2.0		NONE	0	0	0	0	0	
	Oct	1.1	0.3	>1.1	+	+	-	-	MS	-		-	-				NONE	0	0	0	0	0	Shallow penetration
KM-02	Jul	0.0	0.0	IND	-	+			MS?					IND			IND	IND	IND	IND	IND	IND	
	Oct																						no image
KM-03	Jul	3.7	0.5	1.5	-	+	-	-	MS/SASI	-		+	-	sandy over silty	2.6		FEW	0	0	0	0	0	
	Oct	0.0	IND	IND	-	+?			IND					IND			IND	IND	IND	IND	IND	IND	pull out
KM-04	Jul	3.9	0.4	1.6	+	+	-	-	FSMS/SACL	-		+	-	sandy over clayey	2.3		FEW	0	0	0	0	0	Snail
	Oct	4.0	0.7	1.7	+	+	-	-	FSMS/SACL	-		+	-	sandy over clayey	1.9		FEW	0	0	0	0	0	Small Diopatra tube
KM-05	Jul	9.1	1.2	1.4	+	+	+	-	FSMS/SICL	-		+	-	sandy over clayey	3.5		SOME	0	0	0	0	0	Tube made of detritus
	Oct	2.8	0.3	1.4	+	+	+	-	FSMS/SICL	-		+	-	sandy over clayey	1.7		NONE	0	0	0	0	0	
KM-06	Jul	5.4	0.3	1.1	+	-	-	-	FSMS/SACL	+	0.2	+	-	sandy over clayey	3.3		NONE	0	0	0	0	0	
	Oct	5.4	0.2	1.8	+	-	-	-	FS/SI	-		+	-	sandy over silty	1.8		NONE	0	0	0	0	0	pull out
KM-07	Jul	18.9	0.4	0.5	-	-	-	-	SICL	-		-	+	darker over lighter over darker	3.9	8.8	MANY	0	0	0	1	3	Tubes made of detritus
	Oct	12.6	1.4	2.0	-	-	-	-	SICL	-		-	+	lighter over darker	9.5		NONE	0	3	0	0	0	
KM-08	Jul	16.8	0.9	0.2	-	-	-	-	SICL	-		-	+	lighter over darker	13.3		SOME	0	0	0	0	20	Tubes made of detritus
	Oct	10.6	1.1	1.6	-	-	-	-	SICL	+	0.2	-	-				NONE	0	1	2	0	0	
KM-09	Jul	6.2	0.7	1.0	+	+?	-	-	FSSI	-		-	-				FEW	0	2	0	1	0	
	Oct	8.2	1.0	1.1	+	+?	-	-	FSSI	-		-	-				FEW	0	2	0	0	0	
KM-10	Jul	0.7	1.3	IND	+	-			SH					IND			NONE	IND	IND	IND	IND	IND	Oyster bed
	Oct	0.0	0.0	IND	+	-			SH					IND			NONE	IND	IND	IND	IND	IND	Oyster bed
KN-01	Jul	10.9	0.6	1.8	-	-	+	-	SICL/CL	-		+	-	silty over clayey	9.9		NONE	0	4	0	0	0	
	Oct	11.4	0.7	1.0	-	-	+	-	SICL	+	0.3	-	-				NONE	0	0	0	0	0	
KN-02	Jul	18.1	2.1	2.6	-	-	+	+	SICL	-		-	+	lighter over darker	10.0		NONE	0	0	0	0	0	
	Oct	17.7	0.8	4.6	-	-	+	+	SICL	-		-	+	lighter over darker	6.8		NONE	0	0	0	0	0	
KN-03	Jul	19.4	1.0	0.3	-	-	-	-	SICL	-		-	-				FEW	0	0	0	0	30	
	Oct	18.9	0.6	4.2	-	-	-	+	SICL	-		-	+	lighter over darker	6.3		NONE	0	0	0	0	20	
KN-04	Jul	13.3	0.9	0.3	+	-	+	-	SICL	+	0.2	-	+	lighter over darker	6.0		FEW	0	0	0	4	0	
	Oct	12.4	1.9	3.4	-	-	-	+	SICL	-		-	+	lighter over darker	6.4		NONE	0	0	0	0	0	Pull out
KN-05	Jul	16.6	2.7	1.3	-	-	+	+	SICL	-		-	+	lighter over darker	1.4		NONE	0	1	0	0	25	
	Oct	11.6	1.1	0.3	+	-	-	-	SICL	-		-	-				NONE	0	0	0	0	15	

Table 3-20. Cont'd

Station	Date	Penetration (cm)	Surface Relief (cm)	RPD (cm)	Shell Hash	Bedforms	Detritus	Recent Deposition	Grain Size	Floc Thickness: Floc	Floc Thickness: (cm)	Sediment Layering: Grain Size	Sediment Layering: Color	Sediment Layering: Layer Detail	1st Layer Thickness (cm)	2nd Layer Thickness (cm)	Tubes	Infauna	Burrows	Voids: Oxic	Voids: Anaerobic	Voids: Gas	Comments
KN-06	Jul	15.5	0.1	0.4	+	-	+	-	SICL	-		-	+	lighter over darker, Detritus layer	5.1	3.5	NONE	0	0	0	0	0	
	Oct	8.3	2.7	0.6	+	-	+	-	SICL	-		-	-				FEW	0	0	0	0	0	
KN-07	Jul	11.1	0.3	1.3	-	-	-	-	SICL	-		-	-				SOME	1	1	0	1	0	Tubes made of detritus
	Oct	3.3	0.2	0.9	-	-	-	-	SICL	-		-	-				NONE	0	0	0	0	0	Shrimp
KN-08	Jul	4.2	0.9	0.9	+	-	-	-	SIFS	-		-	-				SOME	0	2	0	0	0	Tubes made of detritus
	Oct																						no image
KN-09	Jul	10.1	1.1	2.4	+	-	-	-	SIFS	-		-	-				SOME	0	3	1	0	0	
	Oct																						no image
KN-10	Jul	1.7	3.3	0.6	-	-	-	-	SIFS	-		-	-				NONE	0	0	0	0	0	Disturbed, Tubes made of detritus
	Oct	2.6	5.2	0.8	-	-	-	-	SIFS	-		-	-				NONE	0	0	0	0	0	Disturbed, Shell?
KS-01	Jul	9.2	0.1	3.3	-	-	+	+	CLSI	-		-	+	lighter over darker	5.4		SOME	0	3	0	0	0	
	Oct	3.9	1.2	IND	-	-	-	-	CLSI					IND			IND	IND	IND	IND	IND	IND	pull out
KS-02	Jul	15.3	1.6	2.3	-	-	+	+	SICL	-		-	+	lighter over darker	3.4		NONE	0	0	0	0	0	
	Oct	9.9	1.9	IND	-	-	-	-	SICL					IND			IND	IND	IND	IND	IND	IND	Disturbed
KS-03	Jul	11.6	1.4	2.6	-	-	+	+	SICL	-		-	+	lighter over darker	4.3		NONE	0	2	0	0	0	
	Oct	11.7	0.8	0.5	-	-	-	-	SICL	-		-	+	lighter over darker	1.5		NONE	0	0	0	0	0	
KS-04	Jul	12.7	0.6	1.1	-	-	+	-	SICL	+	0.1	-	+	lighter over darker	3.1		SOME	0	0	0	1	0	
	Oct	9.1	1.0	1.3	-	-	+	-	SICL	+	0.2	-	+	lighter over darker	3.9		NONE	0	0	0	1	0	
KS-05	Jul	10.8	0.9	1.6	-	-	+	+	SICL	-		-	+	lighter over darker	2.1		SOME	0	3	0	0	0	
	Oct	4.1	1.7	0.2	+	-	-	-	SICL	-		-	-				FEW	0	0	0	0	0	Disturbed
KS-06	Jul	10.4	0.3	3.3	+	-	+	-	SIFS	-		-	-				SOME	0	2	1	2	0	Tube made of detritus
	Oct	12.2	1.4	1.5	+	-	+	-	SIFS	-		-	-				FEW	0	3	0	0	0	Biogenic mounds
KS-07	Jul	6.0	1.7	1.9	+	-	-	+	SI/FSMS/SIFS	-		+	-	silty over sandy over silty	1.3	2.5	FEW	0	0	0	0	0	
	Oct	5.3	0.7	1.2	+	-	-	-	SIFS/SICL	-		+	-	sandy over silty	1.9		MANY	0	1	0	0	0	
KS-08	Jul	11.6	0.8	0.9	+	-	+	-	SIFS	-		-	-				NONE	0	1	0	0	0	
	Oct	4.3	0.7	1.3	+	-	-	-	SIFS	-		-	-				SOME	0	2	0	0	0	Small Diopatra tube
KS-09	Jul	12.4	0.7	1.4	-	-	-	-	SICL	-		-	-				SOME	0	4	0	0	0	Tubes made of detritus
	Oct	6.0	1.1	0.5	+	-	-	-	SICL	-		-	-				SOME	0	3	0	1	0	Small Diopatra tube
KS-10	Jul	5.0	0.4	0.9	-	-	-	-	SIFS	-		-	-				SOME	0	0	0	0	0	Small Diopatra tubes
	Oct	2.3	1.6	1.1	+	-	-	-	SIFS	-		-	-				SOME	0	0	0	0	0	Small Diopatra tubes, Spiochaetopterus tube

