THE EFFECTS of LOG RAFT GROUNDING

ON THE

BENTHIC INVERTEBRATES OF THE COOS ESTUARY

PAUL ZEGERS

December, 1978

STATE OF OREGON

DEPARTMENT OF ENVIRONMENTAL QUALITY

South West Regional Office

1937 W Harvard Boulevard

Roseburg, Oregon 97470

INTRODUCTION

The water surface area of the Coos Bay Estuary at high tide is 10,973 acres (Percy, et al, 1974). There are 4,569 acres of Tidelands (Gaumer, et al, 1973). It is the largest of Oregon's estuaries, representing 27% of the total coastal estuarian resources of Oregon.

Although estuaries comprise less than 5% (Hargis, 1975) of the earths surface they are vital in the maintenance of the productivity of the Oceans. Estuaries are among the most productive land in the world. They provide protection for fish and shellfish at various stages of their life cycle. These areas support a great variety and abundance of organisms. Most importantly, estuaries serve as nurseries for a great many fish and marine animals including many commercially important species which spend most of their adult lives offshore.

Depending on geographic region, from 65 to 90% of fish landings are comprised of estuarine-dependent species (Stroud, 1971). Ten million American anglers catch nearly 1-1/2 billion pounds of fish in coastal waters a year, 57% of this catch taken directly from estuaries (Clark, 1975). The 1973 total U.S. landing of all seafood items totaled 4.7 billion pounds valued at over $900 million (Broadhead, 1975). In 1971 the commercial harvest of food fish delivered at Coos Bay was 8,809,929 pounds for an estimated value of over $1.9 million (Percy, 1974).

Man's activities have historically altered natural estuarine systems. Filling and draining for development, dumping and dredging have been major impacts which remove habitat from productivity.

Estuaries are unique environments, comprising a small area of the globe, yet are not only important economically but also crucial to the productivity of the oceans. It is important to carefully examine man's influence on this environment to insure future protection of this valuable resource.

In Coos Bay the estuary has historically been important to the timber-based economy for the handling, transportation and storage of logs. Log handling, transportation and storage in water has been shown to adversely affect the environment in several ways. Leachates from stored logs and from accumulated wood debris degrade water quality. (Schuytema & Shankland, 1976) Floating wood debris is not aesthetically pleasing. Floating debris can be a navigational hazard to small boats. With time, floating debris sinks and becomes accumulated on the bottom.

The presence of log rafts stored over mudflat areas may also affect the biological productivity of these areas. During low tides, rafts may go aground and rest on these areas, physically disturbing the benthic environment. The cycle of grounding and floating associated with tidal fluctuations continually kneads and destroys the structure of the mudflats.

The purpose of this study was to determine if the grounding of log rafts on the mudflats affected the kinds and numbers of organisms that dwell in the mud and if any effect found was detrimental to the biological productivity of the areas.

The project was undertaken because the practice was suspected of causing a problem. Under Environmental Quality Commission log handling policy, documentation of the problem is required before requiring remedial action.

METHODS

During the spring of 1977 the Coos Bay estuary system was surveyed for suitable sampling locations. The criteria for a suitable site follows:

1) readily accessible by boat
2) exposed mud flat at low tide
3) provision for a suitable log raft grounding and control area within a very short horizontal distance and within the same tidal zone
4) physical characteristics which prevent storage of logs to insure control areas would remain free from log rafts throughout the study
5) Similar substrate in grounded and control areas
6) Geomorphic difference from other sites selected, i.e., different areas within the estuarian system.

By choosing control and grounded sites physically close together, in the same tidal zone, and in the same type of substrate, all obvious variables except for the presence or absence of logs were eliminated.

Examination of the bay yielded very few sites which met all these requirements. Those selected are shown on Figure A. The sites chosen are specifically described below:

Lillian Creek (see Figure 1)

This site was primarily chosen because it did not require a boat for accessibility. It, therefore, could be sampled during bad weather conditions or when time was limited. It is the site of an abandoned log dump at the confluence of Lillian Creek with the Coos River. Physical barriers preventing log storage in the control area are lacking. However, since the area is abandoned with very little movement of log rafts, an assumption was made that the control area would remain free from log rafts. The site provides for control and grounded samples to be taken within 50 feet horizontally from one another (see Figure 1). Substrate is a thick loosely compacted deep mud with a considerable amount of small bark chips. Location was within a tidally influenced fresh water stream so Salinities would be low.

Cooston Channel Site (see Figure 2)

Cooston Channel is located in the upper reaches of the bay northeast from Catching Slough. The location of pilings and a bend in the channel limit storage of logs resulting in a large control area within a zone of very heavy log storage. The area is specifically located immediately across from pilings marked "3" and"4" in Cooston Channel. Horizontal distances between log storage areas and control areas varied between 80 and 400 feet depending on the location of stored logs. The substrate throughout the area is composed of a fine silt mud with an anearobic layer beginning at 5 cm (Bolinger, et al, 1970). The channel is 12-13 feet deep with a wide range of salinities depending on season and tidal level.

Isthmus Slough Area (see Figure 3)

The Isthmus Slough sampling area was located about one mile south of Davis Slough on the east bank. A series of old pilings and the remains of two ship

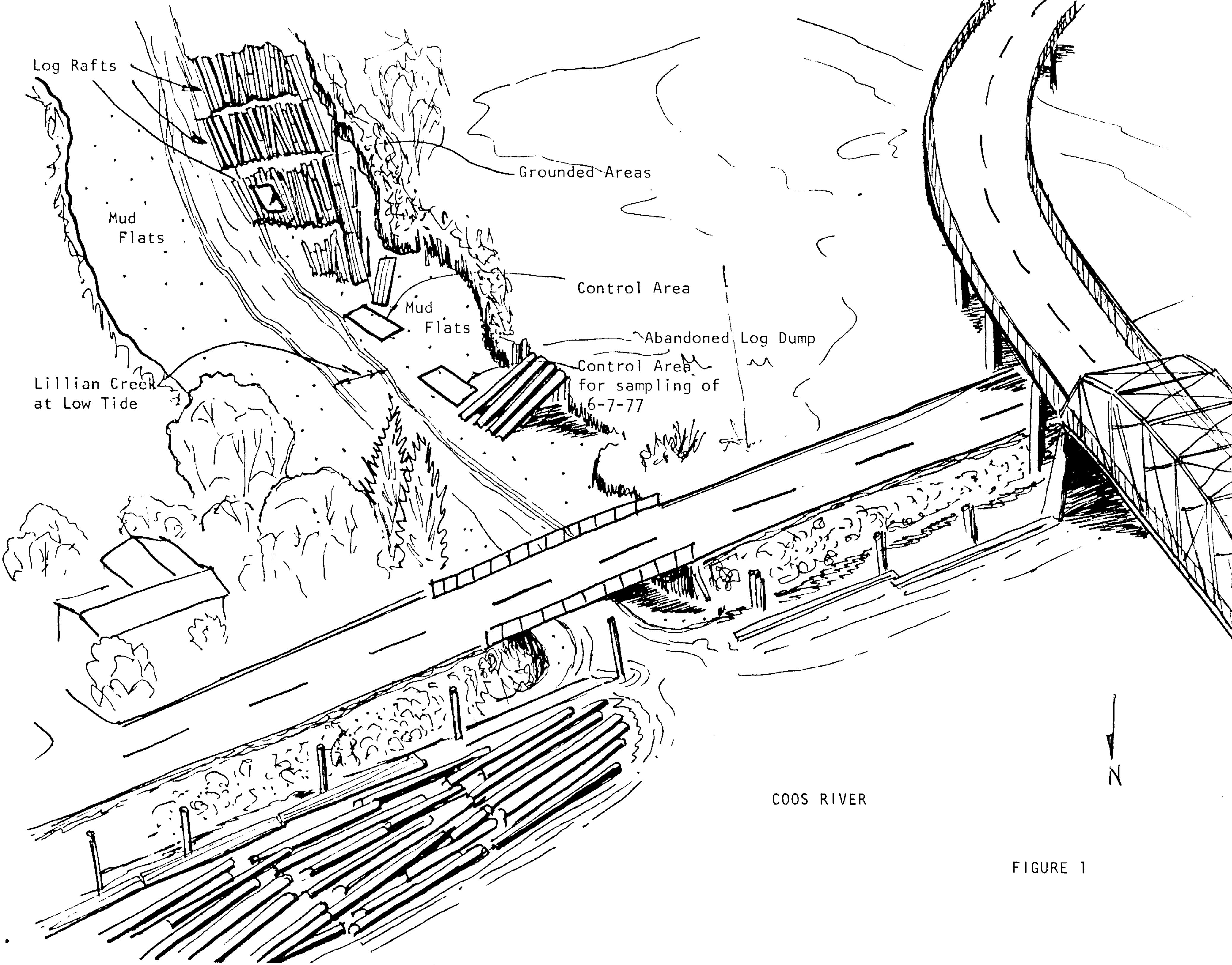

Log Rafts
Grounded Areas
Mud
Flats
Control Area
Mud
Flats
Abandoned Log Dump
Control Area
for sampling of
6-7-77
Lillian Creek
at Low Tide
COOS RIVER
N

FIGURE 1

hulls provide a control area adjacent to a pen of loosely packed old logs. The two sampling locations were within 15 feet of one another. This site was one of the only areas in Isthmus Slough where a suitable control site could be found adjacent to a grounded raft. The substrate consisted of 10-15 cm deep silt and coarse sand/clay with a layer of bark chips and wood debris underneath.

Isthmus Slough Site #43 (see Figure 4)

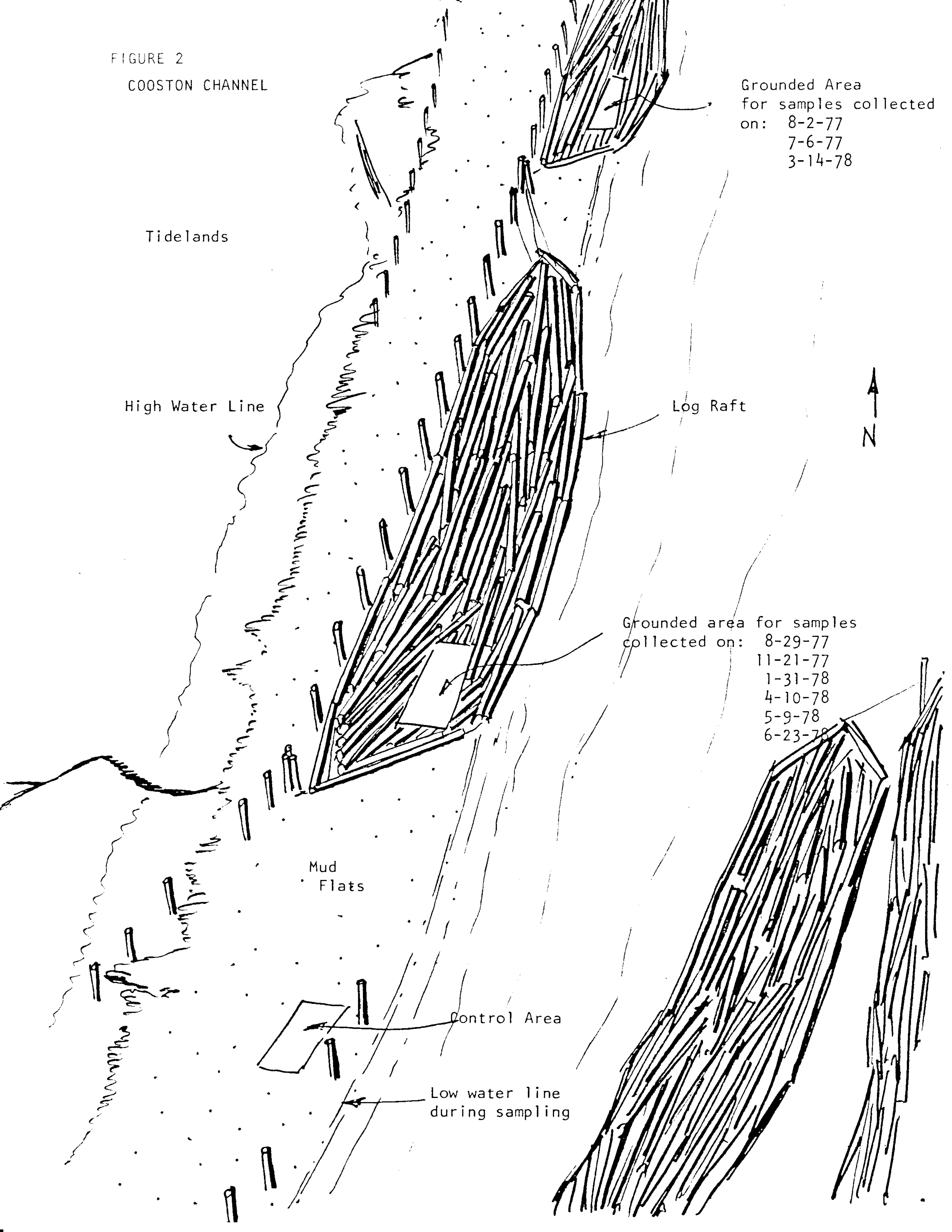
A limited amount of data was collected from a sampling site referred to as "Site 43". This area was located on the east bank of the bay directly across from the City of Coos Bay and adjacent to a navigational aid labled "43". The site was first identified as being suitable in November, 1977 and unfortunately was removed by dredging after March, 1978. Prior to its removal only 3 biological surveys were conducted. A sharp bend in the channel provided a mud spit that served as the control area. The control and grounded sites were within 40 feet of each other.

The substrate consisted of coarse mud with less than 1" to the anaerobic layer (Fitchko & Smolen, 1970). There are no fresh water inlets to the area.

At each area, sampling sites were chosen to allow core samples in grounded and adjacent control (non-grounded) areas. These sites were also chosen to be similar in appearance and also within the same tidal zone. Reference points were selected at each area to insure sampling within the same tidal zone from survey to survey. It was arbitrarily designated that a tidal zone be a band of no greater width than eight feet. This was done for consistency and to insure organisms sampled from control and ground sites were from the same tidal zone. Twelve core samples were taken during each survey, six from the control area and six in the grounded area. The depth of these cores were generally 15 cm. During the first several surveys this depth of the sample varied between 10 to 20 cm due to substrate conditions. For example, originally depths of 10 cm were taken in Isthmus Slough because of bark accumulations at that level. Later, for consistency, 15 cm. cores were sampled. The 20 cm deep cores were abandoned for the following reasons:

1) 15 cm. of substrate saved time to process during sieving.
2) Smith (1977) reported that 97% of benthic organisms in Snohomish River Estuary in Washington occurred in top 8 cm. of the mud flats.

