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Dungeness Crab Survey for the Southwest Ocean Disposal Site Off Grays Harbor, Washington, June 1990

B. J. Higgins
W. H. Pearson

Battelle/Marine Sciences Laboratory
Sequim, Washington

September 1991

Prepared for the
U. S. Army Corps of Engineers - Seattle
District under Related Services Agreement
with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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DUNGENESS CRAB SURVEY FOR THE SOUTHWEST OCEAN DISPOSAL SITE OFF GRAYS HARBOR, WASHINGTON, JUNE 1990

B. J. Higgins
W. H. Pearson

Battelle/Marine Sciences Laboratory
Sequim, Washington

September 1991

Prepared for the
U.S. Army Corps of Engineers - Seattle
District under Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

As part of the Grays Harbor Navigation Improvement Project, the Seattle District of the U.S. Army Corps of Engineers has begun active use of the Southwest Ocean Disposal Site off Grays Harbor, Washington. Disposal site boundaries were established to avoid an area of high densities of juvenile Dungeness crab, Cancer magister, observed during the site selection surveys. To fulfill requirements for disposal site management, a tiered monitoring plan was established with quantitative decision criteria for moving between the tiers. This survey was the Tier 1 element that was to verify that the location of the area of high crab density observed during site selection surveys has not shifted into the Southwest Ocean Disposal Site. Specifically, the Tier 1 observations in June 1990 would be used to determine whether crab density in June within the disposal site was 100 times higher than in the area to the north. If the crab density within the disposal site had not exceeded this threshold value, Tier 2 activities would not be required to begin.

The survey indicated that the highest crab densities were outside the Southwest Ocean Disposal Site. In June 1990, mean densities of juvenile Dungeness crab (carapace width <50 mm) were 146 crab/ha within the disposal site (8 stations) and 609 crab/ha outside and north of the disposal site (7 stations). At nearshore locations outside the disposal site, juvenile crab density was 3275 crab/ha (2 stations). These 1990 mean juvenile crab densities are 10 to 100 times lower than the mean density of 30,086 crab/ha for 33 stations in the Southwest Navigation Lane found during the Spring 1985 Ocean Survey. Despite the lower overall abundance, the spatial distribution of crab was such that the high crab densities in 1990 have remained outside the Southwest Ocean Disposal Site. The survey data have confirmed the appropriateness of the initial selection of the disposal site boundaries and indicated no need to move to the second monitoring tier.

ACKNOWLEDGEMENTS

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The USACE Seattle District's contract Technical Representative was Bert Brun. We would like to acknowledge the participation of the USACE vessel MV Mamala, with its master Thomas Landum and crew, for providing the platform and operational assistance. The FV Karelia from Westport with its master Vern Heikkila and crew supported the trawling operations. Beak Consultants provided two fisheries biologists, Leonard Rogers and Julie Anderson, who processed the trawl catches. Dr. Walter H. Pearson of MSL trained the trawling crew. Liam Antrim of MSL reviewed the manuscript.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Seattle District of the U.S. Army Corps of Engineers (USACE) has started active use of the Southwest Ocean Disposal Site as part of the Grays Harbor Navigation Improvement Project. During disposal of dredged materials, disposal sites are to be managed so that any significant adverse impacts on resources, resource use, or other amenities are contained within the site and do not migrate beyond its boundaries. Effective disposal site management rests on appropriate selection and location of the site.

The Seattle District supported numerous studies to address concerns about impacts on resources and resource use in the selection of ocean disposal sites off Grays Harbor, Washington. The Southwest Ocean Disposal Site was one of two sites selected from several candidates studied by Battelle/Marine Sciences Laboratory (MSL) during the 1984 and 1985 Ocean Surveys (Pearson et al. 1987). The locations of these two disposal sites were established to minimize potential impacts on resources or resource use around the sites.

A major concern in disposal site selection was locating the sites to avoid high concentrations of Dungeness crab, Cancer magister. During the Spring 1985 Survey, a large concentration of newly settled young-of-the-year (YOY) crab was observed north of the Southwest Navigation Lane between the 100- and 120-ft contours (Pearson et al. 1987). Stations north of the Southwest Navigation Lane had YOY densities of 400,000 crab/ha. After coordination with the various state and federal resource agencies, the Seattle District established the shape and location of the disposal site to avoid this area of high densities of juvenile Dungeness crab. The disposal site management plan (USACE 1989) described disposal operations timed to avoid the high crab concentrations during their seasonal occurrence.

The process to select ocean disposal sites includes development of site management and monitoring plans. In preparing site management plans, potential impacts are considered and addressed and contingency plans created to manage potential adverse impacts. Monitoring and management are coupled in that the general objective of site monitoring is to determine whether changes

in disposal operations are needed. The conceptual plan for disposal site monitoring and management (Pearson 1987) and the 1989 Environmental Impact Statement Supplement (EISS) for the Grays Harbor Navigation Improvement Project (USACE 1989) presented a tiered monitoring plan coupled to management options. In response to deficiencies in previous monitoring approaches, many investigators and agencies have called for such a tiered approach (Fredette et al. 1986; Segar and Stamman 1986; Zeller and Wastler 1986). In a tiered approach, simple techniques for monitoring of physical, chemical, and biological characteristics occupy the lower tiers while more complex monitoring techniques occupy higher tiers (Zeller and Wastler 1986). Work at the higher tiers is undertaken only when a need is demonstrated by the results of activities at the lower tier. In the first monitoring tier for the Grays Harbor Navigation Improvement Project, a field survey during disposal activities was to confirm that the crab distribution in and around the disposal site was as expected. This project is the implementation of the specific part of the monitoring plan that addresses questions about the 1990 distribution of Dungeness crab in and around the Southwest Ocean Disposal Site.

1.2 OBJECTIVE

The objective of this survey was to quantify the abundance of Dungeness crab within and near the Southwest Ocean Disposal Site. The field activity addressed the Tier 1 element in the monitoring plan (Pearson 1987; USACE 1989) that was to verify that the location of the area of high crab density has remained as expected and that the crab density in and around the disposal site gives no indication that the area of high crab density has shifted into the disposal site. In the tiered approach, the decision rules indicating the need to go to a higher tier or to employ remedial action are to be defined beforehand (Fredette et al. 1986; Segar and Stamman 1986). The 1990 Tier 1 observations of crab distribution were to be used to evaluate the decision criteria for moving to Tier 2 monitoring. Specifically, the data were to be used to determine whether crab density in June within the disposal site was 100 times higher than in the area to the north, which would be evidence that the area of high density had shifted into the site. Such a finding would

indicate the need to know more about the current crab distribution and perhaps change the disposal procedures or other aspects of site management. If the crab density within the Southwest Ocean Disposal Site had not exceeded the threshold value, Tier 2 activities would not be triggered and disposal activities would continue as planned.

At the USACE's request, a survey was also undertaken near the South Jetty to the northeast of the Southwest Ocean Disposal Site. This sampling was conducted to assess whether the South Jetty area could receive dredged materials for replenishing eroding beaches. Information on the crab abundance in the nearshore area south of the South Jetty was needed to assess the feasibility of disposal of dredged materials there. This latter survey was not part of the original monitoring plan.

1.3 SCOPE

To accomplish the study objectives, an underwater television (TV) system was towed along four track lines of approximately 3 nmi long near the disposal area. Previously surveyed observation locations were revisited to compare present distribution with that previously observed. Trawling with a plumb-staff beam trawl followed the TV tows to quantify the abundance of Dungeness crab. The trawls were sorted for other dominant taxa of macroepifauna as well as the Dungeness crab.

1.4 STUDY LOCATIONS

The Southwest Ocean Disposal Site is receiving sandy materials dredged from the Grays Harbor Bar and entrance. Figure 1 shows the general region around Grays Harbor, Hoquiam/Aberdeen, and Westport. Figure 2 indicates the approximate positions of the 8-Mile and Southwest Ocean Disposal Sites. The Southwest Ocean Disposal Site covers 2 mi^2 and is centered near the Southwest Navigational Lane Buoy "GH". The disposal site boundaries form a parallelogram, and the positions of the site corners given in the USACE EISS (USACE 1989; page 2-14) are:

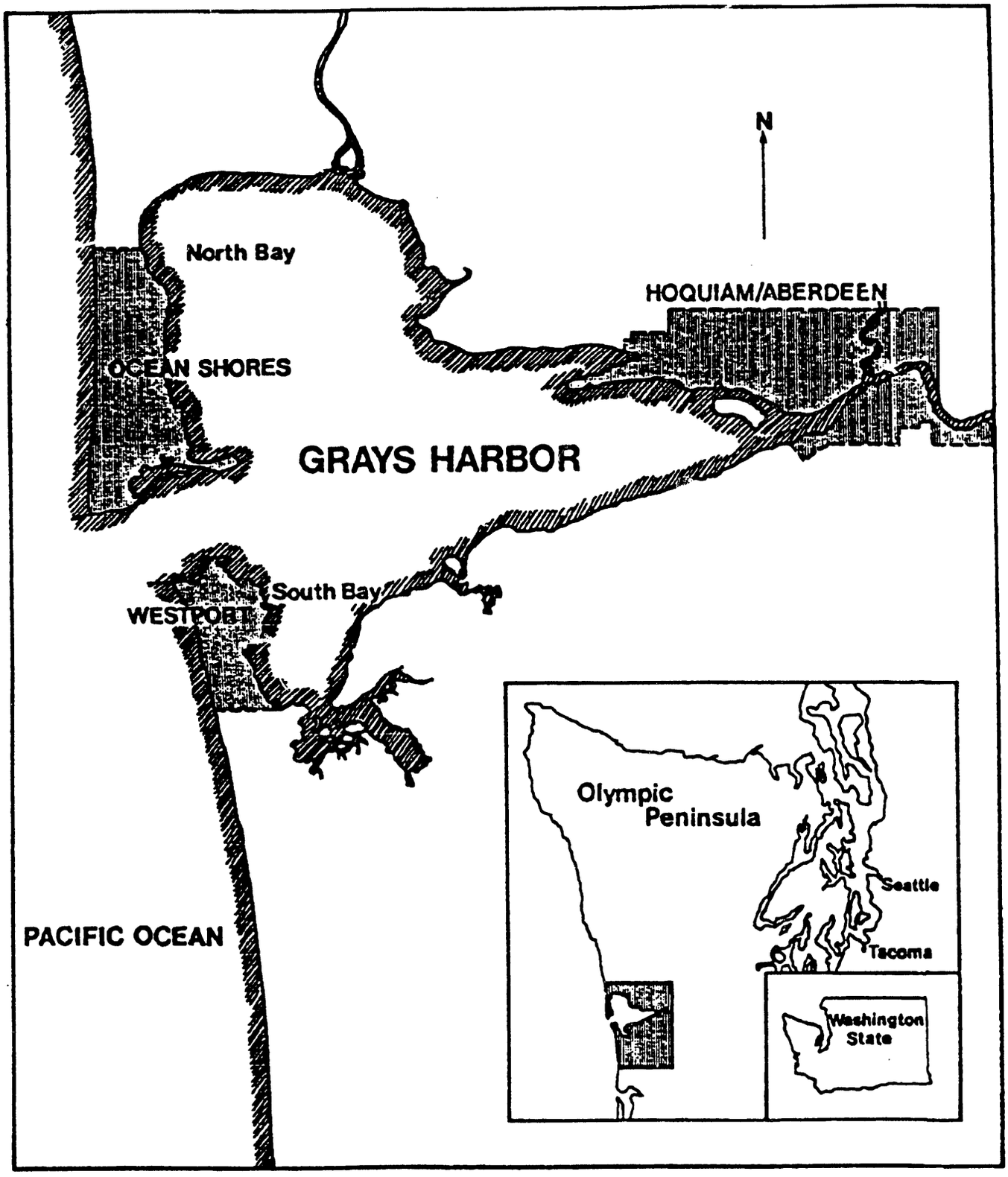

FIGURE 1. The Location of Grays Harbor and the Study Area

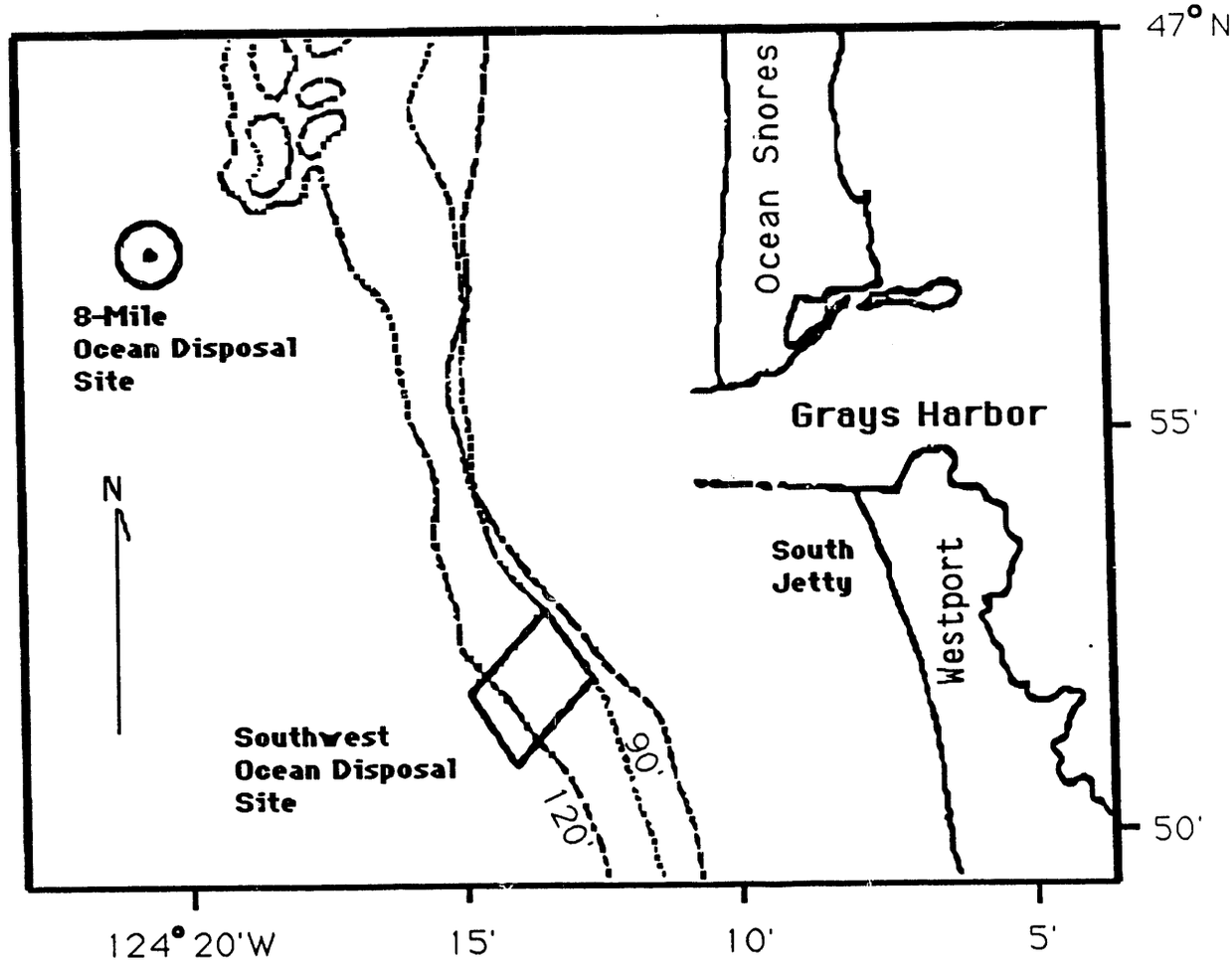

FIGURE 2. The Ocean Disposal Sites for Dredged Materials from the Grays Harbor Navigation Improvement Project

Corner	Latitude	Longitude
NE	46° 52.94'N	124° 13.81'W
SE	46° 52.17'N	124° 12.96'W
SW	46° 51.15'N	124° 14.19'W
NW	46° 51.92'N	124° 14.95'W

The disposal site boundaries were established to avoid an area of high crab density. The results of previous trawling and TV tows during 1985 indicated that YOY Dungeness crab were abundant between the 100- and 120-ft contours north of the disposal site. Therefore, in developing the decision criteria in the monitoring plan, this northern region was selected for comparison with the disposal site.

Sampling south of the South Jetty (Figure 2) was to occur at nearshore locations in depths between 30 and 60 ft. Station positions were not

established beforehand because the high density of crab pots expected in the region would require the station position to be determined based on observations at the time of sampling.

2.0 MATERIALS AND METHODS

The sampling procedures of this survey were similar to those of the Spring 1985 Ocean Survey (Pearson et al. 1987). The planned operations included

- TV tows to guide trawling locations
- Beam trawling to quantify crab abundance
- Conductivity Temperature Depth (CTD) casts to characterize the hydrographic environment.

The observations from the TV tows were to guide the trawling operations. The trawls were intended to quantify the crab abundance at locations indicated by the TV observations.

2.1 UNDERWATER TELEVISION SYSTEM

The USACE vessel MV Mamala towed the underwater TV system. The advantages of using the MV Mamala included navigational equipment and a large cabin for the electronic equipment. The TV system consisted of a Remotely Operated Vehicle (ROV) weighted with chain. The chain was added to allow the system to ride just above the bottom and give the operator positive control. The control unit was in the vessel's cabin sheltered from the weather and glare. The TV system was deployed from the stern. The ship proceeded slowly (about 1 knot) with the bridge crew monitoring the TV signal displayed by a secondary monitor on the bridge. While the ship was under way the observer noted the time, location, and depth every 1 min (approximately every 400 ft along the towed path). The video signal was recorded and voice annotated. Crab observations from the TV system were to be used to guide the location of the trawling operations, which would then quantify the crab abundance.

The scope of the 1990 survey included revisiting some of the TV tow locations from the 1985 Ocean Surveys. Because the particular path of a TV tow is dependent on prevailing wind and wave conditions, it was not possible to precisely follow the previous paths. Figure 3 shows the tow paths from the 1985 Ocean Surveys (Pearson et al. 1987). The following summarizes the observations from the 1985 Surveys:

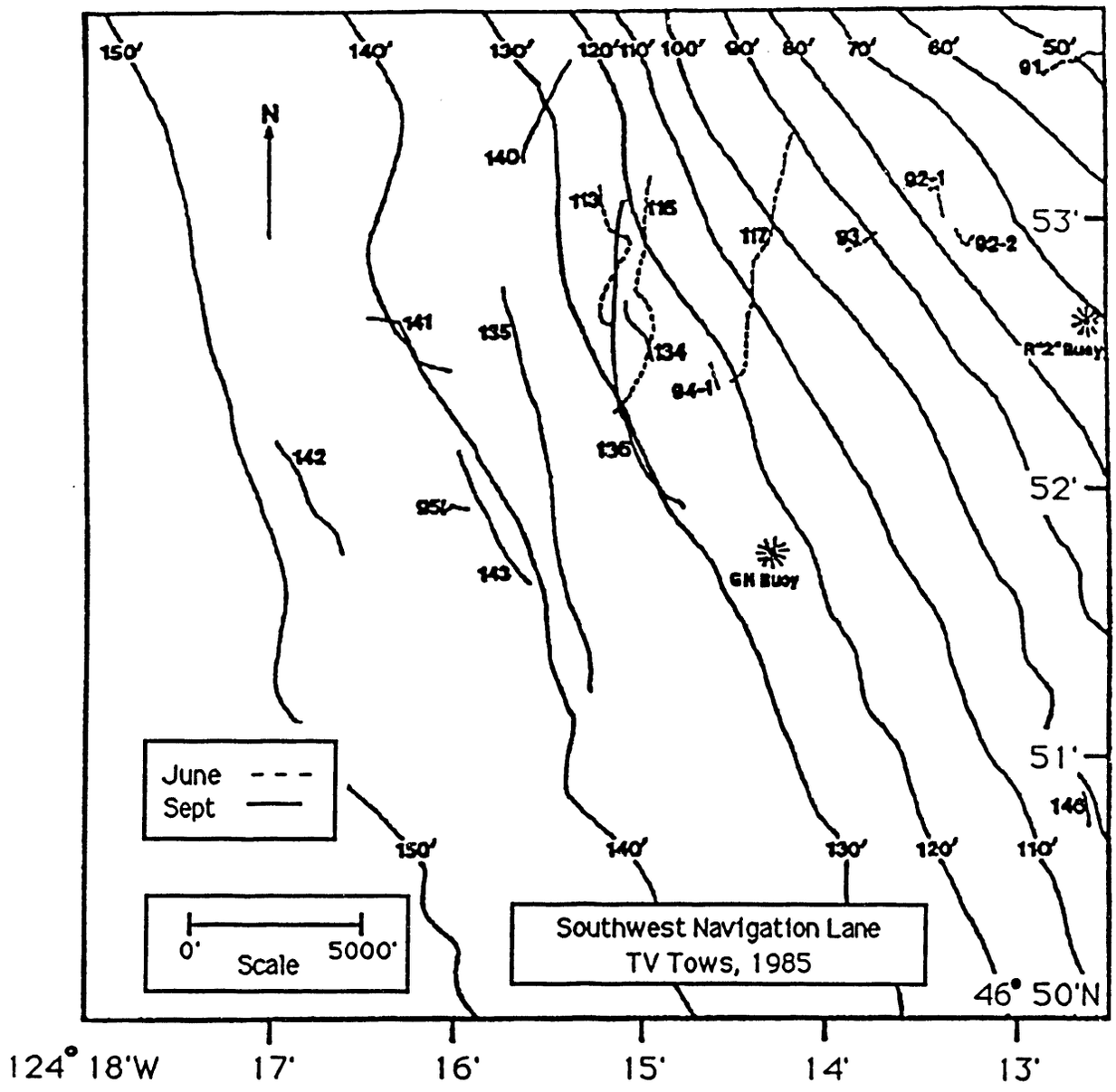

FIGURE 3. Paths for TV Tows Conducted During the 1985 Ocean Surveys (Pearson et al. 1987)

Station 113 - Tow Length: 0.6 nmi
very silty sand, rippled, then less silty, flatter, more rippled; tremendous number of juvenile crab, then no crab, some starfish.

Station 116 - Tow Length: 0.95 nmi
rippled silty sand, then less silty, less rippled; one adult crab, tremendous number of juvenile crab, then abruptly very few crab.

Station 117 - Tow Length: 0.98 nmi
rippled hard sand, then siltier; nine adult crab, then moderate numbers of juvenile crab.

Station 135 - Tow Length: 1.53 nmi
rippled sand, siltier; starfish, snails, worm tubes, flatfish, sculpins, one crab.

Station 136 - Tow Length: 1.21 nmi
rippled sand, then siltier; round fish, flatfish, starfish, snails.

In the South Jetty region, a preliminary survey of three TV tows was planned. One-hour tows along the 30-, 45-, and 60-ft-depth contours would yield TV tow paths of about 1 nmi each.

2.2 TRAWLING

To obtain crab distribution and density estimates, the same trawl design and trawling parameters that had proved successful during the 1984 and 1985 Ocean Surveys were used in the 1990 survey. The chartered fishing vessel FV Karelia used a single warp to tow a 3-m plumb-staff beam trawl. Conditions permitting, the trawls were to be parallel to the depth contours. The trawls were of 10-min duration with a scope of 4 to 1 and vessel speed of 2 to 4 knots. If the net was fouled, the sample was discarded, and the station redone. The trawl design followed that of Armstrong et al. (1985) and has been described in detail by Pearson et al. (1987).

The survey plan for the Southwest Ocean Disposal Site included a minimum of

- four trawl stations within the disposal site between the 100- and 120-ft contours
- four trawl stations near the previously surveyed ocean stations (selected from Stations 113, 116, 117, 135, 137)
- four additional trawl stations set at the Chief Scientist's discretion based on TV observations.

The locations for additional discretionary trawls were based on limited TV observations. Beyond the four trawl stations inside and the four stations outside the Southwest Ocean Disposal Site, the additional trawl stations included

- two trawls set along the disposal site boundary
- two trawls within the disposal site
- three trawls north of the disposal site
- one trawl west of the disposal site.

For data analysis, the stations at the disposal site boundaries were grouped with those within the site.

The station list in Table 1 shows that the entire survey successfully completed 18 stations. Figure 4 shows the trawling locations. Sixteen instead of the 12 stations planned for the Southwest Ocean Disposal Site were accomplished.

The effort for the South Jetty was to be secondary to that for the Southwest Ocean Disposal Site. In the South Jetty region, three trawls were planned along the 30-, 45-, and 60-ft contours. Two of the three trawls planned for the South Jetty were conducted (Table 1, Figure 4). The 45-ft-depth contour could not be sampled because the numerous crab traps at that depth contour prevented safe trawling operations. The region has been an active crabbing area for local industry.

All trawls were sorted for Dungeness crab, other crab, and major epifaunal taxa. Using a check list, each trawl's catch was fully processed for the dominant species in the general categories of crustacean, echinoderms, mollusks, flat fish, round fish, and other. Appendix A provides the species list and sorting categories. Taxonomic references were used to identify fish and crustaceans. Because mollusks were rarely collected, all mollusks were placed in one category.

From the trawl data, relative density of crab as crab/hectare was calculated by dividing the number of crab by the area swept. The area swept was calculated from the distance towed and effective fishing width (2.3 m)

TABLE 1. Station List and Distances Trawled for the June 1990 Crab Survey

Station Number	Date	Time (PDT)	Latitude N (deg. min.)	Longitude W (deg. min.)	Depth (feet) (a)	Dist. Towed (nmi)	Area Swept (ha) (b)	Comment
Training	18-Jun-90	14:21	46 54.93	124 06.36	38			
		14:30	46 54.89	124 06.00	37			
201	19-Jun-90	11:39	46 52.41	124 14.56	103	0.265	0.112	North
		11:49	46 52.66	124 14.74	102			
202	19-Jun-90	10:02	46 52.32	124 15.12	120	0.221	0.094	North
		10:12	46 52.53	124 15.28	118			
203	19-Jun-90	13:05	46 51.47	124 14.09	105	0.238	0.101	Within
		13:15	46 51.69	124 14.29	107			
204	19-Jun-90	13:37	46 51.58	124 14.35	109	0.252	0.107	Within
		13:47	46 51.83	124 14.42	108			
205	20-Jun-90	8:25	46 52.98	124 14.40	78	0.300	0.127	North
		8:25	46 53.28	124 14.38	76			
206	20-Jun-90	9:21	46 52.04	124 15.48	127			Fouled net
		9:31	46 52.34	124 15.62	128			
206	20-Jun-90	9:49	46 52.09	124 15.53	128	0.291	0.123	North
		9:59	46 52.38	124 15.57	127			
207	20-Jun-90	10:35	46 52.36	124 13.47	78	0.306	0.130	Within
		10:45	46 52.66	124 13.59	76			
208	20-Jun-90	11:14	46 52.10	124 13.76	89	0.310	0.131	Within
		11:24	46 52.39	124 13.97	90			
209	20-Jun-90	12:44	46 51.87	124 13.97	100	0.238	0.101	Within
		12:54	46 52.07	124 14.26	101			
210	20-Jun-90	13:25	46 51.13	124 14.62	125	0.212	0.090	West
		13:35	46 51.32	124 14.84	ND			
211	21-Jun-90	8:20	46 53.40	124 14.45	63	0.288	0.122	North
		8:30	46 53.65	124 14.74	66			
212	21-Jun-90	8:57	46 52.69	124 15.15	104			Fouled net
		9:07	46 52.96	124 15.20	100			
212	21-Jun-90	9:27	46 52.75	124 15.09	102	0.226	0.096	North
		9:37	46 52.95	124 15.33	102			
213	21-Jun-90	10:03	46 52.69	124 15.69	125	0.254	0.107	North
		10:13	46 52.92	124 15.92	125			
214	21-Jun-90	10:53	46 51.30	124 15.41	133	0.253	0.107	Boundary
		11:03	46 51.54	124 15.58	134			

TABLE 1. (contd)

Station Number	Date	Time (PDT)	Latitude N (deg. min.)	Longitude W (deg. min.)	Depth (feet) (a)	Dist. Towed (nmi)	Area Swept (ha) (b)	Comment
215	21-Jun-90	11:51	46 51.89	124 14.77	117			Fouled net
		12:01	46 52.11	124 14.85	115			
215	21-Jun-90	12:19	46 51.90	124 14.77	117	0.256	0.109	Boundary
		12:29	46 52.15	124 14.89	118			
216	21-Jun-90	13:07	46 51.87	124 13.44	84	0.210	0.089	Within
		13:17	46 52.08	124 13.47	85			
217	22-Jun-90	8:25	46 52.95	124 09.85	31	0.220	0.093	South Jetty
		8:35	46 53.17	124 09.85	30			
218	22-Jun-90	9:02	46 52.76	124 10.56	40	0.291	0.123	South Jetty
		9:12	46 53.04	124 10.72	40			

(a) Ships observed depths uncorrected for tidal height. ND indicates no data.
(b) Area swept is computed for the 3- m trawl from the distance traveled as a straight line and the effective net width. The equation is: dist. traveled (n.mile) x 0.426 (ha/(nmi x m)) x effective width (m)