Table 3-20. Cont'd

Station	Date	Pene-tration (cm)	Surface Relief (cm)	RPD (cm)	Shell Hash	Bed-forms	Detri-tus	Recent Deposition	Grain Size	Floc Thickness: Floc	Floc Thickness: (cm)	Sediment Layering: Grain Size	Sediment Layering: Color	Sediment Layering: Layer Detail	1st Layer Thickness (cm)	2nd Layer Thickness (cm)	Tubes	Infauna	Burrows	Voids: Oxic	Voids: Anaerobic	Voids: Gas	Comments
RN-01	Jul	22.6	0.4	0.9	-	-	+	+	SICL/CL	-		+	-	silty over clayey	18.7		FEW	0	0	0	0	0	
	Oct	14.4	0.4	0.5	-	-	+	+	SICL	-		-	+	lighter over darker	8.8		NONE	0	0	0	0	0	
RN-02	Jul	2.5	1.9	3.3	-	-	-	+	SICL	+	0.3	-	+	lighter over darker	4.4		NONE	0	0	0	0	0	
	Oct	11.7	2.2	IND	+	-	-	+	SICL	-		-	+	lighter over darker	5.3		NONE	0	0	0	0	0	
RN-03	Jul	10.2	2.0	2.7	-	-	+	-	CLSI	-		-	+	lighter over darker	6.9		FEW	0	0	0	0	0	
	Oct	12.1	1.3	0.6	-	-	-	-	CLSI	-		-	+	darker over lighter	10.1		SOME	0	0	0	0	0	
RN-04	Jul	12.1	0.4	2.0	+	-	+	-	SICL/CL	-		+	-	silty over clayey	6.0		NONE	0	0	0	0	0	
	Oct	6.6	0.6	0.4	+	-	+	-	SICL/CL	-		+	-	silty over clayey	4.7		NONE	0	0	0	0	0	
RN-05	Jul	3.6	0.6	0.6	-	-	+	-	CLSI	-		-	-				NONE	0	0	0	0	0	
	Oct	7.2	1.5	1.6	+	-	+	-	CLSI	-		-	-				MANY	0	0	0	0	0	Tubes made of detritus
RN-06	Jul	13.8	0.1	0.4	-	-	+	-	SICL	-		-	-				FEW	0	1	0	0	20	
	Oct	7.0	0.5	1.4	+	+	+	-	FSSI/SICL	-		+	-	sandy over silty	1.7		FEW	0	1	0	0	0	
RN-07	Jul	13.8	1.1	1.0	-	-	-	-	SICL	-		-	-				SOME	0	4	0	0	0	Tubes made of detritus
	Oct	11.6	0.8	0.5	+	-	-	-	SICL	-		-	-				MANY	1	5	0	0	0	
RN-08	Jul	17.7	0.8	0.6	-	-	-	-	SICL/CLSI	-		+	-	silty over clayey	13.9		SOME	0	0	0	0	0	
	Oct	8.5	0.6	1.9	+	-	-	-	SICL	-		-	-				FEW	0	0	0	2	0	
RN-09	Jul	0.0	0.0	IND	+	+			FSMS					IND			NONE	IND	IND	IND	IND	IND	
	Oct	4.7	0.6	1.7	+	+	-	-	FS/SIFS	-		+	-	sandy over silty	1.8		NONE	0	0	3	0	0	
RN-10	Jul	7.7	0.6	1.1	+	-	-	-	SIFS	-		-	-				MANY	0	3	0	0	0	Tube made of detritus
	Oct	4.1	0.2	1.4	+	+?	-	-	SIFS	-		-	-				NONE	0	0	0	0	0	
RS-01	Jul	14.7	0.9	1.3	-	-	+	-	CLSI	-		-	-				SOME	0	0	0	0	0	Dark area of intense reduction
	Oct	4.1	1.1	0.9	-	-	+	-	CLSI	-		-	-				FEW	0	0	0	0	0	Dark area of intense reduction
RS-02	Jul	12.6	1.1	0.8	+	-	+	-	SICL	+	0.6	-	-				MANY	1	0	0	0	0	
	Oct	8.1	0.8	2.7	+	-	-	-	SICL	-		-	-				NONE	0	0	0	0	0	Disturbed
RS-03	Jul	15.6	0.9	1.1	+	-	+	-	SICL	-		-	-				SOME	0	0	0	0	0	Tube made of detritus
	Oct	7.8	0.6	0.1	+	-	-	-	SICL	-		-	-				NONE	1	0	1	1	0	Disturbed
RS-04	Jul	18.7	0.4	1.9		-	-	-	SICL	-		-	-				SOME	0	2	0	1	0	Tube made of detritus
	Oct	10.7	0.7	3.4	+	-	-	-	SICL	+	0.2	-	-				NONE	0	0	0	3	0	
RS-05	Jul	16.6	0.4	1.8	-	-	+	-	SICL	-		-	-				SOME	0	3	1	1	0	
	Oct	12.5	1.0	2.8	-	-	+	-	SICL	+	0.1	-	-				FEW	0	0	0	1	0	

Table 3-20. Cont'd

Station	Date	Penetration (cm)	Surface Relief (cm)	RPD (cm)	Shell Hash	Bedforms	Detritus	Recent Deposition	Grain Size	Floc	Floc Thickness (cm)	Sediment Layering: Grain Size	Sediment Layering: Color	Sediment Layering: Layer Detail	1st Layer Thickness (cm)	2nd Layer Thickness (cm)	Tubes	Infauna	Burrows	Voids: Oxic	Voids: Anaerobic	Gas	Comments
RS-06	Jul	15.7	0.9	0.8	-	-	+	-	SICL	-		-	+	lighter over dark over darker	6.3	6.2	SOME	0	0	0	0	0	
	Oct	20.7	2.1	1.7	+	-	-	-	SICL	-		-	+	lighter over darker	6.2		NONE	0	0	0	0	0	
RS-07	Jul	17.7	0.8	2.1	-	-	+	-	SICL	-		-	+	lighter over darker	6.9		SOME	0	1	0	0	0	Tubes made of detritus
	Oct	9.1	1.8	3.7	+	-	-	-	SICL	+	0.1	-	+	lighter over darker	5.0		NONE	1	3	0	0	0	Disturbed
RS-08	Jul	7.3	1.1	1.5	-	-	-	-	SIFS	-		-	-				SOME	2	6	0	0	0	Tubes made of detritus
	Oct	7.6	0.6	0.6	+	-	-	-	SIFS	-		-	-				NONE	0	0	0	0	11	
RS-09	Jul	8.3	1.2	1.4	-	-	-	-	SICL	-		-	-				MAT	2	9	1	0	0	3 Types of tubes
	Oct	8.2	0.8	3.9	-	-	-	+	SICL	-		-	+	lighter over darker	4.7		NONE	0	0	0	0	0	
RS-10	Jul	9.9	1.9	2.6	-	-	-	-	SICL	-		-	-				MAT	1	9	1	0	0	3 Types of tubes
	Oct	>23	IND	IND	-	-	-	+	SICL	-		-	+	lighter over darker	15.2		IND	0	0	0	0	0	

Qualifiers:

IND	Value could not be estimated from slide
>	Value was greater than prism penetration

Ordered Category Classes: Range of Numbers

NONE	0
FEW	1 to 5
SOME	6 to 20
MANY	>20
MAT	>100

Sediment Categories:

	Class	Phi Scale Range	Modal Phi
CS	Coarse-sand	1 to 0	0.5
MS	Medium-sand	2 to 1	1.5
FS	Fine-sand	4 to 2	3.0
FSSI	Fine-sand with Silt	5 to 4	4.5
FSSICL	Fine-sand-silt-clay	6 to 4	5.0
SI	Silt	8 to 5	6.5
SIFS	Silt with Fine-sand	6 to 5	5.5
SICL	Silty-clay	8 to 6	7.5
CLSI	Clayey-silt	>8 to 6	8.5
CL	Clay	>8	10

Table 3-21. Summary of prism penetration, surface relief, and RPD by sediment type for Kelly Island. Maximum N was 96 (50 station in July and 46 in October).

GRAIN-SIZE	N	Prism Penetration (cm)		Surface Relief (cm)		RPD (cm)	
		Mean	SD	Mean	SD	Mean	SD
SH	2	0.4	0.5	0.7	0.9	•	•
MS	2	0.6	0.8	0.2	0.2	1.1	•
MS/SASI	1	3.7	•	0.5	•	1.5	•
MS/CL	1	5.4	•	1.0	•	1.7	•
FSMS	1	0.0	•	0.0	•	•	•
FSMS/SACL	3	4.4	0.8	0.5	0.2	1.5	0.3
FSMS/SICL	2	6.0	4.5	0.8	0.6	1.4	0.0
FS/SIFS	1	4.7	•	0.6	•	1.7	•
FS/SI	1	5.4	•	0.2	•	1.8	•
FSSI	2	7.2	1.4	0.9	0.2	1.1	0.1
FSSI/SICL	1	7.0	•	0.5	•	1.4	•
SIFS	14	6.5	3.6	1.3	1.4	1.3	0.7
SIFS/SICL	1	5.3	•	0.7	•	1.2	•
SI/FSMS/SIFS	1	6.0	•	1.7	•	1.9	•
SICL	50	12.6	4.5	1.1	0.6	1.6	1.2
SICL/CL	4	13.1	6.8	0.5	0.1	1.3	0.8
SICL/CLSI	1	17.7	•	0.8	•	0.6	•
CLSI	8	8.1	4.1	1.1	0.6	1.6	1.1

Sediment compaction, as estimated by prism penetration, was related to sediment type with highest compaction (lowest penetration) in medium-sands and shell beds, and lowest (highest penetration) compaction in silty-clays (Table 3-21). Average bed roughness or surface relief, across the 15 cm width of the faceplate, was about the same in all sediment types (Table 3-21). The range of surface relief was 0.0 to 5.2 cm over the entire study area (Table 3-20). In physically dominated sandy habitats surface relief was typically small sand ripples or bedforms about 1 cm high. In finer sediment habitats surface relief was typically uneven surfaces caused by biogenic activity of benthic organisms and were also about 1 cm high.

Detritus appeared to form a significant part of the sediments at 37% of the station-dates and was more previlant in July than October (Table 3-20). There were 24 stations with detritus in July and 12 in October. Detritus formed a subsurface sedimentary layer at Station KN-06 in July that was 3.5 cm thick. The detritus layer was on top of darker colored sediment and was overlaid by 5.1 cm of lighter colored sediment.

3.3.1.2 Grain Size Layering

At most stations sediments were homogeneous with depth from the sediment surface, but gain-size layering occurred at 12 stations, which represented 17 station-date combinations (Table 3-20). Sandy sediments overlaid silty or clayey sediments in both July and October at KM-04, KM-05, KM-06 and KS-07, in July only at KM-01 and KM-03, and in October only at RN-06. Sediment layering changed at KS-07 from July to October with the thin layer of silty sediments that overlaid a sandy layer in July not present in October. The average thickness of the sandy layers was 2.3 (0.3 SD) over silty and 2.4 (0.8 SD) clayey sediments (Table 3-22). The occurrence of sandy layers over finer sediments may be an indication that these stations are near transition points from finer to coarser sediment bottoms. The sand layers possibly being transported over finer sediments during storm events. Silty sediments overlaid clayey sediments in both July and October at one station (RN-04) and in July only at Stations KN-01, RN-01 and RN08. The average thickness of the silty layers was 9.1 (6.4) cm, about four-times thicker than the sandy layers (Table 3-22).

Table 3-22. Sediment layer statistics for Kelly Island stations. Maximum N was 96 (50 station in July and 46 in October).

Sediment Layering	N	Layer Thickness (cm)			
		Mean	SD	Min	Max
Grain-Size:					
Sandy over Clayey	6	2.5	0.8	1.7	3.5
Sandy over Silty	5	2.0	0.4	1.7	2.6
Silty over sandy over silty	1	1.3 / 2.5*	•		
silty over clayey	5	10.6	5.8	4.7	18.7
Color:					
lighter over darker	25	6.1	3.3	1.4	15.2
lighter over dark over darker	1	6.3	•		
Darker over Lighter	1	10.1	•		
darker over lighter over darker	1	3.9	•		
Floc Layers:	11	0.2	0.1	0.1	0.6

* silty layer / sandy layer

Thin flocculent layers of silty sediments that ranged in thickness from 0.1 to 0.6 cm overlaid both sandy and silt-clay sediments at 10 stations (Tables 3-20 and 3-22). The occurrence of flocculent layers was about evenly divided between the July and October sampling dates (5 in July and 6 in October). Station KS-04 was the only station to have floc layers in both July and October. All of the floc layers appeared to be recently deposited, possibly from wind generated suspension/resuspension events, because they appeared to be well oxidized. Had the silty sediments come from deeper anaerobic sediments, such as those generated by a dredging operations, their color would have been grayer reflecting the reduced geochemical state of compound adsorbed to the silt particles.

3.3.1.3 Color Layering

Color differences between what appear to be similarly grain-size sediment occurred at about 25% of the station-date combinations (Table 3-20). Lighter over darker sediments was the most common color layering and occurred at 24 of the 26 station-date combinations with color layers (Table 3-22). In both July and October lighter colored sediment overlaid darker at Stations RS-06, RS-07, KN-02, KN-04, KS-03 and KS-04. Stations KM-08, KN-05, KN-06, KS-01, KS-02, and KS-05 in July, and KN-03, RN-01, RS-09 and RS10 in October had lighter over darker color layers. Darker over lighter sediments occurred at two stations, KM07 in July and RN-03 in October. At Station KM-07 in July the dark/light layers were over a third darker layer. Three layers were also seen at RS-06 (Table 3-20). The lighter colored layers were about four-time thicker than the RPD layers. On average lighter colored layers were 6.1 (3.2) cm, darker colored layers were 5.9 (3.0) cm thick, compared to the average RPD layer depth of 1.4 to 1.6 cm. Thus it appeared that the light colored layers were not directly related to surficial oxidized layers that formed above the RPD layer but were most likely associated with subtle changes in the geochemistry of the sediments, in particularly the geochemistry of organic compounds. Lighter colors are indicators of less reduced conditions and darker colors more reduced conditions. These color layers may be associated with major input or disturbance events capable of depositing/resuspending cm thick layers of sediment.

