A Trench Through Mudflat Communities of Macroinvertebrates on Roberts Bank, Fraser River Delta, B.C.

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A TRENCH THROUGH MUDFLAT COMMUNITIES OF MACROINVERTEBRATES ON ROBERTS BANK, FRASER RIVER DELTA, B.C.

by

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ABSTRACT

Levings, C. D., R. Armour, and N. G. McDaniel. 1978. A trench through mudflat communities of macroinvertebrates on Roberts Bank, Fraser River delta, B.C. Fish. Mar. Serv. MS Rep. 1501: 51 p.

This report deals with ecological aspects of macroinvertebrate communities and their response to construction of a ditch to bury an electric cable across Roberts Bank on the Fraser River delta. Data were obtained in monthly sampling over the period June 1975 to April 1976, and more frequently when ditching was occurring. Number of individuals and number of species showed peaks over the period November to February. Decreases in abundance of crustacea (e.g. *Corophium* spp. (Amphipoda) and *Tanais stanfordi* (Tanaidacea) were documented for autumn months. Concentration of algal pigments in sediments (chlorophyll *a*) reached a peak in November - December. Organisms were most abundant in the upper 5 cm of cores. A hydraulic jetting device was used for trenching in the sand portion of the Banks and a backhoe mounted on pads was used through mud. Where hydraulic ditching was used, numerical abundance of macroinvertebrates was depressed for a relatively short distance (approximately 10 to 20 m) on the north side of the ditch. Backhoe operations resulted in more disruption of habitat and effects were more persistent. Biological data, together with visual observations of modified sediment distributions, suggest that prevailing tidal currents moved displaced sediment north over this portion of Roberts Bank. The construction of the trench created microhabitats for invertebrates utilizing algae and vascular plant (*Zostera marina, Carex lyngbyei*) debris.

Key Words: mud, benthos, food organisms, sediment transport, tidal currents, intertidal environment.

RÉSUMÉ

Levings, C.D., R. Armour, and N. G. McDaniel. 1978. A trench through mudflat communities of macroinvertebrates on Roberts Bank, Fraser River delta, B. C. Fish. Mar. Serv. MS Rep. 1501: 51 p.

Le présent rapport traite de l'écologie des communautés de macro-invertébrés et des effets qu'a sur ces derniéres le creusage d'une tranchée destinée à enfouir un câble électrique dans le banc Roberts, dans le delta du Fraser. Les données utilisées proviennent d'échantillonnages mensuels, de juin 1975 à avril 1976, et plus fréquents pendant le creusage. Les nombres de sujets et d'especes relevés montrent des maximums entre novembre et février. On remarque aussi une diminution du nombre de crustacés (par exemple, Corophium spp. (Amphipoda) et Tanais stanfordi (Tanaidacea)) en automne. La teneur en pigments d'algues des sédiments (chlorophylle a) a atteint un maximum en novembre et décembre. Les organismes étaient plus abondants dans les 5 premiers cm des carottes. Le creusage des trachées s'est fait à l'aide d'un jet d'eau dans les parties sablesuses et à l'aide d'une pelle rétro montée sur des coussinets spéciaux dans les parties boneuses. Le creusage au jet d'eau a réduit le nombre de macroinvertébrés dans un corridor relativement étroit (10 à 20 m) du côté nord de la tranchée. Les perturbations de l'habitat causées par la pelle rétro ont été plus graves et plus durables. Les données biologiques et l'examen des modifications apportées à la distribution des sédiments portent à croire que les courants dominants de marée ont entraîné les sédiments remaniés vers le nord, sur cette partie du bank Roberts. Le creusage de la tranchée a créé des micro-habitats propices aux invertébrés qui se nourrissent de débris d'algues et de plantes vasculaires (Zostera marina, Carex lyngbyei).

Mots clés: boue, benthos, proies, transport des sédiments, courants de marée, environnement intertidal.

INTRODUCTION

Since intertidal benthic organisms on the Fraser delta feature in food webs leading to organisms of commercial and aesthetic significance (fish, birds) (Goodman 1975; Vermeer and Levings 1977), information on the effects of disruption on these organisms is of considerable interest.

The present report describes the results of observations made before, during and after ditching to bury an electric cable across Roberts Banks on the Fraser River delta in southwestern B.C. (Fig. 1). A hydraulic jetting apparatus was used to dig through sand on the lower portions of the beach, and a mechanical backhoe was used through mud in the upper tidal flats. Biological observations were focussed on three major topics: (1) impact of the ditching on habitats (2) an investigation of temporal change in the mud flat assemblages (3) a description of "small scale" differences in distribution and zonation. The influence of hydraulic apparatus used for excavation of commercial clams in Puget Sound was investigated by Tarr (1977), and an extensive review of dredging for shell has been provided by Bouma (1976). However, no studies have been reported from mudflat habitats in British Columbia or on community effects. Basic data on temporal changes in benthic communities at the Fraser estuary have not been obtained.