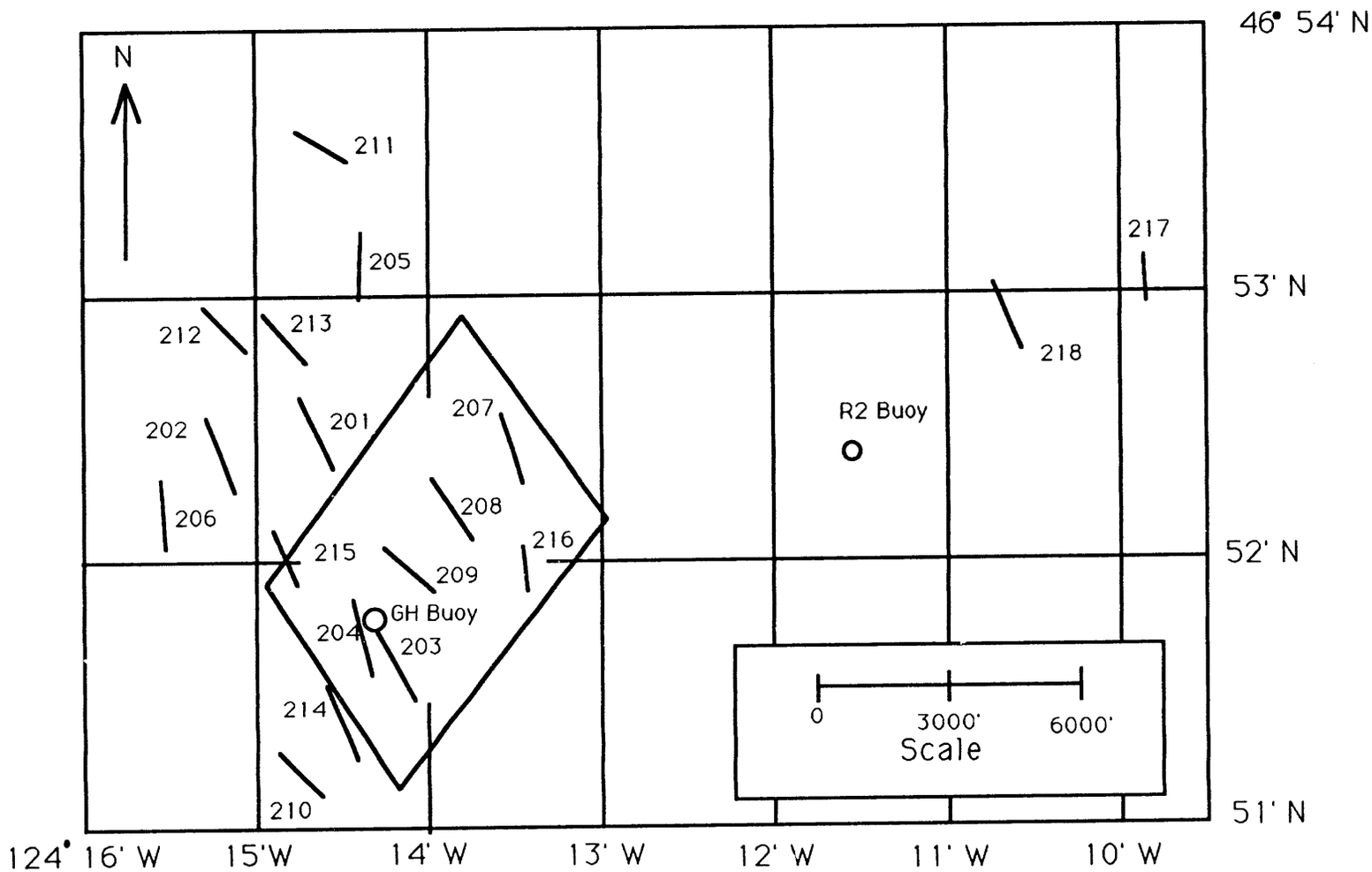

FIGURE 4. Locations for the June 1990 Trawling Stations

previously determined for this design (Armstrong et al. 1985). No attempt to correct trawl data for net efficiency was made, and, therefore, all densities mentioned in this report are relative rather than absolute densities.

2.3 HYDROGRAPHIC CASTS

Daily hydrographic casts to obtain depth profiles of temperature, salinity, and light transmission were initially planned for each sampling region. These data would have complemented information collected during the 1984 and 1985 Ocean Surveys. However, the CTD's winch had electrical power connection problems so that this effort was not performed. Lack of these data does not affect the evaluation of the decision criteria because the Tier 1 criteria are based solely on crab density data.

3.0 RESULTS

3.1 TELEVISION TOWS

During this survey, the TV system was towed along four paths in and around the Southwest Ocean Disposal Site as follows:

19 June 1990, 0834 to 1159, depths from 90 to 127 ft
Towing started within the disposal area and extended outside following a heading of approximately 320°M.

19 June 1990, 1204 to 1357, depths from 114 to 124 ft
Towing started outside the disposal area to travel through areas of the Spring 1985 Survey stations north of the Southwest Ocean Disposal Site. Wind and current conditions dictated a ship's heading of approximately 320°M.

20 June 1990, 0806 to 1015, depths from 101 to 139 ft
Towing started within the disposal area and extended outside at a heading of 320°M.

20 June 1990, 1040 to 1224, depths from 90 to 124 ft
Towing started outside the disposal area as dictated by the wind and current drift with a heading of 270°M. An abandoned crab pot was struck with no damage to the TV system.

In each of these tows, only a few small (40-mm) fish and no crab were observed. For the Southwest Ocean Disposal Site, the TV operations were substantially impaired by the poor visibility (0.5 m) encountered at depths over 60 ft. The Dungeness crab and other marine life were not discernible under these conditions. To offset the loss of coverage that the TV tows would have provided, the number of trawls was increased.

On 20 June 1990, TV tows were attempted in the nearshore area of the South Jetty. The high density of active crab pots prevented safe deployment of the TV system.

3.2 TRAWLING

The number and catch weights of Dungeness crab are summarized in Table 2. The trawl data results by station and taxa appear in Appendix B. Data from measurements on the adult Dungeness crab appear in Appendix C. Figures 5, 6, and 7 present the spatial distribution of the density of all Dungeness crab, adult crab, and juvenile crab, respectively.

TABLE 2. Mean Density and Weights of Crustaceans and Dungeness Crab for June 1990 Survey In and Around the Southwest Ocean Disposal Site

Station Number	Region	Area Swept(ha)	Total Crustacean Catch Wt(g)	Catch Wt(g/ha)	Total Dungeness Crab Wt(g)	Total Dungeness Crab Number	Crab Density (crab/ha)	Adult Crab (>50 mm) Wt.(g)	Adult Crab (>50 mm) Number	Adult Crab Density (crab/ha)	Juvenile Crab (<50 mm) Wt(g)	Juvenile Crab (<50 mm) Number	Juvenile Crab Density (crab/ha)
203	Within[1]	0.101	375	3710	17	5	50	0	0	0	17	5	50
204	Within	0.107	366	3420	0.1	4	37	0	0	0	0.1	4	37
207	Within	0.13	2860	22000	2440	132	1020	2410	8	62	34	124	953
208	Within	0.131	3780	28900	3350	18	137	3350	11	84	3	7	53
209	Within	0.101	2830	28000	2460	9	89	2460	6	59	0.1	3	30
214	Within	0.107	90	841	0	0	0	0	0	0	0	0	0
215	Bound[2]	0.109	833	7640	461	4	37	460	1	9	1	1	9
216	Within	0.089	1240	3900	844	6	67	844	3	34	0.1	3	34
Mean					1200	22	180	1190	4	31	7	18	146
SD					1350	45	342	1350	4	34	12	43	327
201	North	0.112	5020	44800	4280	88	786	4260	8	71	26	80	714
202	North	0.094	1400	14900	954	64	681	908	2	21	46	62	660
205	North	0.127	4340	34200	4100	151	1190	4040	11	87	65	140	1100
206	North	0.123	3360	27300	2920	89	724	2890	6	49	27	83	675
211	North	0.122	1240	10200	969	124	1020	928	3	25	41	121	992
212	North	0.096	3260	34000	2720	9	94	2720	9	94	0	0	0
213	North	0.107	553	5170	430	14	131	428	1	9	2	13	122
Mean					2340	77	661	2310	6	51	30	71	609
SD					1570	53	415	1570	4	34	23	52	411
210	West	0.09	535	5940	287	9	100	276	1	11	11	8	89
217	Shore	0.124	1390	11200	1180	242	1950	1110	3	24	74	239	1930
218	Shore	0.164	2880	17600	2710	764	4660	2580	6	37	134	758	4620
Means					1940	503	3300	1845	4	30	104	498	3280
SD					1080	369	1916	1040	2	9	42	367	1902

(1) "Within" indicates trawl inside the Southwest Ocean Disposal Site.
(2) "Bound" indicates trawl at the boundary.