FIGURE 2
COOSTON CHANNEL



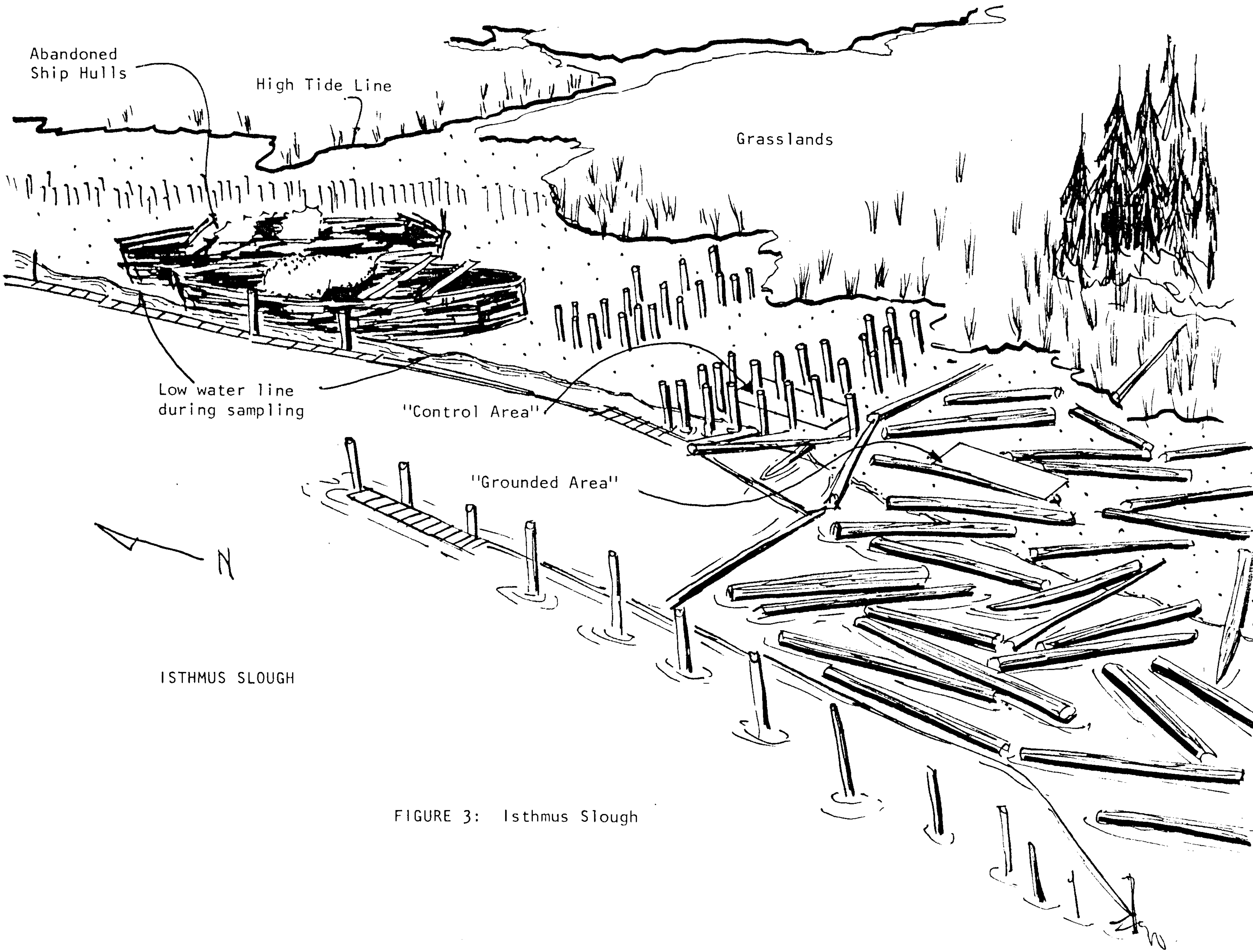


FIGURE 3: Isthmus Slough

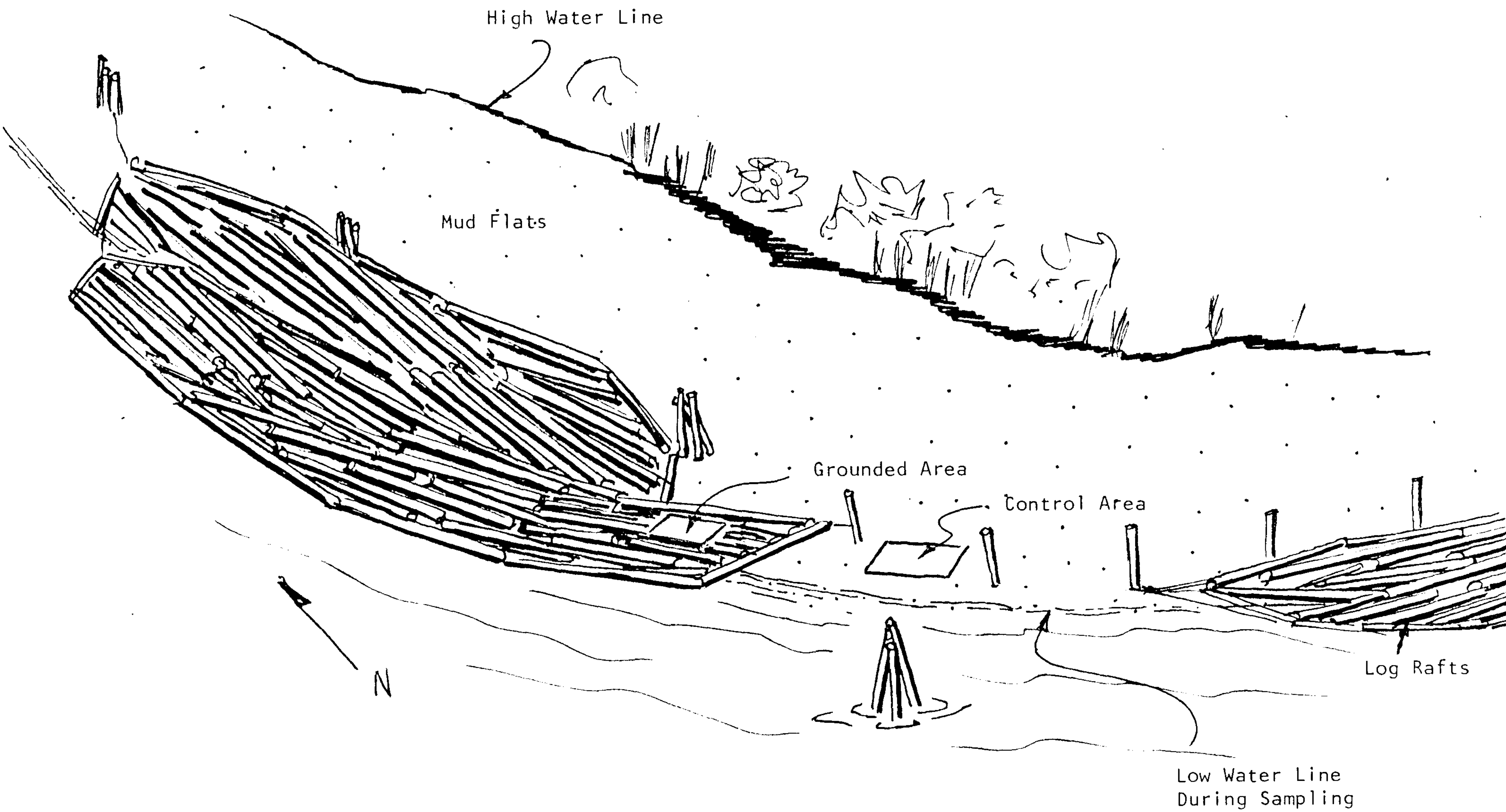


FIGURE 4: Isthmus Slough
Site #43

3) Literature has shown that the majority of species dwell in the top 10 cm. layer of mud flats (see Discussion Section).

A core diameter of 10.2 cm. was chosen for convenience. This diameter was assumed to be suitable for sampling most mud dwelling invertebrates since, 1) it was larger than those used in a similar study (Smith, 1977) and, 2) preliminary study showed that the core size was large enough to give statistical difference between cores from control and grounded areas.

Samples were sieved within 48 hours after collection. The smallest diameter sieve retained all material greater than or equal to 0.9 mm. Upon sieving organisms were 1) either immediately sorted from debris and preserved in 10% formalin or, 2) all material retained by the smallest sieve diameter was preserved in 10% formalin and organisms were separated from debris at a later time for identification and tabulation.

An attempt was made to identify all organisms to species level. Organisms which were not identifiable, either from lack of taxonomic information or due to mutilation or loss of features used for identification, were counted and labeled "unidentified".

Temperature and salinity data of water adjacent to sampling areas were taken in the field and recorded. Other information recorded in the field was: time, tidal level, weather and general observations

and approximate distances: from control to grounded plots
samples to water
between control cores (maximum & minimum)
between grounded cores (maximum & minimum)

RESULTS

Data was reduced and tabulated by individual specie (actual organism) (or best identification possible) and also grouped by Phylum (worms, crustacean, mollusc, etc). Comparisons of total number of organisms from control and grounded sites were also made. The arithmetic mean number of individuals and the 95% confidence interval for all comparisons made are summarized in Tables 1-4.

Figures 5-8 graphically depict comparisons of grounded and control populations for phylum and total organisms data for each of the experimental sites. Data was reduced to average number of organisms per core plus or minus the confidence interval at the 95% level. This information was plotted versus time on tables by Phylum. The confidence interval was plotted as a band. Therefore, the true mean can be assumed to fall within this band with 95% confidence. When the control and experimental bands overlap it cannot be assumed that a difference in means occurs between the two populations. It also does <u>not</u> necessarily imply that the populations are the same as more sophisticated statistical analysis may show differences.

Data for cumacea and copepodes were not added into total Arthropode calculations, but were handled separately. This was because the species in these groups that were encountered were free swimming and not dwelling in the mud flats. Also, some individuals were smaller than the minimum sieve opening size and, therefore, results were suspect. Therefore, in order to prevent biasing the arthropode data the cumacean and copepode data is reported but not added into the total.

<u>Cooston Channel</u> (Fig. 5)

Cores taken during sampling on 7-6-77 were 20 cm. deep; all others were 15 cm. Therefore, caution should be taken when direct comparisons of data are undertaken.

Annelides (Fig. 5a), as a group, showed a significantly greater number of individuals in the control plot than in the grounded plot throughout the entire sampling period. The average number of annelides decreased during the winter months and organisms in the control area remained statistically more numerous than those in the grounded area.

A similar pattern was observed for total number of organisms per core (see Fig. 5d).

Molluscs remained fairly uniform in number throughout the study with the control showing significantly higher average numbers than the grounded with the exception of three sampling periods in the late spring where no statistical difference between population could be shown.

Arthropodes (Fig. 5b) also showed decreased average numbers of individuals for

TABLE 1 Average No. of organisms per core ±95% confidence interval for Cooston Channel

COOSTON CHANNEL		7-6-77	8-2-77	8-29-77	11-21-77	1-31-78	3-14-78	4-10-78	5-9-78	6-23-78
ANNELIDA	control	16.66 ± 6.1	20.5 ± 11.2	26.8 ± 9.6	10.83 ± 2.76	3.83 ± 2.4	32.83 ± 8.45	20.0 ± 4.87	24.0 ± 6.61	3 2. ± 10.03
	grounded	0 ± 0	0.66 ± 1.39	1.17 ± 1.53	0.33 ± 0.59	0.0 ± 0.0	0.17 ± 0.47	0.83 ± 1.13	0.0 ± 0.0	0.83 ± 0.86
Amphicteus mucronata	control	1.0 ± 1.45	0.33 ± 0.94	2.17 ± 1.34	3.17 ± 1.34	0.83 ± 0.47	1.67 ± 1.87	1.67 ± 0.93	2.5 ± 1.2	2.83 ± 1.98
	grounded	0 ± 0	0.5 ± 0.96	0.67 ± 1.12	0.17 ± .97	0 ± 0	0 ± 0	0.5 ± 0.63	0 ± 0	0.83 ± 0.86
Heteromastus filiiformis	control	7.67 ± 3.89	11.5 ± 8.7	12.17 ± 4.78	2.17 ± 1.52	1.67 ± 1.57	14.83 ± 4.07	9.33 ± 3.45	10.33 ± 4.90	21.83 ± 5.20
	grounded	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.17 ± 0.47	0 ± 0	0 ± 0	0 ± 0
Nereis sp.	control	1.83 ± 0.86	2.5 ± 2.79	4.5 ± 1.88	4.67 ± 1.57		0.33 ± 0.67	1.0 ± 0.73	1.17 ± 0.86	2 ± 1.45
	grounded	0 ± 0	0.17 ± 0.47	0.50 ± 0.96	0.17 ± 0.47		0 ± 0	0.33 ± 0.67	0 ± 0	0 ± 0
Capitella capitata	control	1.0 ± 1.92	6.17 ± 5.69	8 ± 4.59	0.83 ± 1.13	1.33 ± 1.39	16.0 ± 3.8	8 ± 1.62	9.17 ± 3.20	5.33 ± 3/45
	grounded	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
unid. annelides	control	5.17 ± 2.76							0.83 ± 0.86	
	grounded	0 ± 0							0 ± 0	
ARTHROPODA	control	23.8 ± 10.8	11.5 ± 9.9	30.0 ± 14.3	0.5 ± 0.62	5.83 ± 3.66	6.50 ± 3.68	10.83 ± 5.78	3.5 ± 2.15	2.67 ± 0.94
	grounded	0.33 ± 0.59	1.33 ± 4.77	0.17 ± 0.47	0.17 ± 0.47	0.83 ± 1.13	0.17 ± 0.47	0.5 ± 0.63	0.17 ± 0.47	0 ± 0
Corophium sp.	control	23.8 ± 10.8	11.33 ± 10.07	29.33 ± 12.79	0.17 ± 0.47	5.83 ± 3.66	6.50 ± 3.68	10.83 ± 5.78	3.5 ± 2.15	2.67 ± 0.94
	grounded	0.33 ± 0.59	0.33 ± 2.14	0.17 ± 0.47	0.17 ± 0.47	0.83 ± 1.13	0.17 ± 0.47	0.5 ± 0.63	0.17 ± 0.47	0 ± 0
unid. isopode	control		0.17 ± 0.47							
	grounded		0 ± 0							
unid. cumacean	control	1.5 ± 1.58	0.33 ± 0.94	0.67 ± 1.12	0.67 ± 0.59	0.17 ± 0.47	0 ± 0	0.83 ± 1.13	0.17 ± 0.47	0.5 ± 0.90
	grounded	3.5 ± 3.6	2.33 ± 0.94	1.67 ± 1.73	0.5 ± 0.63	0 ± 0	0.67 ± 0.93	1 ± 1.03	0.66 ± 1.39	0 ± 0
unid. amphipodes	control			0.67 ± 1.87						
	grounded			0 ± 0						
unid. copepode	control			0 ± 0	0.33 ± 0.67					
	grounded			0.5 ± 0.63	0 ± 0					
MOLLUSCA	control	4.0 ± 1.45	2.67 ± 1.73	2.17 ± 0.47	4.33 ± 1.87	3.5 ± 0.96	1.5 ± 1.31	3.17 ± 1.69	2.83 ± 1.70	8.17 ± 4.20
	grounded	0.17 ± 0.47	0.17 ± 0.47	0 ± 0	1.5 ± 1.2	0.33 ± 0.94	0.5 ± 0.63	1.5 ± 2.15	2.0 ± 1.92	2.33 ± 1.18
Macoma sp.	control	1.17 ± 11.86	1.17 ± 1.13	0.83 ± 0.86	2.33 ± 1.73	2.33 ± 0.94	1.17 ± 1.34	2.17 ± 8.4	0.83 ± 1.13	3.67 ± 1.21
	grounded	0 ± 0	0 ± 0	0 ± 0	0.83 ± 0.47	0.17 ± 0.47	0.5 ± 0.63	1.17 ± 1.13	0.33 ± 0.67	1.33 ± 1.18
Tellina sp.	control	2.83 ± 2.21	1.5 ± 1.73	1.33 ± 0.59	2.0 ± 1.26	1.17 ± 0.86	0.17 ± 0.47	1 ± 1.45	2.0 ± 1.62	4.67 ± 2.68
	grounded	0.17 ± 0.47	-.17 ± 0.73	0 ± 0	0.67 ± 0.93	0.17 ± 0.47	0 ± 0	0.33 ± 0.67	1.67 ± 2.00	1.0 ± 0.27
TOTAL ORGANISMS	control	46 ± 15.08	34.67 ± 11.56	59.0 ± 16.8	15.67 ± 2.9	14 ± 4.6	40.67 ± 8.27	34 ± 9.15	30.33 ± 8.04	42.83 ± 13.95
	grounded	0.5 ± 0.96	2.17 ± 2.56	1.5 ± 2.27	2.0 ± 2.05	1.17 ± 0.86	0.83 ± 1.34	2.83 ± 4.42	2.17 ± 1.97	3.17 ± 1.53