STUDY SITE

The study area was located on the north portion of Roberts Bank, near the south end of 34th Street in Delta (Fig. 1). Three different sampling patterns were utilized: (1) "regular' stations (prefix A and B); (2) "zone" stations (prefix Z); and (3) "post-ditching" transects (prefix P, Q, X AND Y). Stations labelled A, B, P, Q and Z were all located in muddy substrates about 3.2 m over chart datum (O.D.). Transects X and Y were at a lower elevation (approximately 2.0 m) in sand.

REGULAR SAMPLING

"Regular" stations A and B were sampled on approximately a monthly basis from June 1975 to April 1976 inclusive to determine the composition and numerical abundance of the macro-invertebrate fauna with time at an "experimental" (A) and "control" site (B). Station A was located in the vicinity of the proposed ditch while B was about 100 m to the south. Five replicate samples were collected at each station using a metal hand-corer (25 cm diameter) forced 20 cm into the substrate (volume 9817 cm^3). Samples were obtained within an area of about 10 m diameter. Samples were placed in plastic bags for transport to the lab. Replicate samples for sediment grain size analyses (250 mL) and sediment chlorophyl (5 mL) were also taken using plastic coring devices.

Several other sampling methods were also employed on an infrequent basis at Stations A and B. In June and July 1975, quadrat samples (0.06 m^2 x 2 cm deep) were taken (AQ 1-5, BQ 1-5). In August 1975 sampling was carried out using the 25 cm diameter core where only the top 3 cm were retained for analysis (AT 1-5, BT 1-5). In September 1975 the 24 cm diameter core was used to obtain 20 cm deep cores which were divided into four fractions (0-5 cm, 5-10 cm, 10-15 cm and 15-20 cm layers), analyzed separately.

ZONE STATIONS

To examine the vertical distribution of the fauna within the sediment column and to determine the differences in the fauna (composition, abundance) of the sediments in channels, on ridges, and on algae-covered ridges of the sediment waves, three zone stations (Z) were established. Channel (C), ridge (R), and algae-covered ridge (A) were sampled using the 25 cm diameter core in October 1975. Two replicates were obtained at each station, these were subdivided into depth fractions: 0-5 cm, 5-10 cm, 10-15 cm and 15-20 cm layers. Samples for sediment grain size analyses and sediment chlorophyll were also collected for each zone.

POST-DITCHING SAMPLES

To assess the impact of hydraulic ditching on the fauna of the sandy sediments at lower tidal elevations, two transects (X and Y) were established perpendicular to the ditch, 700 and 1200 m respectively from the dyke (see Fig. 1). Six samples about 10 m apart were taken with a small core (8.5 cm diameter) forced 5 cm into the substrate, on each transect. This sampling was carried out in January and in February 1976. Sediment samples for grain size analyses and sediment chlorophyll were also obtained.

To assess the impact of backhoe operations on the fauna of the muddy sediments at higher tidal elevations, two transects (P and Q) were established perpendicular to the ditching zone, roughly 500 m and 250 m distant from the dyke respectively. Six samples were taken about 20 m apart using the small core (8.5 cm diameter) forced 5 cm into the substrate. Sediment samples for grain size analyses and for sediment chlorophyll were collected.

Access to the sampling area was by means of the road atop the dyke. Supplementary qualitative observations were made and photographs taken during several phases of the survey.

LABORATORY METHODS

BIOLOGICAL SAMPLES

Core and quadrat samples for macro-invertebrate species composition and abundance analyses were returned to the lab and held at 5°C until initial sieving could be done (no later than 24 h after collection). Organisms were separated from the muddy or sandy sediments by washing the samples through a 500 μ mesh sieve until the fauna and larger bits of organic debris were concentrated. Samples were than fixed in 10% formalin in preparation for analysis.

Since most samples contained very large numbers of only a few species (as many as 4×10^4 in a 25 cm diameter core, 20 cm deep), subsampling by wet weight was necessary in all cases. After subsampling, organisms were concentrated whenever possible by elutriation and stained with Rose Bengal for a minimum of 24 hours (this stain worked well for all fauna except those with relatively impermeable exoskeletons, such as tanaids, cumuceans, and certain insect larvae). Initial sorting was carried out using 12X magnification. Individual taxa were enumerated, tentatively identified and stored in 50% propanol. Identifications were later confirmed using available taxonomic literature, although for some groups (Oligochaeta, Copepoda) no attempt was made to identify specimens to the species level.