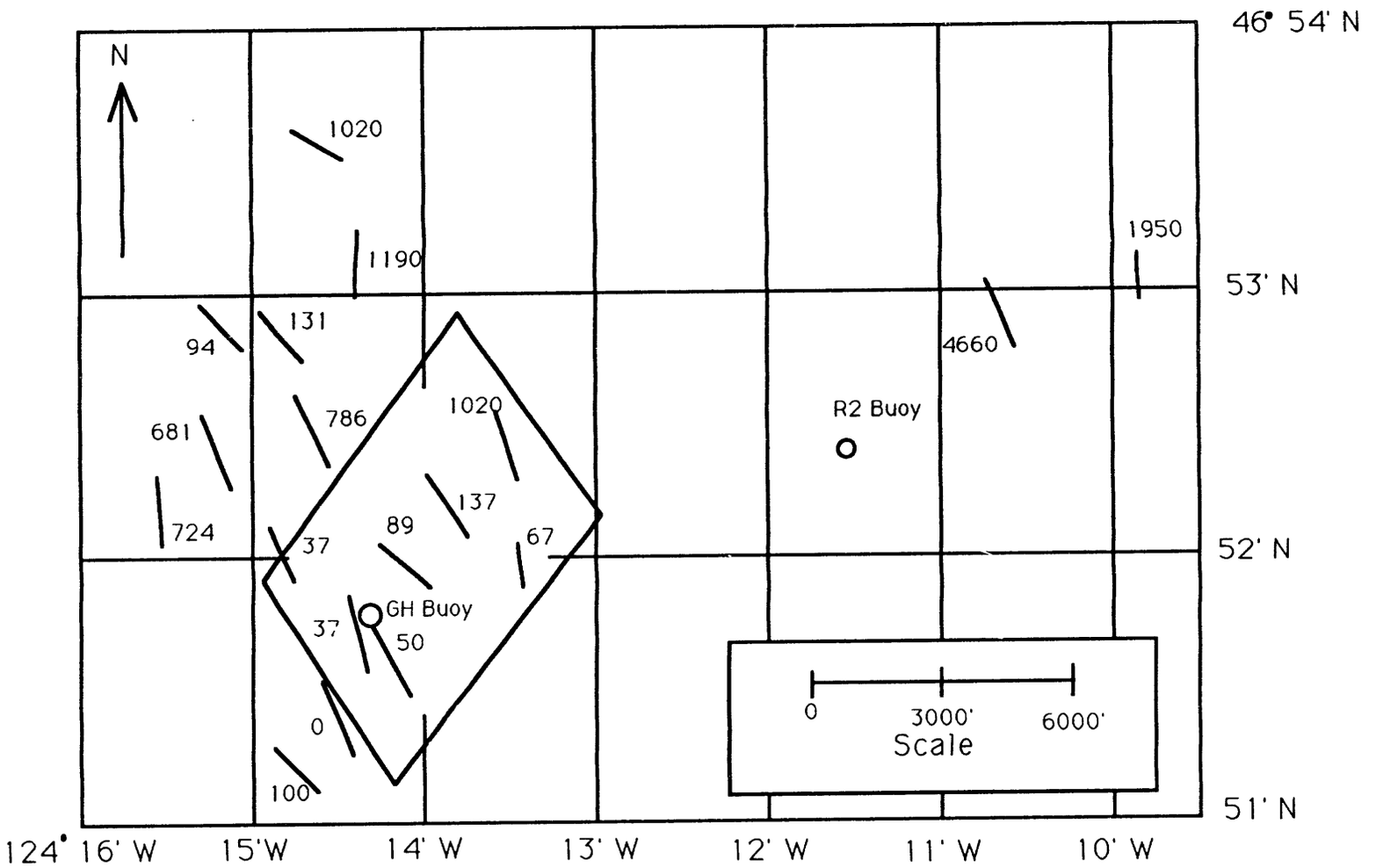

FIGURE 5. Dungeness Crab Density (crab/ha) for June 1990

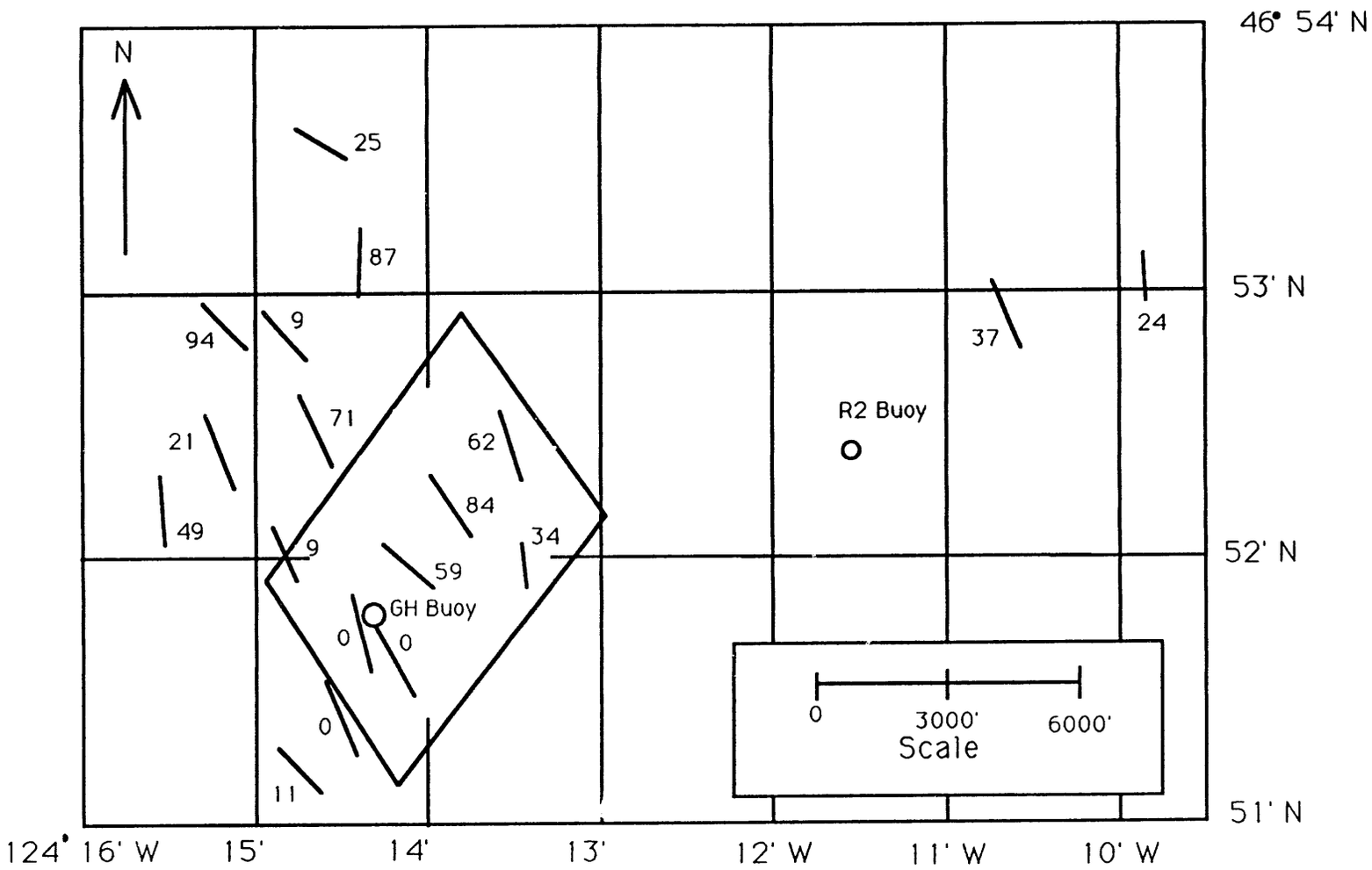

FIGURE 6. Adult Dungeness Crab Density (crab/ha) for June 1990

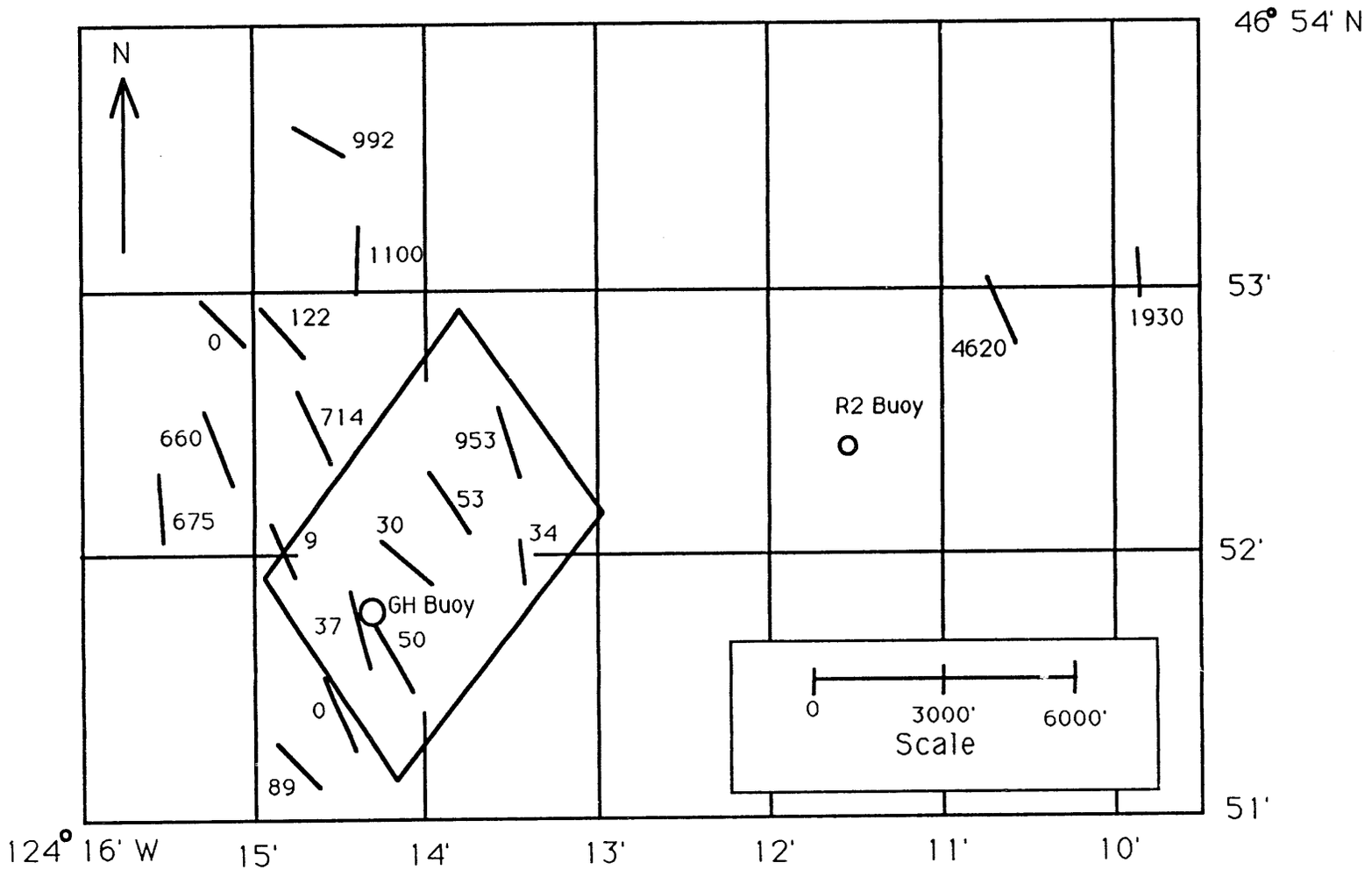

FIGURE 7. Juvenile Dungeness Crab Density (crab/ha) for June 1990

The catch weight of the macroepifauna (total catch weight less the debris weight) averaged 66 kg/ha for all 18 stations of the entire survey (all stations within and outside the Southwest Ocean Disposal Site and at the South Jetty, Appendix B). The macroepifauna showed no significant difference, with a one-tailed t-test, between trawl stations within the Southwest Ocean Disposal Site and outside and north of the site ($t = -0.25$; d.f. = 14; $p = 0.4032$). The mean epifaunal catch weight was 67 kg/ha within the Southwest Ocean Disposal Site and 72 kg/ha outside and north of the site.

Dungeness crab was the only crab species caught, and, as expected, the juvenile crab comprised 95% by number but only 3% by weight of the crab catch from the entire survey. From all 18 stations, the mean densities for total crab, adult crab, and juvenile crab were 709, 38, and 671 crab/ha, respectively. From all 18 stations, the mean weights for total crab, adult crab, and juvenile crab were 1442, 1405, and 38 g/ha, respectively.

