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A Study on the Utility of Log Piling Structures as Artificial Habitats for Red King Crabs and Other Fauna

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A Study on the Utility of Log Piling Structures as Artificial Habitats for Red King Crabs and Other Fauna

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Abstract

During construction of a new breakwater at St. Herman Harbor in Kodiak, AK, a large area of underwater habitat was buried beneath tons of extraneous rock. Red king crabs were among the potential inhabitants of this altered habitat. Previous observations suggest that juvenile king crabs use wooden dock pilings as habitats. In order to test the hypothesis that pilings could be used to mitigate for loss of natural habitat, six piling and beam structures were constructed from untreated spruce and placed in pairs at 3 different locations in ocean bays near Kodiak, AK. Divers from the Kodiak facility of the Alaska Fisheries Science Center conducted a year-long study of faunal recruitment to the piling structures, by making quarterly surveys to count organisms on the pilings and adjacent seafloor areas. Abundance of juvenile (age 0 to1+) king crabs increased steadily from July 1997 through March 1998 as crabs recruited to the structures, then declined in June 1998. Crab abundance was significantly higher on piling structures than on the adjacent substratum. Site, season, and their interaction had significant effects on abundance. Abundance was higher at more exposed sites than at more sheltered sites (i.e., abundance was proportional to exposure or proximity to open ocean) but this was not a significant effect. Red king crabs were associated with the presence of green urchins, decorator crabs, leather stars, and sculpins. Each of the three sites could be discriminated by their unique community of inhabitants. Pilings do indeed attract juvenile king crabs, but the reason is unknown.

Pilings are inefficient habitats because they do not provide much surface area per volume, and do not persist in the environment. For these reasons, we do not recommend their use as artificial habitats to mitigate for the loss of natural habitat.

Contents

Introduction

In 1997, a new breakwater was constructed at the south end of St. Herman Harbor, at Near Island, Kodiak, AK (Plate 1A)[1]. The U. S. Army Corps of Engineers (USACE) was responsible for funding and planning of the breakwater construction. Construction of the breakwater required placing many tons of rock on the bottom of the harbor at depths from 20 to 60 feet. The surface area of this "footprint" displaced >3.5 hectares of natural seafloor habitat. As a result, there was concern that economically important marine organisms might be displaced by the habitat alterations. Red king crab (RKC; *Paralithodes camtschaticus)* was probably the most valuable species found in the area. For this reason, the USACE wanted to know if artificial habitats could be used to mitigate natural habitat loss for RKC.

At Kodiak, RKC up to 1.5 years of age are commonly found on wooden pilings covered with a variety of fauna as biological structure, suggesting that pilings associated with piers are good habitat for juvenile crabs. Based on the results of previous studies, (Dew et al., 1992) the National Marine Fisheries Service (NMFS) convinced the U.S. Coast Guard not to remove a condemned pier (Marginal Pier) in Womens Bay, Kodiak Island, Alaska, which contains hundreds of pilings and is a common site for recruiting king crab. The USACE also installed 50 pilings at a site in Womens Bay as additional crab habitat; although these pilings were not routinely surveyed, RKC were occasionally observed there, though most of the pilings were destroyed by ice within a few years.

During their first year of life, juvenile red king crab seek highly complex habitats for shelter. Common habitats include seastars (Dew, 1990) as well as sponge and bryozoan colonies (Sundberg and Clausen, 1977), hydroid and mussel colonies, stalked ascidians, and polychaete

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[1]Dates, locations, and reference numbers for each photo are listed in Appendix Table 1.

tubes (Stevens and MacIntosh, 1991), and shell debris and cobble (McMurray et al., 1986; Loher and Armstrong, 2000). Postlarval (glaucothoe stage) RKC will settle in large numbers on various types of artificial collectors (Donaldson et al., 1991). After they reach a size exceeding 25 mm carapace length, RKC start to exhibit aggregative (podding) behavior (Powell and Nickerson, 1965; Dew, 1990). Biological structure is scarce in the Bering Sea, yet is typically the only location where juvenile RKC are found. Laboratory studies have demonstrated that RKC postlarvae prefer to settle among structurally complex habitats whether artificial (aquarium filter material) or biological (hydroids and complex red algae), over those with less structure (gravel), and will not settle on structure-less open sand (Stevens and Kittaka, 1998; Stevens, in press). Selection for such habitats is probably an adaptive response to high predation levels.

This study was undertaken to determine whether submerged log piling structures would attract juvenile king crabs, and if such structures could be used as artificial habitat to mitigate for habitat displacement caused by construction of breakwater and marina facilities.

Materials and Methods

Six log piling structures (habitats) were built by a subcontractor (Fig. 1) for deployment in pairs. Each structure consisted of four corner posts (3 m spruce logs with intact bark) sunk into 0.8 × 0.8 × 0.5 m concrete blocks. Adjacent and opposing pairs of corner posts were connected by horizontal 5 × 20 cm (2" × 8") beams of rough milled spruce, and similar beams connected the base of each post to the upper cross beam, in an X-shape (Fig. 1). Two structures, labeled North (N) and South (S), were placed in approximately 10 m of water at each of three sites (Fig. 2): inside the breakwater (IB), outside the breakwater (OB), and in Womens Bay (WB), approximately 8 km away. The paired structures at the IB and OB sites were placed

27.4 m and 57.3 m apart, respectively (Fig. 3). In Womens Bay, the North and South structures were separated by about 600 m but were placed 34.1 m and 39.3 m, respectively, from Marginal Pier (Fig. 4). Marginal Pier is a 60+ year old dock consisting of hundreds of creosote-treated wooden pilings, many of which have rotted through and fallen over, and most are covered with fauna including sponges, anemones, hydroids, bryozoans, barnacles, and sea stars. A fourth pair of survey sites included four pilings of Marginal Pier nearest to each of the WBN and WBS habitats; these were labeled MPN and MPS, respectively. All structures were placed in the water between 19 and 22 May 1997. The IB and OB sites were within 100 m of the rock breakwater, but we did not survey it because the profusion of kelp prevented adequate sampling of the rock surface and crevices.

In order to compare counts of organisms on the structures to the surrounding environment, benthic transect lines were staked out on opposite sides of each structure. At the IB and OB sites, a line ran from one structure to the other and served as a guideline between them. Because the OB sites were closest together, the standard transect line length was defined as half the distance between these structures, or 13.7 m. Lines of similar length were extended on the opposite sides of each structure as well. Thirteen person-dives over 5 days were required for placing marker buoys, and an additional sixteen person-dives over 4 days were required to measure and install bottom transect lines (Table 1, and Appendix Table B).

Surveys were conducted by scuba every 3 months from June 1997 to June 1998 for a total of five quarterly samples (Table 1; Plate 1B). Twelve index species were selected for counting (Table 2). During each survey, three divers descended a marker line to the bottom, one diver counted all individuals on the outside of the structure, one counted on the inside of the structure, and one photographed specific parts of the structure, such as piling tops, sides, crossbeams, and the concrete bases (Plate 1C). Counts on the inside and outside of the structure were added together. Then two divers swam along either side of the bottom transect lines holding a 1 m wand in front of them, and counted all megafauna on the substratum within a 1 m swath between the tips of the wand. The total bottom area surveyed around each structure was 54.8 m^2 (2 × 2 × 13.7 m), about equivalent to the total surface area of the structure. Each bottom transect was treated as an individual sample, so there were two replicate substratum samples for each structure sample. Divers then swam to the second structure at the site, and repeated the counts and transects. Each pair of structures was surveyed on separate days within a week. At the Marginal Pier site, divers also counted organisms on the bottom 3 m of the four pilings nearest to each structure. Occasionally, RKC were collected and carapace length (CL) was measured from the right orbit to the midpoint of the rear margin of the carapace.

During each of the five quarterly sampling seasons, a total of 20 samples were counted: one sample count was made on the structure, and two on the adjacent substratum, at each of the six structures, for a total of 18 samples, plus the two MP samples. Therefore, the total data matrix included 100 sample counts. Preliminary analysis showed that variances among samples were not homogeneous, indicating severe departures from normality. This situation was not remedied by square root or arc-sine transformations. Therefore, analysis of the data by normal parametric statistics was not appropriate (Zar, 1984). For this reason, and because the data are counts of (relatively) rare events, we chose to use a generalized linear model (GLM) type of ANOVA, that was based on a Poisson distribution rather than the normal distribution. The GLM allowed us to model RKC counts as a function of several factors. Only the data from the structures was analyzed in this manner; substratum counts were excluded because of their low numbers, and counts from Marginal Pier were excluded because they were a different type of piling (older, creosote treated) and could only be compared to the nearby structures in Womens Bay. Factors included in the analysis were Quarter, Site, Habitat (north or south within pairs), and 2-way interactions between those three variables. Following this, a non-parametric Mann-Whitney U-test was used to make comparisons between pairs of sample sites. Sites compared were Marginal Pier versus site WB, site IB versus site OB, site IB versus WB, and OB versus WB.

Multiple regression of crab counts, transformed to log(X+1), versus all other species was conducted to determine which species were associated with RKC. Discriminant analysis was conducted to determine if sites and locations (on or off structures) could be distinguished by the species assemblages present. Resulting functions were used to reclassify all samples by cross-validation, that is, the case being classified was left out of the data used to derive the equation used to classify it. Statistical analysis was conducted using S-Plus version 4.5 or SPSS version 10.

Results

Red king crab abundance

A total of 54 dives were made for counting organisms and making photographs or video of the structures. A total of 1,306 specimens of the 12 index species were counted. The most abundant index species were mottled seastars (Table 2), followed by sunflower seastars, RKC, and helmet crabs. Raw data are presented in Appendix Table C.

The largest number of RKC (73% of the total excluding Marginal Pier) were observed at the OB site (Fig. 5), followed by the WB sites (20%). Low numbers (7%) were observed at the IB site and on Marginal Pier (Fig. 6). Virtually all RKC observed (99%) were on the structures, and only two RKC were observed on the substratum within the transect boundaries: one on kelp, and one on a boulder. Within each pair of structures, higher numbers of RKC occurred on the southern structure. Few RKC were observed during the first two quarters (June and September) (Fig 7). By January, RKC were common on the structures as young-of-the-year, less than 10 mm CL. Numbers increased through March 1998, then declined in June 1998.

The Poisson-based GLM showed that the effects of Quarter, Site, and Habitat were all significant. (Table 3). The interaction of Quarter × Site was significant because the highest counts occurred in March 1998 at the OB and WB sites, but counts were highest in June 1998 at the IB site. The interactions of Quarter × Habitat and Habitat × Site were not significant. There were not enough degrees of freedom remaining to include a 3-way interaction, and it probably would not have been significant because no 2-way interactions involving Habitat were significant. There was no significant difference in counts of RKC between the WB and MP sites (MWU = 45.0, P = 0.678), WB and IB (MWU = 39.5, P = 0.369), or WB and OB (MWU = 36.0, P = 0.267). Differences between IB and OB were much greater, but still marginally non-significant (MWU = 27.0, P = 0.057).

Regression analysis of log-transformed variables indicated that RKC abundance (LRKC = log(crabs+1)) was significantly correlated with four other species including green urchins (Lurc), decorator crabs (Ldec), leather stars (Lder) and sculpins (Lscl). The resultant prediction equation accounted for almost 70% of the variance in RKC abundance:

$$LRKC = -0.0118 + 0.85(Lurc) + 0.485(Ldec) + 0.505(Lder) + 0.39(Lscl)$$

$(R^2 = 0.681, F = 50.6, P<0.001)$

Discriminant analysis of location for 90 samples resulted in two functions (Fig. 8).

Proportions of samples classified correctly were Structure, 50%; substratum, 90%; and Marginal Pier 70% (Table 4A). Discriminant analysis of sites also resulted in two functions. Proportions of samples classified correctly were IB, 77%; OB 40%; and WB, 73% (Table 4B).

Fouling community succession

During the year, a large quantity of fouling organisms grew on the pilings, including algae, bryozoans, hydroids, anemones, and tunicates. By July 1997, approximately 3 weeks after placement of the structures, barnacles of 1-2 mm diameter had colonized the concrete bases, wood pilings, and crossbeams (Plate 2, A-D). Sediments inside the breakwater (Plate 3A) supported a dense community of tube-building spionid polychaetes (possibly *Spiochaetopterus costarum*), whereas sediments outside the breakwater (Plate 3B) were essentially barren except for occasional seastars. Seastars are potential shelters for red king crabs, which "hitch-hike" in the axes of their arms (Plate 3D). Sea urchins were also quick to colonize the structures (Plate 3C), probably via locomotion, as the earliest ones seen were several years old. Sculpins (potential predators) were also abundant.