TABLE 2 — Average No. of organisms per core ±95% confidence interval for Isthmus Slough

* Too numerous to count

ISTHMUS SLOUGH		7-18-77	9-14-77	9-27-77	12-21-77	4-26-78	9-21-78
ANNELIDA	control	66 ± 21.18	32.33 ± 4.8	28.6 ± 10.04	10.5 ± 2.15	11.5 ± 2.79	33 ± 5.8
	grounded	1.83 ± 1.70	1.0 ± 1.03	0.5 ± 0.63	0.5 ± 0.63	0.67 ± 0.93	17.67 ± 4.3
Amphicteus mucronata	control	36.33 ± 15.48	12.67 ± 3.08	11.8 ± 4.95	1.67 ± 0.94	2.83 ± 2.17	15.33 ± 3.38
	grounded	0.67 ± 0.93	0.33 ± 0.67	0.17 ± 0.47	0 ± 0	0.5 ± 0.67	9.33 ± 2.99
Heteromastus filliformis	control					3.17 ± 1.98	
	grounded					0 ± 0	
Nereis sp.	control	19.33 ± 10.75	19.33 ± 2.87	16.4 ± 7.70	8.83 ± 1.98	5.5 ± 1.74	17.67 ± 3.30
	grounded	0.5 ± 0.63	0.33 ± 0.93	0 ± 0	0.5 ± 0.63	0 ± 0	8.33 ± 4.57
unid. annelide #1	control	3.83 ± 4.26	0.33 ± 0.67	0.4 ± 0.76		0 ± 0	
	grounded	0.17 ± 0.47	0.33 ± 0.67	0.33 ± 0.67		0.17 ± 0.47	
unid. annelide #2	control	6.5 ± 4.52					
	grounded	0.5 ± 0.96					
ARTHROPODA	control	8.5 ± 12.75	8.5 ± 3.75	9.8 ± 4.42	3.17 ± 1.84	3.17 ± 2.23	4.67 ± 1.57
	grounded	0.33 ± 0.94	0.33 ± 0.67	0.17 ± 0.47	1.0 ± 1.45	0.33 ± 0.94	2.0 ± 2.05
Corophium sp.	control	8.5 ± 12.75	8.5 ± 3.75	8.17 ± 4.95	3.17 ± 1.81	3.17 ± 2.23	4.67 ± 1.57
	grounded	0.33 ± 0.94	0.33 ± 0.67	0.17 ± 0.47	1 ± 0.47	0.33 ± 0.94	3.0 ± 2.05
unid. copepode	control	0.83 ± 1.53	*	*			
	grounded	1.00 ± 1.45	*	*			
unid. cumacean	control	2 ± 2.41	0.83 ± 0.86	2.6 ± 2.85		0.33 ± 0.67	
	grounded	0.67 ± 0.93	0.50 ± 0.63	1.00 ± 1.26		0 ± 0	
NEMERTEA (unid.)	control	2.67 ± 4.80					
	grounded	0 ± 0					
TOTAL ORGANISMS	control	77.17 ± 32.30	40.83 ± 6.67	38.4 ± 7.48	13.67 ± 2.48	14.67 ± 4.39	37.67 ± 6.52
	grounded	2.17 ± 1.69	1.33 ± 0.59	0.67 ± 0.59	1.5 ± 1.74	1 ± 1.45	19.67 ± 5.2

Table 3 Average No. of organisms per core ±95% confidence interval for Lillian Creek

LILLIAN CREEK		6-7-77	10-11-77	12-6-77	2-15-78	5-24-78	7-6-78
ANNELIDA	control	60.0 ± 22.75	17.00 ± 4.36	9 ± 2.41	9.67 ± 0.94	6.67 ± 1.43	22.67 ± 2.37
	grounded	10.8 ± 7.04	3.33 ± 0.60	0.17 ± 0.47	1.33 ± 0.61	1.50 ± 0.96	2.17 ± 2.89
Amphicteus mucronata	control	8.00 ± 4.56	6.33 ± 2.01	5.17 ± 2.34	5.33 ± 1.39	4.33 ± 1.73	17.00 ± 3.52
	grounded	2.33 ± 3.01	1.33 ± 1.38	0 ± 0	0 ± 0	0.83 ± 0.86	0.67 ± 0.93
Heteromastus filliformis	control	0.6 ± 0.76	1.33 ± 1.18	0.33 ± 0.67	0.50 ± 0.96		0 ± 0
	grounded	0 ± 0	0 ± 0	1.17 ± 1.97	0.33 ± 0.67		0.83 ± 1.34
Nereis sp.	control	0 ± 0	3.83 ± 1.53	2.83 ± 0.86	3.00 ± 1.62	2.00 ± 1.02	5.67 ± 2.78
	grounded	0.4 ± 0.76	0.33 ± 0.67	0 ± 0	1.00 ± 1.45	0.67 ± 0.59	0.67 ± 0.99
unid. annelides	control	49.8 ± 21.93	5.5 ± 2.15	0.67 ± 1.12	0.83 ± 0.86	0.33 ± 0.67	
	grounded	7.6 ± 4.23	1.67 ± 1.87	0 ± 0	0 ± 0	0 ± 0	
ARTHROPODA	control	5.20 ± 7.17	3.67 ± 1.87	1.17 ± 1.34	1.67 ± 1.18	1.33 ± 1.18	0.0 ± 0.0
	grounded	0 ± 0	0 ± 0	0 ± 0	0.33 ± 0.59	0 ± 0	0.0 ± 0.0
Corophium sp.	control	5.00 ± 6.94	3.67 ± 1.87	1.17 ± 1.34	1.67 ± 1.18	1.33 ± 1.18	
	grounded	0.0 ± 0.0	0 ± 0	0 ± 0	0.33 ± 0.59	0 ± 0	
unid. Amphipode	control	0.20 ± 0.62					
	grounded	0.0 ± 0.0					
unid. Copepode	control	1.4 ± 1.86					
	grounded	2.2 ± 2.67					
MOLLUSCA	control	6.2 ± 3.85	0.5 ± 0.63	1.50 ± 1.20	2.17 ± 0.86	1.67 ± 0.94	9.83 ± 3.73
	grounded	2.0 ± 1.70	0 ± 0	0.17 ± 0.97	0 ± 0	0.5 ± 0.63	1.83 ± 1.53
Macoma sp.	control	5.2 ± 3.01	0.17 ± 0.47	0.83 ± 0.86	2.17 ± 0.86	1 ± 1.03	4.17 ± 1.29
	grounded	1.8 ± 1.81	0 ± 0	0 ± 0	0 ± 0	0.33 ± 0.67	1.33 ± 0.94
Tellina sp.	control	1.0 ± 2.4	0.17 ± 0.47	0.67 ± 0.59		0.67 ± 0.59	5.67 ± 2.78
	grounded	0.2 ± 0.62	0 ± 0	0.17 ± 0.47		0.17 ± 0.47	0.5 ± 0.90
NEMERTEA							
Paranamertes peregrina	control	0 ± 0					
	grounded	0.2 ± 0.62					
TOTAL ORGANISMS	control	71.4 ± 26.84	21.17 ± 4.84	11.67 ± 2.70	13.50 ± 1.20	9.5 ± 2.60	32.5 ± 4.85
	grounded	13.2 ± 6.00	3.33 ± 0.60	0.33 ± 0.94	1.67 ± 1.18	2.0 ± 1.25	2.83 ± 2.23

TABLE 4 Average No. of organisms per core ±95% confidence interval for Isthmus Slough Site #43.

SITE #43		11-7-77	1-19-78	3-28-78
ANNELIDA	control	35.17 ± 6.10	15.17 ± 4.67	16.83 ± 3.3
	grounded	0.33 ± 1.84	1.17 ± 1.69	0.33 ± 0.67
Amphicteus mucronata	control		2.0 ± 1.45	3.0 ± 1.03
	grounded		0 ± 0	0 ± 0
Heteromastus filliformis	control	22.33 ± 7.53	9.33 ± 2.01	11.0 ± 3.08
	grounded	0.33 ± 0.93	0 ± 0	0.17 ± 0.47
Nereis sp.	control	6.0 ± 1.62	2.17 ± 2.23	2.83 ± 1.13
	grounded	0.50 ± 0.96	0.5 ± 0.96	0.17 ± 0.47
Capitella capitata	control	6.5 ± 4.52	1.67 ± 0.60	
	grounded	0 ± 0	0.67 ± 0.93	
unid. annedlides	control	0.33 ± 0.67		
	grounded	0 ± 0		
ANTHROPODA	control	2.67 ± 2.48	1.17 ± 2.34	0.67 ± 0.94
	grounded	0.33 ± 0.67	0 ± 0	0 ± 0
Corophium sp.	control	2.67 ± 2.48	1.17 ± 2.34	0.67 ± 0.94
	grounded	0.33 ± 0.67	0 ± 0	0 ± 0
unid. cumacean	control	0.17 ± 0.48		3.83 ± 1.34
	grounded	0.33 ± 0.67		0 ± 0
MOLLUSCA	control	1.5 ± 1.53	2.67 ± 1.57	3.67 ± 1.87
	grounded	0 ± 0	0 ± 0	0.5 ± 0.96
Macoma	control	0.5 ± 0.67	2 ± 1.03	3.67 ± 1.87
	grounded	0.0 ± 0.0	0 ± 0	0.50 ± 0.96
MOLLUSCA (con't.) Tellina	Control	1.0 ± 1.25	0.67 ± 0.9	
	grounded	0.0 ± 0.0	0 ± 0	
TOTAL ORGANISMS	control	39.33 ± 6.56	19.0 ± 2.99	21.77 ± 3.66
	grounded	2.33 ± 1.70	1.17 ± 1.69	0.83 ± 1.13

the control area during winter months. Two sampling points did not show statistical differences between control and grounded populations. These were in early August and again during late November. Also, the number of arthropodes in the control area remained low during July of 1978 compared with July of 1977. Salinity and Temperature data are reported in the Appendix.

Site 43

The average number of annelides per control core was significantly greater than those for grounded cores for each sampling period.

Data for Molluscs showed significantly greater average numbers for control samples in January and March but no difference between populations could be shown in November.

No statistically significant difference in populations of Arthropodes was observed between control and grounded areas. Temperature and salinity data is presented in the Appendix.

Lillian Creek

Care must be taken in evaluation of Figure 6 since cores taken during sampling of 6-7-77 were 20 cms. deep, while those of all other sampling dates were 15 cms deep. Also, on 6-7-77 a slightly different location for control area was used for sampling (see Figure 1). (The control area was changed to allow better accessability and make it closer to the grounded area.) The total average number of organisms per control core decreased dramatically during winter months and increased somewhat during the following summer.

A similar trend occurred for annelide data. Both total organisms and total annelide showed significantly (at the 95% confidence interval) greater numbers of organisms in control areas than in grounded areas.

Both arthropodes and molluscs were generally found in low numbers. Although mean values were generally greater for cores in control areas, statistics used were not powerful enough to detect differences (in most cases) between control and ground populations. Arthropodes were found with great enough number and uniformity to detect statistical differences between areas during

10-77 and 5-78. Likewise, differences were detected during 2-78 and 7-78 in Mollusc populations. Salinity and temperature are reported in the Appendix.

Isthmus Slough

Sometime between September and December, 1977 logs were removed from the grounded sampling area in Isthmus Slough. The area remained free of logs throughout the remainder of the study.

Figure 7 summarizes data collected. The core depth of sampling for 7-18-77 was 10 cm. and the core depth for all other sampling dates was 15 cm. Samples collected at Isthmus Slough followed similar trends as those from the three other sites; showing depressed population levels for control populations during winter months for Annelides and total organisms collected. There was always a significantly greater number of organisms in control cores than in grounded cores throughout the study.

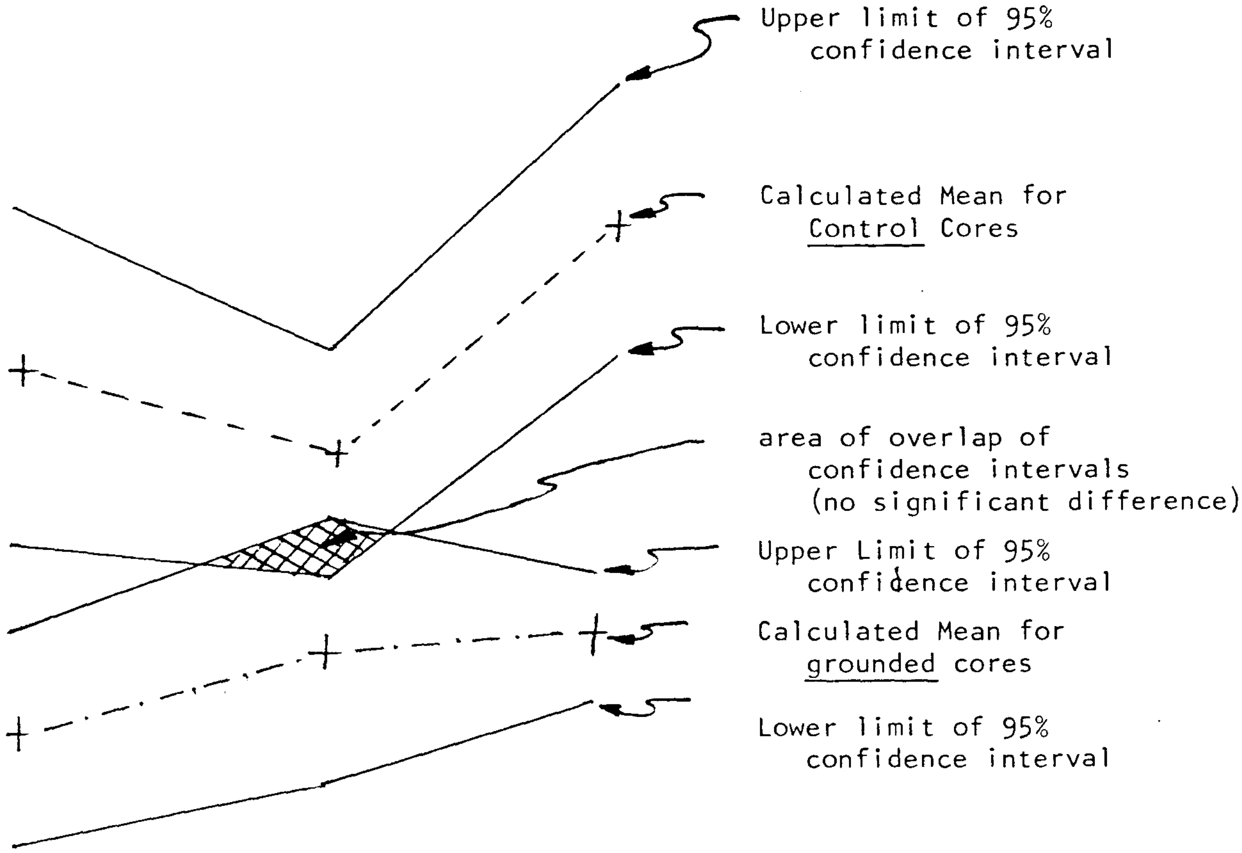
The mean number of arthropodes found per core was always greater in control cores than in grounded cores. However, variability in data causing wide confidence intervals resulted only in the detection of significant differences on 9-14-77 and 9-27-77.

Molluscs were not found within this tidal interval of Isthmus Slough throughout the study.