The density of juvenile crab was higher outside the Southwest Ocean Disposal Site. The mean densities of juvenile crab were 146 crab/ha within the Southwest Ocean Disposal Site and 609 crab/ha to the north outside the site (Table 2). One-tailed t-test results show that the mean density of juvenile crab outside the disposal site was significantly higher than within the disposal site ($t = -2.427$; d.f. = 13; $p = 0.0152$). One location, Station 210, located west of the Southwest Ocean Disposal Site had a juvenile crab density of 89 crab/ha. At the two nearshore stations by the South Jetty, the mean juvenile crab density was 3275 crab/ha. Taken together, the trawl data indicate that the area of high juvenile crab density was located outside the Southwest Ocean Disposal Site in June 1990.

As expected from the results of the 1984 and 1985 Ocean Surveys, the 1990 densities of adult Dungeness crab were an order of magnitude lower than the juvenile crab densities (Table 2). Although the density of adult crab within the disposal site during the 1990 Survey was lower than outside, the difference was not significant (one-tailed t-test: $t = -1.14$; d.f = 13; $p = 0.1375$). Only 7% of all the adult crab were male (Appendix C). All adult female were without egg masses. Only one adult crab was observed to be soft-shelled. Overall, the adult crab carapace width ranged from 107 to 190 mm. Juvenile crab had carapace widths ranging from 2 to 3 mm.

In June 1990, the density of total Dungeness crab and juvenile crab was highest shoreward of the 60-ft-depth contour, and density fell steeply with increasing depth to the lowest densities between the 80- and 100-ft-depth contours (Figure 8). Seaward of the 100-ft contour, crab density increased but remained 10 times less than the nearshore peak. No relationship between density of adult crab and water depth was discernible.

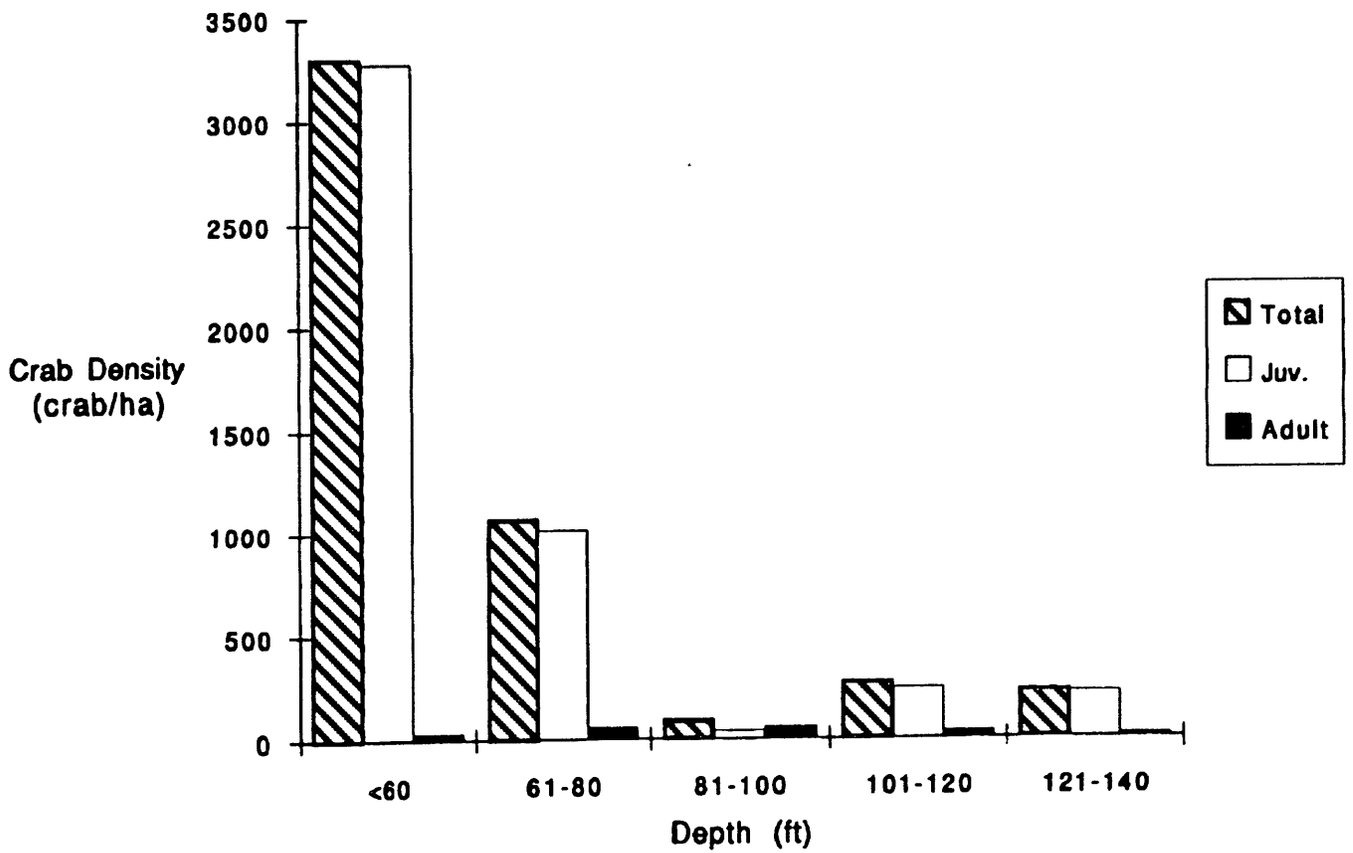

FIGURE 8. Depth Distribution of Mean Dungeness Crab Density (crab/ha) During the Spring 1990 Survey

4.0 DISCUSSION

A major objective of the first monitoring tier was to verify that the location of the area of high crab density and seaward extent of crab density were similar to those observed during the 1985 Ocean Surveys and that the area of high crab density had not shifted into the Southwest Ocean Disposal Site. The results of the 1990 Crab Survey confirm that the area of high density of juvenile crab has not shifted into the disposal site. The juvenile crab density outside the Southwest Ocean Disposal Site was about four times that within the site.

In developing of the monitoring plan, analysis of the replicate trawls in the 1985 Ocean Survey found that four trawls per area would be sufficient to detect differences when juvenile crab density differed by a factor of 10. The 1990 Crab Survey detected crab density differences of a factor of 4 with seven and eight trawls per area. Thus, for crab densities on the order of a few hundred crab per hectare, eight trawls per region of interest have proved adequate and are the recommended level of effort in future crab monitoring surveys for the Southwest Ocean Disposal Site.

During the Spring 1985 Ocean Survey, both trawls and TV tows indicated that the juvenile crab abundance increased with increasing depth to a peak between the 100- and 120-ft-depth contours and then fell abruptly (Figure 9). The 1990 Survey was more limited but showed the peak density to be shoreward of the 60-ft contour. The difference in depth distribution between the 1985 and 1990 Survey results could be attributable to the larger, more systematic effort to determine the depth distribution in 1985 but is more likely related to extremely high densities of juvenile crab observed in 1985.

Comparison of the overall crab densities between 1985 and 1990 illustrates the high variability in YOY crab abundance already noted in the multi year studies by Armstrong et al. (1987). In June 1990, mean density of juvenile Dungeness crab was 671 crab/ha with a range from 146 crab/ha within the disposal site to 3275 crab/ha at the two nearshore stations. The 1990 mean juvenile crab density was about 50 times less than the mean density of 30,086 crab/ha for all 33 stations in the Southwest Navigation Lane found during the Spring 1985 Ocean Survey (Pearson et al.

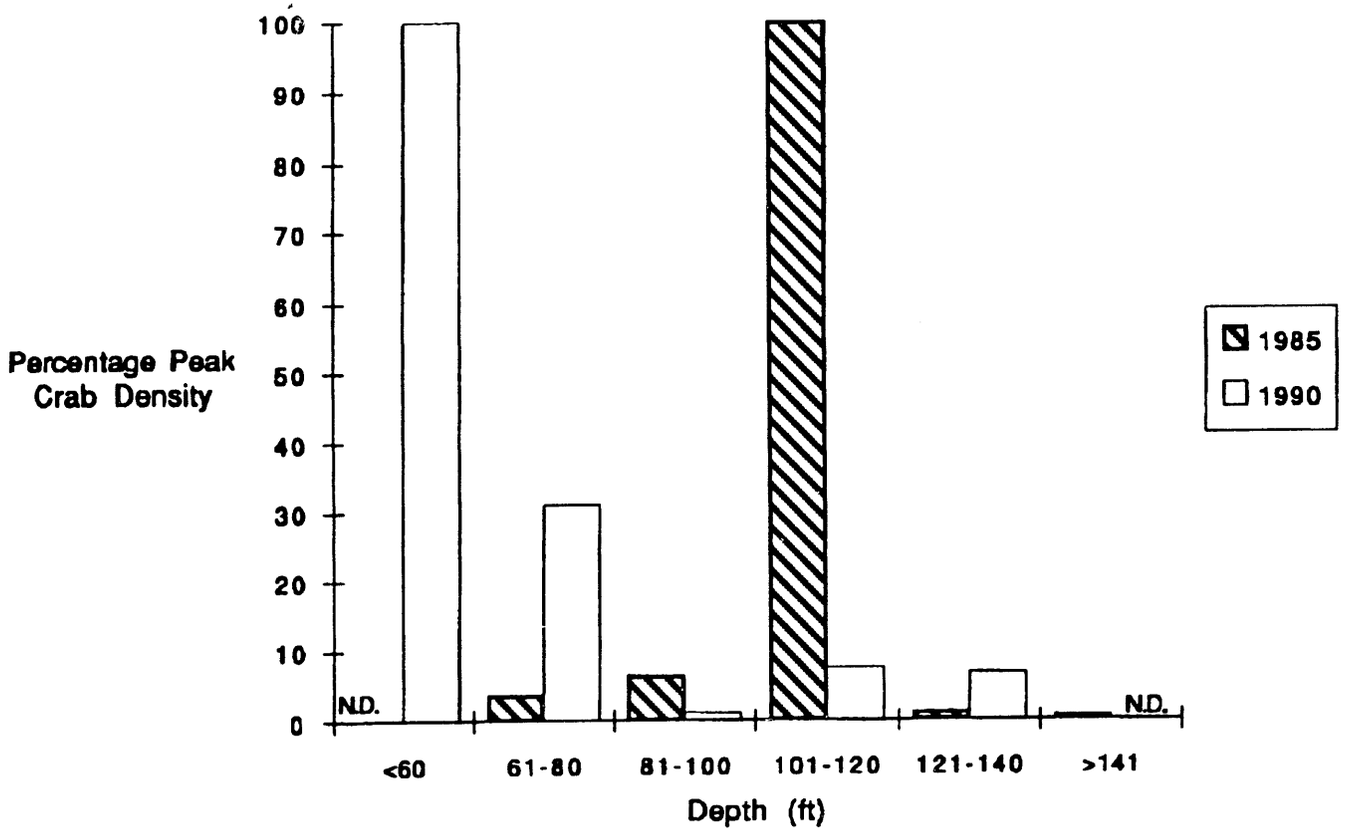

FIGURE 9. Depth Distribution of Juvenile Dungeness Crab as Percent of Maximum Density for Spring 1985 and Spring 1990