By September 1997, small clumps of green algae were growing on the piling tops (Plate 4A). Nudibranchs, hydroids (Plate 4B) and barnacles (Plate 4C) had colonized the pilings and crossbeams. However, structures inside the breakwater had lower densities of fouling organisms, especially barnacles, than structures outside the breakwater (compare Plates 4D and 2D). Inside the breakwater, polychaete density seemed to have declined (Plate 5A), although it was not determined quantitatively, and sediments outside the breakwater were still barren (Plate 5B). Calcareous tube-building polychates (probably *Serpula vermicularis*) were abundant on debris (discarded Coast Guard materials) near the WBN site (Plate 5C), and on the old pilings of

Marginal Pier (Plate 5D), along with plumose anemones (*Metridium senile*). In Womens Bay, pilings were starting to be colonized by filamentous red algae as well as barnacles and hydroids (Plates 6, A-D). By December, pilings and crossbeams had been colonized by encrusting bryozoans. Decorator crabs (Plate 7A) and red king crabs (Plate 7B) were starting to appear as well. Calcareous tube worms and nudibranchs (*Flabellina fusca*) with their egg strings were common (Plates 7C, 7D).

In March, piling tops had lost their cover of green algae and were starting to develop tufts of red algae and small shoots of brown algae such as *Laminaria* sp. (Plate 8A, 8B). Translucent white tunicates (probably *Molgula* sp.) and hydroids were abundant on the crossbeams (Plate 8C). Barnacles were still abundant, but many had died, possibly the result of predation by nudibranchs. Filamentous red algae obscured the sheltered sediments inside the breakwater (Plate 9A), but not outside the breakwater (Plate 9B) and was also present on pilings in Womens Bay (Plate 9C, 9D).

By June, Piling tops were once again covered with green algae (Plate 10A). Boring organisms created a lot of sawdust-like castings on the structures that were easily stirred up by the divers (present as white particles in Plates 10 A-D). Barnacles had colonized much of the space on pilings and crossbeams, though many were just empty shells. Pairs of helmet crabs in premating embrace were seen on the structures (Plate 10C), and snails and hermit crabs were also abundant (Plate 10D). Red king crabs were common on the structures (Plates 11A, 11B).

Discussion

These observations demonstrate that log piling structures may serve as potential habitats for juvenile RKC. The number of crabs on the artificial habitats was 2 orders of magnitude greater than on a similar area of adjacent seafloor. Crabs were more abundant at a site (OB) that was exposed to prevailing weather and current, and less abundant at a nearby site (IB) protected behind a large breakwater, or at the head of Womens Bay, several kilometers from open water. This distribution could result from recruitment processes involving the transport of larvae on ocean currents until they reach suitable exposed habitat sites. As more larvae settle on exposed sites, fewer would remain in the water to settle at protected sites. The breakwater and its many crevices may also have "filtered" out many larvae prior to their arrival at the inside. This hypothesis could also account for the higher numbers of RKC on the southern-most habitats within each pair. At each site, exposure to the open ocean decreases, and distance from it increases, along an axis from south to north. The abundance of infaunal polychaete tubes at the IB site is indicative of sheltered habitat, whereas lack of their presence at the OB site was probably the result of wave action and current scour.

The number of crabs observed on the structures increased during our survey, but dropped off the following summer. By that time, the earliest arrivals were 1.5 years old and had reached a size at which they could begin to "hitch-hike" on seastars and were less vulnerable to predation, so they may have left the structures. Newer recruits did not replace them at the same rate, possibly due to annual variation in recruitment patterns, or simply because crabs of the next (1998) year class were not yet large enough to be seen by divers at that time of year (June). One of the most important components of the fouling community are hydroids (Plates 11C, 11D). Hydroids are an important habitat for newly settled glaucothoe-stage postlarvae of red king crab, which choose them over alternative habitats due to their complex 3-dimensional structure (Stevens, in press). Hydroid colonies do not develop until late summer, and their presence on the pilings and buoy lines may attract settling RKC glaucothoe to the pilings.

Abundance of juvenile RKC was highly correlated with green urchins and three other species, including decorator crabs, leather stars and sculpins. Why these species are associated with crabs is unknown. RKC and decorator crabs may have similar food preferences; sculpins may be crab predators; but urchins and seastars are not predators or food competitors of RKC. In all cases the urchins and seastars were large specimens, not recent recruits, and must have climbed up onto the structure. Perhaps the common link between these organisms was simply their penchant for hard substrata.

Discriminant analysis showed that the biological communities on the structures were similar to the surrounding substratum, and to Marginal Pier pilings, but the latter location had little overlap with nearby substrata. Sites inside and outside the breakwater were similar, but Womens Bay had little overlap with either of the other sites.

Why juvenile RKC prefer to settle on pilings is not clear. The most likely explanation is that they are attracted to the shelter of fouling organisms that grow there, as demonstrated by Stevens and Kittaka (1998) and Stevens (in press). However, fouling organisms were not highly abundant when the first recruits began to appear, and most crabs were observed on bare wood. Perhaps crabs are attracted to the physical structure of the pilings, settling in small pits among the bark and rough milling marks. Another possibility is that the vertical height of the pilings puts them up above the surrounding substratum where they are more likely to "intercept" incoming crab larvae. Or perhaps crabs are attracted by chemicals released by the decaying spruce wood. Occasional observations suggest that new steel pilings added to the St. Herman Harbor marina do not seem to attract the fouling organisms or crabs that were observed on wood pilings, although we have not conducted a systematic survey of these. Furthermore, the smooth steel surfaces are much more difficult for crabs to climb.

As a result of this work, we have made recommendations to the USACE that new dock structures in the Kodiak area be built with pilings, as opposed to sheet-metal bulkheads with backfill, as proposed by some developers. Use of pilings preserves the underlying substratum that would be covered by filling, and adds hard vertical structure useful to crabs and other fauna. We cannot recommend that piling structures be deployed to mitigate for habitat loss at this time for several reasons. First, the reason for attraction is still not understood. Second, although pilings attract king crabs, pilings have limited surface area, and low fractal dimension, i.e., they are devoid of highly complex interstitial spaces, which is apparently the structural feature that makes various natural and artificial habitats attractive to juvenile RKC (Stevens and Kittaka, 1998; Stevens, in press). If habitat enhancement is deemed worthwhile for future research, other types of structures might be more effective, by providing more surface and interstitial area in a more compact structure. Furthermore, pilings are not permanent structures and will not last long in a marine environment unless treated with toxic chemicals. Better structures might include crushed rock or gravel, or specifically designed man-made substrata. Most likely, the new breakwater itself provides more habitat of better quality than the original substratum that it replaced.

Acknowledgments

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Table 1. Dates of diving and sampling activity. Quarter 0 represents pre-sampling activities.

Quarter	Abbreviation	Dates	Activity
0		5/12/97 - 5/20/97	Place marker buoys
0		5/29/97 - 6/06/97	Install transect lines
1	Sum97	6/10/97 - 6/11/97	Count, photo, video
2	Aut97	9/09/97 - 9/10/97	Count, photo, video
3	Wtr97	12/09/97 - 12/15/97	Count, photo, video
4	Spr98	3/06/98 - 3/11/98	Count, photo, video
5	Sum98	6/09/98 - 6/12/98	Count, photo, video

Table 2. Total number and proportion of each species observed on log structures.

Common name	**Code**	**Scientific name**	**Number**	**Percent**
mottled seastar	ET	*Evasterias troschellii*	592	45.3 %
sunflower seastar	Pyc	*Pycnopodia helianthoides*	285	21.8 %
red king crab	RKC	*Paralithodes camtschaticus*	138	10.6 %
helmet crab	Tel	*Telmessus cheiragonus*	94	7.2 %
green sea urchin	Urc	*Strongylocentrotus droebachiensis*	61	4.7 %
decorator crab	Ore	*Oregonia gracilis*	40	3.1 %
leather star	Drm	*Dermasterias imbricata*	35	2.7 %
sculpins > 15 cm	Scl	family *Cottidae*	33	2.5 %
blood star	Hen	*Henricia leviuscula*	14	1.1 %
kelp crab	Pug	*Pugettia gracilis*	6	0.5 %
rose star	Crs	*Crossaster papposus*	4	0.3 %
California sea cucumber	Cuk	*Parastichopus californiensis*	4	0.3 %

Table 3. GLM analysis for effects of factors on counts of red king crabs on piling structures. Data from substratum transects and marginal pier are excluded. All data were transformed to log(x+1) prior to analysis.

Source	df	Res. Dev.	P
Null	29	293.24	< 0.001
Quarter (QTR)	25	141.21	< 0.001
Site (SIT)	23	56.83	< 0.001
Habitat (HAB)	22	33.94	< 0.001
QTR × SIT	14	15.31	< 0.001
QTR × HAB	10	12.15	< 0.001
SIT × HAB	8	7.93	< 0.001

Table 4A. Results of discriminant analysis and reclassification of samples. Grouping tested was location (Structure, substratum, or Marginal Pier). Numbers are percentage of original samples that were assigned to each group by discriminant functions using cross-validation. Source data are in the left column, predicted group is across top row. Bold values are correct reclassifications.

Source / Prediction	Structure	Substratum	Marg. Pier	Cases
Structure	**50 %**	33.3 %	16.7 %	30
Substrate	6.7 %	**90 %**	3.3 %	60
Marg. Pier	30 %	0 %	**70 %**	10

Table 4B. Results of discriminant analysis and reclassification of samples. Grouping tested was sites: Inside breakwater (IB), outside breakwater (IB) or Womens Bay (WB). Numbers are percentage of original samples that were assigned to each group by discriminant functions using cross-validation. Source data are in the left column, predicted group is across top row. Bold values are correct reclassifications.

Source / Prediction	IB	OB	WB	Cases
IB	**76.7 %**	16.7 %	6.7 %	30
OB	50 %	**40 %**	10 %	30
WB	23.3 %	3.3 %	**73.3 %**	30

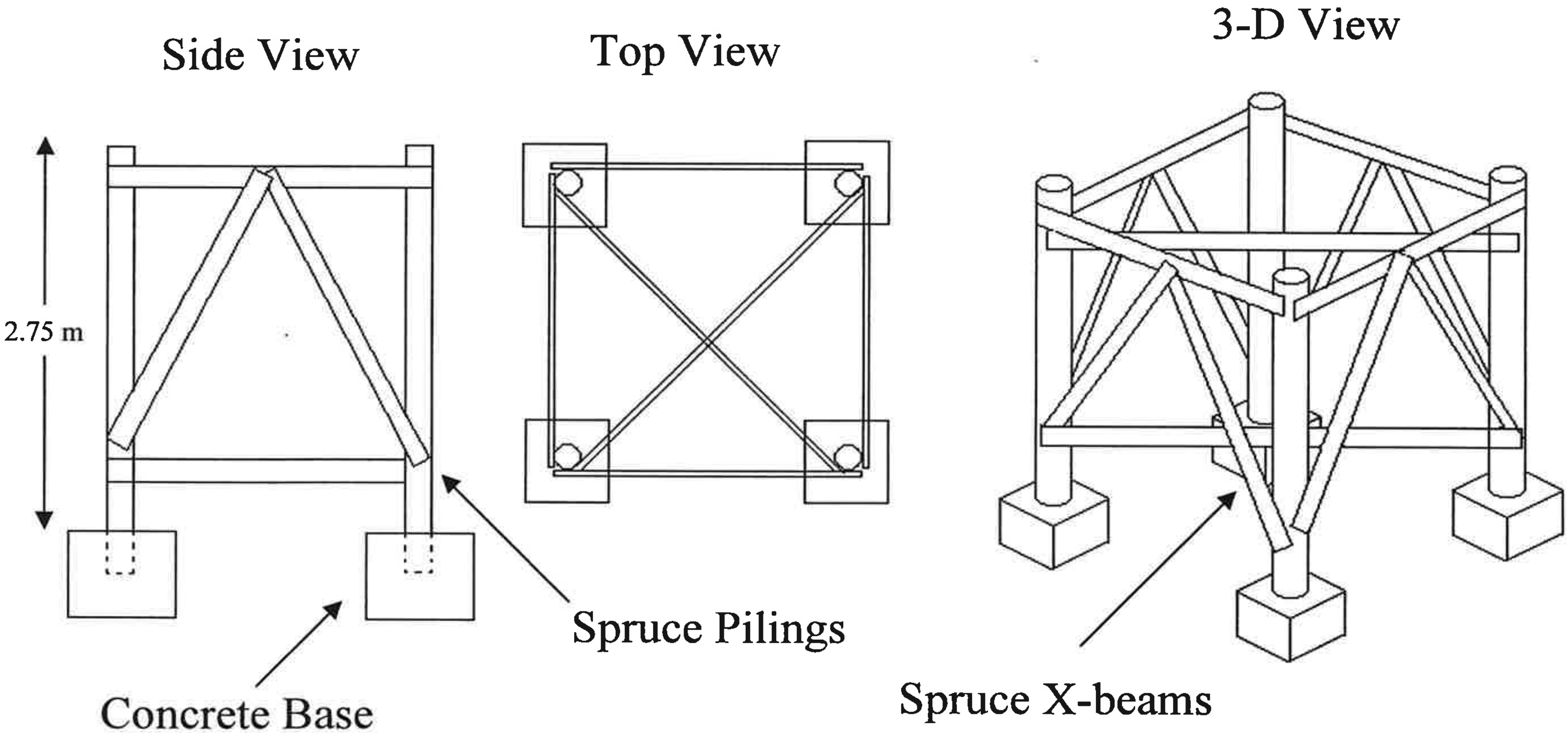

Figure 1. Schematic diagram of crab habitat structures. Vertical pilings were spruce logs with intact bark. Bases are 0.8 • 0.8 • 0.5 m concrete blocks. Cross-beams are 5 • 20 cm spruce. Height of, and distance between corner posts was 2.75 m.