Also of interest is that during the Fall of 1978 following the removal of logs, the average number of organisms in the previously grounded area increased to levels almost 10 times what they were the previous fall. However, this increased level was still significantly lower than average numbers from control cores, and apparently the recovery was incomplete. Temperature and salinity data are reported in the Appendix.

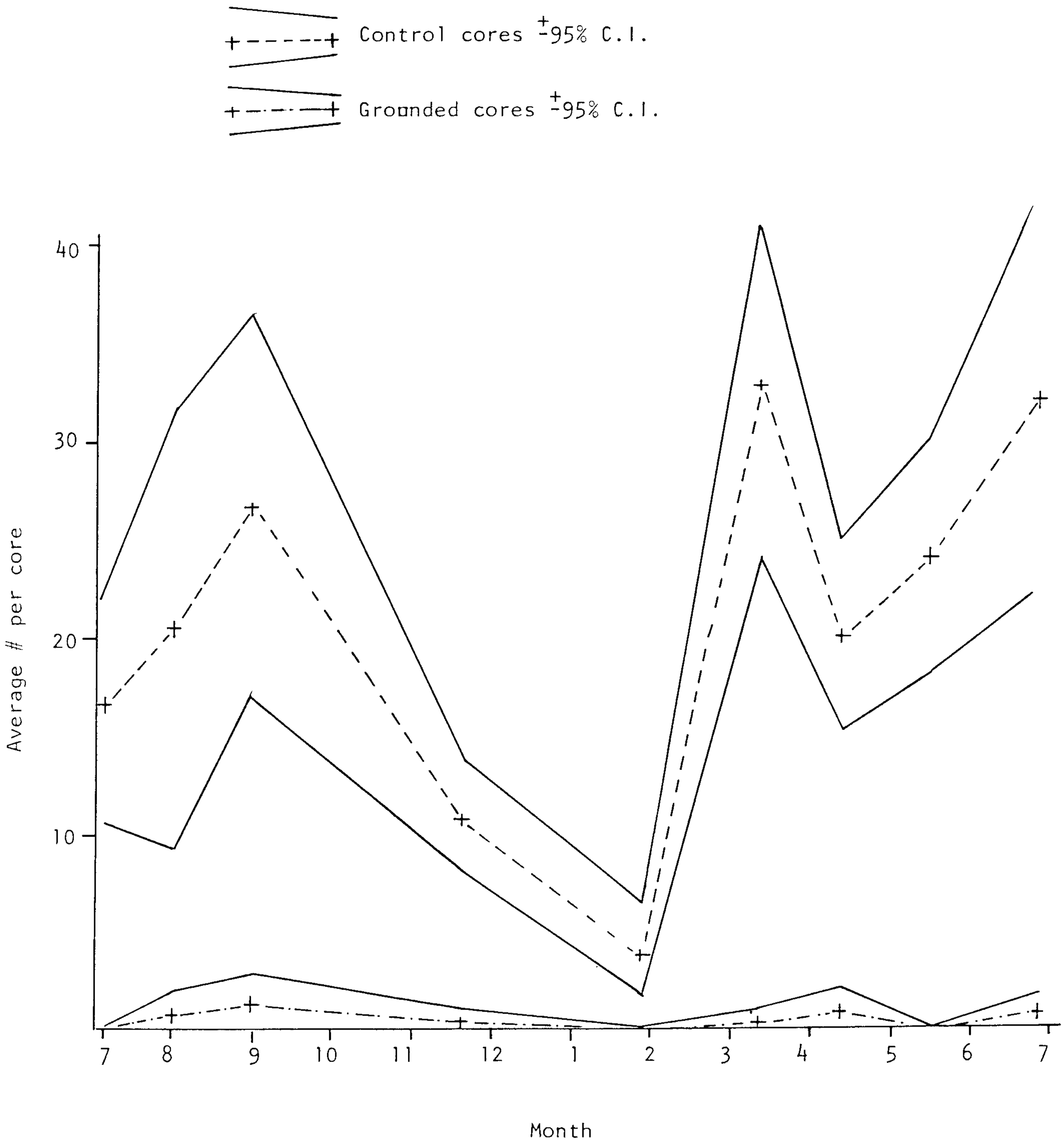
Data for individual species from the various sites are summarized in Tables 1-4. Further explanation of this data will not be covered here, but will be described for the more important members in the Discussion.

KEY TO FIGURES:



The 95% confidence intervals (C.I.) were generated mathematically and plotted as a solid line for both the upper and lower level of the interval. From the recorded data it can be stated with 95% certainty that the true mean falls within this upper and lower limit. If the bands for the control and grounded do not overlap, the means can be considered statistically different. If the bands overlap (represented by cross hatching) the means cannot be assumed to be from different populations (not statistically different with the test used). However, this overlap does not necessarily imply that the sample groups come from the same population. More sophisticated testing or further data collection may (or may not) prove them to be significantly different.

FIGURE 5a Average No. of annelids per core at Cooston Channel plotted against time



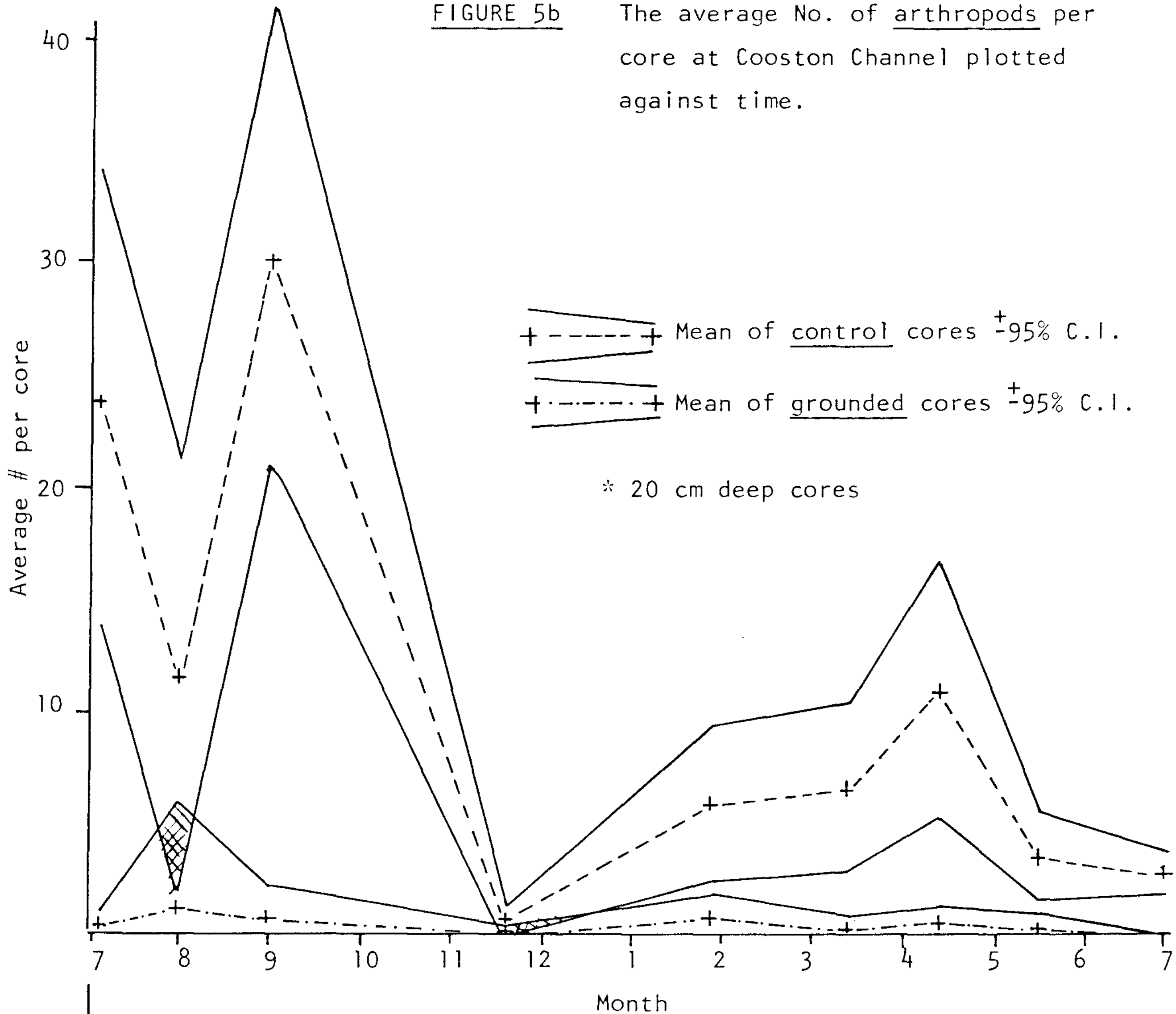


FIGURE 5b The average No. of arthropods per core at Cooston Channel plotted against time.

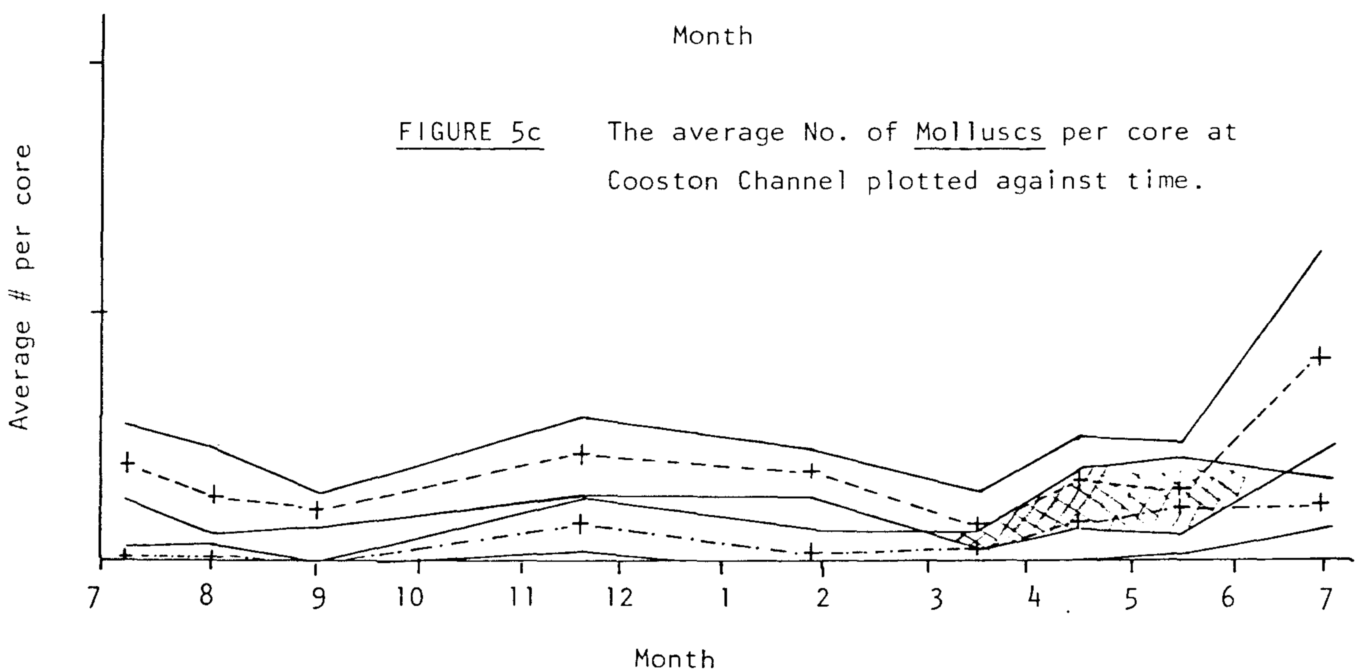
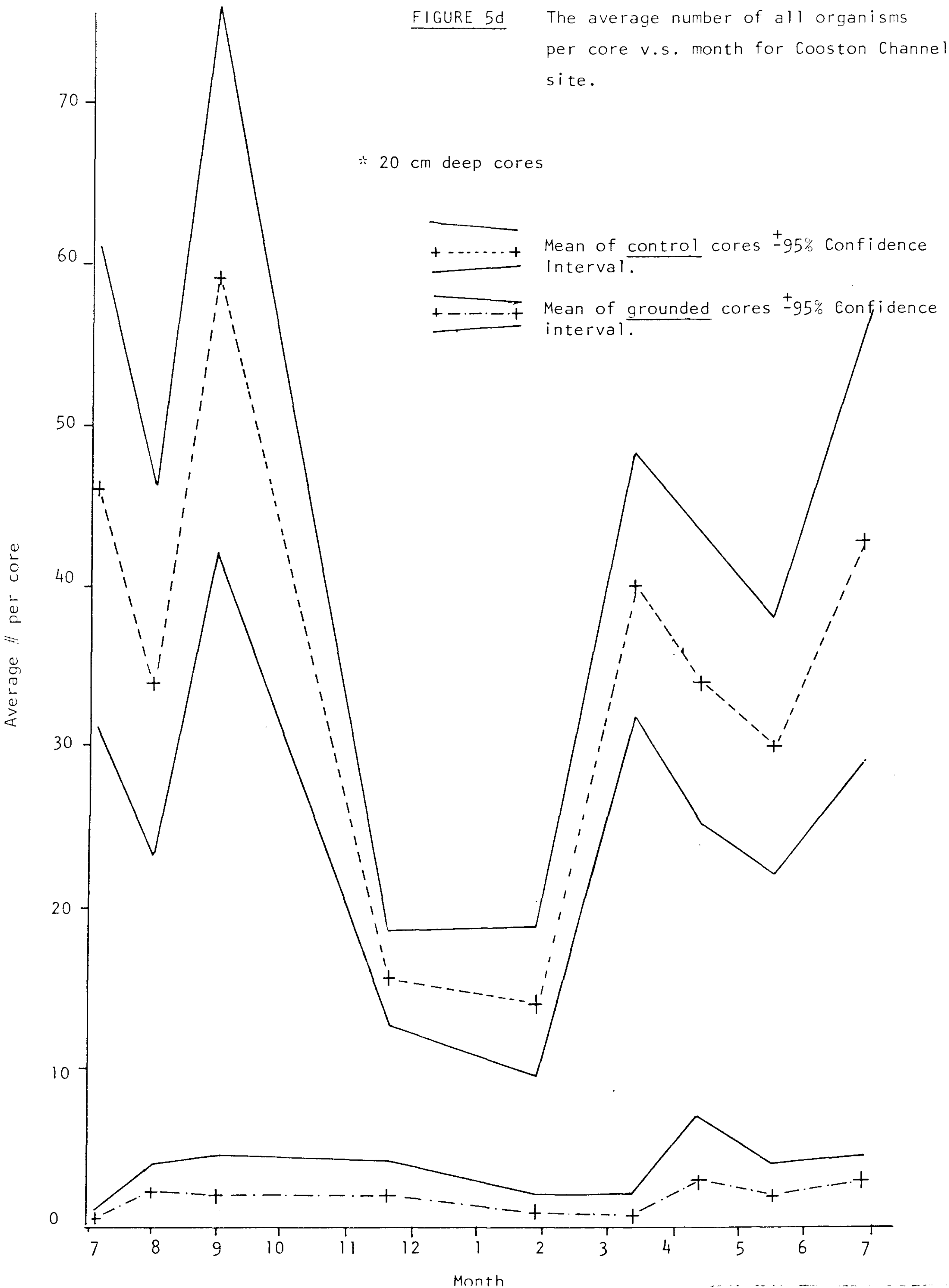


FIGURE 5c The average No. of Molluscs per core at Cooston Channel plotted against time.

FIGURE 5d The average number of all organisms per core v.s. month for Cooston Channel site.