CHLOROPHYLL AND PHAEO-PIGMENTS

Sediment samples for chlorophyll *a* and phaeo-pigment analyses were treated using a photometric technique (modified from Strickland and Parsons, 1972). Samples were thawed, placed in plastic centrifuge tubes, and stirred and ground with 20 ml of 90% acetone for 5 minutes. Samples were then allowed to stand for 12 hours at 5°C before centrifuging for 10 minutes at 7500 rpm. Extinction of the supernatant was then measured before and after acidification at 665 nm and 750 nm, using a Carey recording spectrophotometer. The centrifuged sediments were wet weighed, so that results could be normalized and expressed for 20 grams wet weight sediment for all samples.

SEDIMENT

Sediment samples collected for grain size analysis were frozen, and have yet to be analyzed.

RESULTS

INVERTEBRATES OBSERVED

A total of 30 invertebrate taxa were detected in the sampling (Table 1). Nine taxa (30%) were polychaetes, 6 (20%) were molluscs, and 11 (36.6%) were crustaceans. In addition, 3 insect taxa (10%, Dolichopodidae, Chironomidae, and Tipulidae), a sipunculid (*Golfingia* sp.) and a nemertean were observed.

TEMPORAL VARIATION

Variation in number of individuals at the experimental and "control" stations followed similar patterns over the study period. There were no station effects as judged by an analysis of variance ($F = 0.03$; d.f. = 1, 19: n.s.). Fluctuations in abundance (log 10) at both stations were statistically significant as judged by analysis of variance for temporal effects (Station A - $F = 8.14$; d.f. = 9, 39; $p = 0.95$; Station B - $F = 11,75$; d.f. = 10, 43; $p = 0.95$). Peak values (mean of 5 replicates) of approximately 20,000 individuals $core^{-1}$ (equivalent to approximately 407000 m^{-2}) were observed in October 1975 and February 1976 (Fig. 2).

The number of species reached a weakly-defined peak (Fig. 3) in winter months, and an analysis of variance for temporal effects was statistically significant at both stations (Station A - $F = 9.95$; d.f. = 9, 40; $p = 0.95$; Station B - $F = 7.53$; d.f. = 11, 47; $p = 0.95$). There were no significant differences between stations, as judged by analysis of variance ($F = 0.07$; d.f. = 1, 21; $p = 0.95$).

Changes in populations of the species composing the assemblages were dependent on their life history characteristics, and some inter-station differences were evident. At both stations, numbers of *Tanais stanfordi*, for example, reached a peak in August through November (mean values approximately 2000 $core^{-1}$) and gradually declined to approximately 500 $core^{-1}$ in spring (Fig. 4). *Manayunkia aestaurina* abundance fluctuated in slightly different patterns at the two stations. At Station B, two peaks in abundance were noted (October, February) whereas a single peak in February was observed at Station A (Fig. 5). At both stations, numbers of *Corophium* spp. reached a peak in summer and declined to low levels in winter months (Fig. 6). The abundance of *Macoma* was relatively uniform over the period July to March (Fig. 7).

Temporal differences in concentrations of algal pigments were evident at the two stations (Fig. 8). Station B displayed a marked peak in November, while maximum values for Station A were observed a month later. Another peak in abundance in March was evident at both stations. Trends in concentrations of chlorophyll *a* and phaeopigments were parallel at both stations.

DISTRIBUTION OF ORGANISMS IN CORES

Organisms were most abundant in the upper 5 cm of cores (Fig. 9). In samples from the "ridge" zone, abundance decreased in an almost exponential manner with depth, whereas in the "channel" and "algae-covered ridge" zones, the pattern was less evident. The vertical distribution of *Manayunkia aestuarina*, *Tanais stanfordi*, *Corophium salmonis*, *Macoma balthica*, and Oligochaeta showed similar trends in the "channel" and "ridge" zones. On the algae-covered ridges, the shifts in abundance with depth were not as clear, suggesting that some species burrowed deeper in sediments covered with algae compared to "bare" substrate. Abundance data (mean of 2 cores) from the replicate samples were subjected to analysis of variance, which showed that differences in abundance with depth were statistically significant whereas those attributable to "ridge type" were not (Table 2).

THE DITCHING OPERATIONS

In the lower intertidal sector of Roberts Bank, a hydraulic ditching apparatus was used to "jet" a trench through the sand sediments characterizing this lower zone. This apparatus was floated onto the Banks at high tide, and required water depths of approximately 1 m or greater for operation. This jetting apparatus worked in our study area (i.e. in the higher elevations of the sand zone) during the period January 19 to 23, 1976.

At sectors that were too high and muddy for operation of the jetting apparatus, a backhoe mounted on pads (Fig. 10) was used to dig the trench. The backhoe operation was in progress from approximately March 26 to April 4, 1976.