There was evidence of recent physical resuspension at 16 station-dates in the form of thick light colored, high reflectance, layers at the sediment surface. These layers did not appear to be biogenic in origin because they were very uniform in color and texture. Light colored layers produced from biogenic activity have a much more textured appearance that is created by organisms moving and mixing the sediment. The shallow water depth at the Kelly Island stations likely exposes the bottom to frequent resuspension by storm waves. These recent resuspension layers range in thickness from a few cm to about 10 cm and occurred with about the same frequency in July and October, nine and seven station-dates, respectively. At three stations the resuspension layer occurred in both July and October (KN-02, RN-01, RN-02).

3.3.1.4 Apparent Color RPD Layer

There was no difference in the grand average apparent color redox potential discontinuity (RPD) layer depth at all stations between July and October. July average was 1.4 (0.8 SD) cm and 1.6 (1.2) cm in October (Tables 3-20 and 3-23). The variation in RPD layer depth, expressed by the range, was also about the same for both sampling dates. The shallowest RPD layer depth of 0.1 cm occurred at Station RS-03 and the deepest 4.6 cm at Station KN-02 both in October. There was no obvious pattern between RPD layer depth and sediment type with sandy and silty sediments having averaged RPD layer depths of 1.6 (0.2) and 1.3 (0.4) cm, respectively (Table 3-23).

Biogenic activity at the 50 stations appeared to be of secondary importance in structuring surface sediments and did not produce deep RPD layer depths. Physical processes appeared to be the primary determinant of RPD depth. Biological processes dominated surface sediment at only five stations (KM-07, KS-06, RS-08, RS-09, and RS-10) in July and none in October. The averaged July RPD layer depth at the five biologically dominated stations was 1.9 (1.1) cm and 1.4 (1.0) cm for the other 45 physically dominated stations. In October, the average at the five stations that were biologically dominated in July was still above the average of other physically dominated stations, 2.0 (1.4) cm. Tube mats, burrows, and subsurface feeding activities were the primary biogenic activities that contributed to deeper RPD layers at these stations in July.

Table 3-23. Summary of apparent color RPD layer depth by date and sediment type for Kelly Island. Maximum N was 96 (50 station in July and 46 in October).

	N	Depth of RPD Layer (cm)			
		Mean	**SD**	**Min**	**Max**
July	47	1.4	0.8	0.2	3.3
October	41	1.6	1.2	0.1	4.6
Grain-Size:					
MS	1	>1.1	•		
MS/CL	1	1.7	•		
MS/SASI	1	1.5	•		
FSMS/SACL	3	1.5	0.3	1.1	1.7
FSMS/SICL	2	1.4	0.0	1.4	1.4
FS/SIFS	1	1.7	•		
FS/SI	1	1.8	•		
FSSI	2	1.1	0.1	1.0	1.1
FSSI/SICL	1	1.4	•		
SIFS	14	1.3	0.7	0.6	3.3
SIFS/SICL	1	1.2	•		
SI/FSMS/SIFS	1	1.9	•		
SICL	47	1.6	1.2	0.1	4.6
SICL/CL	4	1.3	0.8	0.4	2.0
SICL/CLSI	1	0.6	•		
CLSI	7	1.6	1.1	0.6	3.3

Tubes at the sediment surface were widely distributed and occurred at 69% of the station-date combinations. Most of the tubes were small, <1 mm in diameter, and likely belonged to opportunistic spionid polychaetes that are typical of pioneering successional Stage I communities. These small tubes occurred in both July and October in about the same numbers. Larger tubes, >1 mm in diameter, that belonged to the polychaetes *Diopatra* and *Spiochaetopterus* were less common and occurred at 22 and 1 of the station-date combinations, respectively. Both of these polychaetes are typical of intermediate successional Stage II communities. *Diopatra* constructs its tube out of small shell fragments or detritus particle. At 15 station-dates *Diopatra* tubes were entirely made with detritus fragments, an indication that detritus fragments are common at the sediment surface. Diopatra tubes were more widely distributed in July, occurring at 17 stations, than in October, five station occurrences (Table 3-20).

The distribution of subsurface biogenic features (burrow structures, infaunal organisms, water filled voids) was sediment related, with most occurring at fine sediment stations, and tended to mirror patterns seen for surface biogenic features. Burrows occurred at 33% of the station-dates with the number of burrows per image highest in silty-clay sediments. Water filled voids, both oxic and anaerobic, occurred at 21% of the station-dates with a pattern of occurrence similar to burrows (Table 3-20). Both voids and burrows are biogenic structures indicative of infaunal activities and tend to be most common in sediments with significant amounts of fine sediments that would support these structures, usually >25% silt-clay content (Rhoads 1974). About a third (36%) of the water filled voids were oxic (apparently filled with oxidized sediment indicating current or recent infaunal activity) and anaerobic two-thirds (apparently relic voids from previous infaunal activity). Infauna were occurred at eight station-date combinations all silty sediments (Table 3-20).

3.3.2 Characterization of Benthos

Fifty-one taxa were identified from benthic samples collected along transects radiating from Kelly Island (Appendix Table D). The ten most abundant infaunal taxa were common to many of the benthic stations, and among these, seven were present at all stations (Table 3-24). The polychaete worms were represented by the most species with six followed by the bivalve mollusks with three. In terms of abundance, however, the most commonly occurring taxon comprised the oligochaete worms, which ranged up to a mean of 10,000 organisms closest to shore at the Kelly Island North transect (KIN-3).

Indices of diversity were similar among stations, and there did not appear to be any patterns to suggest differences related to distance from shore along transect or location, north to south, in Delaware Bay (Table 3-25). The mean number of taxa for stations within transects generally ranged from 10 to 17. And while that number increased with distance from shore for the north and south transects, it was nearly reversed for the middle transect. Likewise, a consistent pattern was not discerned for the Shannon-Wiener or Simpson's Diversity Indices. Overall, the means of the Shannon-Wiener index ranged from 1.75 to 3.02, while those of the Simpson's Diversity Index ranged from 0.53 to 0.82.

Total abundance ranged greatly among the benthic sampling locations (Table 3-25). The highest mean abundance of 19,954 organisms/m^2, recorded at KIN-3 located 2,000-ft from shore on the north transect, was more than a magnitude greater than that at KIS-3 on the south transect at 1,608 organisms/m^2. Total abundance depended principally on annelid polychaete/oligochaete and bivalve abundance. In general, abundances among these three groups often accounted for a third or more of the total. In contrast, amphipod abundance contributed very little to the total and means among all stations ranged 239 organisms/m^2 or less.

Total biomass was generally variable among benthic sampling locations, and overall, ranged from 0.7 to 7.4-g/m^2 (Table 3-25). For the most part, total biomass appeared to follow the abundance of bivalves. Bivalves are generally heavier bodied organisms than most others, and in this study, their biomass often accounted for more than half of the total. By contrast, polychaete worms, which were comparably abundant, most often made up less than 10% of the total biomass. Amphipod biomass was uniformly low throughout the study area at 0.02-g/m^2 or less.

Table 3-24. Ten most abundant infaunal taxa in benthic samples collected near Kelly Island during October 2001

GROUP	KIS-3	KIS-5	KIS-7	KIM-3	KIM-5	KIM-7	KIN-3	KIN-5	KIN-7
Nemertinea									
Nemertinea	34.1	22.7	113.6	34.1	11.4	51.1	34.1	39.8	56.8
Annelida: Polychaeta									
Asabellides oculata	85.2	250.0	34.1	596.6	11.4	28.4	51.1		767.0
Glycinde solitaria	22.7	142.0	323.9	108.0	113.6	329.5	119.3	119.3	312.5
Leitoscoloplos spp.	34.1	68.2	45.5	85.2	62.5		51.1	39.8	
Mediomastus ambiseta	159.1	1119.3	3028.4	931.8	397.7	1886.4	4392.0	1977.3	1130.7
Polydora cornuta		5.7	45.5				5.7		5.7
Streblospio benedicti	39.8	585.2	380.7	204.5	79.5	375.0	1477.3	738.6	22.7
Annelida: Oligochaeta									
Oligochaeta	568.2	3068.2	721.6	380.7	289.8	3687.5	10494.3	9255.7	1017.0
Mollusca: Gastropoda									
Acteocina canaliculata	17.0	51.1	142.0	90.9	73.9	193.2	11.4	5.7	721.6
Mullusca: Bivalvia									
Gemma gemma	45.5	471.6	68.2	983.0	142.0	5.7	2136.4	210.2	
Macoma balthica	28.4	5.7					5.7		
Mulinia lateralis	409.1	1636.4	329.5	2068.2	1619.3	1159.1	500.0	676.1	170.5
Arthropoda: Cumacea									
Leucon americanus			5.7	17.0	17.0	85.2	28.4	284.1	39.8
Arthropoda: Amphipoda									
Ampelisca abdita		90.9	28.4	238.6	5.7	39.8	73.9	153.4	73.9

Table 3-25. Parameters of benthic community characterization for the samples collected along transect from Kelly Island. Results reported are a mean among four replicate samples with standard error in parentheses below. AFDW – Ash-free dry weight

Parameter	KIS_3	KIS_5	KIS_7	KIM_3	KIM_5	KIM_7	KIN_3	KIN_5	KIN_7
Number of Taxa (#/Sample)	10.5 (1.0)	13.8 (0.8)	17.0 (2.1)	17.3 (0.8)	10.3 (0.9)	12.5 (1.0)	12.3 (1.9)	13.0 (1.1)	15.8 (1.1)
Shannon-Wiener Index	2.50 (0.17)	2.56 (0.14)	2.38 (0.13)	3.02 (0.07)	1.97 (0.15)	2.23 (0.15)	1.90 (0.13)	1.75 (0.11)	2.81 (0.19)
Simpson's Diversity Index	0.75 (0.03)	0.76 (0.03)	0.66 (0.03)	0.82 (0.01)	0.59 (0.05)	0.70 (0.03)	0.62 (0.04)	0.53 (0.03)	0.81 (0.02)
Total Abundance (#/m2)	1608 (353)	7841 (1124)	5483 (864)	6472 (1092)	2847 (282)	8000 (530)	19954 (4791)	13790 (1244)	4687 (201)
Amphipod Abundance (#/m2)	0 (0)	91 (9)	45 (16)	239 (75)	6 (6)	45 (13)	74 (34)	159 (33)	85 (19)

Table 3-25. Cont'd									
Parameter	**KIS-3**	**KIS-5**	**KIS-7**	**KIM-3**	**KIM-5**	**KIM-7**	**KIN-3**	**KIN-5**	**KIN-7**
Bivalve Abundance (#/m2)	489 (60)	2119 (343)	398 (56)	3097 (356)	1767 (104)	1165 (74)	2659 (634)	898 (155)	182 (44)
Polychaete Abundance (#/m2)	364 (148)	2193 (506)	3972 (569)	1949 (547)	676 (238)	2631 (227)	6119 (2063)	2903 (79)	2273 (256)
Total Biomass AFDW (g/m2)	2.4 (0.9)	7.4 (2.9)	0.7 (0.2)	7.1 (2.2)	3.1 (0.4)	2.2 (0.5)	2.8 (0.8)	1.6 (0.6)	1.6 (0.8)
Amphipod Biomass AFDW (g/m2)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.02 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.01 (0.00)
Bivalve Biomass AFDW (g/m2)	1.59 (0.93)	3.55 (0.70)	0.22 (0.04)	4.42 (0.95)	3.02 (0.35)	1.48 (0.20)	1.65 (0.42)	0.83 (0.26)	0.23 (0.07)
Polychaete Biomass AFDW (g/m2)	0.22 (0.08)	0.17 (0.04)	0.23 (0.07)	0.25 (0.09)	0.07 (0.04)	0.14 (0.03)	0.28 (0.08)	0.16 (0.03)	0.50 (0.16)

All of the benthic organisms identified from the Kelly Island sampling would be considered typical of the estuarine habitats characterized in this report with one exception. The isopod, *Synidotea laticauda*, is a Pacific Coast species that has only recently been described for Delaware Bay. In this study, this species was already found to be pervasive at Kelly Island and present at eight of nine sampling locations (Appendix Table D). A native of San Francisco Bay, this species was most likely introduced to the bay during ballast water exchange. By life history, it primarily feeds on detritus and is probably well adapted to the conditions present along the Kelly Island shorefront characterized by the remnants of decaying salt marsh.