1987). Also, some Spring 1985 stations showed crab densities on the order of 400,000 crab/ha. Because juvenile crab density has been observed to vary orders of magnitude from year to year (Armstrong et al. 1987), and because 1985 was an exceptional year for YOY crab abundance, the differences between 1985 and 1990 are not surprising. It is important to note that despite the lower densities in 1990 compared to 1985, the results of the 1990 Survey showed no shift of the area of high crab density into the Southwest Ocean Disposal Site.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the decision criteria in the first tier of the monitoring plan was completed with favorable results. In June 1990, mean density of juvenile Dungeness crab (carapace width <50 mm) was 146 crab/ha (8 stations) within the Southwest Ocean Disposal Site and 609 crab/ha (7 stations) to the north outside the site. The specific criteria for moving from Tier 1 to Tier 2 is that the crab density in June 1990 within the Southwest Ocean Disposal Site would have to be 100 times higher than in the area to the north. Because the crab density within the Southwest Ocean Disposal Site did not exceed this threshold value, Tier 2 activities are not required. The additional observation of a mean juvenile crab density of 3275 crab/ha at two nearshore stations outside the disposal site further supports the position that the area of high crab density had not shifted into the site. Because the survey results show that the high crab density area has not shifted into the Southwest Ocean Disposal Site, the survey has confirmed the appropriateness of the initial selection of the disposal site boundaries and indicates no need to move to the second monitoring tier.

In light of the results of the 1990 Survey, we recommend continuing to follow the basic monitoring plan and maintaining future crab monitoring activities at the first tier. Because the TV tows were limited by low visibility, we recommend that the future monitoring activities use trawling rather than TV tows as the primary data collection technique.

6.0 REFERENCES

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APPENDIX A

SPECIES LIST AND MAJOR TAXA FROM TRAWLS IN THE JUNE 1990 DUNGENESS CRAB SURVEY OF THE GRAYS HARBOR SOUTHWEST OCEAN DISPOSAL SITE AND NEARBY REGIONS

APPENDIX A. Species List and Major Taxa from Trawls in the June 1990 Dungeness Crab Survey of the Grays Harbor Southwest Ocean Disposal Site and Nearby Regions.

CRUSTACEANS	
Cancer magister	Dungeness crab
Pagurus spp.	Hermit Crab
Scleroplax granulata	Pea Crab
Heptocarpus brevirostris	Coastal shrimp
Crangon alaskensis	Crangon shrimp
ECHINODERMS	
Dendraster excentricus	Sand dollars
Holothuroidea	Sea Cucumber
Ophiuroidea	Brittle star
MOLLUSKS	
FLAT FISH	
Citharichthys sordidus	Pacific sanddab
Hippoglossus stenolepis	Halibut
Isopsetta isolepis	Butter sole
Parophrys vetulus	English sole
Psettichthys melanostictus	Sand sole
Platichthys stellatus	Starry flounder
Atheresthes stomias	Turbot
Post larval	
ROUND FISH	
Microgadus proximus	Pacific tomcode
Squalus acanthias	Dogfish
Spirinchus starksi	Night smelt
Clupea harengus pallasi	Pacific herring
Raja binoculata	Skate (Big)
Liparis pulchellus	Showy snailfish
Ammodytes hexapterus	Sandlance
Agonus acipenserinus	Sturgeon poacher
Ophiodon elongatus	Lingcod
Hexagrammos decagrammus	Kelp greenling
Psychrolutes paradoxus	Tadpole sculpin
Cottidae	Sculpin
OTHER INVERTEBRATES	
Aphrodita japonica	Sea mouse
Scyphozoa	Jellyfish
Sipunculoidea	Peanut Worm
Octopus dofleini	Octopus

APPENDIX B

TRAWLING RESULTS FROM THE JUNE 1990 DUNGENESS CRAB SURVEY OF GRAYS HARBOR OCEAN DISPOSAL SITE AND NEARBY REGIONS

APPENDIX B. Trawling Results from the June 1990 Dungeness Crab Survey of Grays Harbor Southwest Ocean Disposal Site and Nearby Region

Station Number	201		202		203		204		205	
Area Swept (ha)	0.112		0.094		0.101		0.107		0.127	
Catch Weight (kg)	10.01		5.45		4.99		3.02		26.79	
Catch Weight/Hectare (kg/ha)	89.4		58.0		49.4		28.2		210.9	
Debris Weight (kg)	2.95		3.63		0.68		0.45		16.12	
Debris Weight/Hectare (kg/ha)	26.3		38.6		6.7		4.2		126.9	
Catch Wt less Debris/Hectare (kg/ha)	63.0		19.3		42.7		24.0		84.0	
	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER
CRUSTACEAN										
Dungeness Crab	4285	88	954	64	17	5	0.1	4	4134	151
Hermit Crab	54	25			42	3	4	3		
Pea Crab										
Coastal Shirimp										
Crangon Shrimp	680	526	450	340	316	278	362	261	235	98
Totals	5019	639	1404	404	375	286	366	268	4369	249
Wt/Hectare (g/ha)	44813		14936		3713		3421		34402	
Number/Hectare (n/ha)		5705		4298		2832		2505		1961
ECHINODERMS										
Sand Dollars									3	10
Sea Cucumber										
Brittle Star			65	100						
Totals	0	0	65	100	0	0	0	0	3	10
Wt/Hectare (g/ha)	0		691		0		0		24	
Number/Hectare (n/ha)		0		1064		0		0		79
MOLLUSCS										
Totals	0	0	0	0	0	0	0	0	0	0
Wt/Hectare (g/ha)	0		0		0		0		0	
Number/Hectare (n/ha)		0		0		0		0		0
FLAT FISH										
Pacific Sandab			454	2						
Halibut										
Butter Sole			454	2			885	10		
English Sole	143	8	12.5	7	140	6	562	5	60	2
Post Larval Flat Fish	20	2			38	30	7	21	0.1	2
Sand Sole										
Starry Flounder										
Turbot										
Totals	163	10	921	11	178	36	1454	36	60	4
Wt/Hectare (g/ha)	1455		9793		1762		13589		473	
Number/Hectare (n/ha)		89		117		356		336		31
ROUND FISH										
Pacific Tomcod	755	11	50	1	199	3	368	6	120	3
Dogfish										
Night Smelt	295	51	124	15	412	76	350	74	250	32
Pacific Herring										
Skate	92	1								
Showy Snailfish	66	26			134	14	134	13	95	4
Sandlance										
Strugeon Poacher	24	22			58	6	26	4	60	52
Lingcod										
Kelp Greenling										
Tadpole Sculpin										
Sculpin										
Totals	1232	111	174	16	803	99	878	97	525	91
Wt/Hectare (g/ha)	11000		1851		7950		8206		4134	
Numbec/Hectare (n/ha)		991		170		980		907		717
OTHER										
Sea Mouse	0.1	1								
Jellyfish	190	3			230	6	284	17	1110	16
Peanut Worm										
Octopus										
Totals	190	4	0	0	230	6	284	17	1110	16

APPENDIX B. (Contd)

Station Number	206		207		208		209		210	
Area Swept (ha)	0.123		0.130		0.131		0.101		0.090	
Catch Weight (kg)	12.94		9.76		13.39		6.81		15.89	
Catch Weight/Hectare (kg/ha)	105.2		75.1		75.1		67.4		176.6	
Debris Weight (kg)	1.14		2.95		1.59		1.36		0.45	
Debris Weight/Hectare (kg/ha)	9.2		22.7		12.1		13.5		5.0	
Catch Wt less Debris/Hectare (kg/ha)	96.0		52.4		90.1		53.9		117.5	
	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER
CRUSTACEAN										
Dungeness Crab	2921	89	2440	132	3350	18	2464	9	287	9
Hermit Crab	59	3			18	13	7	2	4	3
Pea Crab										
Coastal Shirimp										
Crangon Shrimp	375	280	420	230	411	260	355	338	244	290
Totals	3355	372	2860	362	3779	291	2826	349	535	302
Wt/Hectare (g/ha)	27276		22000		28847		27980		5944	
Number/Hectare (n/ha)		3024		2785		2221		3455		3356
ECHINODERMS										
Sand Dollars	2	8			0.1	11				
Sea Cucumber										
Brittle Star										
Totals	2	8	0	0	0.1	11	0	0	0	0
Wt/Hectare (g/ha)	16		0		1		0		0	
Number/Hectare (n/ha)		65		0		84		0		0
MOLLUSCS										
Totals	10	12	0	0	113	8	0	0	0	0
Wt/Hectare (g/ha)	81		0		863		0		0	
Number/Hectare (n/ha)		98		0		61		0		0
FLAT FISH										
Pacific Sandab	95	1								
Halibut										
Butter Sole							304	4	170	2
English Sole	280	10	214	4	1135	10	273	4	64	1
Post Larval Flat Fish	2	12			4	9	7	16	14	24
Sand Sole	908	4							80	1
Starry Flounder										
Turbot										
Totals	1285	27	214	4	1139	19	584	24	328	28
Wt/Hectare (g/ha)	10447		1646		8695		5782		3644	
Number/Hectare (n/ha)		220		31		145		238		311
ROUND FISH										
Pacific Tomcod	60	1	202	5	1362	13			72	1
Dogfish										
Night Smelt	655	35	400	40	875	137	238	46	72	23
Pacific Herring										
Skate			42	1	152	1			39	1
Showy Snailfish	140	9	430	57	378	23	106	8	100	7
Sandlance										
Sturgeon Poacher			202	55	208	27	146	20	13	5
Lingcod										
Kelp Greenling										
Tadpole Sculpin										
Sculpin			42	1						
Totals	855	45	1318	159	2975	201	490	74	296	37
Wt/Hectare (g/ha)	6951		10138		22710		4851		3289	
Number/Hectare (n/ha)		366		1223		1534		733		411
OTHER										
Sea Mouse										
Jellyfish	4313	36	470	5	2043	5	470	9	94	10
Peanut Worm	1	1								
Octopus										
Totals	4314	37	470	5	2043	5	470	9	94	10