HYDRAULIC DITCHING (Observations on January 24, 26, 1976)

The ditch created by the jetting operation was approximately 1 m deep when freshly dug and the width of the trench was approximately 25 cm before immersion by the immediately subsequent high tide. Measurements made further seaward, where the ditch had been subject to wave action for several high tide periods, showed that trench depth decreased to 10 cm. The edges of the ditch were sharp at the newly dug sector and smooth further seaward, indicating that wave action and currents were responsible for re-deposition of sand. Reduced (blackened) sediments from below the sediment-water interface had been distributed by the jetting activity. At the most recently trenched sector, dispersal of blackened sediment had been to the north of the ditch, indicating longshore currents were in that direction. A black or grey zone about 3 m wide was evident.

BACKHOE DITCHING (Observations on March 29 [digging in progress]; April 17 [equipment being removed])

The trench dug with the backhoe apparatus was about the same depth (1 m) as that dug with jetting but was close to 1 m wide. Sediments were disturbed over a wider area, and the total width of the affected zone was approximately 25 m. Because these muddy sediments were characterized by greater consistency, material dug by the backhoe remained together in large "clumps". These cohesive sediments were not as prone to wave erosion compared to sand and hence were not re-distributed as rapidly after digging.

BIOLOGICAL IMPACTS

HYDRAULIC DITCHING

The magnitude of decreases in the number of invertebrates at stations adjacent to the ditch was different at the X-transect location compared to the site of the Y stations. At the X-transect, effects were limited to a station immediately adjacent (north side) to the ditch, whereas no effects were evident at the Y-transect site.

At the X-transect, mean abundance (4 sampling times) at Station X3 (within 10 m of the ditch) was 746 individuals core^{-1}, compared to 1679 to 2783 core^{-1} at the other stations (Fig. 11). A one-way analysis of variance for station effects ($\log_{10}$ transformation) verified that differences between stations were significant (Table 3). Utilizing the least significant difference test (lsd) (Steel and Torrie 1960), the analysis showed that differences between Station X3 and stations south of the trench were significantly different (95% level). Stations on the north side were not significantly different, however.

Mean abundance on the Y-transect ranged from 1210 to 2626 individuals core^{-1} (Fig. 12). There were no inter-station differences as judged by an analysis of variance (Table 4).

BACKHOE OPERATIONS

Habitat disruption by backhoe ditching affected the abundance of invertebrates at both P and Q transects. At both transects, decreases were significant at only one station. The stations were on the north side of the ditch in both cases.

At the P-transect (furthest seaward; Fig. 1) numerical abundance of invertebrates ranged from 41 (Station P3) to 1834 (Station P4) core^{-1} (Fig. 13). Differences between stations were significant as judged by an analysis of variance (Table 5). Station P3 was the only station where abundance was judged significantly different using the lsd test.

Differences in invertebrate abundance between stations were also significant (Table 6) on the Q-transect, the sampling location closest to the dyke. Mean abundance of invertebrates ranged from 70 (Station Q5) to 1550 (Station Q4) core^{-1}. Abundance at Station Q5 differed significantly from all stations except Q3, as judged by the lsd test.

IMPACTS COMMON TO BOTH TYPES OF DITCHING

Hydraulic and backhoe ditching procedures resulted in the exposure of large numbers of shells of living and dead bivalve molluscs. Most were from soft-shell clams (*Mya arenaria*), bent-nose macoma (*Macoma nasuta*), and small macoma (*Macoma balthica*).

The depression in the mudflat left after trenching was completed created microhabitats for invertebrates utilizing algae and vascular plant debris as cover. Observations on several occasions showed that mats of algae (primarily *Enteromorpha* sp.), fronds of eel grass (*Zostera* spp.), and leaves of sedge (*Carex lyngbyei*) had accumulated in the trench. This debris provided cover for a variety of benthic invertebrates, especially amphipods (*Anisogammarus* spp.) and isopods (*Pentidotea* sp.). Such aggregations of organisms were most frequently observed in the trench dug by jetting. In the sector influenced by the backhoe operation, flushing was reduced because of the comparatively high elevation of the site. Water standing at low tide was blackened, and appeared to be contaminated with sulfides from beneath the sediment.

DISCUSSION

TEMPORAL CHANGE

Temporal changes in abundance at Roberts Bank were moderate compared to those reported for North Atlantic mudflats (e.g. Whitlatch 1977) but were similar to those observed at San Francisco Bay (northern California) by Nichols (1977). Presumably these geographic differences can be related to temperature of the adjacent coastal waters. At Roberts Bank, temperature is correlated with day length, salinity, and river freshet, and therefore indexes the major driving variables for temporal change.