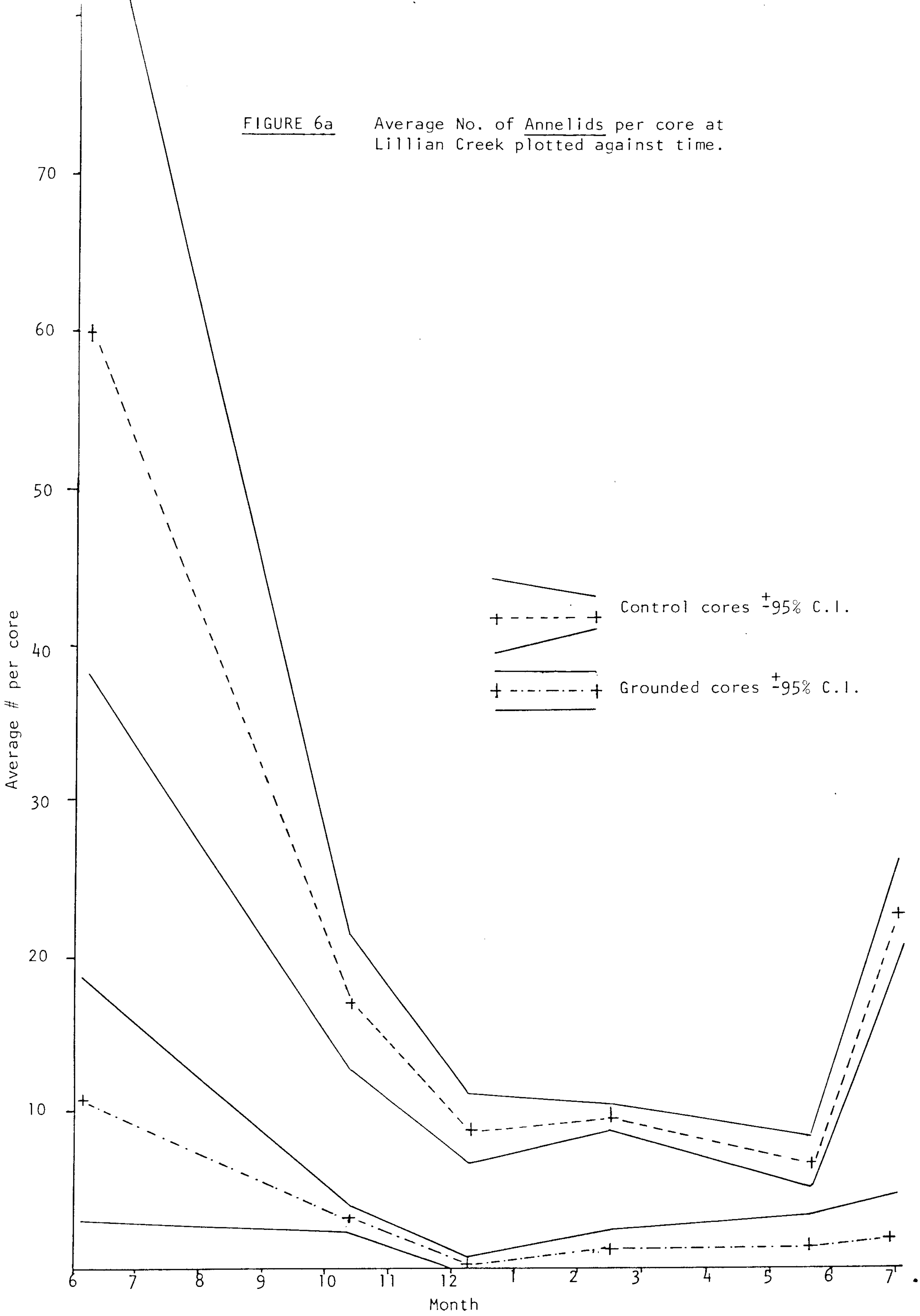


FIGURE 6a Average No. of Annelids per core at Lillian Creek plotted against time.
Control cores ±95% C.I.
Grounded cores ±95% C.I.
Average # per core
70
60
50
40
30
20
10
6
7
8
9
10
11
12
1
2
3
4
5
6
7
Month

FIGURE 6b   Average No. of Arthropods per core at Lillian Creek plotted against time

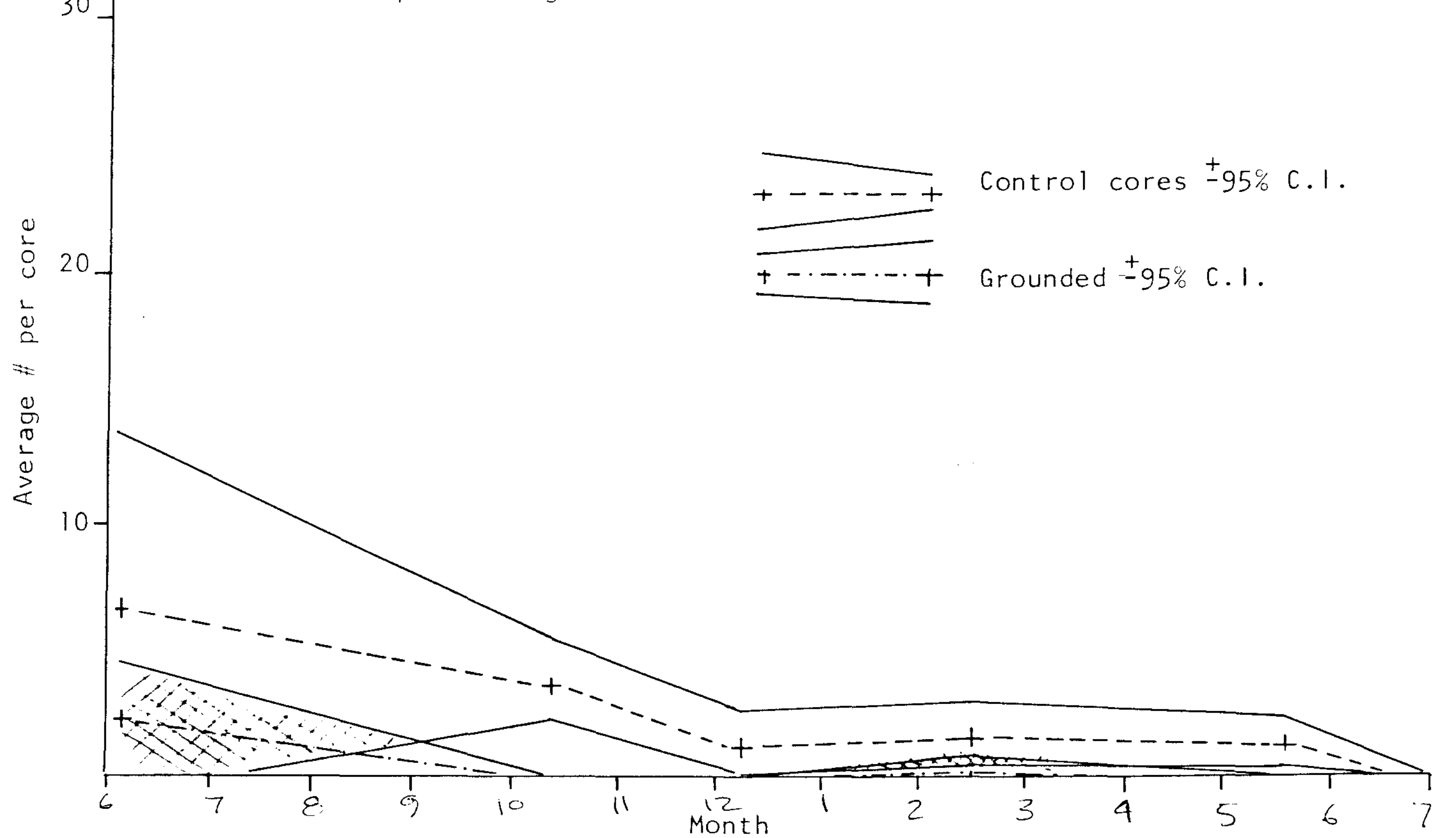
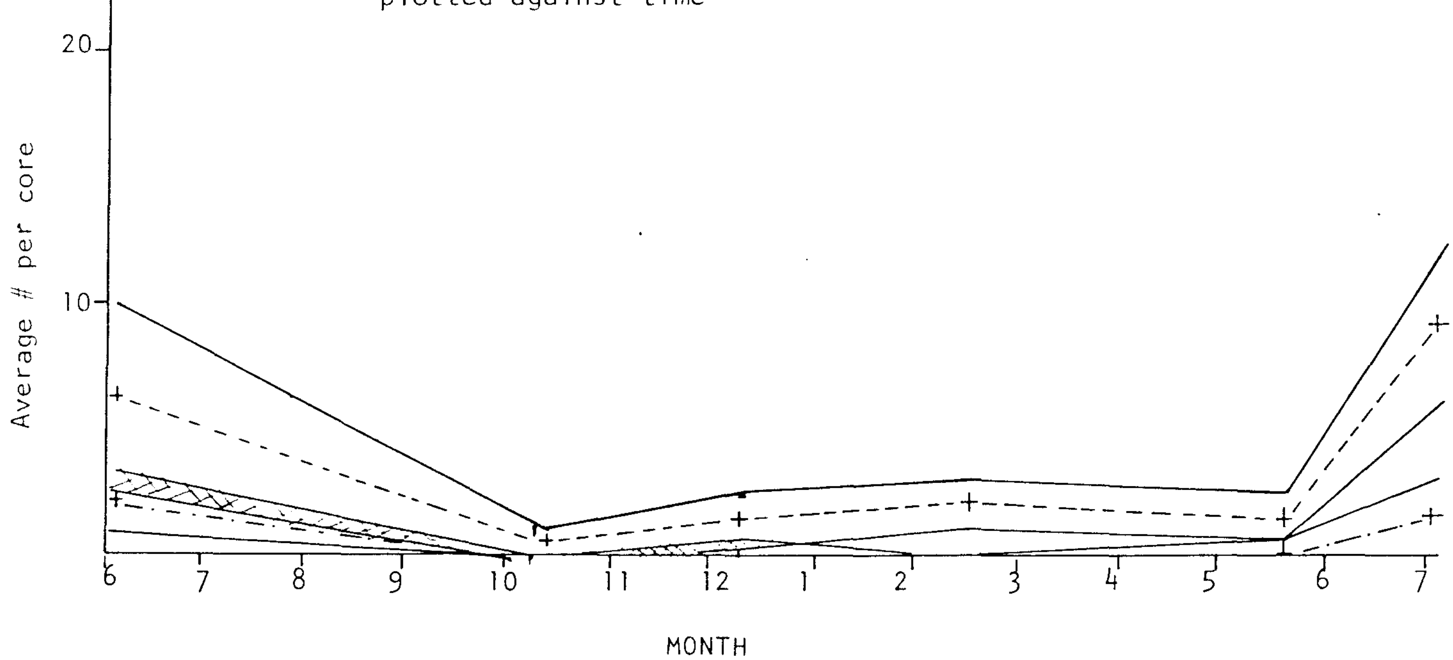


FIGURE 6c   Average No. of Molluscs per core plotted against time



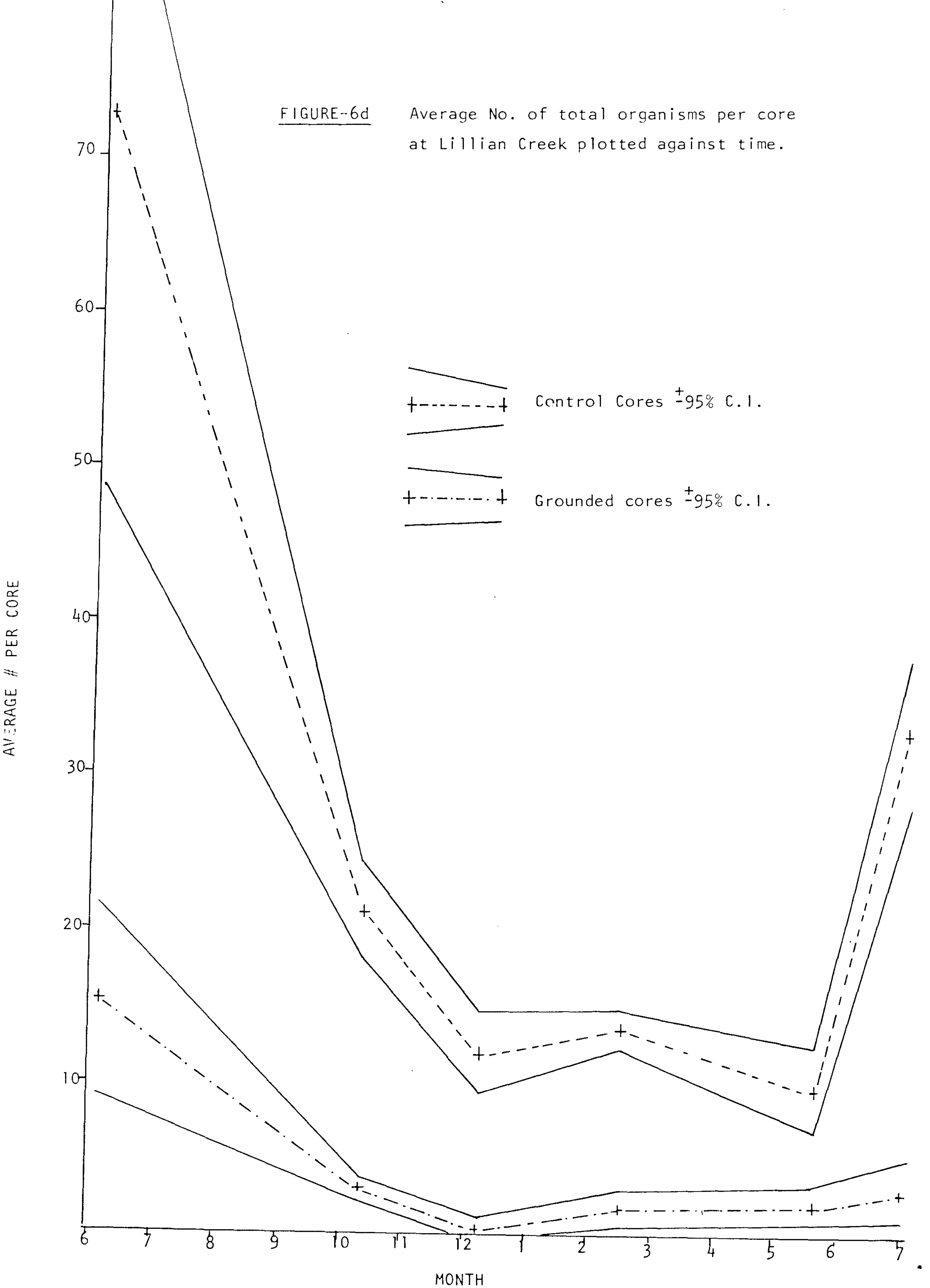


FIGURE-6d Average No. of total organisms per core at Lillian Creek plotted against time.