Sediment samples were analyzed for total organic carbon (TOC) and grain-size at each of the benthic sampling locations. For the most part, TOC and silt-clay characteristics were similar over the sampling area (Table 3-26). Except for KIM-5 and KIS-7, most locations had very fine-grained sediments, silt-clay 64 to 85% with about 6 to 12 % TOC. KIM-5 and KIS-7 were much coarser grained, silt-clay 20 to 25%, with much less TOC, approximately 2.3%. Sediment grain size curves that show the entire range of particle size distribution are provided in Appendix E.

Table 3-26. Percent silt-clay and total organic carbon of sediment samples collected along transects off Kelly Island during 2001

Station	Distance from Shore (ft)	% Silt Clay	%Total Organic Carbo
KIN-3	2000	84.41	8.84
KIN-5	3000	76.68	11.27
KIN-7	4000	64.12	6.40
KIM-3	2000	64.24	10.55
KIM-5	3000	24.17	2.29
KIM-7	4000	81.82	7.18
KIS-3	2000	79.80	8.35
KIS-5	3000	66.26	9.32
KIS-7	4000	19.16	2.34

3.4 HYDROACOUSTIC SURVEY

3.4.1 Data Collection and Acoustic Classification

A total of 151.6 km of transects were assessed, an area approximately equivalent to 26.7 km^2. A total of 21,532 individual acoustic interrogations were logged during the ASCS survey. Data filtering reduced the dataset to 12,896 usable records (Figure 3-14). The footprint of the acoustic beam, or area of habitat integration, is a function of depth due to the spreading angle of the beam. At the minimum survey depth of 3.2 m, the footprint area is 0.30 m^2. At the maximum survey depth of 5.40 m, the footprint area is 0.85m^2. Footprint area at the mean depth is 0.39 m^2. The clustering process indicated that the dataset was best described with six classes (Figure 3-15). Excluding the two un-validated classes, which together had only 712 of the total of 12,896 records, chi-square analysis indicated that the classifications were correct. The three non-shell bottom types were characteristically of low chi-square values, indicating a near random interrogation point distribution around the mean. The oyster shell bottom, with a higher chi-square (15.64) indicates the higher acoustic variability generated from the shell bottom.

3.4.2 Video Validation

Video footage was recorded from forty-six locations (Figure 3-16 and 3-17). To assess variability in bottom habitat within transects most video transects were carried out for several minutes. Due to the large size of the survey area video transects could not be established at the scale of the entire survey area. A total of fifteen transects were determined to have too much within transect variability to be reliably classified as a single visual bottom type. These were removed from further analysis. After repeated examination of the remaining video transects, four dominant bottom categories were identified. These categories (Figure 3-18) were:

- Sand-silt sediments,
- Silt sediments with observable shell bits,
- Oyster shell, and
- Short epi-fauna/flora

There was a degree of ambiguity with these categories, the most obvious limitation was a difficulty distinguishing sand from silt, additionally, the short epi-fauna/flora category may be invertebrate colonies. Other bottom types, observed less frequently, were dominated by tubeworms and tunicates (Figure 3-19). Due to their infrequency and patchiness such colonies were not classed as a bottom category.

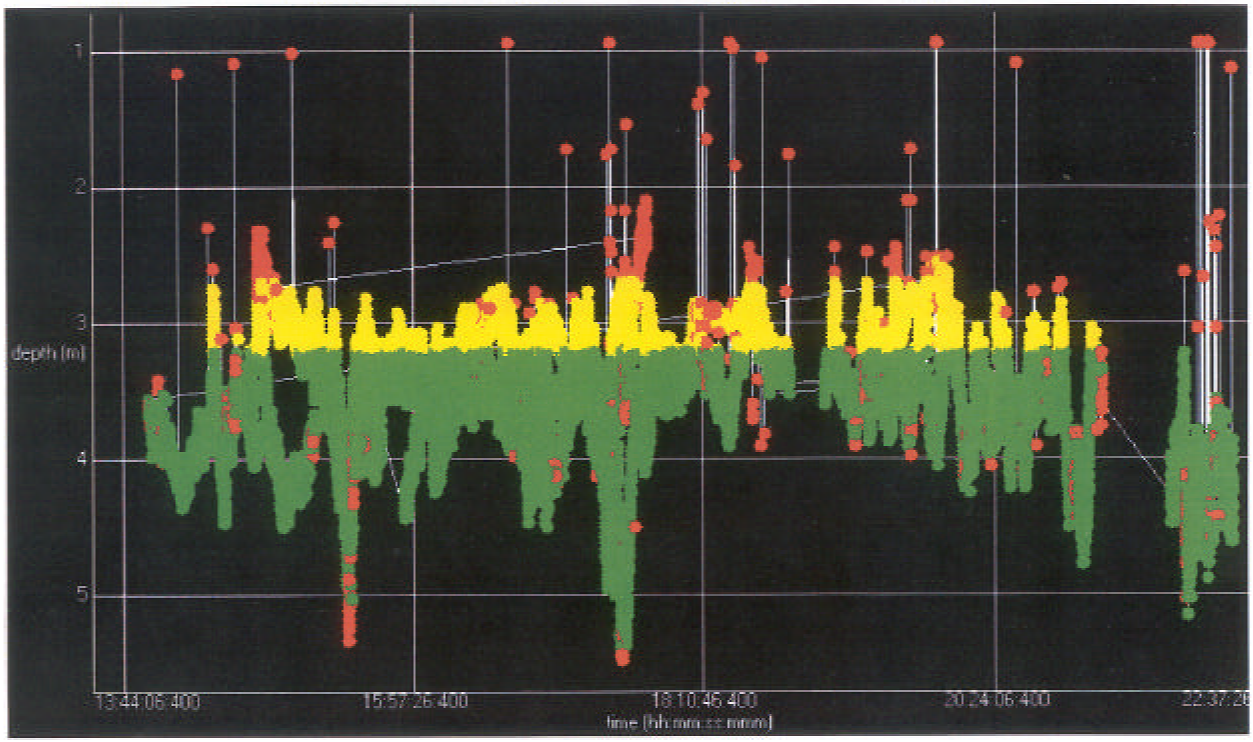
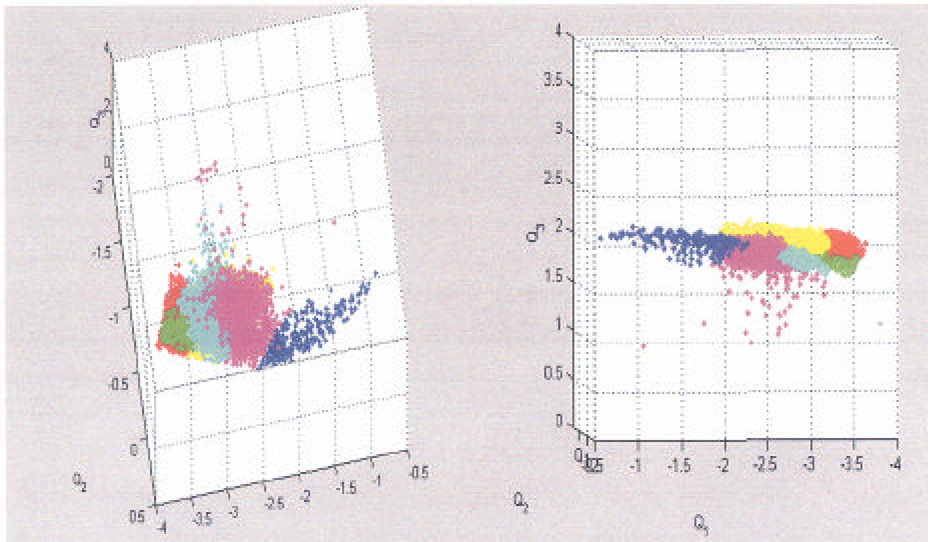


Figure 3-14. Plot of the data filtering process of the Acoustic Seabed Classification System survey. Points represent the total number of individual bottom interrogations in the survey. The majority of points are obscured in this view due to sample density. Multiple days of surveying are over-layered within the daily time window in which they occurred. Anomalous records, such as fish strikes, false bottom picks, and turns in the survey track are depicted in red and were removed from the dataset. Acoustic interrogations from depths less than 3.2 m (yellow) were also removed because of an inability to discriminate waveforms at shallower depths. Green records are the final data set selected for processing.

A



B

Acoustic Class	Color Code	Number of Acoustic Interrogations (n)	Chi-Square Statistic (χ^2)
1	(red)	1191	6.55
2	(green)	456	6.58
3	(dark blue)	256	3.03
4	(light blue)	2967	7.97
5	(yellow)	5151	7.79
6	(pink)	2075	15.64

Total = 12896

Figure 3-15. A) Classed acoustic interrogations viewed as clusters in 3-dimensional Q-space (Q1, Q2, and Q3). Although six acoustic classes are shown here, two are un-validated bottom types of very few members. Class colors correlate to those on the other acoustic figures. Differing locations of class central tendency in the two views indicates acoustic distinctiveness between classes. Cluster dispersion of individual classes illustrates acoustic patterns of variability within individual classes. Close association between individual classes indicates the nature of the transitions between classes. B) Colors representing the six acoustic classes. Total valid interrogations for each are shown, as is the Chi-Square statistic. Increasing Chi-Square values indicate an increasing deviation from a random distribution around the mean.