Biological factors, especially predation by secondary consumers (shorebirds, juvenile fish, and carnivorous invertebrates) are also partially responsible for changes. Nichols (1977) speculated that shorebirds (e.g. snipe, dunlin) were one of the major sources of biomass loss from a mudflat on San Francisco Bay. Since large numbers of these birds also utilize the Fraser mudflats, it is likely that a similar situation prevails. Flocks of up to 20,000 dunlin have been observed on Roberts Bank in early spring (Trethewey, personal communication). Juvenile salmonids and other fish utilize prey items that become available in the water column when the tidal flats are flooded. Coho, chum and chinook are most abundant over Roberts Bank in spring (Goodman 1975) when high tides flood the mud flats during darkness. Fish activity in B.C. estuaries is nocturnal or crepuscular (e.g. Levy and Levings 1978) so that invertebrates are being used as fish food during evening or night hours.

BIOLOGICAL CONSEQUENCES OF DITCHING

Habitats and organisms in the direct path of both hydraulic ditching and the backhoe operation were totally disrupted, but otherwise effects were not widespread. These results support the conclusions reached by Tarr (1977) in his study of the impact of hydraulic clam harvesting at similar habitats in Puget Sound. He found that disruption, including minor dissolved oxygen depletion, increases in dissolved phosphates, and dispersion of silt could be detected not more than 50 m from the hydraulic apparatus.

Data obtained in this study show that stations primarily affected by the ditching operations were those immediately adjacent to the ditch, especially on the north side. Tidal currents further offshore flood north and ebb south (Thomson 1977) but presumably there is a net movement of material to the north.

Movement of sediment by currents could have led to acute effects on invertebrates via burial (Chang and Levings 1978) or poisoning by hydrogen sulfide released from the sediments. Compared to the compact mud on Roberts Bank, sand is easily redistributed by currents, so burial effects might have been most significant on the X and Y transects. McCauley et al. (1976) suggested that decreases in polychaete populations (especially *Polydora ligni*) adjacent to a dredge spoil area in an Oregon estuary were due to dilution by burial. Returns to normal abundance levels were achieved by worms migrating through sediments. *Heteromastus* sp., the most abundant polychaete at our study area, apparently did not exhibit this behaviour. Mortality at the P and Q transects, characterized by mud and silt, may have been primarily due to direct toxicity of water-borne hydrogen sulfide. Based on laboratory experiments, Caldwell (1975) concluded that several species encountered on Roberts Bank (*Gnorimosphaeroma oregonensis*, *Anisogammarus confervicolus*, *Corophium salmonis*, and *Macoma balthica*) were sensitive to this toxicant, even though field measurements have shown high concentrations in undisturbed environments (e.g. Bella et al. 1972).

VERTICAL DISTRIBUTION

As observed by many other workers on muddy shores (summarized by Eltringham 1971) the distribution of organisms within the sediment at Roberts Bank varied with organism size. Macrofauna (animals retained by a 500 µm screen) (Holmes and McIntyre 1971) are somewhat independent of the vertical distribution of properties within the sediment (e.g. dissolved oxygen, salinity), and tend to be uniformly distributed through the sediment column. These animals can either move through the sediment column (e.g. *Corophium*) or can use siphons to pump water and food from overlying water when the tide is in (e.g. *Macoma balthica*). The complex burrow structures of the ghost shrimp *Callianassa californiensis*, which occurs in the vicinity of our X and Y stations (Swinbanks and Murray 1976) are respiration and feeding adaptations of this species. Microfauna or meiofauna (animals passing through a 500 µm) are generally restricted to the upper 1 cm of the substrate, especially in soft sediments such as mud at our stations. Oxygen limitations are generally acknowledged to be a barrier for vertical distribution of these smaller organisms.

Although there were no apparent differences in total abundance of organisms on algal-covered ridges compared to algae-free features, it is possible that more detailed analysis of the data might reveal species-specific patterns. Woodin (1974) reported no correlation, negative or positive, with algal cover and abundance of four species of polychaetes on a mud-sand beach in Puget Sound. The algal ridges, which consist of mud bound with the mucilaginous algae, may impart stability to the sediment ecosystem, however. Ridges without algae may be destroyed by wave action, whereas those colonized might withstand physical destruction. More complete and detailed seasonal data are needed to test this hypothesis.

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Table 1. Taxonomic listing of organisms recorded during sample analyses. Classification follows that of Kozloff, 1974.