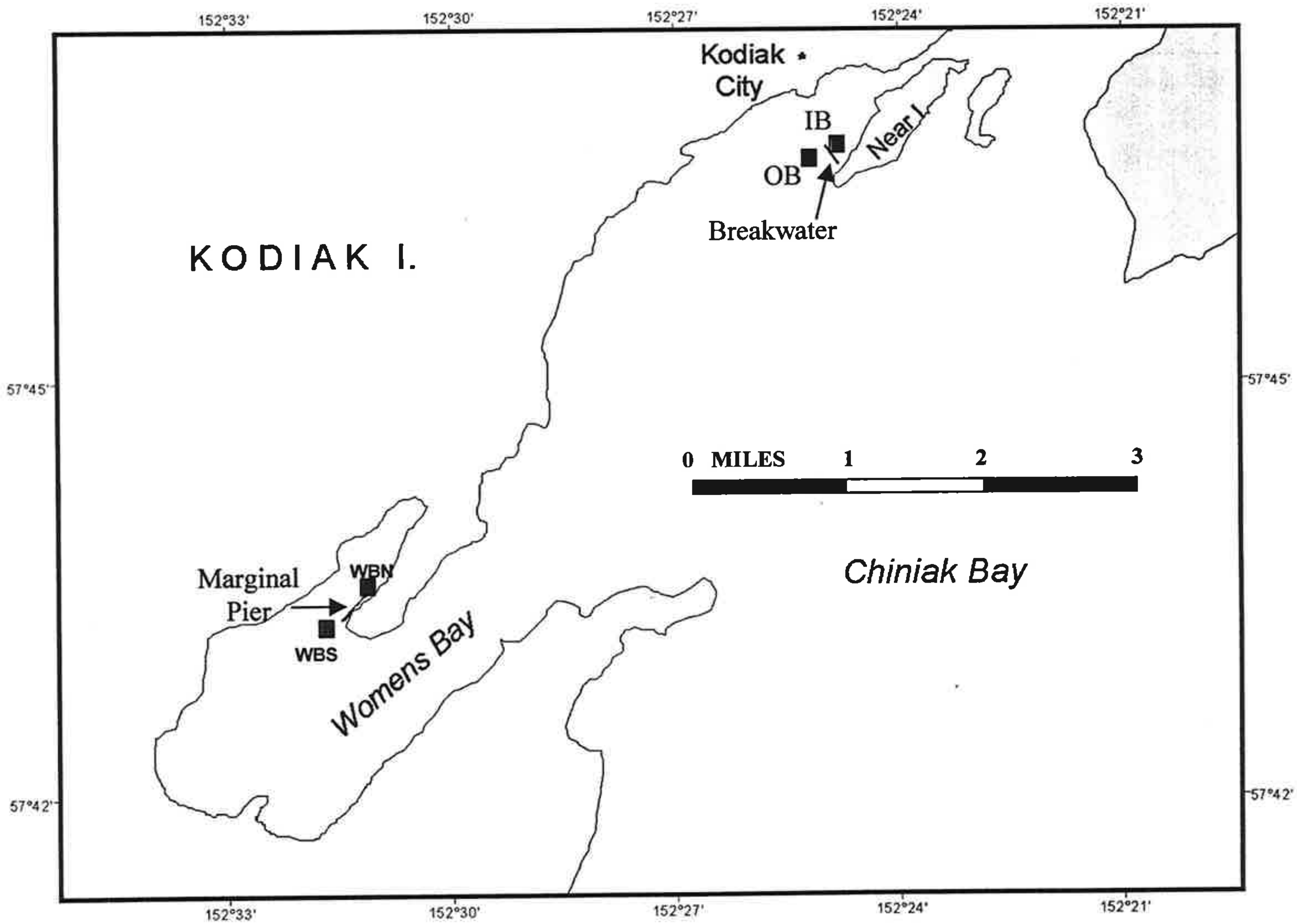

Fig. 2. Map of Kodiak area showing sites where structures were placed. IB, inside breakwater; OB, outside breakwater; WBN, Womens Bay North; WBS, Womens Bay South.

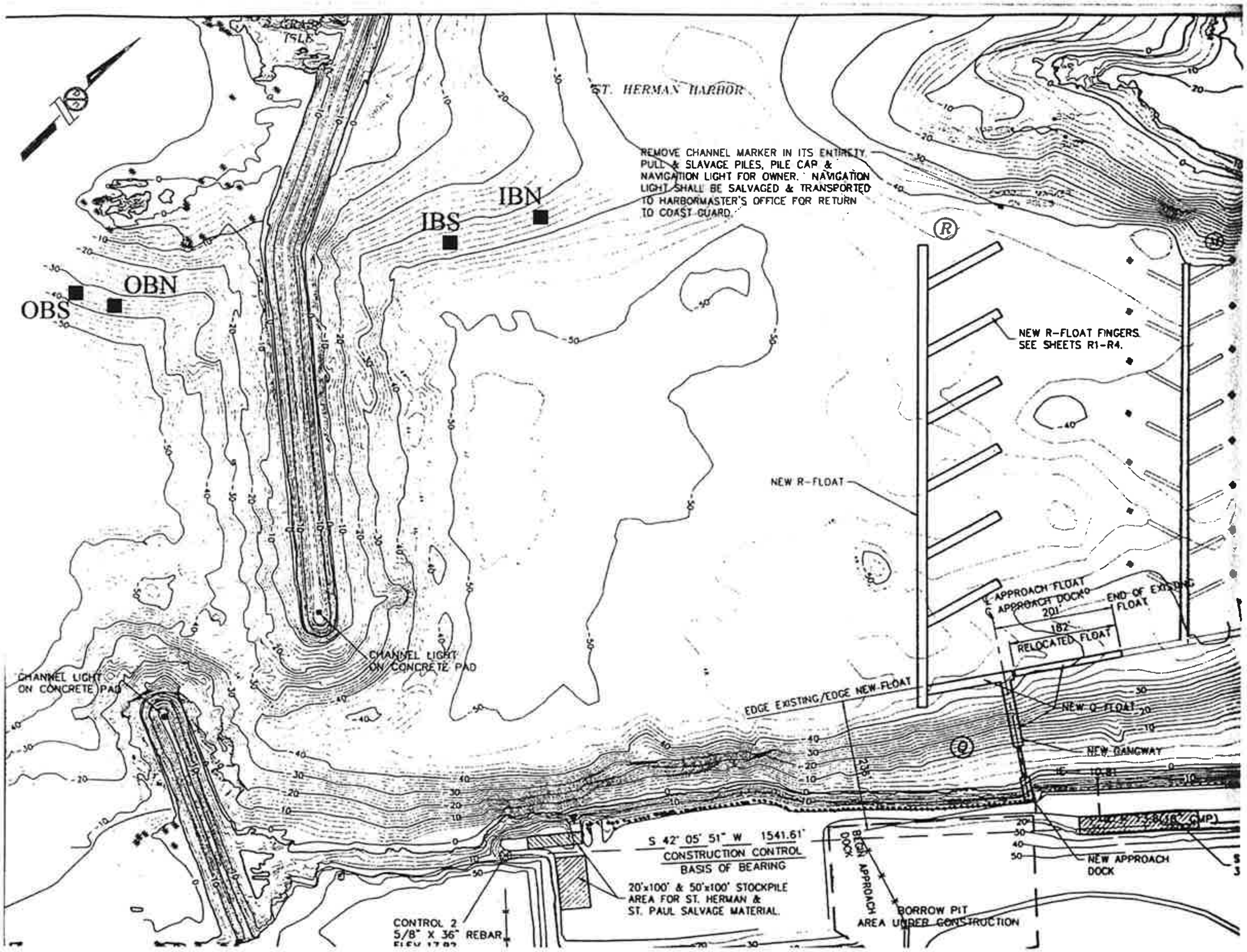

Fig. 3. Bathymetric chart of the St. Herman Harbor Breakwater, and location of crab habitat structures.

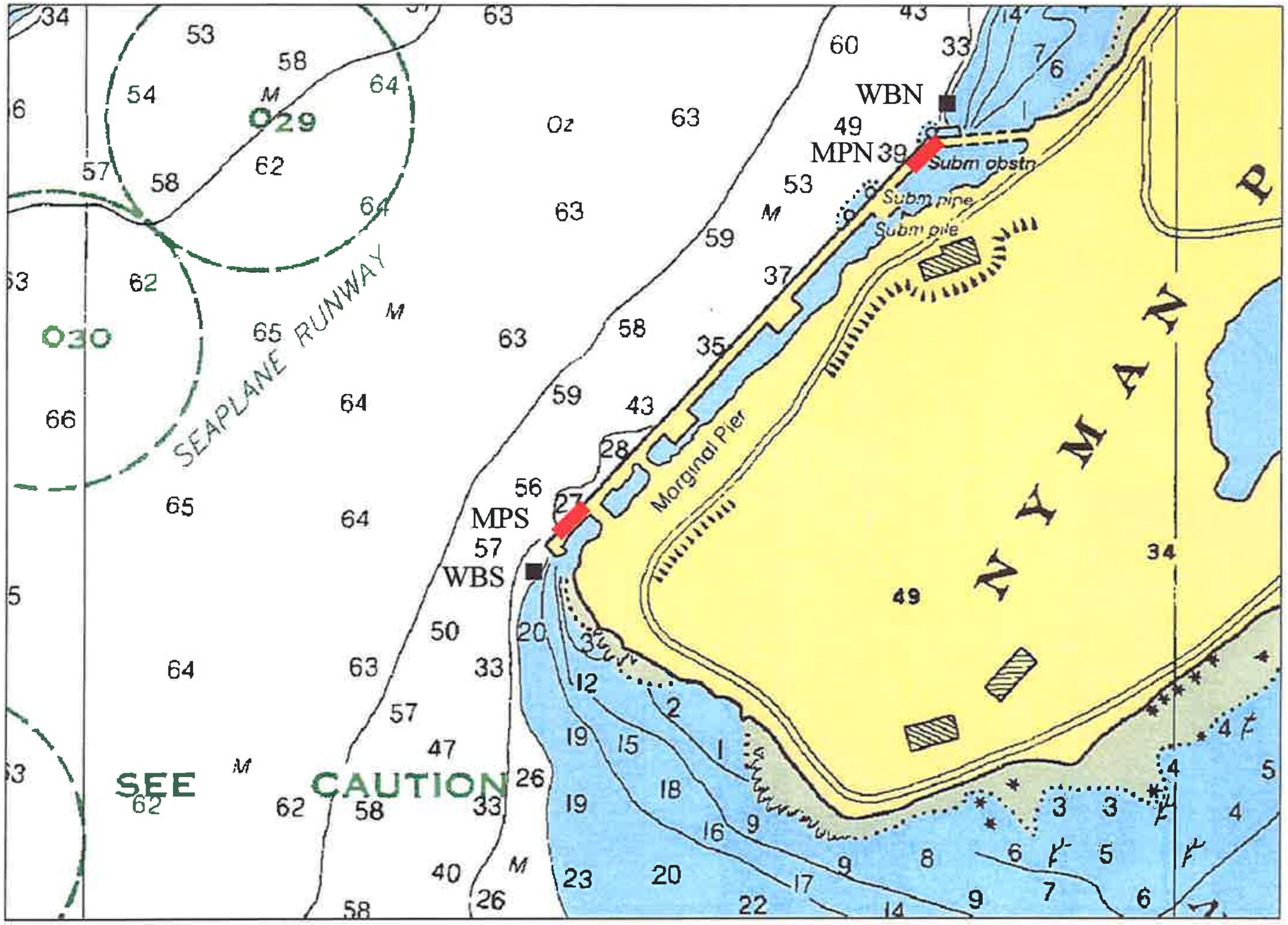

Fig. 4. Bathymetric chart of Womens Bay, showing location of habitat structures (black squares, WBN and WBS) and Marginal Pier sampling sites (red stripes, MPN and MPS).