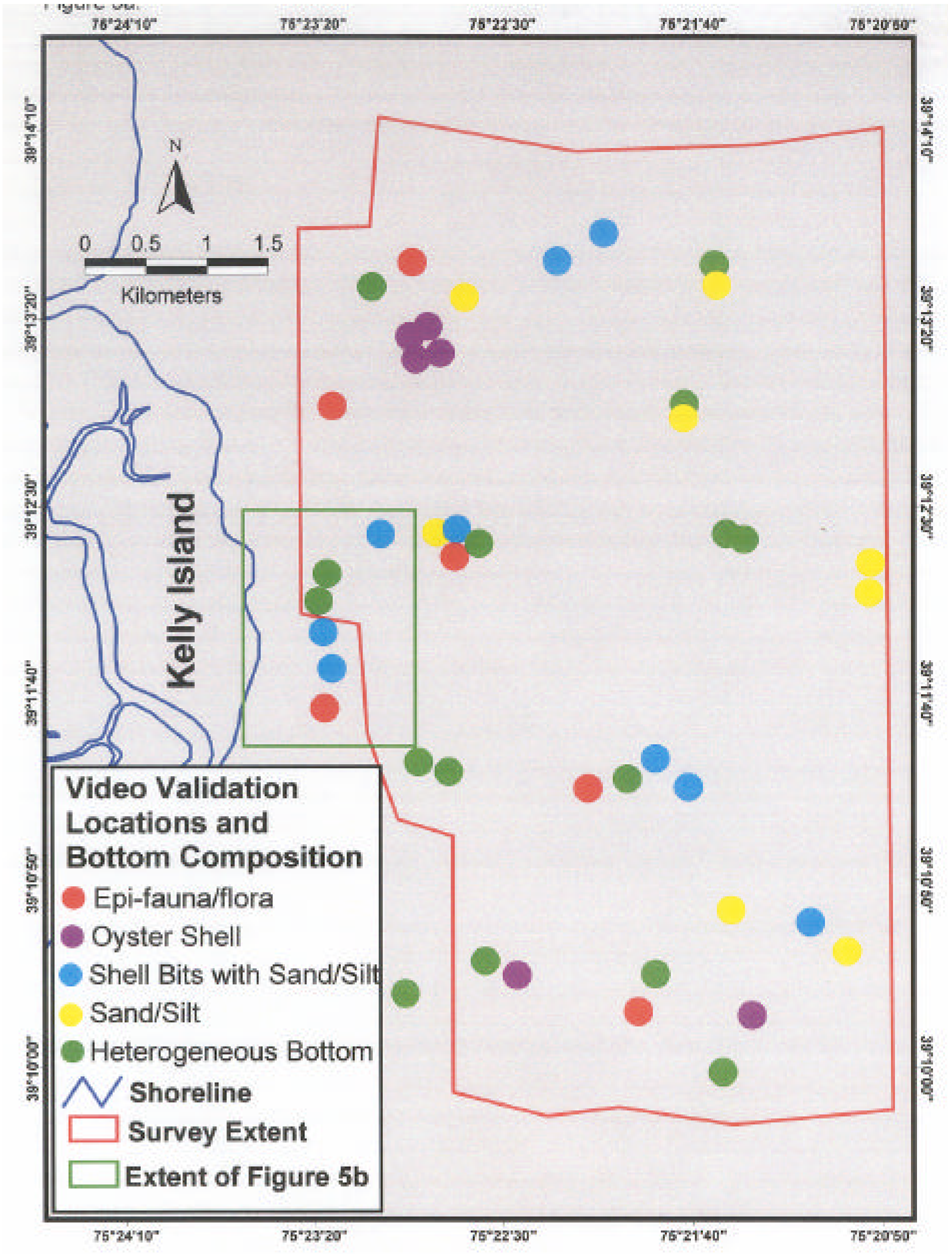


Figure 3-16. A) Location of video validation transects at the survey site. Circles indicate the general location of the transects. Color indicates the video transect classification. The fifteen green transects were not used for classification due to various bottom types being present within their extent. The green box shows the boundary of Figure 3-17.

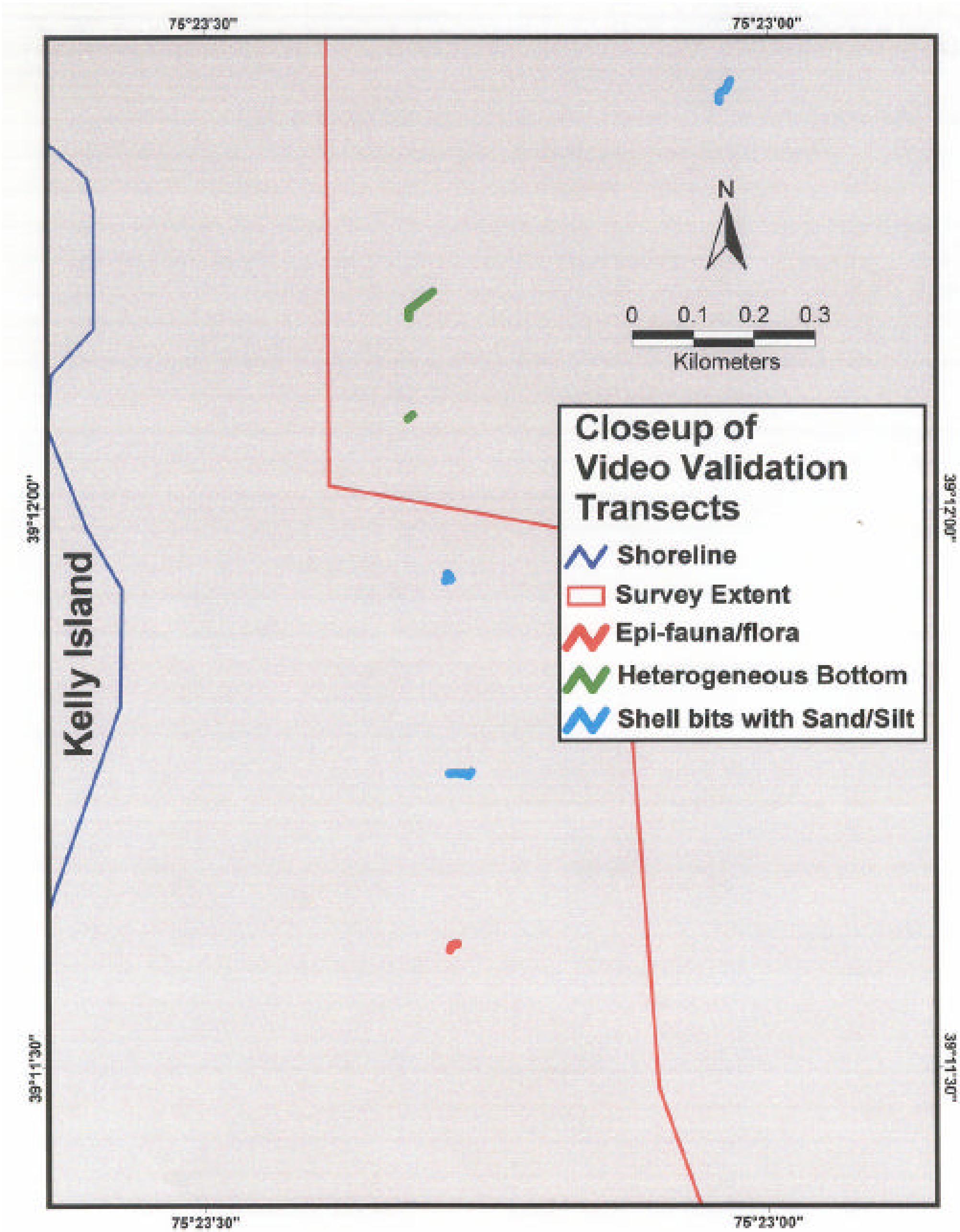


Figure 3-17. Close up of video validation transects conducted near Kelly Island (the green box boundary shown in Figure 3-16). The long dimension of transect is the actual Global Positioning System log of the video sled. Typical transects were several minutes long. Width of the trace is greatly expanded to allow transect color to show.

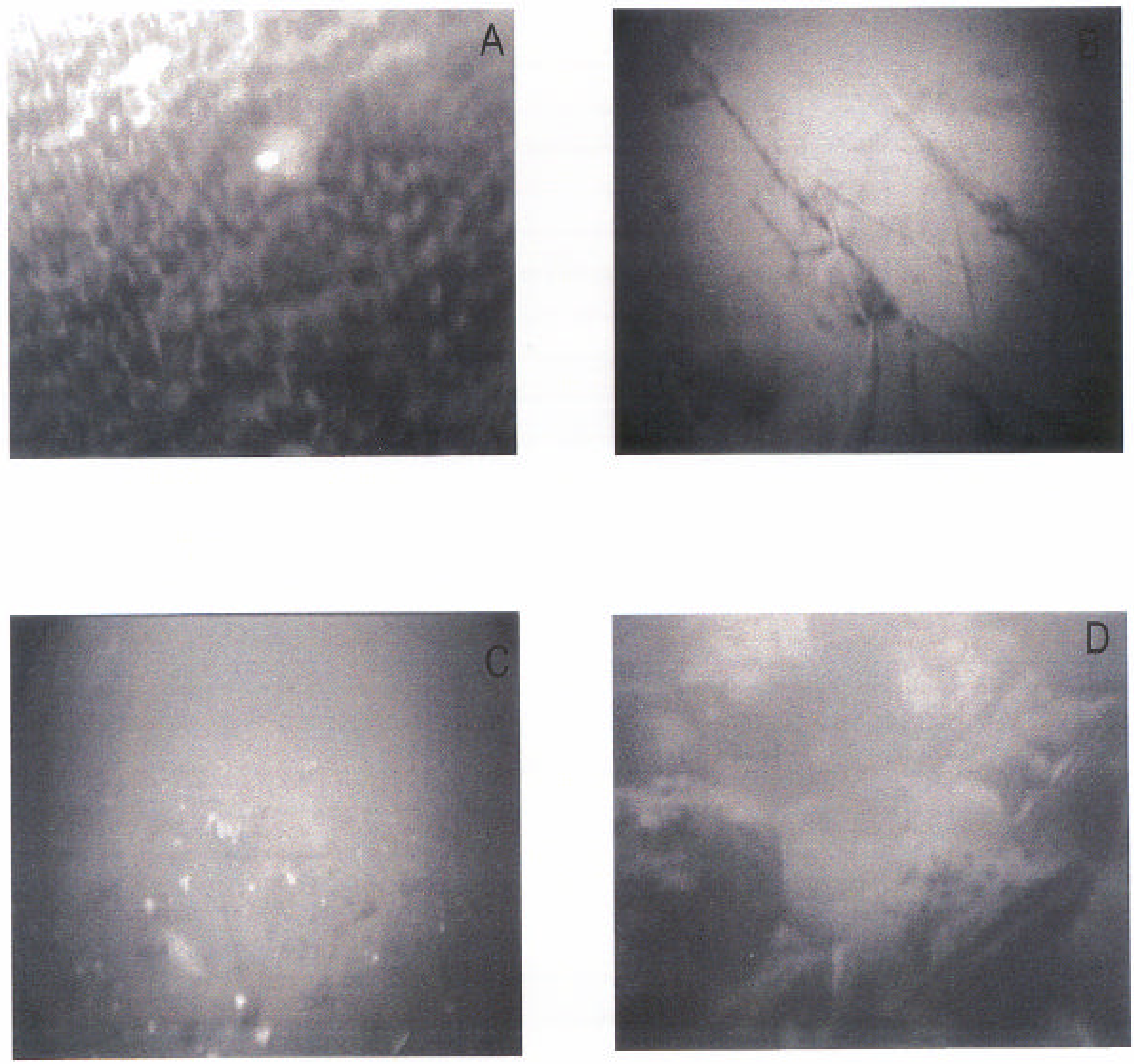


Figure 3-18. Video still images of the four dominant bottom types from video validation transects. A) epi-fauna/flora), B) sand-silt (surface material for video effect), C) sand-silt with shell bits, D) Oyster Shell.