- NEMERTEA
- MOLLUSCA
  - GASTROPODA
    - *Batillaria attramentaria*
  - BIVALVIA
    - *Mytilus edulis*
    - *Macoma balthica*
    - *Mya arenaria*
    - *Venerupis japonica*
    - *Protothaca staminea*
- ANNELIDA
  - OLIGOCHAETA
  - POLYCHAETA
    - AMPHARETIDAE
      - *Amphicteis* sp.
    - CAPITELLIDAE
      - *Heteromastus* sp.
    - GONIADIDAE
      - *Glycinde picta*
    - NEREIDAE
      - *Nereis (Neanthes) limnicola*
    - PHYLLODOCIDAE
      - *Eteone longa*
      - *Eulalia* sp.
    - SABELLIDAE
      - *Manayunkia aestaurina*
    - SPIONIDAE
      - *Pygospio elegans*
      - *Polydora* sp.
- ARTHRODODA
  - CRUSTACEA
    - COPEDODA
      - HARPACTICOIDA
    - MALACOSTRACA
      - CUMACEA
        - *Cumella vulgaris*
      - TANAIDACEA
        - *Tanais stanfordi*
      - ISOPODA
        - *Gnorimosphaeroma oregonensis*

Table 1. (cont'd).

	AMPHIPODA			
		Anisogammarus confervicolus		
		Ampithoe valida		
		Corophium salmonis		
		C. insidiosum		
		C. ascherusicum		
		Corophium spp.		
	DECAPODA			
		Hemigrapsus oregonensis		
	INSECTA			
		DIPTERA		
			Dolichopodidae B	
			Chironomidae A	
			Tipulidae	
SIPUNCULA				
		Golfingia sp.		

Table 2. Analysis of variance for depth in sediment and ridge type using numerical data ($\log_{10}$) from cores.

Source	Sum of Squares	Degrees of Freedom	F-ratio
Depth in sediment	6.8149	3	10.08*
Ridge type	0.0133	2	0.029 n.s.
Error	1.3521	6	
Total	8.1803	11	

n.s. indicates no significant difference (95%)

Table 3. Analysis of variance for station effects using numerical data ($\log_{10}$) from cores on the X-transect. The least significant difference for comparisons between mean values per station was 0.4336.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio
Stations	1.3732	5	0.2746	3.22*
Error	1.5347	18	0.0852	
Total	2.9079	23		

* indicates significance at the 95% level

Table 4 . Analysis of variance for station effects using numerical data ($\log_{10}$) from cores on the Y-transect.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio
Stations	0.4328	5	.0865	1.02 n.s.
Error	1.5222	18	.0845	
Total	1.9550			

n.s. indicates no significant difference (95% level)

Table 5. Analysis of variance for station effects using numerical data ($\log_{10}$) from cores on the P-transect. The least significant difference for comparisons between mean values per station was 0.7301.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio
Stations	9.1049	5	1.8209	7.5372*
Error	4.3487	18	0.2416	
Total	13.4537	23		

* indicates significance at the 95% level

Table 6. Analysis of variance for station effects using numerical data ($\log_{10}$) from cores on the Q-transect. The least significant difference for comparisons between mean values per station was 0.7357.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio
Stations	6.1768	5	1.2353	5.0346*
Error	4.4167	18	0.2453	
Total	10.5935	23		