APPENDIX B. (Contd)

Station Number	211		212		213		214		215	
Area Swept (ha)	0.122		0.096		0.107		0.107		0.109	
Catch Weight (kg)	44.95		15.44		4.77		4.99		12.03	
Catch Weight/Hectare (kg/ha)	368.4		160.8		44.6		46.7		110.4	
Derbris Weight (kg)	36.32		2.04		1.14		0.68		3.86	
Derbris Weight/Hectare (kg/ha)	297.7		21.3		10.6		6.4		35.4	
Catch Wt less Debris/Hectare (kg/ha)	70.7		139.5		33.9		40.3		75.0	
	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER
CRUSTACEAN										
Dungeness Crab	969	124	2722	9	430	14	0	0	461	4
Hermit Crab	68	13	54	6	5	10	2	1	12	3
Pea Crab					0.1	1				
Coastal Shrimp							88	53		
Crangon Shrimp	210	171	483	205	118	91			360	219
Totals	1247	308	3259	220	553	116	90	54	833	226
Wt/Hectare (g/ha)	10221		33948		5169		841		7642	
Number/Hectare (n/ha)		2525		2292		1084		505		2073
ECHINODERMS										
Sand Dollars										
Sea Cucumber					2	2			0.1	1
Brittle Star										
Totals	0	0	0	0	2	2	0	0	0.1	1
Wt/Hectare (g/ha)	0		0		19		0		1	
Number/Hectare (n/ha)		0		0		19		0		9
MOLLUSCS										
Totals	380	83	22	4	61	34	13	1	9	6
Wt/Hectare (g/ha)	3115		229		570		121		83	
Number/Hectare (n/ha)		680		42		318		9		55
FLAT FISH										
Pacific Sandab							8	2	320	3
Halibut										
Butter Sole	500	6	460	5			102	1	422	5
English Sole			1362	18	754	8	1670	14	274	3
Post Larval Flat Fish	27	20	5	8			0.1	3	20	9
Sand Sole			330	5						
Starry Flounder	23	1			685	1				
Turbot					172	4	24	1	42	1
Totals	550	27	2157	36	1611	13	1804	21	1078	21
Wt/Hectare (g/ha)	4508		22469		15056		16861		9890	
Number/Hectare (n/ha)		221		375		121		196		193
ROUND FISH										
Pacific Tomcod	846	76	1140	23						
Dogfish										
Night Smelt	690	82	240	96	46	18	29	21	30	17
Pacific Herring										
Skate										
Showy Snailfish	40	4	28	2	53	1			74	3
Sandlance										
Strugeon Poacher	84	27	11	2					17	2
Lingcod										
Kelp Greenling										
Tadpole Sculpin										
Sculpin										
Totals	1660	189	1419	123	99	19	29	21	121	22
Wt/Hectare (g/ha)	13607		14781		925		271		1110	
Numbec/Hectare (n/ha)		1549		1281		178		196		202
OTHER										
Sea Mouse										
Jellyfish	600	10	2724	4	282	1	650	2	66	1
Peanut Worm					81	30	2	2	221	83
Octopus									8626	1
Totals	600	10	2724	4	363	31	652	4	8913	85

APPENDIX B. (Contd)

Station Number	216		217		218		Mean WT (g)	S.D. WT	Mean Number	S.D. NUMBER
Area Swept (ha)	0.089		0.093		0.123					
Catch Weight (kg)	4.99		91.25		7.04		16.36	21.22		
Catch Weight/Hectare (kg/ha)	56.1		981.2		57.2		153.4	222.4		
Debris Weight (kg)	0.23		88.08		1.36		9.17	21.54		
Debris Weight/Hectare (kg/ha)	2.6		947.1		11.1		88.7	225.6		
Catch Wt less Debris/Hectare (kg/ha)	53.6		34.2		46.1		63.1	32.4		
	WT (g)	NUMBER	WT (g)	NUMBER	WT (g)	NUMBER				
CRUSTACEAN										
Dungeness Crab	844	6	1180	242	2711	764				
Hermit Crab			148	68	96	36				
Pea Crab										
Coastal Shrimp										
Crangon Shrimp	398	345	60	71	72	49				
Totals	1242	351	1388	381	2879	849				
Wt/Hectare (g/ha)	13955		14925		23407		17969	12868		
Number/Hectare (n/ha)		3944		4097		6902			2862	1240
ECHINODERMS										
Sand Dollars	2	5	46	20	72	16				
Sea Cucumber										
Brittle Star										
Totals	2	5	46	20	72	16				
Wt/Hectare (g/ha)	22		495		585		103	227		
Number/Hectare (n/ha)		56		215		130			94	256
MOLLUSCS										
Totals	0	0	19	8	36	13				
Wt/Hectare (g/ha)	0		204		293		309	738		
Number/Hectare (n/ha)		0		86		106			79	174
FLAT FISH										
Pacific Sandab										
Halibut										
Butter Sole	770	12			382	16				
English Sole	40	1	354	3						
Post Larval Flat Fish	38	13	566	158	422	710				
Sand Sole										
Starry Flounder			76	1	167	3				
Turbot										
Totals	848	26	996	162	971	729				
Wt/Hectare (g/ha)	9528		10710		7894		8567	5945		
Number/Hectare (n/ha)		292		1742		5927			295	388
ROUND FISH										
Pacific Tomcod	239	4			192	101				
Dogfish										
Night Smelt	158	41	24	18	74	9				
Pacific Herring			59	6						
Skate			38	1						
Showy Snailfish	29	2			8	2				
Sandlance			452	203	56	19				
Sturgeon Poacher	76	21								
Lingcod			13	3	8	2				
Kelp Greenling			6	2						
Tadpole Sculpin			23	4						
Sculpin										
Totals	502	68	615	236	338	133				
Wt/Hectare (g/ha)	5640		6613		2748		7043	5787		
Number/Hectare (n/ha)		764		2538		1081			867	632
OTHER										
Sea Mouse										
Jellyfish	142	18	276	2	908	15				
Peanut Worm	2	3								
Octopus										
Totals	144	21	276	2	908	15				

APPENDIX C

INDIVIDUAL DUNGENESS CRAB STATISTICS FROM THE JUNE 1990 DUNGENESS CRAB SURVEY OF GRAYS HARBOR SOUTHWEST OCEAN DISPOSAL SITE AND NEARBY REGIONS

APPENDIX C. Individual Dungeness Crab Statistics from the June 1990 Dungeness Crab Survey of Grays Harbor Southwest Ocean Disposal Site and Nearby Regions

Station Number	201								202		203
Gender (a)	F	F	F	F	F	F	F	F	F	F	None
Carapace Width (mm)	135	133	137	134	135	134	136	136	123	134	
Weight (g)	454	454	454	681	400	681	454	681	454	454	
Shell Hardness (b)	H	H	H	H	H	H	H	H	H	H	
Egg Clutch (c)	N	N	N	N	N	N	N	N	N	N	

Station Number	204	205									
Gender	None	F	F	M	F	F	F	F	F	F	F	F
Carapace Width (mm)		120	114	175	117	124	119	107	129	160	145	158
Weight (g)		454	248	780	242	310	300	220	225	480	335	445
Shell Hardness		H	H	H	H	H	H	H	H	H	H	H
Egg Clutch		N	N	-	N	N	N	N	N	N	N	N

Station Number	206						207							
Gender	M	F	F	F	F	F	F	F	F	F	F	F	F	M
Carapace Width (mm)	190	135	127	150	145	143	125	127	114	119	114	110	140	147
Weight (g)	740	360	320	462	544	468	320	310	216	260	226	198	384	492
Shell Hardness	H	S	S	H	H	H	H	H	H	H	H	H	S	H
Egg Clutch	-	N	N	N	N	N	N	N	N	N	N	N	N	-

Station Number	208										
Gender	F	F	F	F	F	F	M	F	F	F	F
Carapace Width (mm)	127	124	111	122	112	111	152	119	126	132	129
Weight (g)	330	280	230	246	232	234	469	274	314	380	358
Shell Hardness	H	H	H	H	H	H	H	H	H	H	H
Egg Clutch	N	N	N	N	N	N	-	N	N	N	N

APPENDIX C. (Cont.) Individual Dungeness Crab Statistics from the June 1990 Dungeness Crab Survey of Grays Harbor Southwest Ocean Disposal Site and Nearby Regions

Station Number	209						210	211		
Gender	F	M	F	F	F	F	F	F	F	F
Carapace Width (mm)	127	168	151	132	132	129	123	117	122	133
Weight (g)	340	651	408	356	358	351	276	248	315	365
Shell Hardness	H	H	H	H	H	H	H	H	H	H
Egg Clutch	N	-	N	N	N	N	N	N	N	N

Station Number	212									213	
Gender	M	F	F	F	F	F	F	F	F	F	
Carapace Width (mm)	137	120	122	157	119	124	111	118	111	135	
Weight (g)	350	240	274	436	378	346	220	260	218	428	
Shell Hardness	H	H	H	H	H	H	H	H	H	H	
Egg Clutch	-	N	N	N	N	N	N	N	N	ND	(d)

Station Number	214	215	216			217		
Gender	None	F	F	F	F	F	F	F
Carapace Width (mm)		146	117	115	126	131	142	156
Weight (g)		460	278	276	290	364	204	556
Shell Hardness		H	H	H	H	S	H	H
Egg Clutch		N	N	N	N	N	N	N

Station Number	218						Mean	S.D.	N
Gender	F	F	F	F	F	F			
Carapace Width (mm)	148	150	147	148	144	122	132	16	79
Weight (g)	472	525	418	424	432	305	376	132	79
Shell Hardness	H	H	H	H	H	H			
Egg Clutch	N	N	N	N	N	N			

(a) F Female, M Male (b) H Hard Shell, S Soft Shell (c) N None (d) ND no data

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