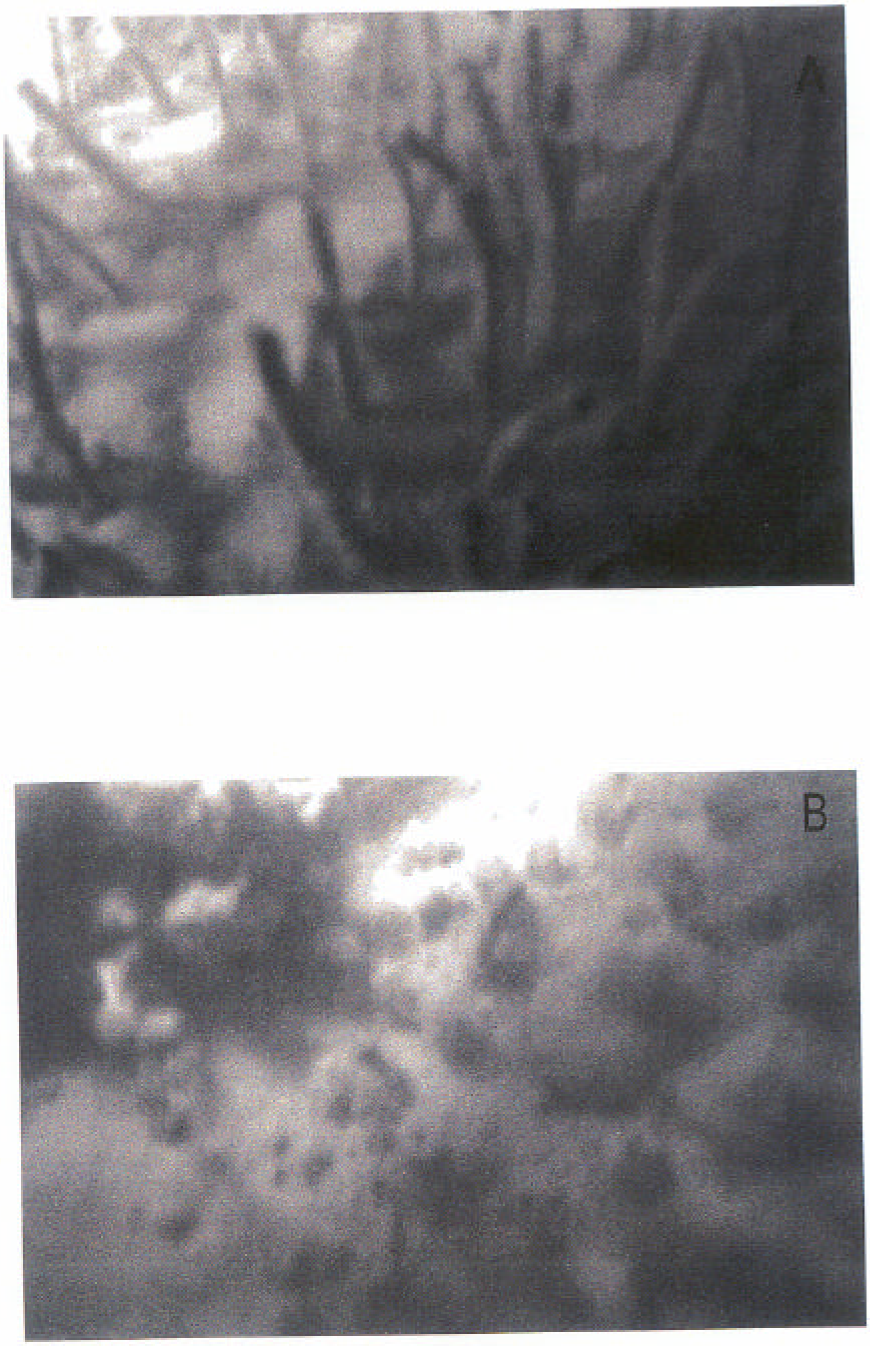


Figure 3-19. B) Video stills of two other less frequent communities observed. A) tubeworm colonies, B) tunicates on presumed buried shell.

3.4.3 Association of ASCS and Video Classifications

Video classification could not visually resolve two of the acoustic classes 2 and 3 (Figure 3-15) but these two classes combined comprised only 5 % of acoustic interrogations and are not large acoustical departures from the other class types. Lack of discrimination was simply due to infrequent distribution of these types and the lack of video images for them.

An examination of the acoustic classes that are associated with the four visual bottom types presented in Figure 3-19 gives some indication of the high degree of small-scale habitat heterogeneity encountered at the site. The most acoustically consistent of the visual bottom categories was sand/silt. Over 50% of acoustic interrogations within 60 m of a sand silt video transect were of sand/silt character. The other five acoustic classifications were present at generally less than 10% of the total acoustic interrogations. The five video transects classified as sand/silt with shell bits (Figure 3-20) showed a very different make-up of acoustic returns. Here, the percentage of sand/silt acoustic returns was similar to the previous visual category. However, the sand/silt with shell bits acoustic category had an almost identical number of acoustic returns within the 60 m buffer around the visual transect.

The oyster shell visual classification (Figure 3-20) shows that when oyster shell is found, it is dense. Although acoustic returns from these areas only show about 50% of interrogations clearly returning from dense shell, the roughly circular area of the mean acoustic footprint covers only 0.39 m^2. The fact that over half of the interrogations had the acoustic signature of shell is significant, considering the observed natural patchiness of oyster bottom.

The epi-fauna/flora classification is perhaps the most difficult to describe in physical terms. The roughly equal proportions of sand / silt and sand / silt with shell bit bottoms clearly associates the sediments with those of the sand / silt with shell bit visual category. Yet the unmistakable dense epi-fauna/flora acoustic signal from habitats associated with these regions caused a distinct classification. It was noted in the video footage that in some areas where this visual habitat was dense, the bottom was irregular, and what appeared to have peat-like outcrops amongst the sand/silt surface.

Of interest in all four of the visual bottom classifications is that oyster shell always comprised at least 5% of the acoustic interrogations within the buffer around the video transect. Again this shows the great heterogeneity of the region. Information presented in this manner validates the confidence in assigning visual criteria to acoustic groupings, and provides an indication of the small-scale spatial variability of the region. This data should not however be extrapolated to explain the association of bottom types of the entire acoustic data set. The 402 acoustic interrogations that fell within the buffer of the 24 video transects chosen as visually homogeneous comprises only 3% of the total number of usable acoustic samples of the study area.

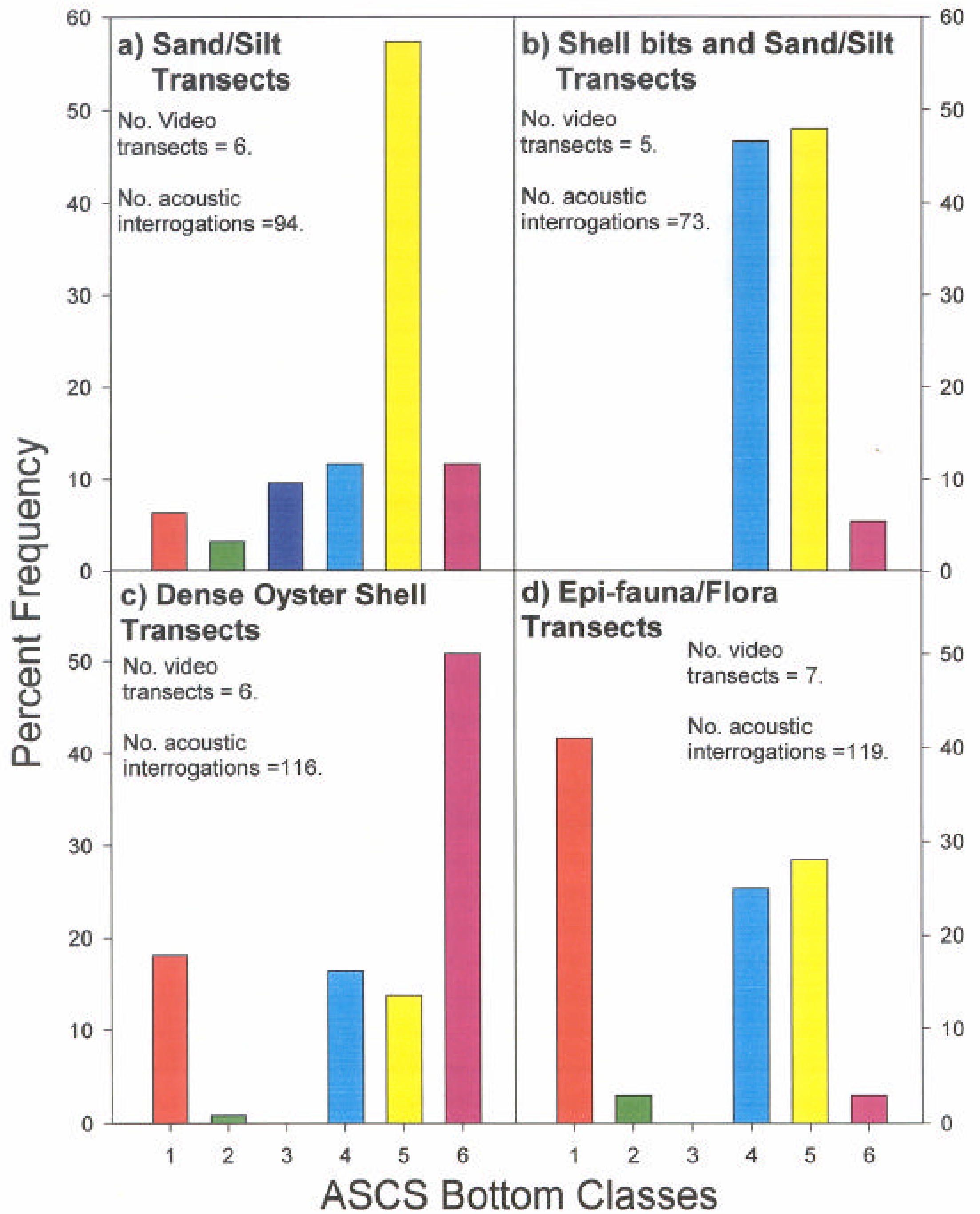


Figure 3-20. Frequency distributions of classed acoustic interrogations occurring within 60 m of video transects. Only video transects where uniform (non-heterogeneous) visual bottom classifications were utilized. A) sand/silt video class, B) sand/silt with shell bits, C) dense oyster shell, D) epi-fauna /flora. Refer to Figure 3-15 for a definition of bottom classes.

The most detailed presentation of the true bottom character and heterogeneity of the region can be seen in the complete set of acoustic interrogations presented in Figure 3-21. This format reveals patterns in the distribution of bottom types within the survey extent. Essentially the survey region can be divided into three principal regions based upon acoustic distributions: an upper half, and a lower half divided vertically in two equal parts. Below latitude 39° 12.0'N, bottoms are relatively homogeneous, and are comprised of two principal types. To the west of 75° 22.0W sediments containing epi-fauna/flora dominate. Along a north-south transitional boundary the sediment changes to a sand/mud uniform bottom with little visible epi-benthic life. The abruptness and vertical nature of the transition was so marked, that we employed video (Figure 3-16) to determine if the transition was an artifact of transect spacing. Video validated that the habitat depiction was accurate. Above latitude 39° 12.0' N, bottoms are a heterogeneous mix of sand/silt, shell bits and sand/silt, and oyster shell.

The continuous interpolated surface of the region (Figure 3-22) simplifies interpretation but may introduce three principal distortions. First, it does not represent the true heterogeneity of the region as seen in Figure 3-21. Secondly, it does not reflect the transitional nature of the bottom. And finally, the shape and extent of polygon bottom types is based on the methods and sequence of continuous surface generation from irregular point data.