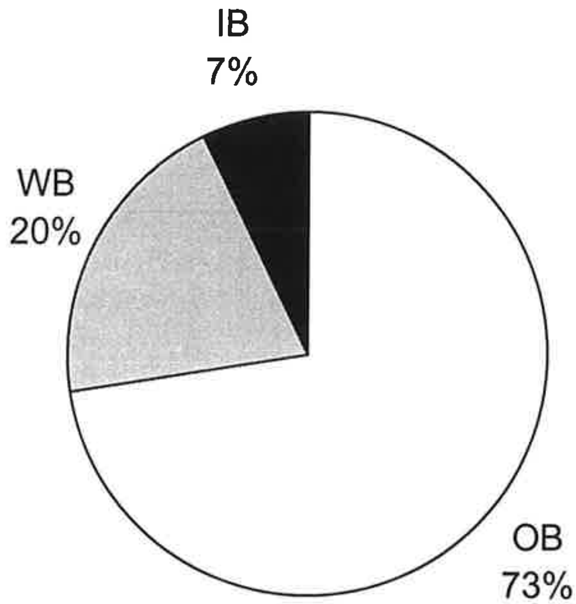

Fig. 5. Proportion of crabs observed at each site, over all habitats and sampling periods, exclusive of Marginal Pier samples.

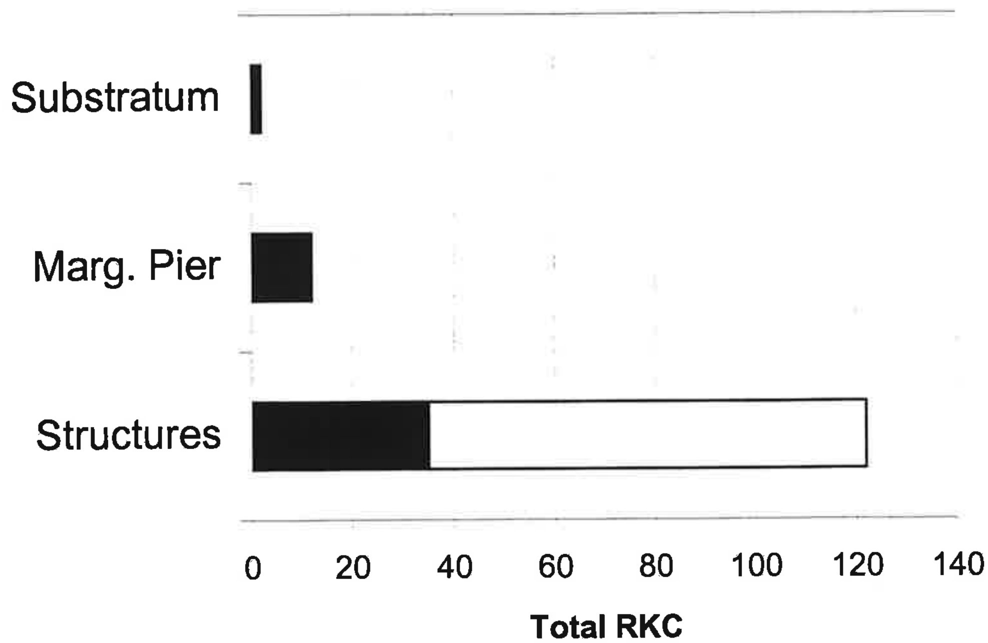

Fig. 6. Counts of red king crabs observed on different types of habitat: structures (North = black, South = white), Marginal Pier pilings, and natural substratum.

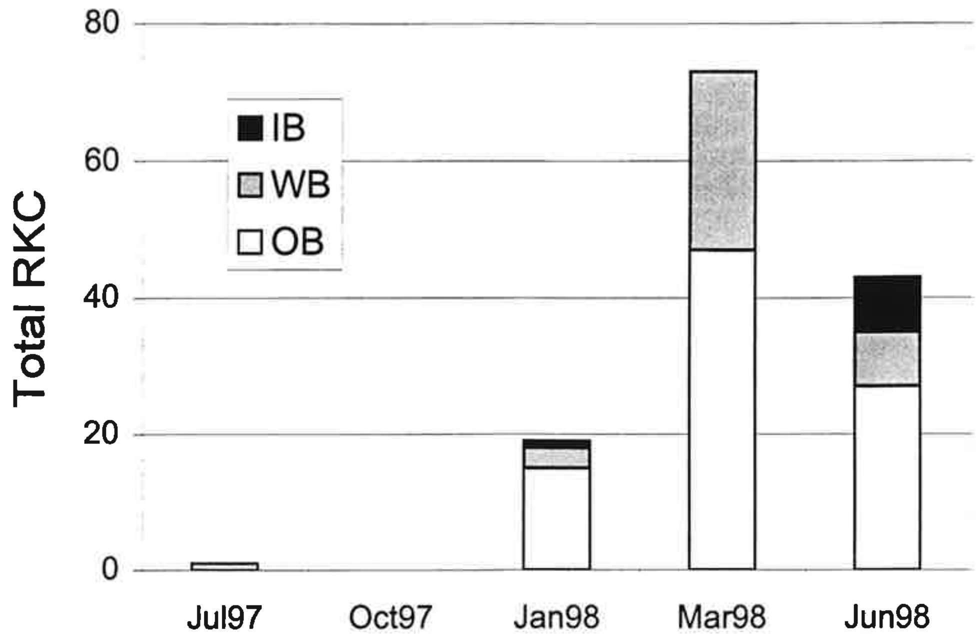

Fig. 7. Counts of red king crabs on all structures and sites, by sampling quarter.

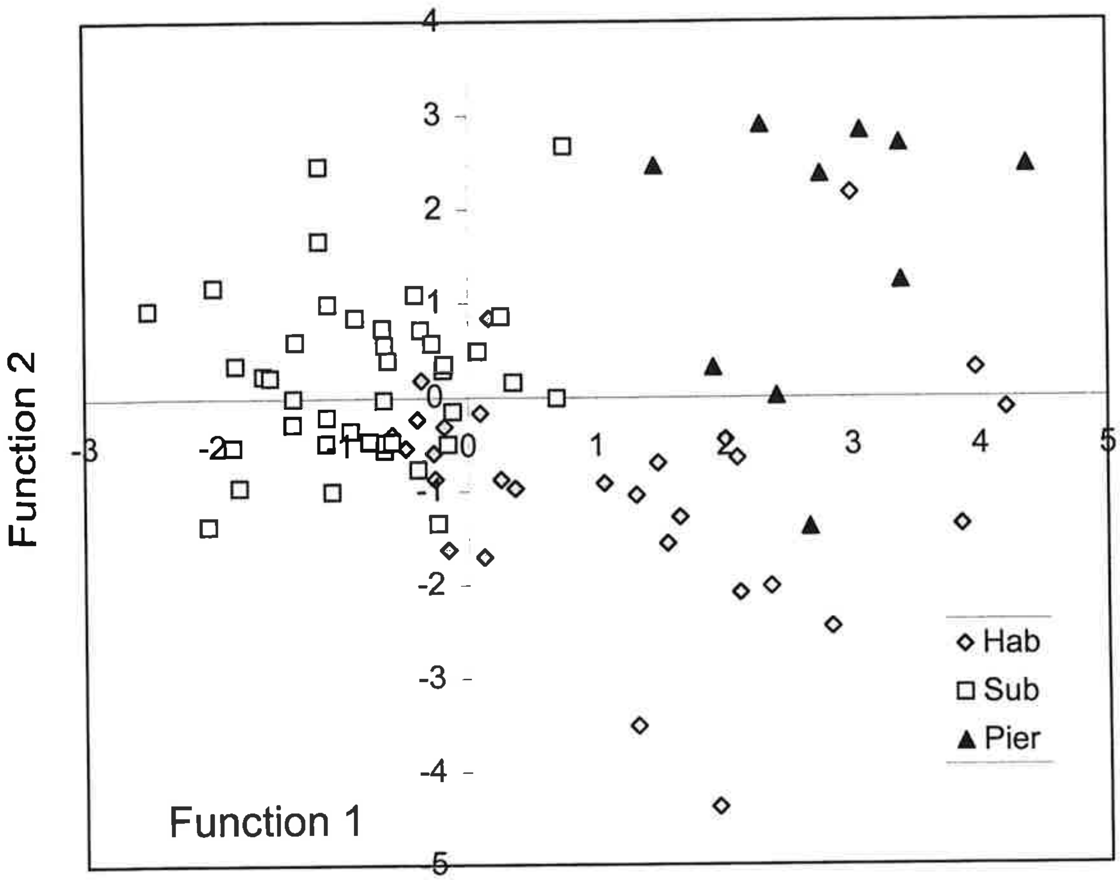

Fig. 8. Discriminant analysis of samples based on organism counts. Hab = structures; Sub = substratum samples; Pier = Marginal Pier samples.

Appendix Table A: Captions, locations, dates and reference numbers for photographs.

Site abbreviations:

OBN/S = Outside breakwater, North/South.

IBN/S = Inside breakwater, North/South.

WBN/S = Womens Bay, North/South.

ID numbers are from NMFS photograph reference collection..

Plate/ Photo	Description	Site	Date	ID#
Plate 1				
A	St. Herman Harbor breakwater under construction.		July, 1997	97- 2.04
B	P. Cummiskey and J. E. Munk prepare for diving.		July, 1997	97- 2.02
C	B. Stevens photographing the piling structures.		March, 1997	97- 5.02
Plate 2				
A	Top of piling.	OBN	July, 1997	97- 3.05
B	Side of piling.	OBN	July, 1997	97- 3.16
C	Crossbeam.	OBN	July, 1997	97- 3.09
D	Concrete base.	OBN	July, 1997	97- 3.10
Plate 3				
A	Sediment near structure.	IBN	July, 1997	97- 2.16
B	Sediment near structure.	OBN	July, 1997	97- 3.14
C	Green urchin on crossbeam	OBS	July, 1997	97- 3.19
D	Red king crab on mottled star on sediment	IBN	July, 1997	97- 3.33
Plate 4				
A	Top of piling.	IBN	Sept., 1997	97- 4.03

Plate/ Photo	Description	Site	Date	ID#
B	Side of piling.	IBN	Sept., 1997	97- 4.04
C	Crossbeam.	IBN	Sept., 1997	97- 4.05
D	Concrete base.	IBN	Sept., 1997	97- 4.06
Plate 5				
A	Sediment near structure.	IBN	Sept., 1997	97- 4.07
B	Sediment near structure.	OBN	Sept., 1997	97- 4.15
C	Fauna on debris near structure.	WBN	Sept., 1997	97- 4.32
D	Fauna on Marginal Pier piling.	WBN	Sept., 1997	97- 4.33
Plate 6				
A	Top of piling.	WBN	Sept., 1997	97- 4.28
B	Side of piling.	WBN	Sept., 1997	97- 4.24
C	Crossbeam.	WBN	Sept., 1997	97- 4.25
D	Concrete base.	WBN	Sept., 1997	97- 4.26
Plate 7				
A	Decorator crab on piling	OBN	Dec., 1997	97- 5.24
B	Red king crab on crossbeam	OBN	Dec., 1997	97- 5.18
C	Nudibranch on crossbeam	WBN	Dec., 1997	97- 5.31
D	Concrete base with worm tubes and nudibranch egg strings.	WBN	Dec., 1997	97- 5.30
Plate 8				
A	Piling top	OBN	March, 1998	98- 10.23
B	Piling side	OBN	March, 1998	98- 10.17
C	Tunicates on crossbeam	OBN	March, 1998	98- 10.12
D	Concrete base	OBN	March, 1998	98- 10.19
Plate 9				
A	Sediment	IBN	March, 1998	98- 10.14
B	Sediment	OBN	March, 1998	98- 10.20

Plate/ Photo	Description	Site	Date	ID#
C	Piling top	WBN	March, 1998	98- 11.03
D	Mottled star on crossbeam	WBN	March, 1998	98- 11.20
Plate 10				
A	Piling top	IBN	June, 1998	98- 16.04
B	Piling side	IBN	June, 1998	98- 16.06
C	Helmet crabs in premating embrace, on crossbeam	IBN	June, 1998	98- 16.19
D	Concrete base	IBN	June, 1998	98- 16.11
Plate 11				
A	Red king crab on crossbeam	IBN	June, 1998	98- 16.27
B	Red king crab on crossbeam	OBN	June, 1998	98- 16.35
C	Hydroids on buoy line	IBN	June, 1998	98- 16.14
D	Shrimp on buoy line	OBN	June, 1998	98- 16.38

Plate 1.