* indicates significance at the 95% level

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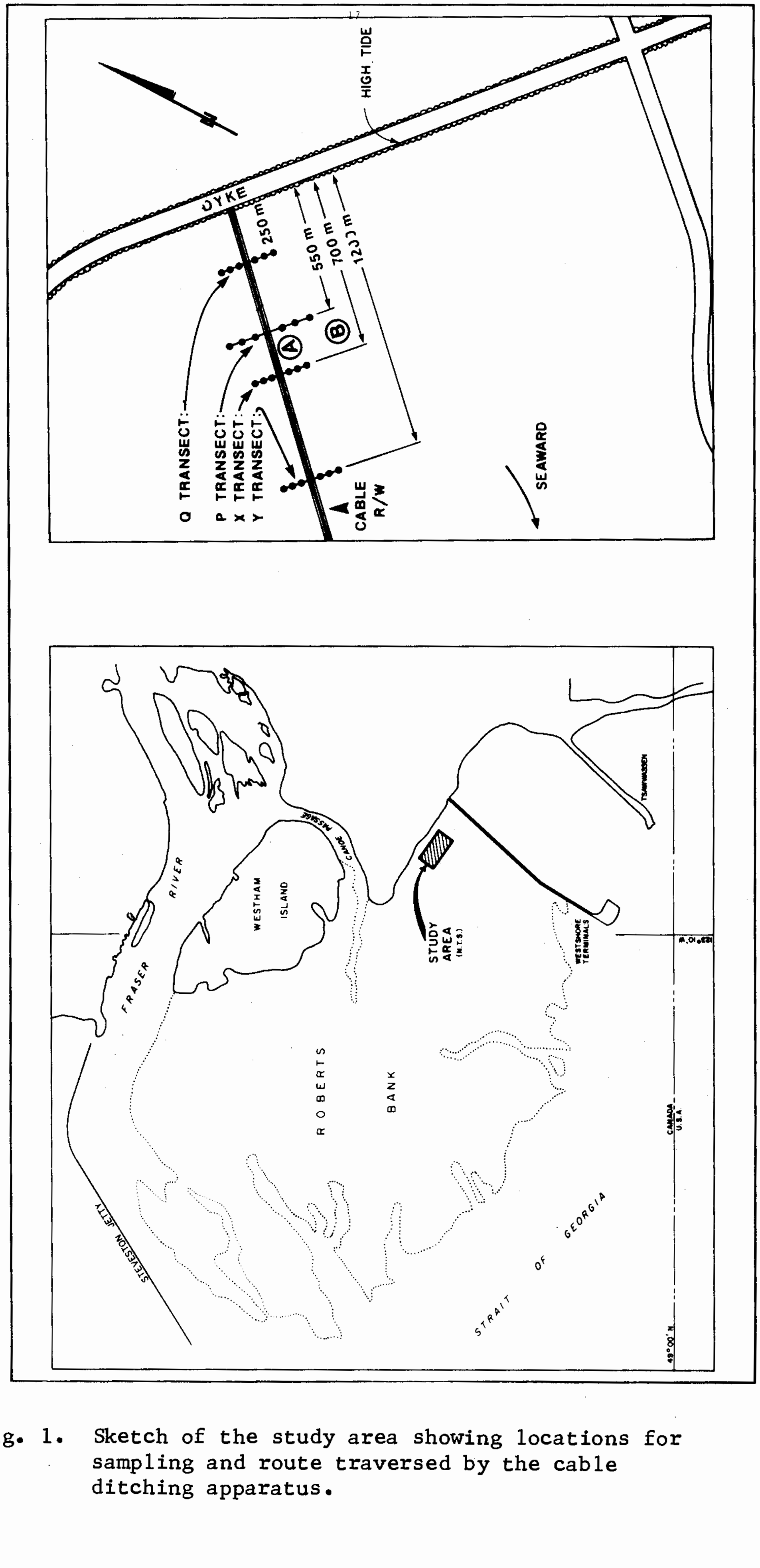


Fig. 1. Sketch of the study area showing locations for sampling and route traversed by the cable ditching apparatus.