To put our results in the context of other project data, other spatial data sets were layered upon the ASCS chart (Figure 3-23). Overall, the distribution of surface material derived from video sediment profiles appears to coincide reasonably well with ASCS bottom types. Sediment profile video revealed that most surface sediments are sands and silts. The small scale heterogeneity characterized by ASCS interrogations does however show the difficulty in matching one to one a sediment profile video snap and an acoustic footprint or surface video location. The scales are not consistent and the GPS precision not adequate. There was an association with worm tubes identified within sediment profiles and the epi-fauna/flora bottom of the acoustics.

Relative abundance of oyster shells collected with trawls also coincided well with the ASCS data. Except for three data points located on bottom classed as epi-fauna/flora (Figure 3-23) all high shell abundance locations were associated with ASCS bottom classed as oyster shell. It must also be considered when examining associations between shell polygons and trawl data that most likely a majority of trawl data came from regions inter-spaced in between ASCS transects.

State oyster seedbed boundaries did show some relation to charted dense oyster shell bottoms. As we are confident of the ASCS shell classification based upon video validation, there is some question if charted seed boundaries truly represent the location of dense shell on the bottom. In our experience with State of Maryland charted oyster bars, legal oyster bar boundaries are not well related to bottom currently capable of supporting oyster development. It may also be noted that the dense oyster shell classification had been generated in context with the entire bottom within the study area. That is, they were weighted no more heavily in terms of classification distinctions than any other bottom type in the cluster analysis. Figure 3-15 shows

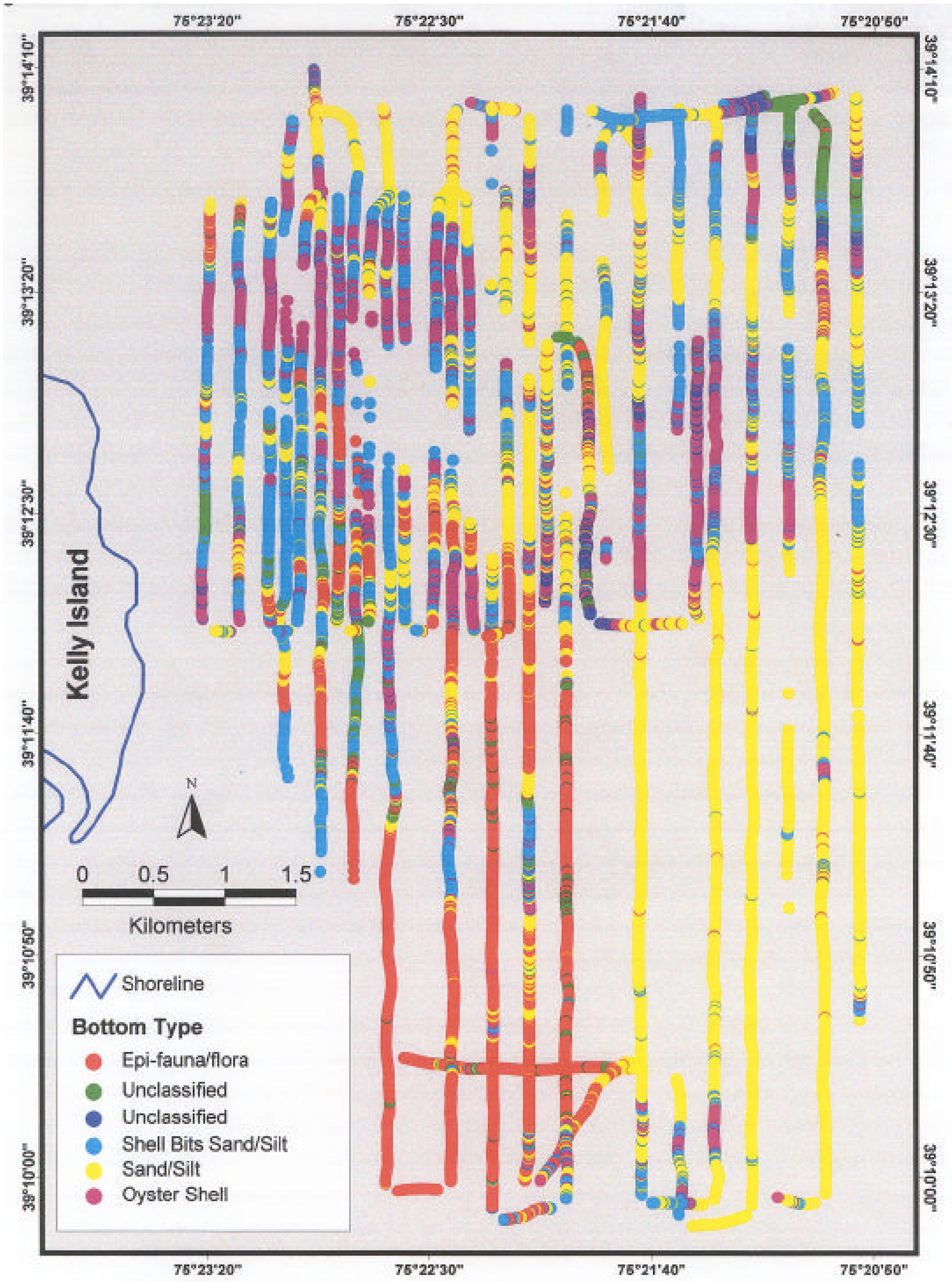


Figure 3-21. Acoustic Seabed Classification System survey results in a point format. Each point is a classed acoustic interrogation. Gaps in the data are the result of editing for data errors and removal of records of less than 3.2 m water depth.

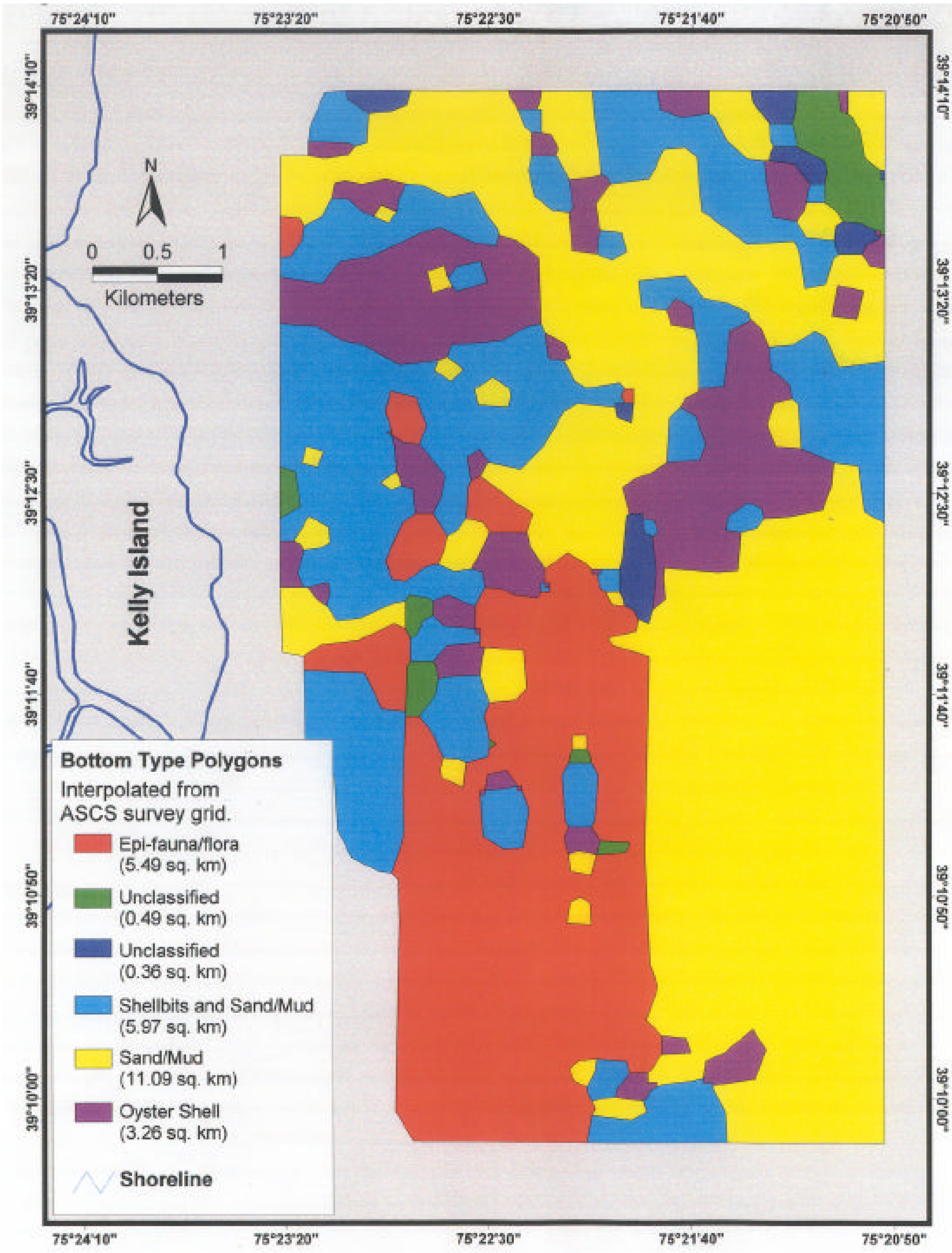


Figure 3-22. Continuous surface representation of the Acoustic Seabed Classification System survey.

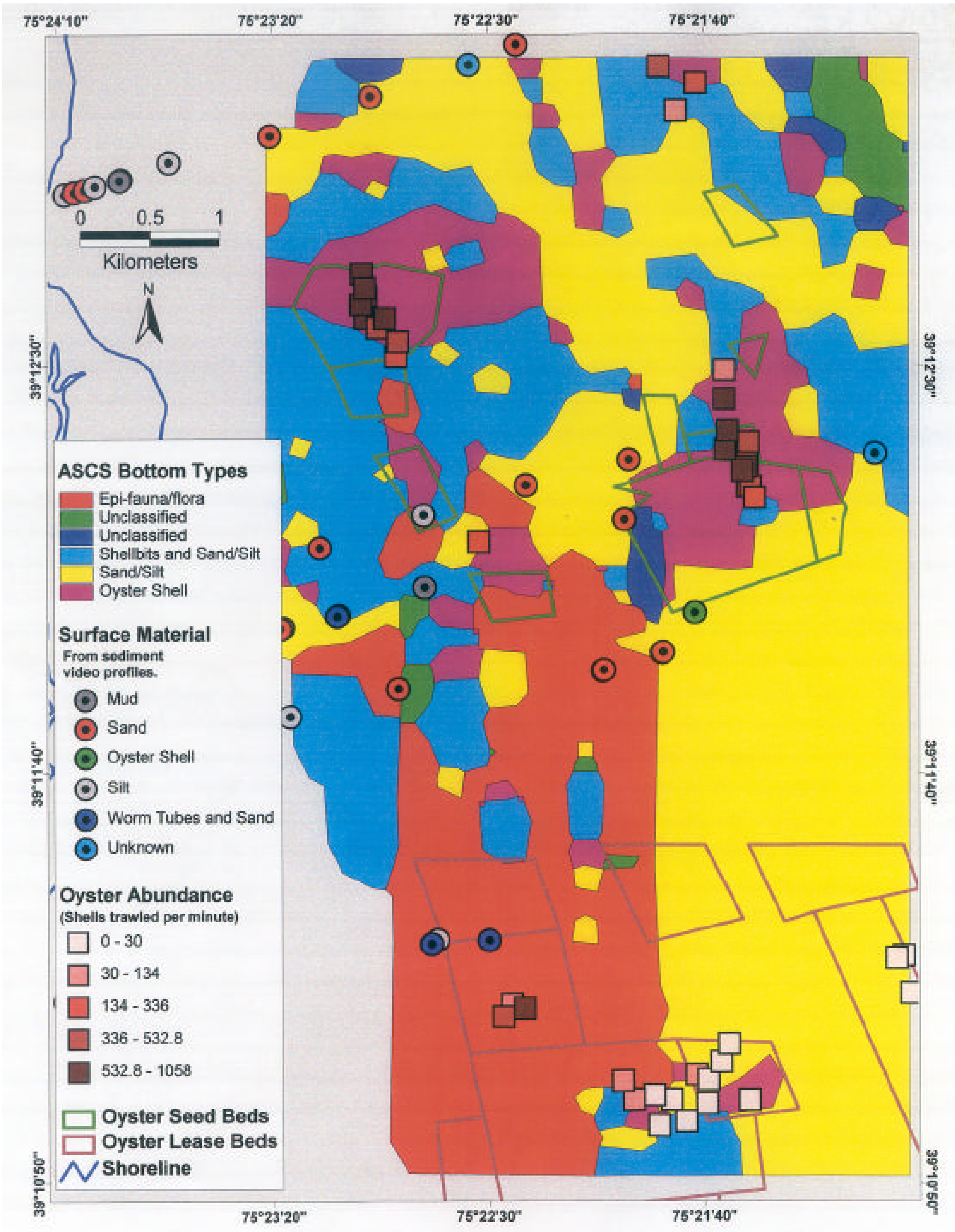


Figure 3-23. Spatial relationships between the Acoustic Seabed Classification System survey and other benthic datasets.