A. St. Herman Harbor breakwater under construction.

B. P. Cummiskey and E. Munk prepare for diving.

C. B. Stevens photographing the piling structures.

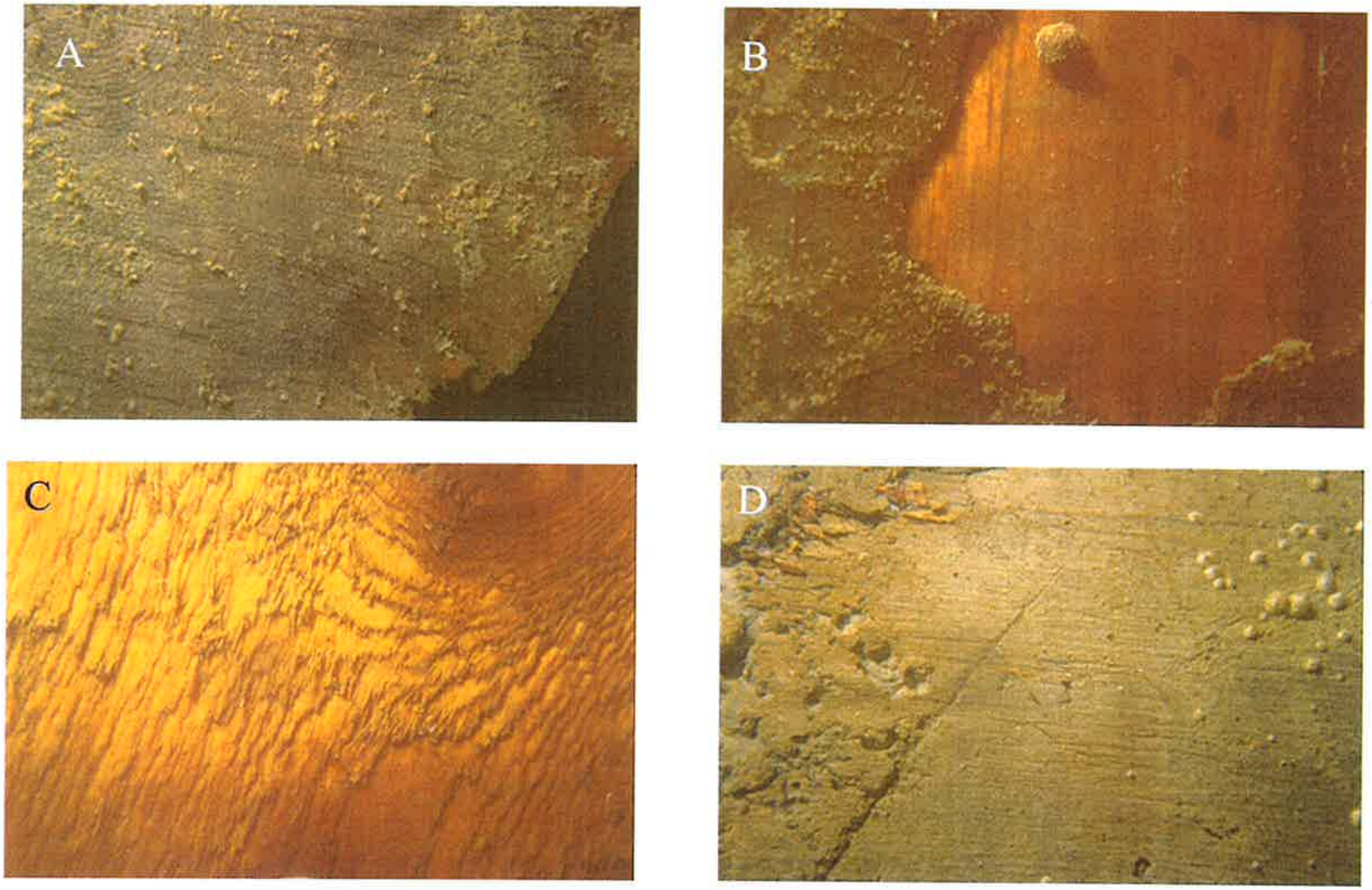

Plate 2
A. Top of piling, OBN, July 1997.
B. Side of piling, OBN, July 1997.
C. Crossbeam, OBN, July 1997.
D. Concrete base, OBN, July 1997.

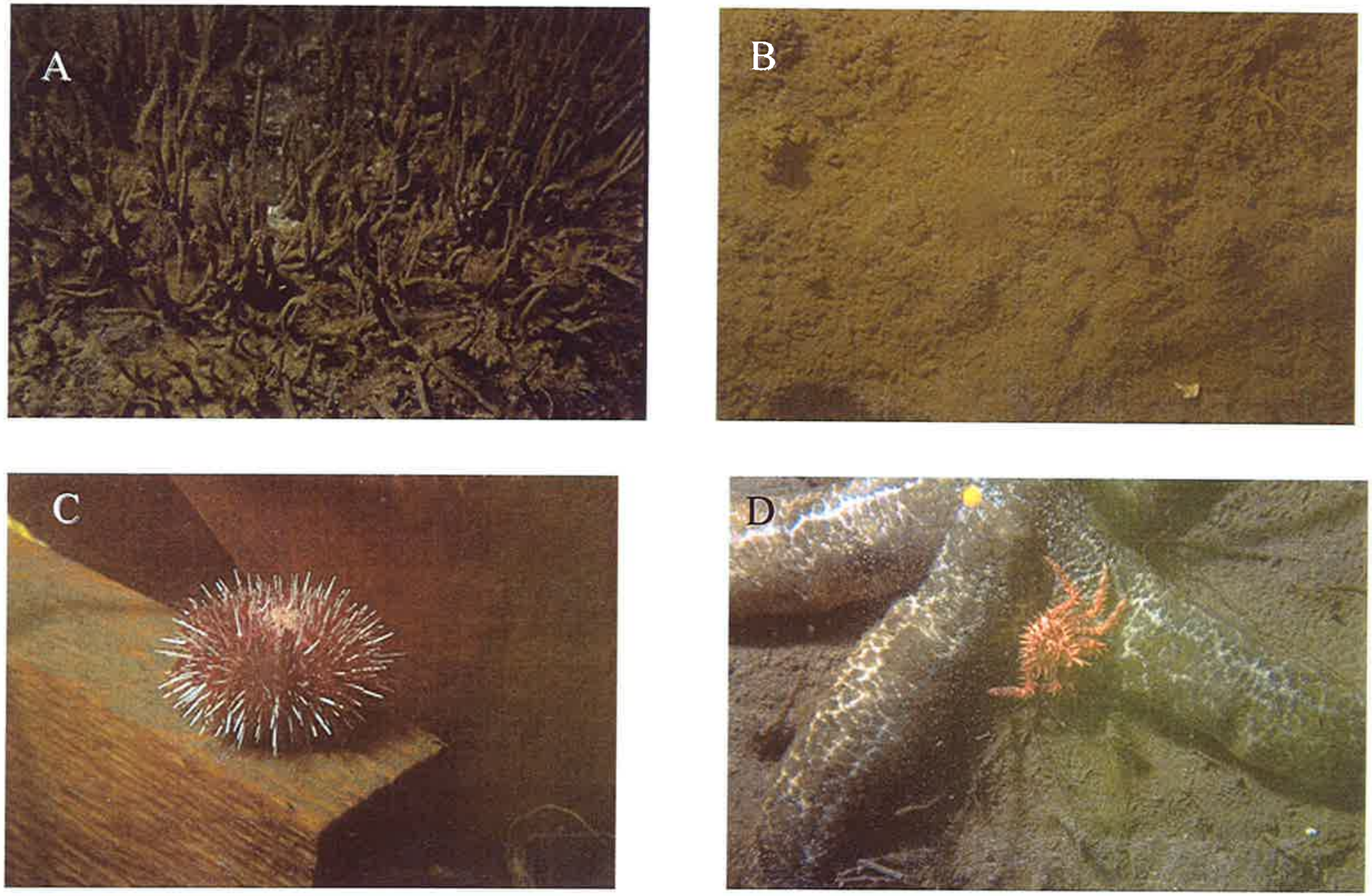

Plate 3

A. Sediment at site IBN, July 1997.

B. Sediment at site OBN, July 1997.

C. Green urchin on crossbeam, OBS, July, 1997.

D. Red king crab on mottled star, near IBN, July, 1997.

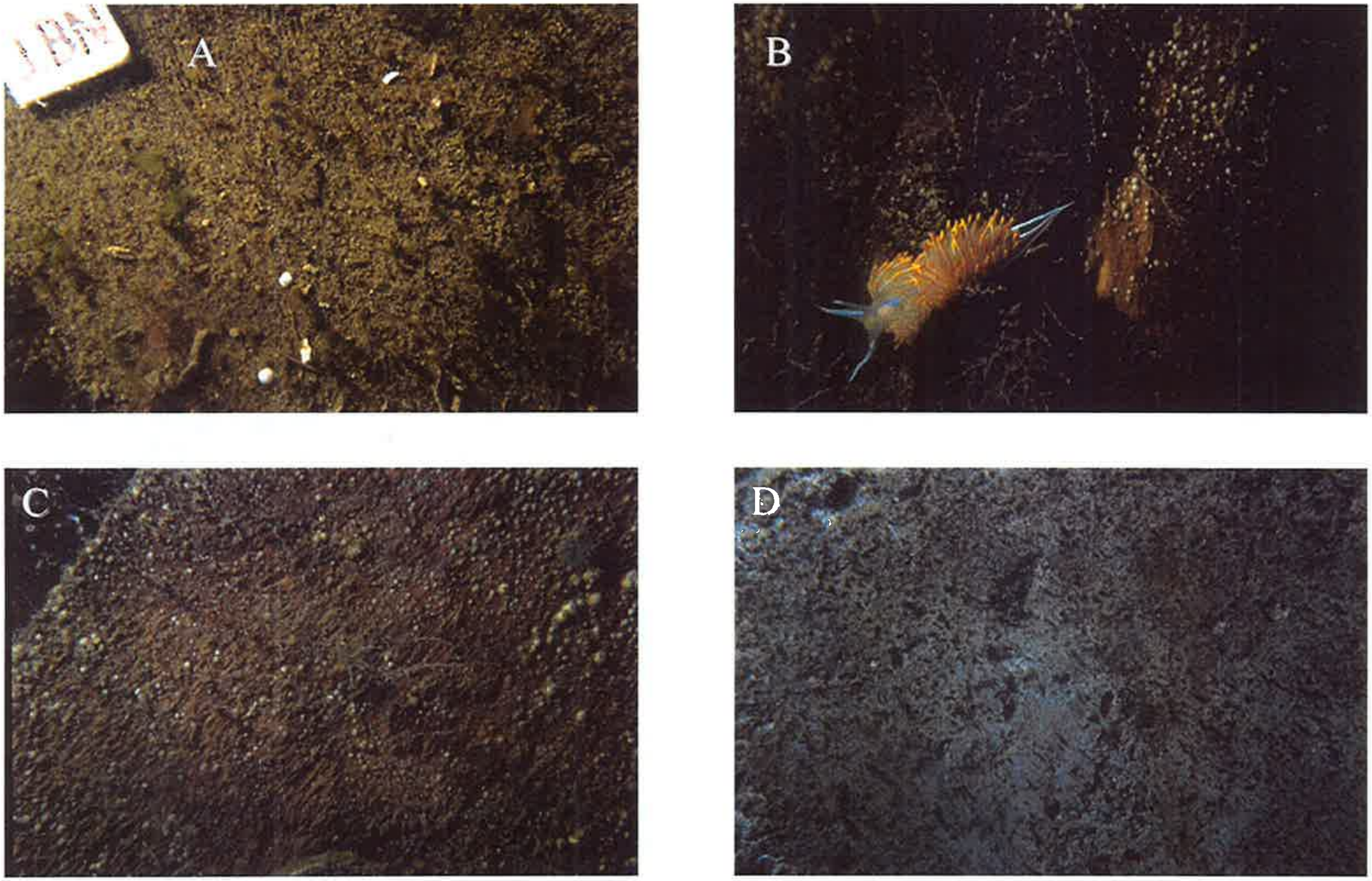

Plate 4.