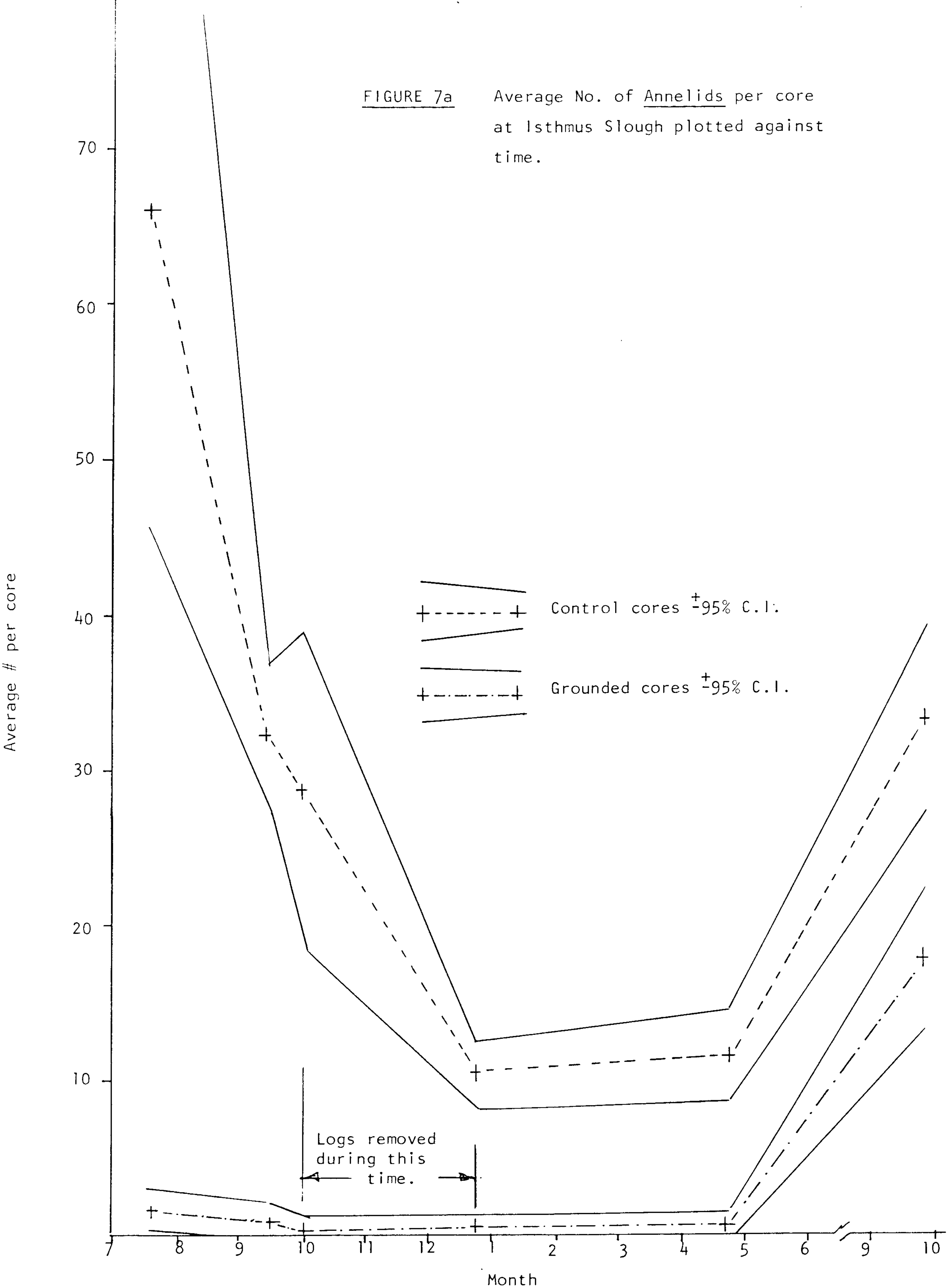


FIGURE 7a Average No. of Annelids per core at Isthmus Slough plotted against time.
70
60
50
40
30
20
10
Average # per core
Control cores ±95% C.I.
Grounded cores ±95% C.I.
Logs removed during this time.
7
8
9
10
11
12
1
2
3
4
5
6
9
10
Month

FIGURE 7b   Average No. of Arthropods per core at Isthmus Slough plotted against time.

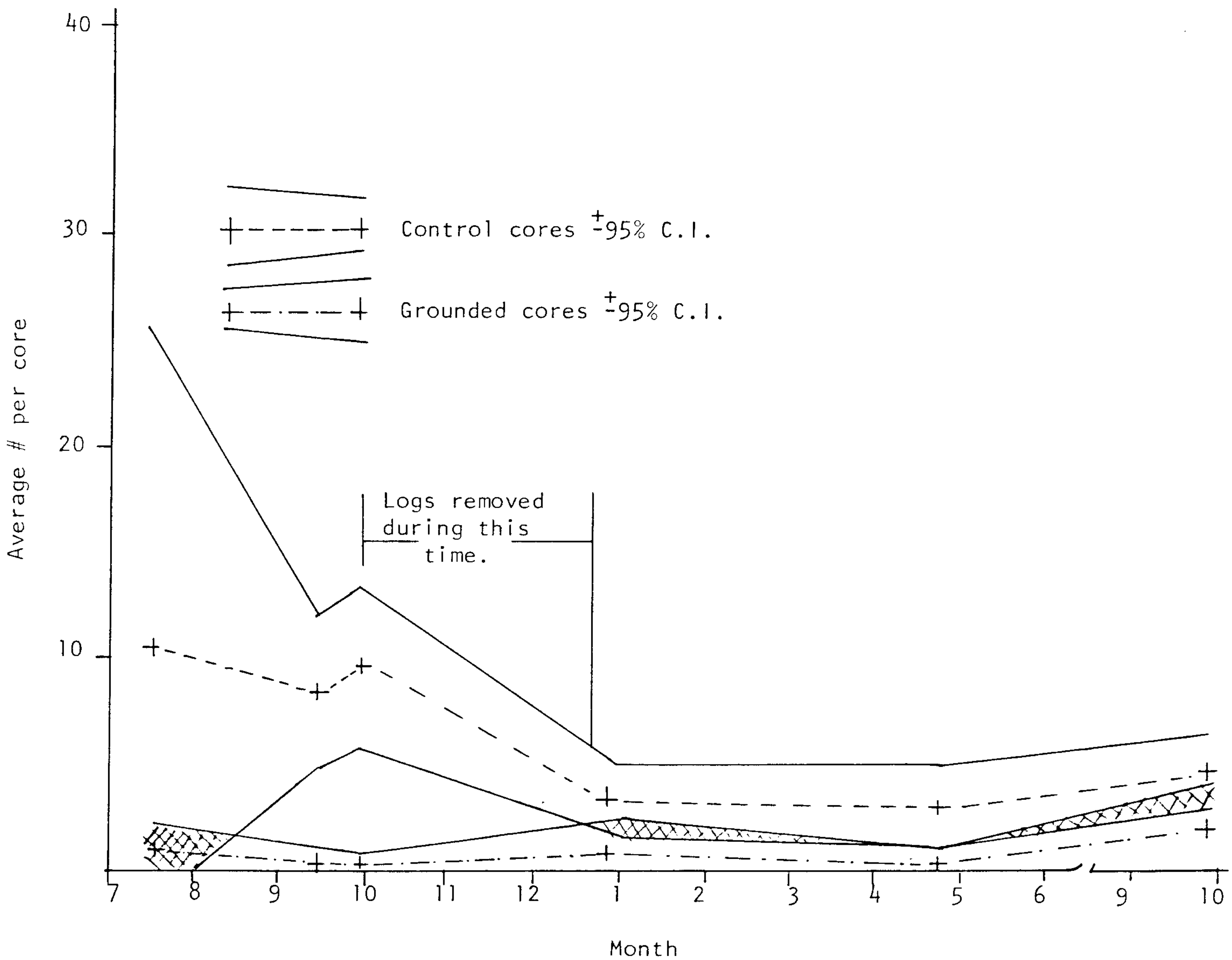
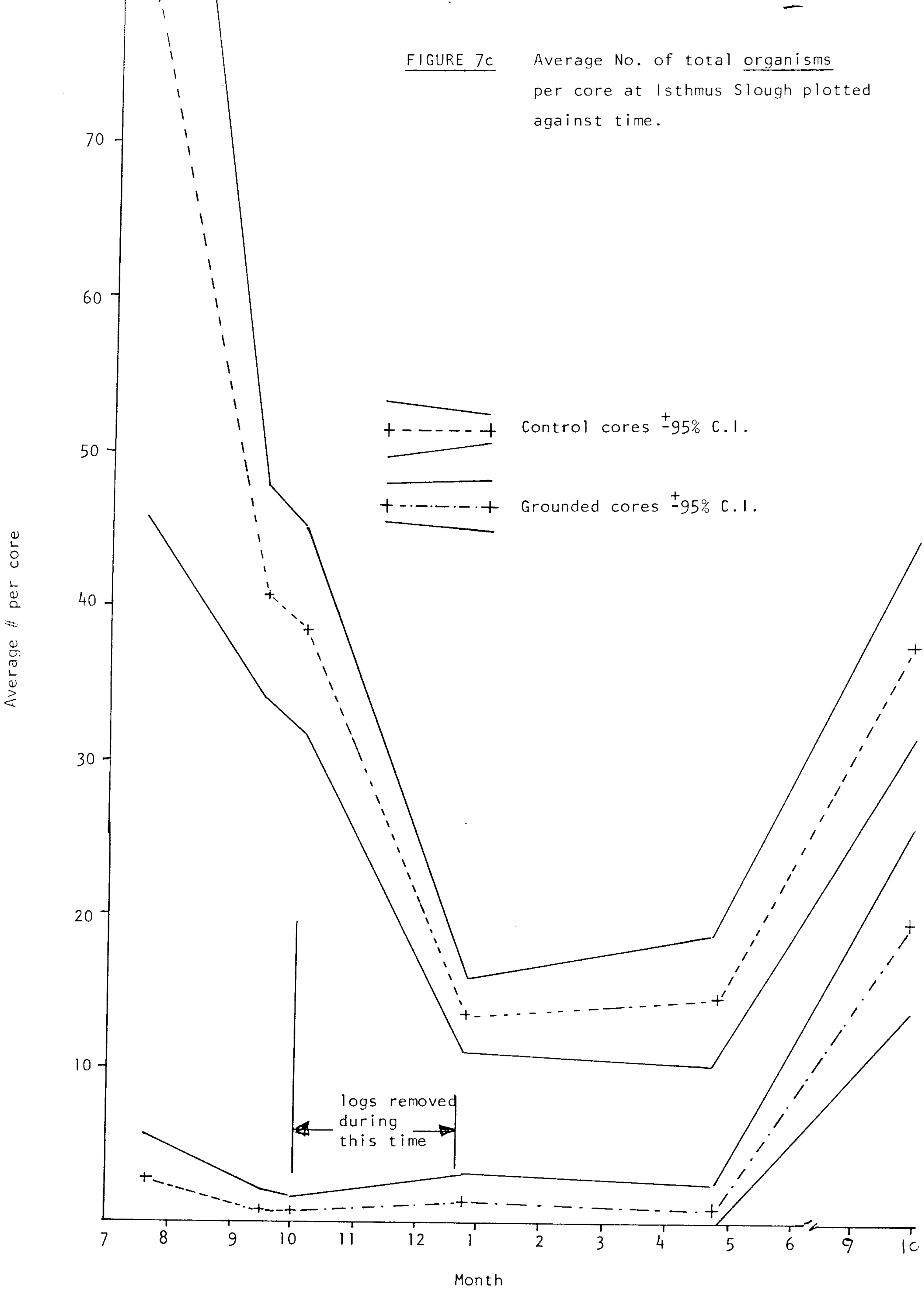


FIGURE 7c Average No. of total organisms per core at Isthmus Slough plotted against time.



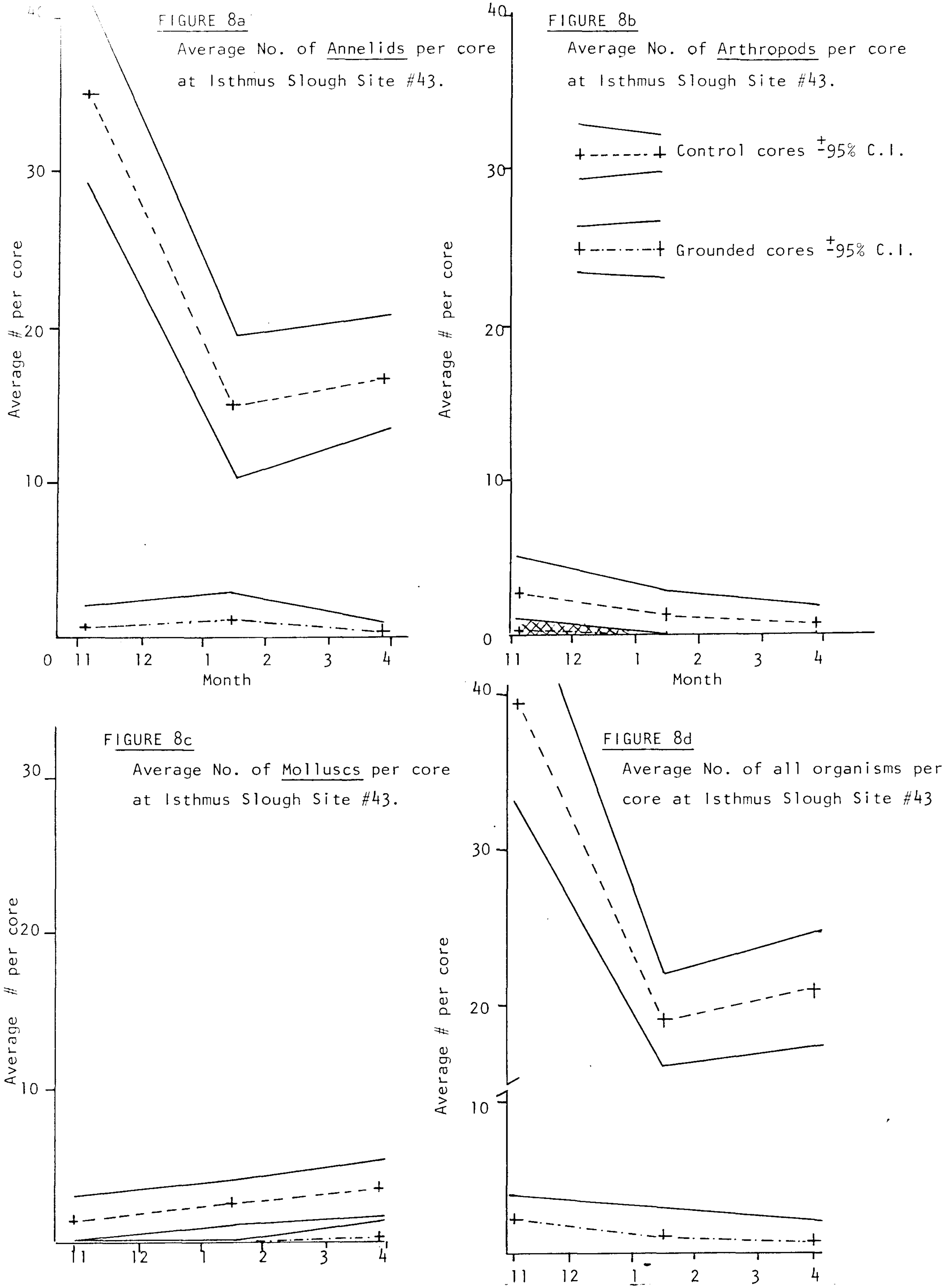


FIGURE 8a
Average No. of Annelids per core
at Isthmus Slough Site #43.
Average # per core
Month
FIGURE 8b
Average No. of Arthropods per core
at Isthmus Slough Site #43.
Control cores ±95% C.I.
Grounded cores ±95% C.I.
Average # per core
Month
FIGURE 8c
Average No. of Molluscs per core
at Isthmus Slough Site #43.
Average # per core
FIGURE 8d
Average No. of all organisms per
core at Isthmus Slough Site #43
Average # per core

DISCUSSION

Initial examination of Tables 1-4 show some comparisons between control and grounded areas which are not statistically significant at the 95% confidence level. This does not imply that there is no difference between the populations in question. The failure to show differences between some of these comparisons could be accounted for by:

1. No difference actually occurred.
2. Limits in sampling procedures and techniques. Certain species were collected in numbers too few for analysis with the applied statistical test.

    a) The sample size was not large enough to generate enough data in some cases.

    b) The natural decrease in numbers of organisms during winter months caused the numbers collected to drop below levels needed for statistical comparisons.