the approximately three times higher Chi-square value for this class. In effect, this bottom type as classified has much greater variability than any of the other bottom classifications. If this oyster bottom was segregated and analyzed independently of other bottoms, a much more detailed pattern of spatial character may emerge.

There was little association between ASCS bottom classifications and oyster lease beds within the study area. A majority of the seven lease beds in the study area were sand/silt or epi-fauna/flora. The detection of dense oyster shell on one lease bed where extensive dredging for oyster shell occurred did show that when surface shell was present, acoustic techniques did detect it. The lack of finding extensive oyster shell in these lease beds may be due in some part to transect spacing. Perhaps shell is so patchy that a greater density of transects may have been required to detect it. However, extensive video transects did not find extensive shell. A factor of ASCS operation may also play a part in detection capability. A 200 kHz transmission frequency was utilized for this survey. This frequency penetrates at most a few cm into sandy sediments. This frequency is the principal operating frequency due to this characteristic – deeper penetration cannot be visually verified. In tests on oyster bars on Chesapeake Bay where up to 15 cm of sand covered dense oyster shell, the 200 kHz frequency simply identified sand. When we employed a lower 50 kHz frequency, this signal penetrated deeper into the sand and detected the shell.

ASCS data were draped over a 3d bathymetry model to identify relationships between bottom classes and depth (Figure 3-24). Although ASCS generates very accurate bathymetry (Figure 3-25), tidal variation throughout the survey times injected error in correcting to M.L.L.W. For this reason NOAA data were preferred for surface development.

3.4.4 Synthesis

Extensive oyster habitat (identified by the presence of exposed shell and related epi-fauna is present in the region associated with oyster seed beds. Because of generally poor visibility it was difficult to determine quantities of live oysters in these beds. Oyster lease areas to the south did exhibit limited regions of shell bottom, but were generally dominated by non-shell surface habitat. Excluding oyster shell habitat, three other principal habitat types were found in the survey region. Two of these were composed of sand - silt substrate being segregated by the presence or absence of shell bits or pieces in the matrix. The final bottom type was defined by biogenic component although the bottom character did appear different from the sand-shell types. This bottom type was dominated by epi-fauna/flora, presumably tubeworms.

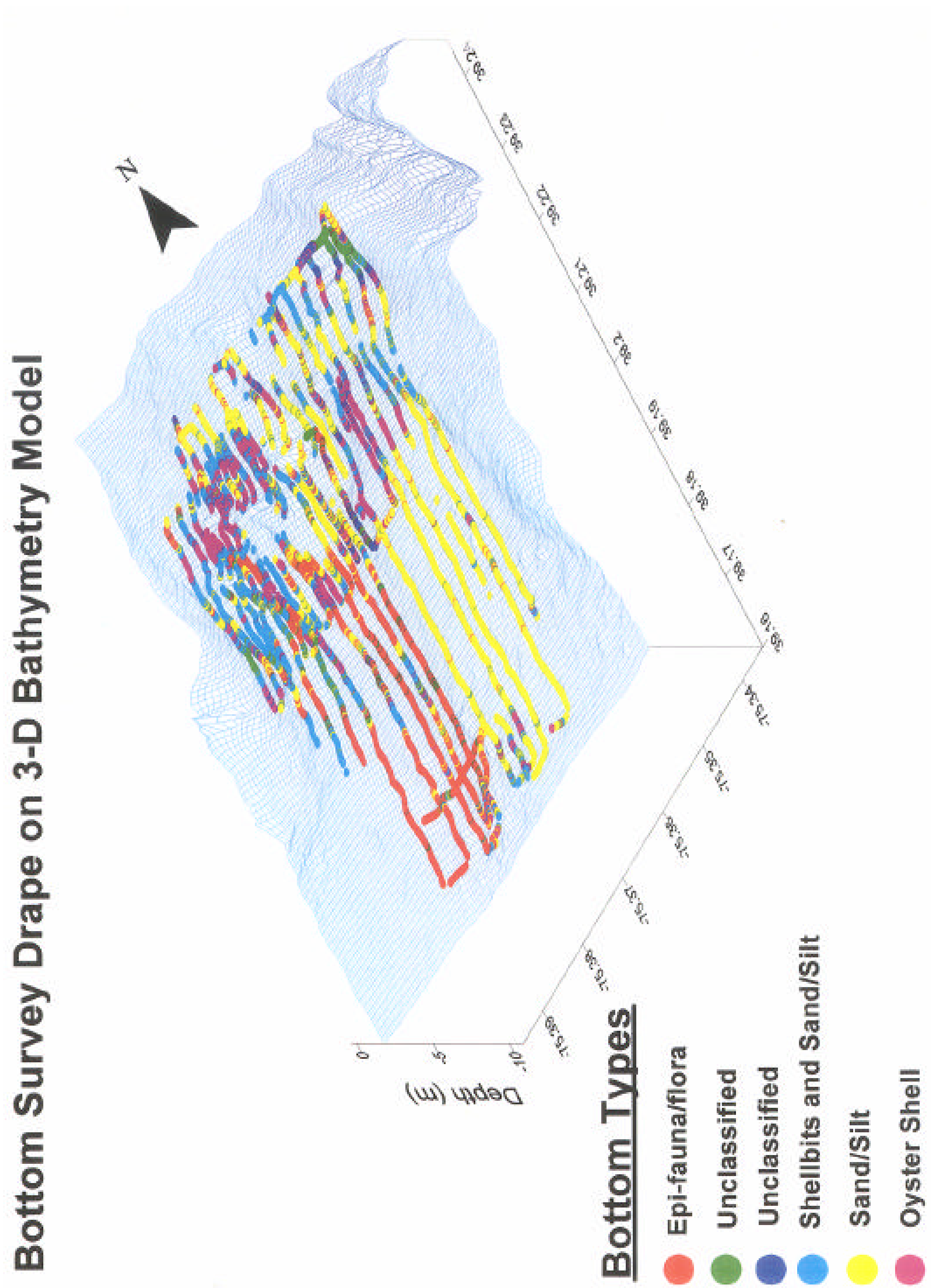


Figure 3-24. Point format Acoustic Seabed Classification System chart of bottom types draped over a 3-dimensional bathymetry model created from NOAA soundings.

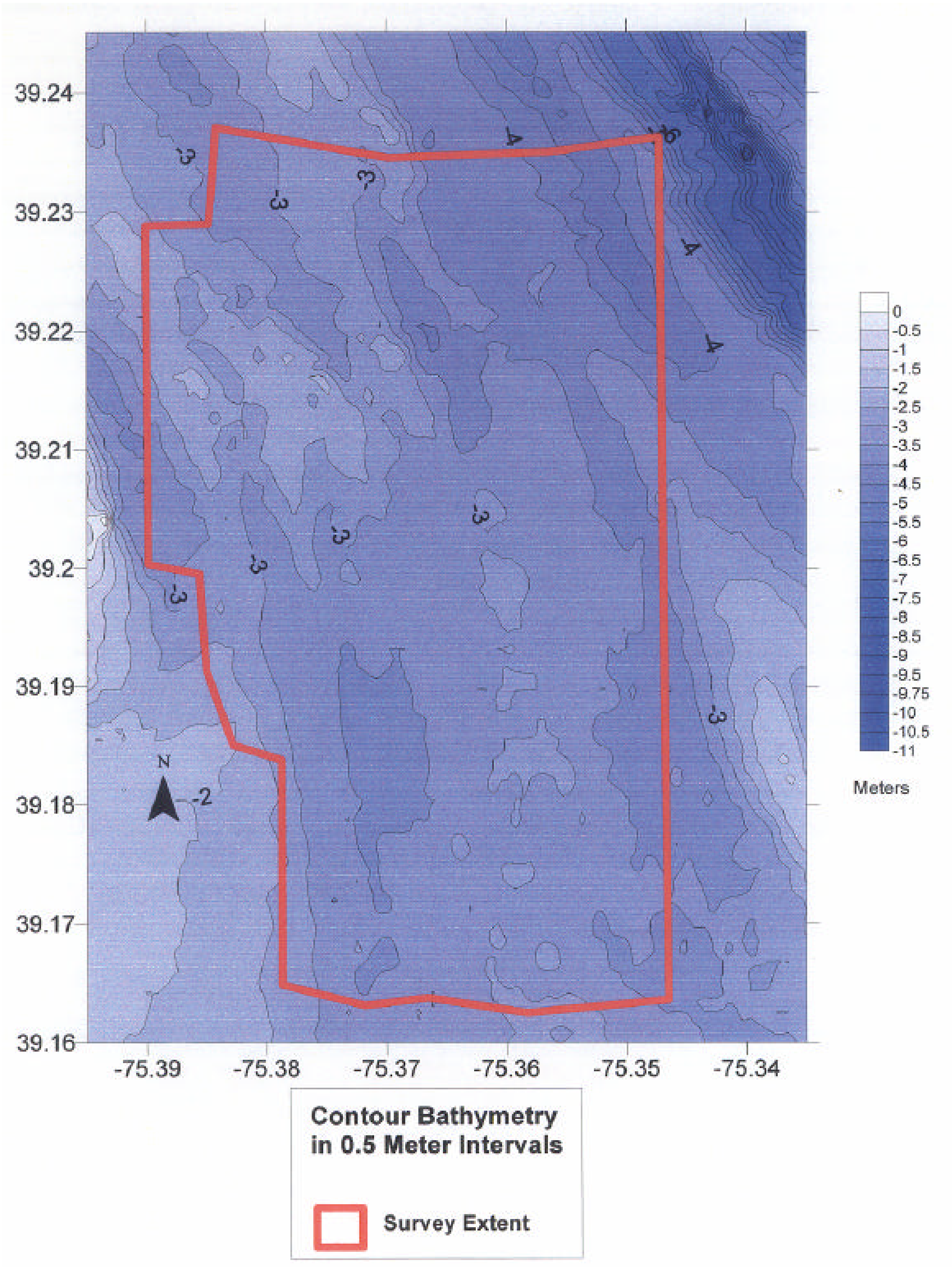


Figure 3-25. Bathymetric contours of the survey region.