A. Piling top, IBN, September 1997.

B. Side of piling, IBN, September, 1997.

C. Crossbeam, IBN, September 1997.

D. Concrete base, IBN, September, 1997.

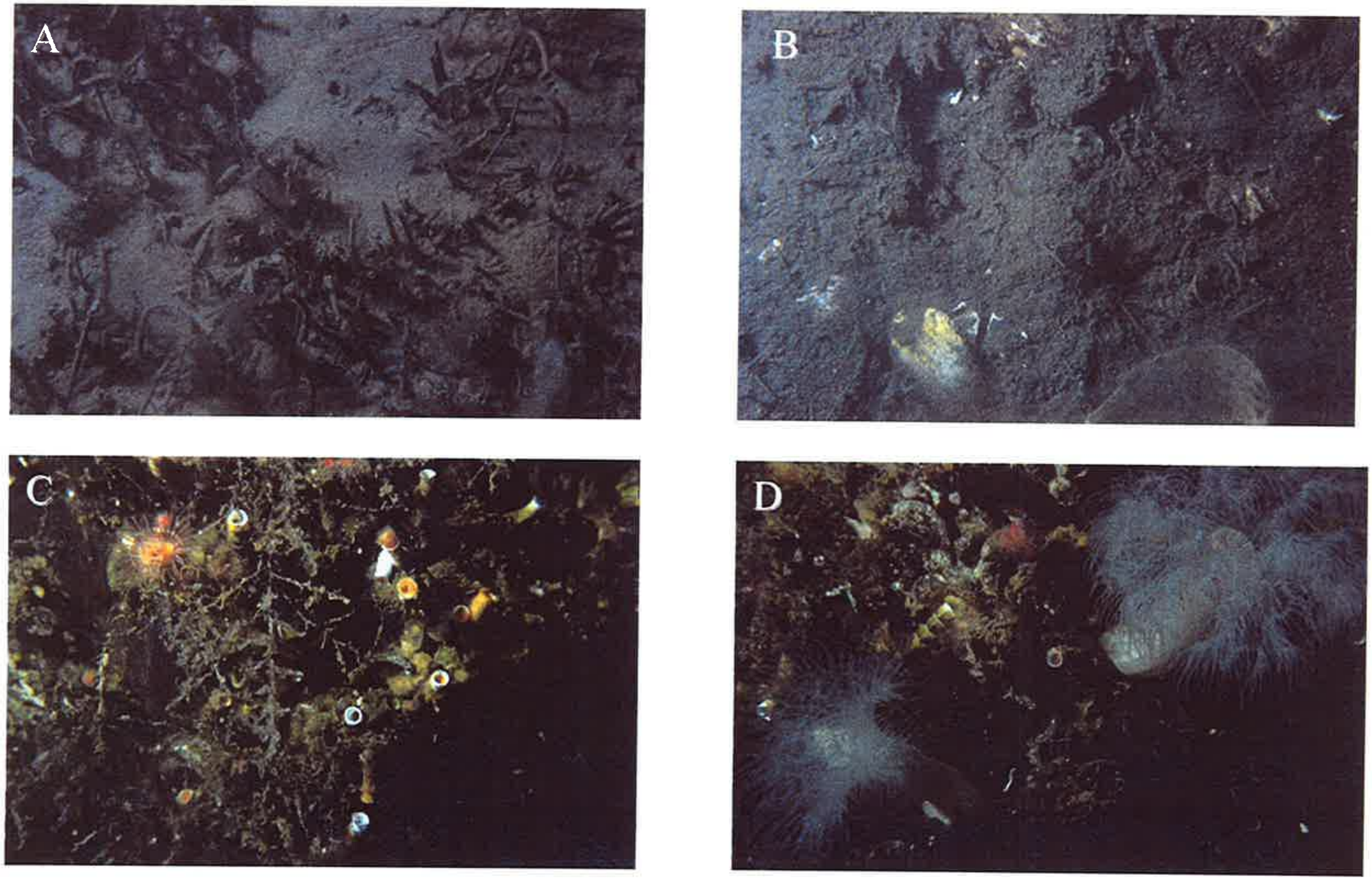

Plate 5.

A. Sediment, IBN, September 1997.

B. Sediment, OBN, September, 1997.

C. Fauna on debris near WBN, September 1997.

D. Fauna on Marginal Pier, September, 1997.

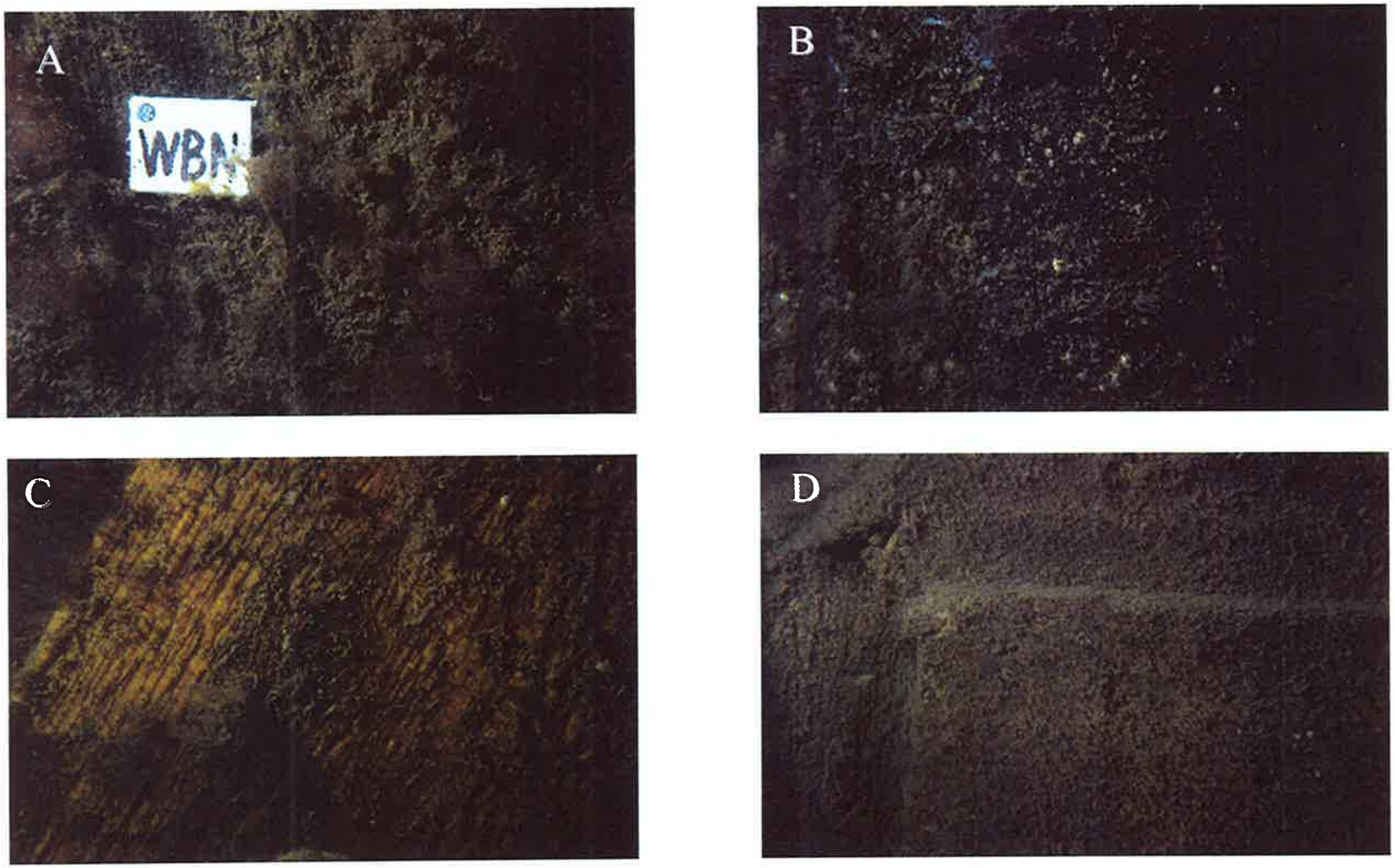

Plate 6.
A. Piling top, WBN, September 1997.
B. Piling side, WBN, September, 1997.
C. Crossbeam, WBN, September 1997.
D. Concrete Base, WBN, September, 1997.

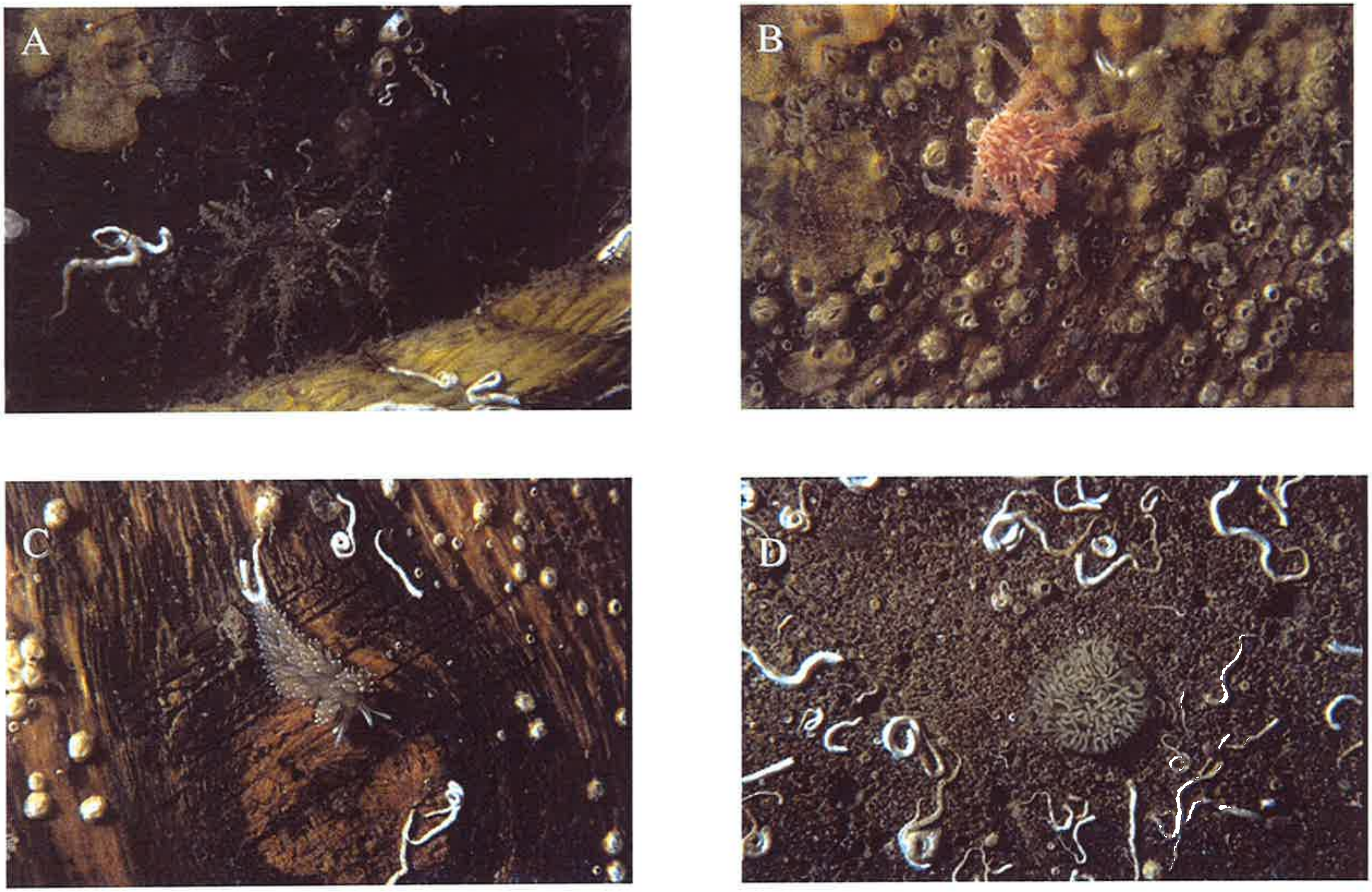

Plate 7.