While more powerful statistics may be able to increase the number of comparisons which demonstrate differences between control and grounded populations, some species were found in large enough numbers to consistently show decreased numbers within the mudflats of raft storage areas.

Also, when species were grouped by Phylum, dramatic population reductions in raft storage areas were generally shown. Some species, which were fairly abundant in undisturbed mudflats were almost entirely eliminated in the log storage area (see Table 1, Cooston Channel; Heteromastus sp. Capitella capitata and Amphicteus mucronata). This reduction in numbers of benthic invertebrates associated with log rafting practices is consistent with work done on the Snohomish River Delta in Washington (Smith, 1977).

The reasons for this reduction in numbers that were considered are:

1. Build up of toxic organic accumulations of wood debris. Bark accumulations in the substrate degrade water quality. One aspect of this degradation is that bark accumulations exert an oxygen demand on the water, thus lowering the disolved oxygen (DO). During summer

months the Oregon Department of Environmental Quality (DEQ) has recorded DO levels below 2.5 mg/l in Isthmus Slough. These levels are below approved water quality standards. Since bark accumulations were encountered in both control and grounded sites the toxic leachates do not appear to be the cause for the reduced numbers in the grounded areas. Several other factors support this conclusion.

The control and grounded areas were close together and the accumulations of bark debris in the substrate would not be expected to be radically different. The control area at Lillian Creek was the site of an abandoned log dump ramp and accumulated bark would be expected to be greater there than at the adjacent grounded site, yet it was the grounded site that had reduced abundance of organisms. At the Isthmus Slough both control and grounded sites contained such an accumulation of bark that it was difficult to locate adequate sites where the core would penetrate deeper than 10 cm. Also, some of the organisms such as, *Neries*, *Heteromastus* and *Capitella*, are pollution indicators and can tolerate unfavorable conditions (Olsen & Burgess, 1967). Therefore, it does not seem likely that bark accumulations and the toxic leachate associated with it are responsible for the decrease in numbers found in the grounded areas.

2. Organisms migrate out of the affected area by burrowing deeper or pioneering new areas.

When habitat and ecological considerations are evaluated, certain aspects can be eliminated. First, adjacent undisturbed areas will with time reach an equilibrium state where organism population reaches an upper limit imposed by the environment. These environmental limits, such as food or space, restrict the number of organisms which can reside in a particular area. In effect, there is no unoccupied area for organisms to migrate to. New areas would have to be produced if aquatic productivity is to be increased.

Since the habitat of certain of the organisms are specialized, burrowing deeper to escape destruction by grounded log rafts does not seem to be an available alternative. For example, Corophium sp., constructs a u-shaped burrow less than 9 cm. deep. When in its burrow the organism creates a current of water which flows through the burrow. This current serves to draw aerated water for respiratory purposes and carries food particles into the burrow. Deeper burrows would require a greater volume of water to be moved through the tubes and the organism would not be able to physically create the current that is required for respiration and feeding. The annelide, Amphicteus mucronata, resides in a shallow burrow and extends its tentacles above the surface for feeding. Other burrowing organisms are limited in the depth of their burrows since oxygen required for respiration only penetrates the mud a very short distance, and the organisms depend on their burrows to oxygenate their environment. Depths to the anearobic layer has been reported to be less than 1" at Site #43 (Fitchko & Smolen, 1970) and 5 cm. (Bolinger, et al, 1970) in Cooston Channel.

Clams with long siphons, by their normally deeper habitats, may be able to survive the grounding of log rafts. The scope of this study did not allow for a sampling regime which would encounter the larger, deeper dwelling clams. The work required to adequately sample these deeper dwelling clams does not justify the need to make a determination regarding the effects of log rafts on these populations, particularly when certain annelides and arthropodes are more important to the food chain (to be discussed later).

3. Another possible cause for the reduced numbers of organisms found in rafted areas is the physical alteration of the substrate. In Alaska, Pease (1974) reported that the physical weight of log rafts compacted the mud to the consistency of sandstone. Casual observations at the various sites examined during this study suggest the opposite to be occurring at least at the surface. The weight of the logs appears to have kneaded the mud and has changed it from the normally firm consistency to a watery soup. The watery consistency of the mud makes construction of burrows and shelters impossible and this loss of habitat seems the most likely cause of reduced numbers of organisms in the log raft areas. The organisms cannot physically burrow in this watery soup since the firm consistency required to support the tunnels is lacking. The area is thus rendered uninhabitable to the burrow constructing organisms.

This change of consistency may also cause erosion problems. When logs were removed from the Isthmus Slough site observations showed this loosely compacted mud was eroded by stormy weather and high tides, exposing a gravel substrate in places. This loss of mud layer may account for the slow recolonization of the previously rafted area which was observed (to be discussed below).

Isthmus Slough

Examination of data reveals that Molluscs were lacking at this area and tidal zone in Isthmus Slough. A number of physical or chemical factors could account for this. It is possible that the thick accumulation of large bark chips encountered in the area at 10 cm. limit the deep burrowing clams.

The most numerous organisms encountered at this site were the Annelides, Amphicteus mucronata and Neries sp., and the Arthropode Corophium sp. The annelides were significantly reduced in abundance in areas of log rafts during the entire study. Corophium sp. was found to be significantly reduced in raft areas on 9-14-77 and 9-27-77. These differences were shown during periods when abundance of Corophium was high. During other sampling dates when abundance was low or variability high, no statistical difference was observed between control and rafted sites. Since Corpphium sp. construct u-shaped tubes for respiration and feeding, it seems likely that Corophium would not be able to survive in an environment that is repeatedly altered by grounded logs. Larger sample sizes could possibly demonstrate differences between control and grounded samples during periods when abundance is low.

During the Fall of 1977 logs were removed from the grounded areas and the area remained clear of logs throughout the remainder of the study. This afforded an excellent opportunity to examine the length of recovery time for the grounded area. The average total number of organisms did not increase for the grounded area until the sampling on 9-21-78. Although there was almost a 10 fold increase in numbers in the grounded area, this represented only partial recovery, since there was still a significantly greater number of organisms in the control area. Smith (1977) estimated recolonization rates from several days to up to 8 weeks. The recolonization of Isthmus Slough was much slower in comparison which may be the result of erosion problems described earlier.

Isthmus Slough Site #43

During the limited sampling of this area the most abundant annelide was Heteromastus filliformis followed by Neries sp., Capitella capitata and Amphicteus mucronata. All showed significant decreases in abundance in log grounded areas. Macoma sp. was the most abundant mollusc and showed significantly decreased abundance during January and March. Means were higher for Corophium sp. in control area but were not found in numbers sufficient to demonstrate statistical differences.

Lillian Creek

For Lillian Creek average abundance of organisms was higher in control areas than in grounded areas. Abundance for most species was not great enough to detect statistical differences with repeatability. However, the annelid Amphicteus mucronata consistently showed a significant decline in abundance in rafted areas. Neries sp also showed significant reduction in numbers in rafted areas during October, December and July.

Cooston Channel

Annelids were abundant in the control area and Heteromastus filliformis, neries sp. and Capitella capitata were statistically more abundant in the control than in the grounded area. The arthropod, Corophium sp. were also numerous in unrafted areas, but numbers generally declined drastically in rafted areas. The Molluscs Macoma sp. and Tellina sp. had mean numbers greater in the control than in the rafted areas but were not found in sufficient numbers to consistently yeild statistically significant numbers. Also, since core samples were limited to 15 cm. deep and these organisms could burrow deeper it is difficult to make determinations regarding Molluscs from this data.

The only instance where organisms were found in statistically greater numbers in the rafted areas were for the cumacean data on 8-2-77. Although this cumacean was not identified, it was observed to be a rapidly free swimming organism. This organism may prefer the calm, shady water under the rafts and become caught in intertidal water in the mud during low tides. Smith, (1977) found that the arthropod, Arisogammaris were more numerous in the rafted areas.

Certain of the organisms encountered during the study are important members of the food web. The food web of an estuary is complex and feeding habits or organisms vary seasonally. The primary food source is from the photosynthetic activites of green plants. Although some organisms eat plants directly, others feed primarily on the detritus formed from the breakdown of the plant material. Also, bacteria which break down the detritus provide an important source of food for filter feeders and detritus feeders. The source of estuarine detritus is largely from the rooted plants Zostera, in the mudflat zones, and Spartina in salt marshes. It is possible that log grounding has a direct impact on primary production by affecting the Zostera production. Thompson, 1971, observed that grounded logs in Isthmus Slough were responsible for the elimination of Zostera beds.

Bacterial growth associated with the breakdown of the plant material represents a major source of protein for the microfauna. The microfauna of the mudflats, in turn, is eaten by predators, such as, Neries sp.. Neries sp. also consume Corophium sp and copepodes. The top predators, fish and birds, feed on Neries, Corophium, Tellina and Macoma (Green, 1968).

Corophium sp. has been shown to be one of the most abundant animals of the teal's (Anas Crecca) diet and is also found in the diet of the mallard (Anas platyrhynchos) (Green, 1968). Numerous shore birds and waders also utilize the mudflat invertebrates in their diets.

Juvenile Salmon use estuaries as a nursery and utilize the benthic invertebrates, particularly Corophium, in their diets (Smith, 1977). Thompson, 1971, reported that Corophium is important in the diet of the Shiner Perch (Cymatogaster aggregata) and the Starry Flounder (Platichthys stellatus).

Eltringham, 1971, lists Neries, Hydrobia and Corophium, because of their abundance, as the three most important members of the macrofauna, and that they are of economic significance since they are the major food items of fish, many of which are commercially exploited. A simplified food web diagram is presented in Figure 9.

Since the mudflats are economically significant to fishery production it is important to evaluate management practices which remove these areas from production.

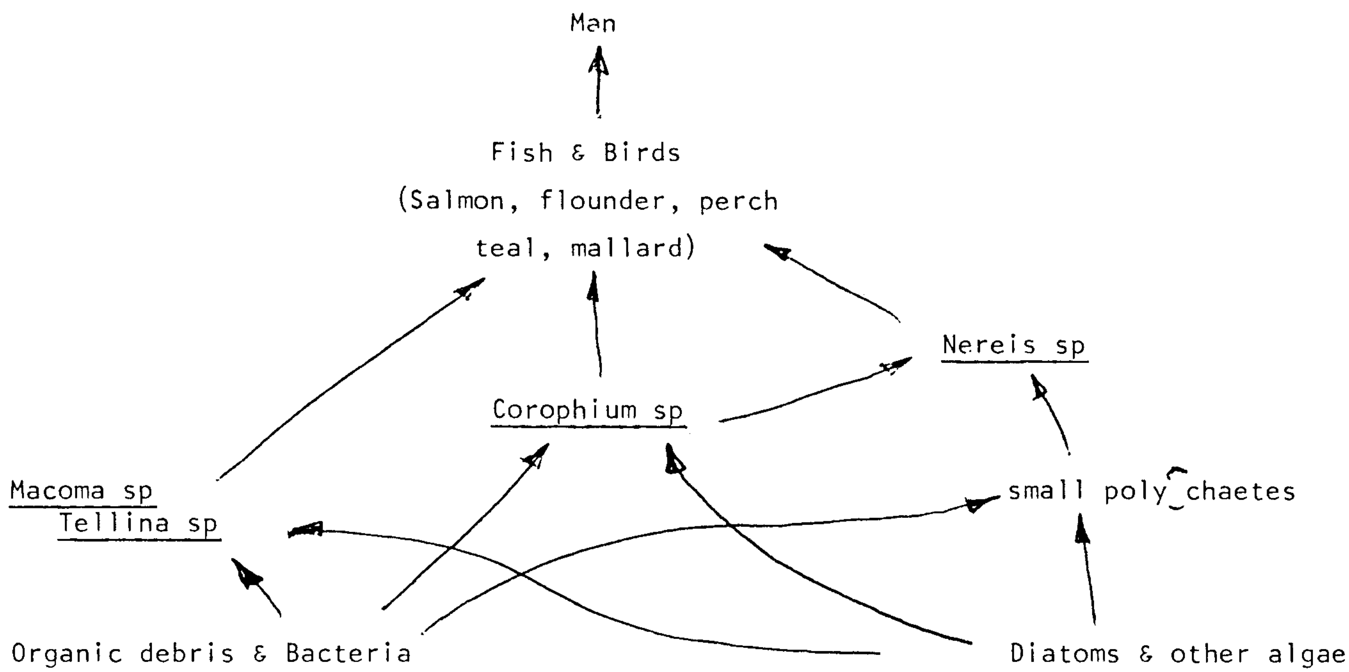


FIGURE 9 Simplified Food Web for Organisms Found in Coos Estuary

During the period 1920-1970, 1500 acres of tidelands have been lost to filling and 2000 acres diked (Percy, et al, 1974). Since over 40% of the tidelands have already been lost from biological production, it is very important to carefully examine all practices which remove additional tidelands from production. In relationship to this, it is of interest to estimate the percent of area affected by log storage. An accurate estimation of acreage being removed from productivity could be made utilizing further work with log raft inventories and aerial photography. It is possible, with present information, to make an estimate. There is a maximum storage of 570 acres of log storage area in Coos Bay and Isthmus Slough (this does not include Coos River storage and Isthmus Slough, south of Davis Slough) (Greenacres Consulting Corp., 1974). This represents 12% of the 4,569 tideland acres. If an assumption is made that between 30 and 60% of the log rafts stored go aground at low tide, then between 3.6 and 7.2% of the total tidelands are affected. Although an accurate determination would be useful to estimate the overall impact, it is, considering the value of every acre of productive tideland, important to consider that if viable alternatives exist to detrimental practices, they be identified and implemented.

CONCLUSIONS

1. Grounded logs adversely affect the benthic organism population in Coos Bay. There was an average reduction in total numbers in grounded areas as follows:

95%	Cooston Channel
89%	Isthmus Slough
95%	Isthmus Slough, Site 43
88%	Lillian Creek

2. Up to 7% of the tidelands are affected by logs going aground at low tide.

3. Other research has shown that some of the benthic invertebrates affected are of value in the food chain of known commercial fish species.

4. Present information does not allow one to estimate the adverse impact on productivity of the estuary.

5. Following the elimination of log storage, evidence exists that the tidelands will repopulate themselves.

6. Since tidelands are valuable in producing organisms important to the commercial fish food chain log storage should be minimized in areas where logs go aground.

RECOMMENDATIONS

A thorough study of alternate methods of log transportation, storage and handling in Coos Bay was prepared by the Greenacres Consulting Corp., and the reader is referred to this paper for further information (Jackson, 1974). Since this study has shown adverse effects to the benthic organisms in the Coos Bay Estuary, the following practices are recommended to minimize the impact associated with log grounding:

1. A phase-out of tideland storage of logs should be encouraged and storage over mudflats should eventually be eliminated if possible.

2. No additional or new tideland storage areas should be allowed. This is already part of the log handling policy adopted by the Environmental Quality Commission.

3. The storage area classification system should be established that would place a priority on storage areas that would favor deeper water storage sites. All deep water storage sites should be used before tideland sites are considered.

4. Establish inventory maximums for existing and future companies using the Bay for log handling, transportation and storage.

5. Storage in bundles or rafts is preferred over loose log pen storage areas. Existing pen areas should be phased out.

6. Work with individual companies to seek economically and environmentally acceptable alternatives.

7. Only logs scheduled to be used within 12 calendar months should be stored in water. Storage longer than 12 months is considered long term storage and should occur on land where feasible.