A. Decorator crab on piling, OBN, December 1997.

B. Red king crab on crossbeam, OBN, December 1997.

C. Nudibranch on crossbeam, WBN, December, 1997.

D. Concrete base, WBN, December, 1997.

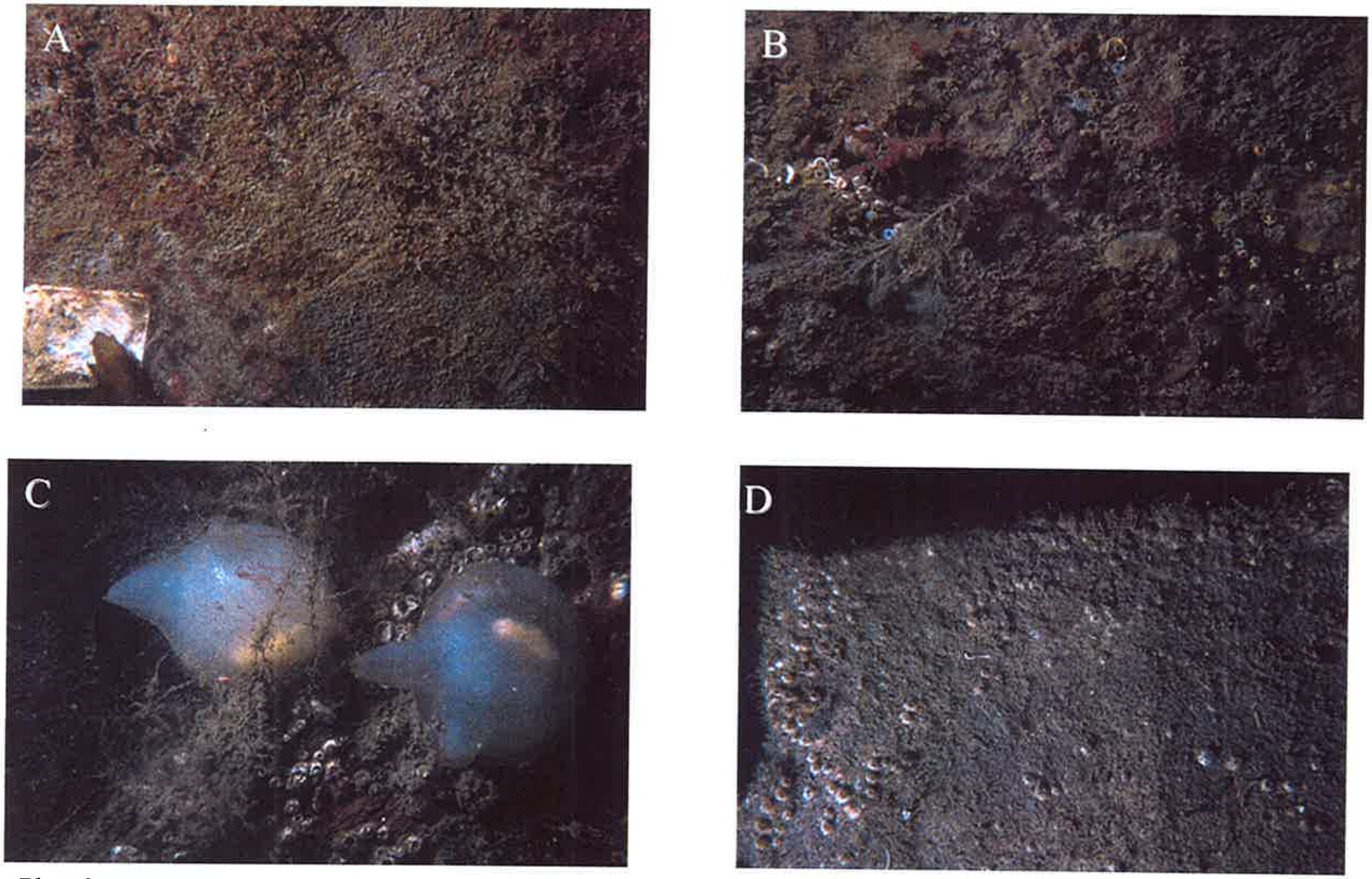

Plate 8.
A. Piling top, OBN, March 1998.
B. Piling side, OBN, March, 1998.
C. Tunicates on crossbeam, OBN, March, 1998.
D. Concrete base, OBN, March, 1998.

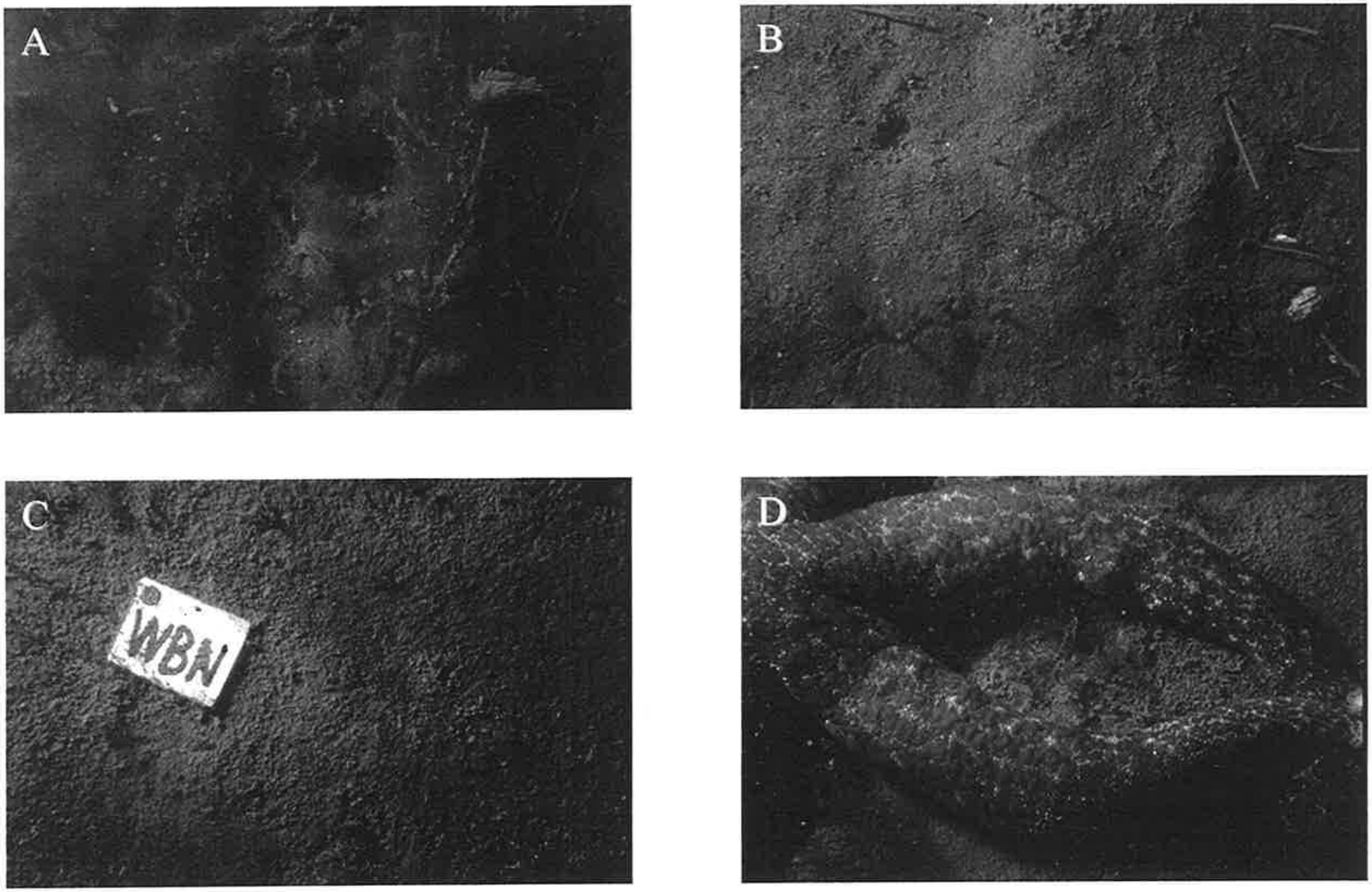

Plate 9.
A. Sediment, IBN, March 1998.
B. Sediment, OBN, March, 1998.
C. Piling top, WBN, March, 1998.
D. Mottled star on crossbeam, WBN, March, 1998.

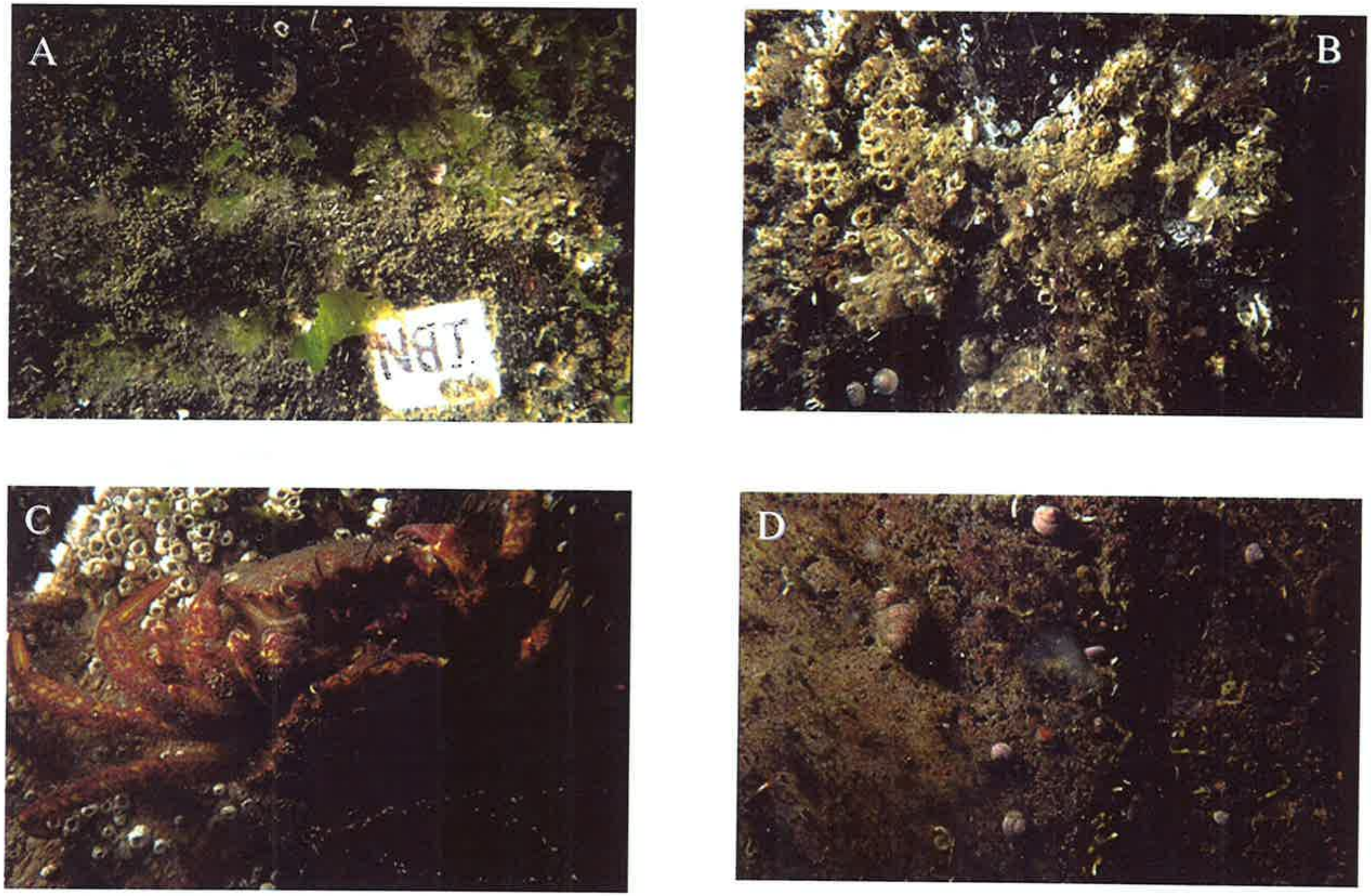

Plate 10.
A. Piling top, IBN, June 1998.
C. Helmet crabs on crossbeam, IBN, June, 1998.

B. Piling side, IBN, June, 1998.
D. Concrete base, IBN, June, 1998.

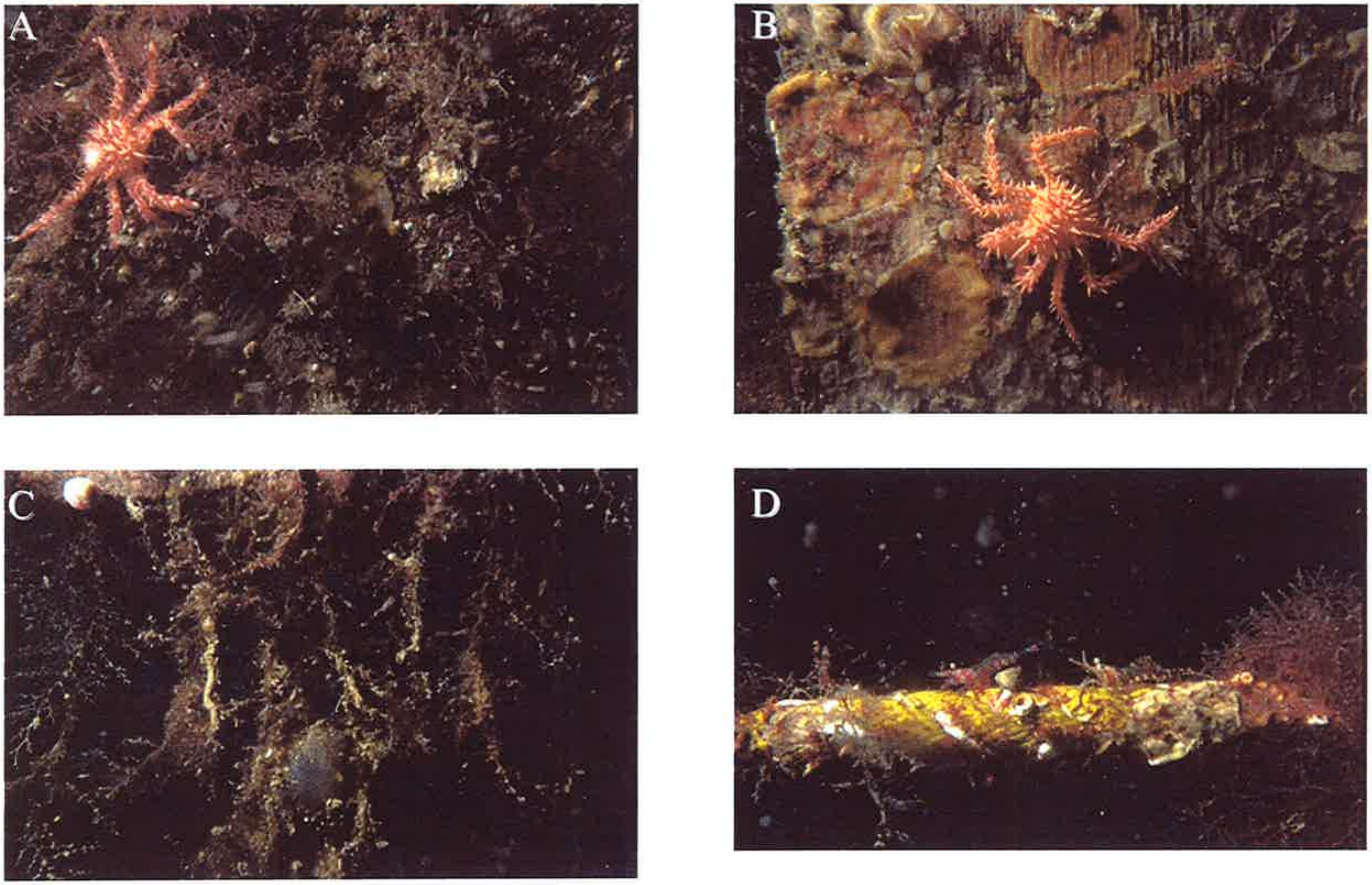

Plate 11.

A. Red king crab on crossbrace, IBN, June 1998.

B. Red king crab on crossbrace, OBN, June 1998.

C. Hydroids on crossbeam, IBN, June, 1998.

D. Shrimp on buoy line, OBN, June, 1998.

Appendix Table B. Dates and details of diving activity.

Quarter	Date	Activity	Site	Divers
0	5/12/97	Place buoy	WBS	M, C
0	5/14/97	Place buoys, photo	OBN, OBS	M, C
0	5/15/97	Place buoys	IBN, IBS	M, C, S
0	5/19/97	Place buoy	WBN	M, C
0	5/20/97	Replace buoy, photo	OBS	M, S
0	5/20/97	Photo	IBN, IBS	M, S
0	5/29/97	Install transect line	WBN	M, C
0	5/29/97	Install transect line	WBS	M, C
0	5/30/97	Install transect line	OBN, OBS	M, C
0	5/30/97	Install transect line	IBN, IBS	M, C
0	6/05/97	Install transect line	OBN, OBS	M, C
0	6/05/97	Install transect line	IBN, IBS	M, C
0	6/06/97	Install transect line	WBN	M, C
0	6/06/97	Install transect line	WBS	M, C
1	6/10/97	Count organisms	OBN, OBS	M, C
1	6/10/97	Count organisms	IBN, IBS	M, C
1	6/11/97	Count organisms	WBN, MPN	M, C
1	6/11/97	Count organisms	WBS, MPS	M, C
2	9/9/97	Count and photograph	IBN, IBS	M, C, S
2	9/9/97	Count and videotape	OBN, OBS	M, C, S
2	9/10/97	Count and photograph	WBN, MPN	M, C, S
2	9/10/97	Count and videotape	WBS, MPS	M, C, S
3	12/9/97	Count, photo	IBN, IBS	M, S
3	12/11/97	Count, photo, video	OBN, OBS	M, C, S
3	12/12/97	Count, photo	WBN, MPN	M, S
3	12/15/97	Count, photo	WBS, MPS	M, S
4	3/6/98	Count, photo, video	IBN, IBS	M, C, S
4	3/9/98	Count	OBN, OBS	M, C
4	3/9/98	Photo, video	OBN, OBS	M, C
4	3/10/98	Count, photo	WBN, MPN	M, C, S
4	3/11/98	Count, video	WBS, MPS	M, C, S
5	6/9/98	Count, photo, video	IBN, IBS	M, C, S
5	6/10/98	Count, photo, video	OBN, OBS	M, C, S
5	6/11/98	Count, photo	WBN, MPN	M, C, S
5	6/12/98	Count, video	WBS, MPS	M, C, S

Notes:

Quarter 0 refers to activities prior to first counting period.

Abbreviations for sites are:

IBN, IBS	Inside Breakwater, North and South
OBN, OBS	Outside Breakwater, North and South
WBN, WBS	Womens Bay, North and South
MPN, MPS	Marginal Pier, North and South

Divers initials:

M	J. Eric Munk
C	Peter A. Cummiskey
S	Bradley G. Stevens

Appendix Table C. Counts of red king crab and other species observed on pilings. See Table 1 for Quarter (QTR codes, Table 2 for Species codes. Site, Habitat (Hab), and Location (Loc) codes are listed below.

Sample	Qtr	Site	Hab	Loc	RKC	Tel	Ore	Pug	Pyc	ET	Drm	Hen	Crs	Cuk	Urc	Scl	Total
1	1	1	1	1	0	3	0	0	0	0	0	0	0	0	0	0	3
2	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	1	2	0	0	0	0	1	0	0	0	0	0	0	0	1
4	1	1	2	1	0	6	0	0	0	0	0	0	0	0	0	0	6
5	1	1	2	2	0	0	0	0	2	0	0	0	0	0	0	0	2
6	1	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	2	1	1	0	0	0	0	5	1	0	0	0	0	0	0	6
8	1	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	2	1	2	0	0	1	0	3	2	0	0	0	0	0	0	6
10	1	2	2	1	0	0	0	0	5	0	0	0	0	0	1	0	6
11	1	2	2	2	1	0	0	0	6	0	0	0	1	1	0	0	9
12	1	2	2	2	0	0	0	0	3	0	1	0	0	0	0	0	4
13	1	3	1	1	0	4	0	0	0	2	0	0	0	0	0	1	7
14	1	3	1	2	0	2	1	0	1	0	0	0	0	0	0	0	4
15	1	3	1	2	0	0	0	0	1	2	0	0	0	0	0	0	3
16	1	3	1	3	0	4	2	0	2	12	0	0	0	0	0	0	20
17	1	3	2	1	0	10	0	1	1	1	0	0	0	0	0	0	13
18	1	3	2	2	0	2	0	0	0	1	0	0	0	0	0	0	3
19	1	3	2	2	0	4	0	0	1	3	1	0	0	0	0	0	9
20	1	3	2	3	0	0	0	0	3	12	1	1	0	0	0	0	17
21	2	1	1	1	0	2	0	0	0	0	0	0	0	0	0	0	2
22	2	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
23	2	1	1	2	0	1	0	0	1	0	0	0	0	0	0	1	3
24	2	1	2	1	0	2	0	0	3	0	0	0	0	0	0	1	6
25	2	1	2	2	0	0	0	0	1	2	0	0	0	0	1	0	4
26	2	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
27	2	2	1	1	0	0	0	0	2	2	0	0	0	0	0	0	4
28	2	2	1	2	0	0	0	0	2	0	0	0	0	0	0	0	2
29	2	2	1	2	0	0	0	0	0	1	0	2	0	0	0	0	3
30	2	2	2	1	0	0	0	0	2	2	0	0	0	0	3	0	7
31	2	2	2	2	0	0	0	0	0	0	1	0	0	0	0	0	1
32	2	2	2	2	0	0	0	0	1	0	0	0	0	0	0	0	1
33	2	3	1	1	0	2	0	0	4	6	0	0	0	0	0	1	13
34	2	3	1	2	0	0	0	0	1	1	0	0	0	0	0	1	3
35	2	3	1	2	0	0	0	0	0	3	0	0	0	0	0	0	3
36	2	3	1	3	0	0	0	1	2	11	0	0	0	0	0	0	14
37	2	3	2	1	0	3	0	0	1	10	0	0	0	0	0	2	16
38	2	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
39	2	3	2	2	0	0	0	0	1	1	2	0	0	0	0	0	4
40	2	3	2	3	0	0	0	0	1	9	0	2	0	0	0	0	12

Appendix Table C -- Cont.

41	3	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	3
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44	3	1	2	1	0	0	0	0	5	1	0	0	0	0	0	0	6
45	3	1	2	2	0	0	0	0	1	0	0	0	0	0	0	0	1
46	3	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
47	3	2	1	1	4	0	0	0	2	0	0	0	0	0	1	0	7
48	3	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
49	3	2	1	2	0	0	0	0	1	0	0	0	0	0	0	0	1
50	3	2	2	1	11	0	0	0	2	2	0	3	1	0	10	1	30
51	3	2	2	2	0	0	0	0	1	0	0	0	0	0	0	1	2
52	3	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
53	3	3	1	1	1	1	0	0	2	16	0	0	0	0	0	0	20
54	3	3	1	2	0	0	0	0	0	1	0	0	0	0	0	0	1
55	3	3	1	2	0	0	0	0	0	3	0	0	0	0	0	0	3
56	3	3	1	3	0	0	0	1	2	29	0	0	0	0	0	0	32
57	3	3	2	1	1	0	0	1	2	50	1	0	0	0	0	1	56
58	3	3	2	2	0	0	0	0	0	2	0	0	0	0	0	1	3
59	3	3	2	2	0	0	0	0	2	6	3	0	0	0	0	0	11
60	3	3	2	3	1	0	0	1	1	41	1	0	0	0	0	0	45
61	4	1	1	1	0	0	0	0	10	0	0	0	0	0	0	0	10
62	4	1	1	2	0	0	0	0	3	0	0	0	0	0	0	0	3
63	4	1	1	2	0	0	0	0	5	0	0	0	0	0	0	0	5
64	4	1	2	1	0	0	0	0	5	2	0	0	0	0	0	0	7
65	4	1	2	2	0	0	0	0	2	0	0	0	0	0	0	0	2
66	4	1	2	2	0	0	0	0	8	0	0	0	0	0	0	0	8
67	4	2	1	1	12	0	8	0	3	1	0	0	0	0	3	0	27
68	4	2	1	2	0	0	0	0	2	0	0	0	0	1	0	0	3
69	4	2	1	2	0	0	0	0	3	0	0	0	0	0	0	0	3
70	4	2	2	1	35	0	4	0	5	0	0	1	0	0	17	0	62
71	4	2	2	2	0	0	0	0	2	1	0	0	0	0	0	1	4
72	4	2	2	2	0	0	0	0	4	0	0	0	0	0	0	0	4
73	4	3	1	1	2	1	0	0	1	19	0	0	0	0	0	0	23
74	4	3	1	2	0	0	0	0	0	1	0	0	0	0	0	0	1
75	4	3	1	2	0	0	0	0	0	7	0	0	0	0	0	0	7
76	4	3	1	3	7	1	0	0	1	8	0	0	0	0	3	0	20
77	4	3	2	1	15	0	0	0	3	41	1	0	0	0	0	1	61
78	4	3	2	2	0	0	0	0	1	2	0	0	0	0	0	0	3
79	4	3	2	2	0	0	0	0	3	3	1	0	0	0	0	0	7
80	4	3	2	3	2	2	0	0	3	16	2	1	0	0	1	0	27
81	5	1	1	1	2	6	3	0	5	0	0	0	0	0	1	4	21
82	5	1	1	2	0	0	1	0	0	2	0	0	0	0	0	0	3
83	5	1	1	2	0	1	0	0	1	0	0	0	0	0	0	0	2
84	5	1	2	1	6	6	0	0	3	0	0	0	0	0	1	2	18
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Appendix Table C -- Cont.

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88	5	2	1	2	0	0	0	0	5	2	0	0	0	0	1	0	8
89	5	2	1	2	0	0	0	0	3	0	0	0	0	0	1	0	4
90	5	2	2	1	13	0	0	0	5	3	3	2	1	0	10	0	37
91	5	2	2	2	1	0	0	0	5	0	0	0	0	0	0	0	6
92	5	2	2	2	0	0	0	0	5	0	0	0	0	0	0	0	5
93	5	3	1	1	0	5	0	0	4	79	0	0	0	0	0	0	88
94	5	3	1	2	0	0	0	0	1	4	0	0	0	0	0	0	5
95	5	3	1	2	0	0	0	0	1	10	0	0	0	0	0	0	11
96	5	3	1	3	0	2	0	1	1	16	0	0	0	0	2	0	22
97	5	3	2	1	6	9	0	0	3	42	4	0	0	0	0	3	67
98	5	3	2	2	0	0	0	0	3	2	0	0	0	0	0	1	6
99	5	3	2	2	0	1	0	0	2	4	1	0	0	0	0	0	8
100	5	3	2	3	2	1	1	0	2	19	1	0	0	0	1	0	27
Total					136	82	37	6	195	526	25	12	3	2	58	25	1107
Percent					12.3%	7.4%	3.3%	0.5%	17.6%	47.5%	2.3%	1.1%	0.3%	0.2%	5.2%	2.3%	

Codes	**Site**	**Hab**	**Loc**
1	IB	North	Structure
2	OB	South	Substratum
3	WB		Marginal Pier