ABSTRACT

A study was conducted from June, 1977 to September 1978 to determine if the practice of storing log rafts over tidelands in areas where they go aground during periods of low tides has adverse affects on the benthic invertebrates of the mudflats. Samples were taken from each of 4 sites within the Coos Estuary system on a somewhat alternating basis.

At each site, samples were compared from control areas (no logs stored) and from adjacent storage areas. These comparisons revealed significantly reduced numbers of benthic invertebrates in the mudflats under log rafts. The annelides were particularly affected by the storage practices. Certain of the species affected are important members of the estuarine food web. Recommendations are given to minimize the affect associated with log grounding.

LITERATURE CITED

1. Bolinger, A., Fouler, B., and Elliott, L. "Bay Project Report Area B-10" Oregon Institute of Marine Biology Charleston, Oregon, 1970.

2. Broadhead, Gordon C., "Our Estuaries and Commercial Fishing Trends". Estuarine Pollution Control and Assessment; Proceedings of a Conference Vol. 1 U.C. EPA, February, 1975.

3. Clark, John, "Status of Estuarine Ecosystems in Relation to Sportfish Resources". Estuarine Pollution Control and Assessment; Proceedings of a Conference Vol. 1 U.S. EPA, February, 1975.

4. Eltringham, S.K., "Life in mud and Sand" English Universities Press, 1971

5. Fitchko, R. and Smollen, M., "Study of Physical and Biological Parameters of Area A-7". Oregon Institute of Marine Biology, Charleston, Oregon, 1970.

6. Green, J., "The Biology of Estuarine Animal", University of Washington, Seattle & London, 1968.

7. Hargis, W.J., "Evaluation of Water Quality in Estuaries and Coastal Waters." Estuarine Pollution Control and Assessment; Proceedings of a Conference Vol. 1. U.S. EPA, February, 1975.

8. Jackson, Alec (Greenacres Consulting Corp.) "The Environmental and Economic Impact of Alternate Methods of Log Transportation, Storage and Handling in the Coos Estuary - Phase 1" Greenacres Consulting Corp. Bellevue, Washington, May 1974.

9. Olsen, T. and Burgess, F.J. "Pollution and Marine Ecology" John Wiley & Sons, Inc., New York, 1967.

10 Pease, B.C. "Effects of Log Dumping and Rafting on the Marine Environment of Southeast Alaska", U.S. Dept. of Agriculture Forest Service, Portland, Oregon, 1974.

APPENDIX

		Water Temperature °C	Salinity S°/00
Cooston Channel			
7/6/77	Control	20.0°	12.0
	Grounded	20.0°	13.0
8/2/77	Control	23.0°	20.5
	Grounded	24.0°	20.0
8/29/77	Control	18.5°	16.0
	Grounded	19.0°	15.0
11/21/77	Control	6.5°	2.5
	Grounded	6.5°	2.5
1/31/78	Control	9.5°	1.0
	Grounded	9.8°	1.0
3/14/78	Control	11.0°	2.0
	Grounded	11.0°	2.5
4/10/78	Control	12.5°	3.0
	Grounded	12.3°	3.0
5/9/78	Control	15.0°	3.0
	Grounded	14.8°	3.0
6/23/78	Control	19.0°	6.5
	Grounded	19.0°	6.4
Isthmus Slough			
7/18/78	Control	18.8°	15.0
	Grounded	18.8°	15.0
9/14/77	Control	18.0°	16.0
	Grounded	18.5°	16.0
9/27/77	Control	16.5°	15.5
	Grounded	16.5°	15.5
12/21/77	Control	8.7°	0.0
	Grounded	8.7°	0.0
4/26/78	Control	12.0°	0.0
	Grounded	11.8°	0.0
9/21/78	Control	20.0°	15.0
	Grounded	20.0°	15.0

		Water Temperature °C	Salinity S°/00
Isthmus Slough "Site #43"			
11/7/77	Control	11.0°	10.5
	Grounded	11.5°	10.2
1/19/78	Control	10.5°	5.5
	Grounded	10.5°	5.5
3/28/78	Control	14.0°	10.0
	Grounded	14.0°	10.0
Lillian Creek			
6/7/77	Control	18.5°	2.0
	Grounded	18.5°	2.0
10/11/77	Control	17.0°	8.0
	Grounded	17.0°	8.0
12/6/77	Control	10.5°	0.05
	Grounded	10.0°	0.05
2/15/78	Control	10.2°	0.01
	Grounded	10.2°	0.0
5/24/78	Control	16.0°	0.05
	Grounded	15.5°	0.05
7/6/78	Control	20.0°	6.0
	Grounded	20.5°	6.2

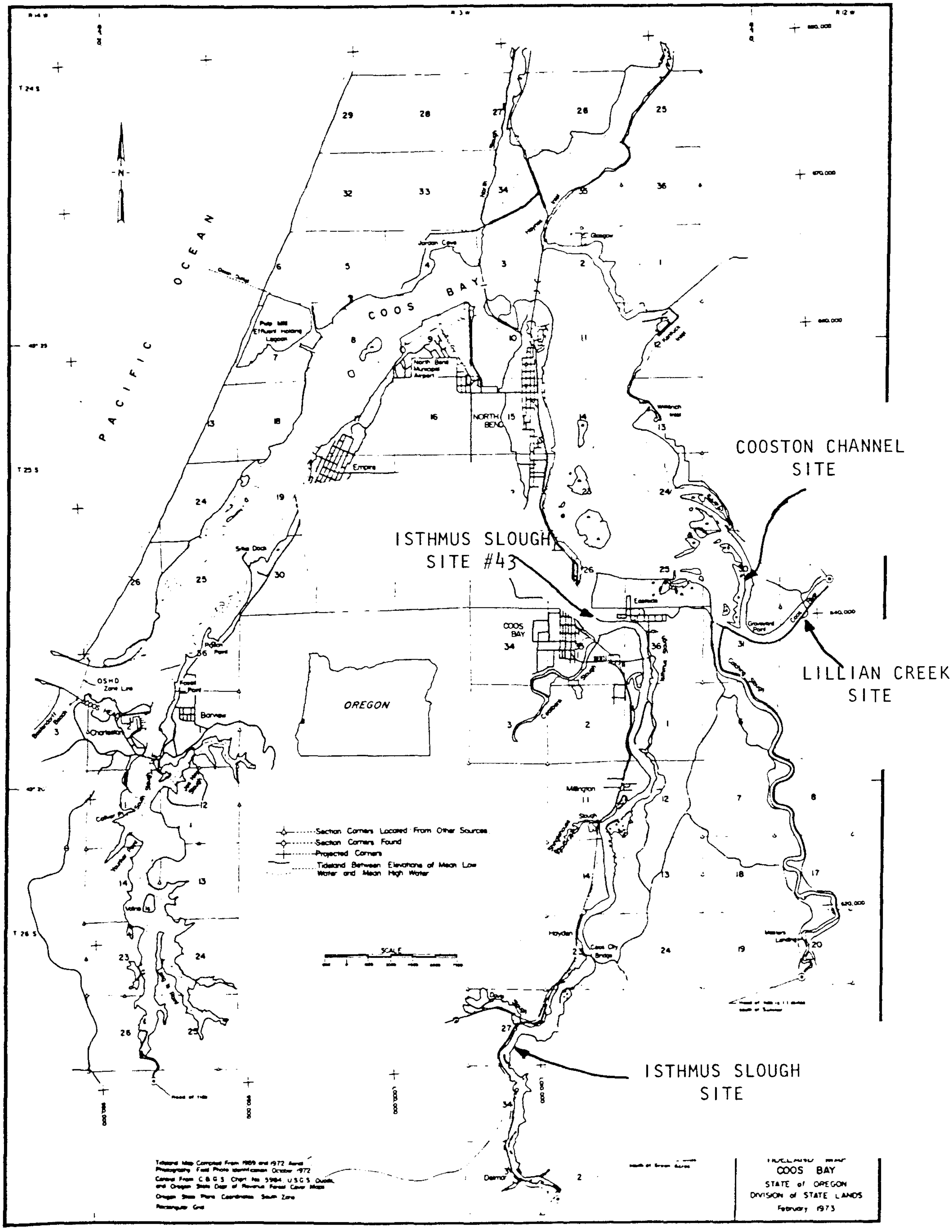
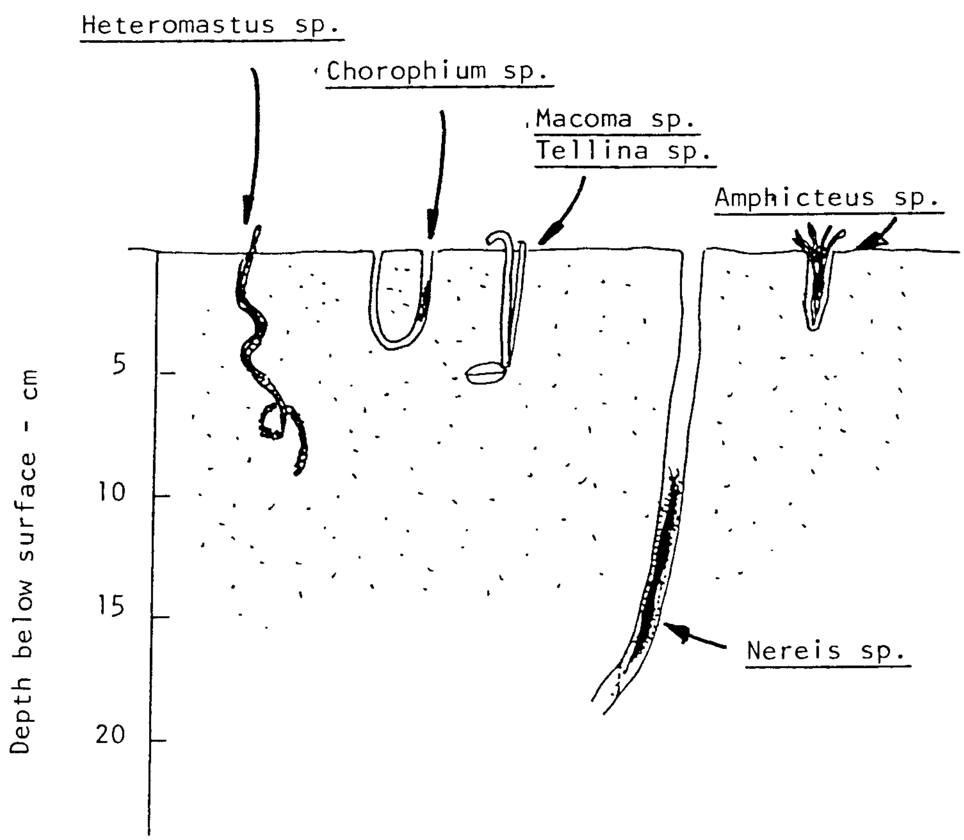

COOSTON CHANNEL SITE
ISTHMUS SLOUGH SITE #43
LILLIAN CREEK SITE
ISTHMUS SLOUGH SITE
PACIFIC OCEAN
COOS BAY
OREGON
NORTH BEND
COOS BAY
Empire
Charleston
Barview
Eastside
Millington
Hayden
Glasgow
Jordan Cove
North Bend Municipal Airport
Pulp Mill Effluent Holding Lagoon
Dellmar
COOS BAY
STATE of OREGON
DIVISION of STATE LANDS
February 1973

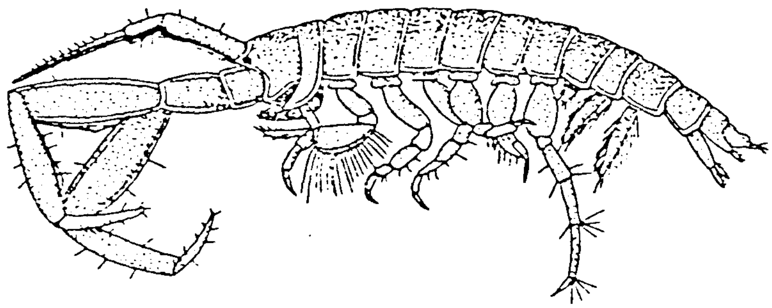
FIGURE A



Adapted from Green, 1968

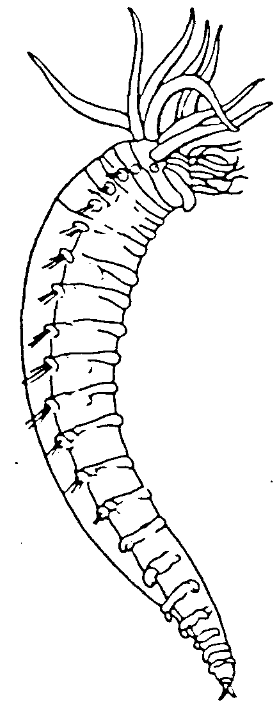
REPRESENTATIVE ORGANISMS

FOUND IN COOS ESTUARY



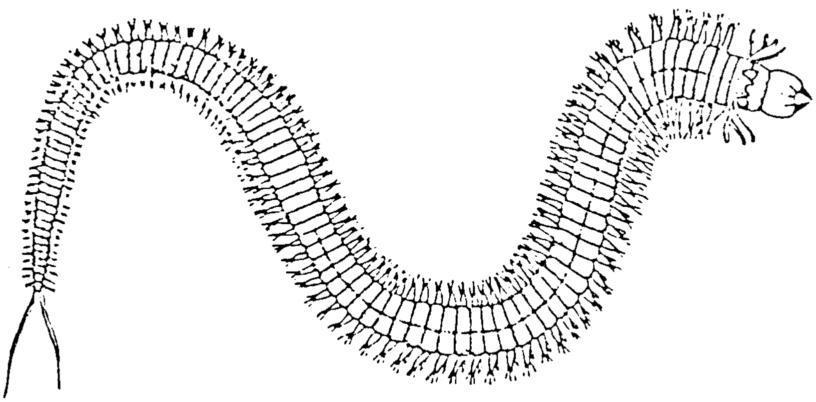
Chorophium sp.

Actual size approx. 7 mm.



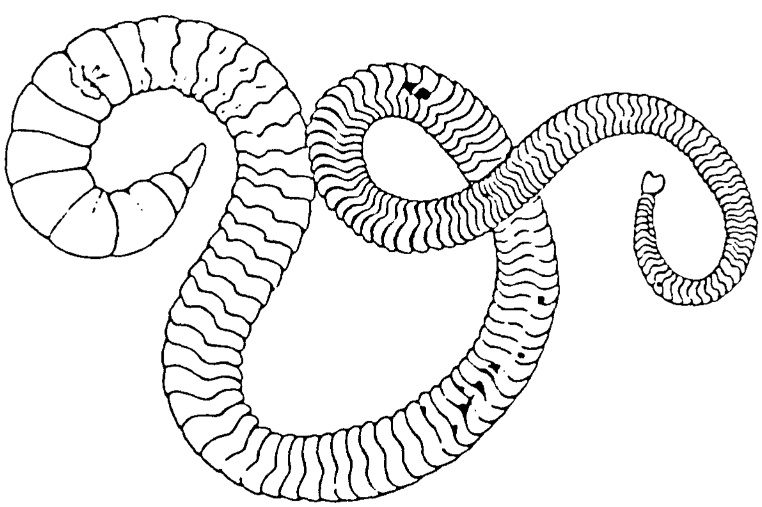
Amphicteus sp.

Actual size: approx. 5 mm.

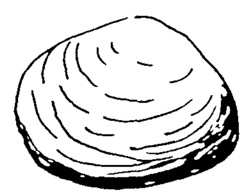


Nereis sp.

Actual size: 10 cm.



Capitella capitata
Actual size: approx. 4 cm.



Macoma sp.

Tellina sp.

Actual size: approx. 2 cm.