FIG. 2

Number of Individuals

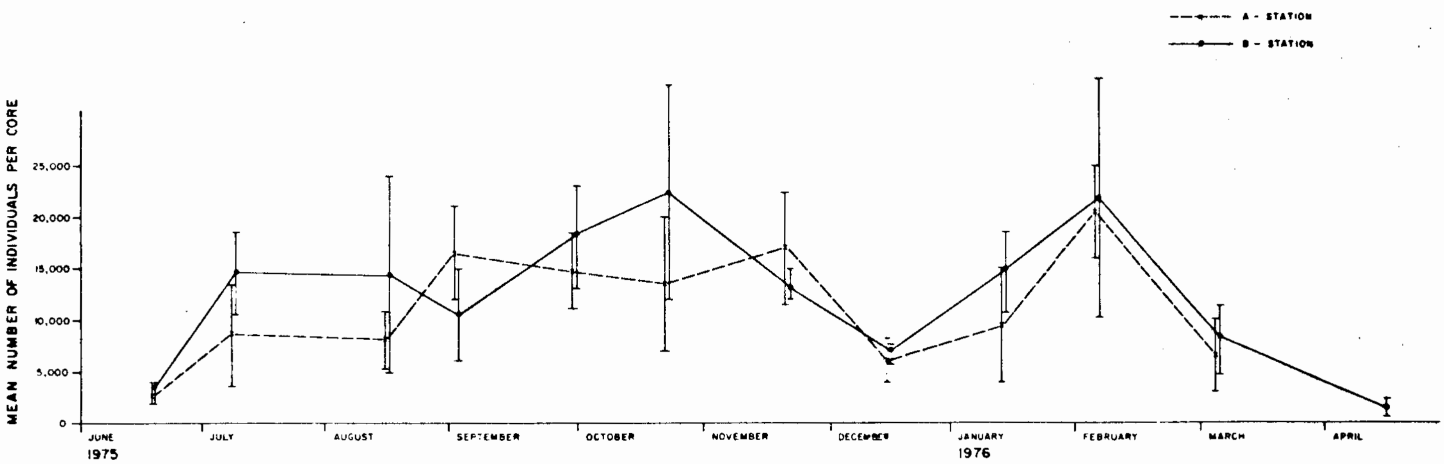


FIG. 3

Number of Species

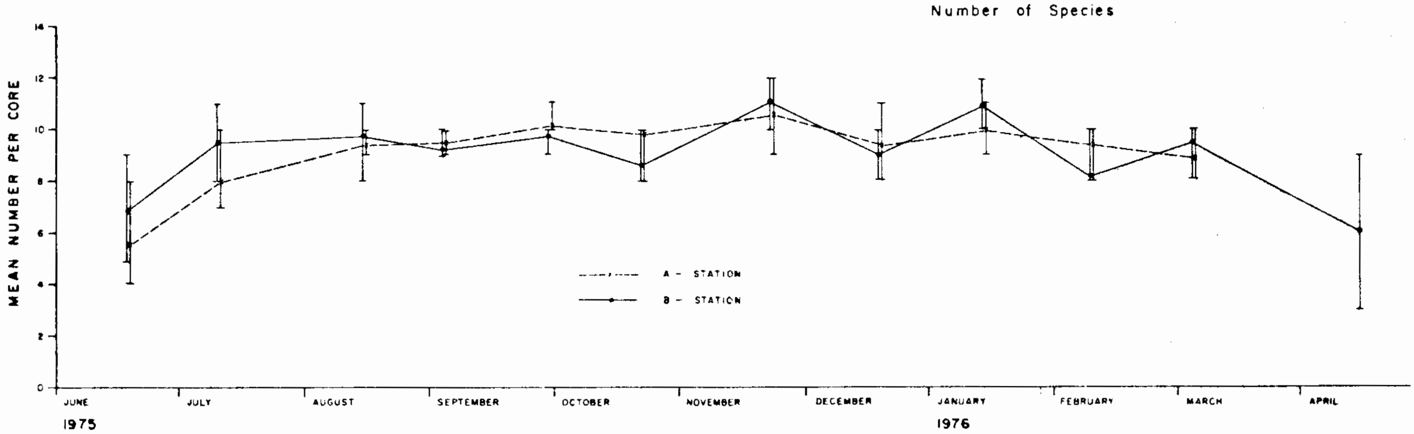


FIG. 4

Tanais stanfordi

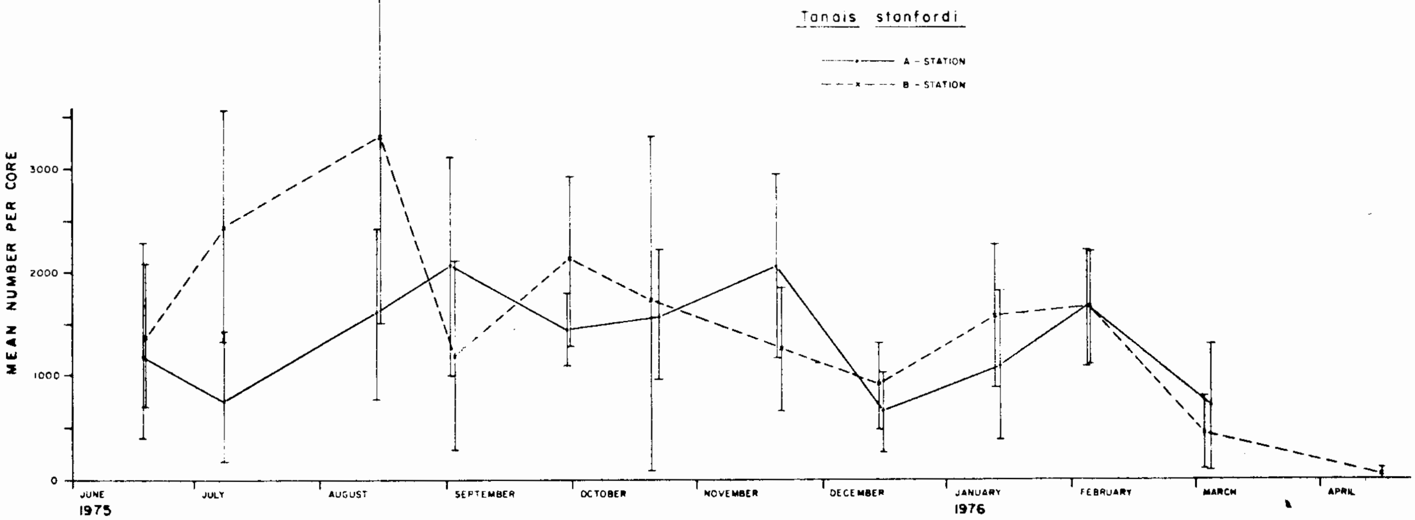


FIG. 5

Manayunkia aestuarina

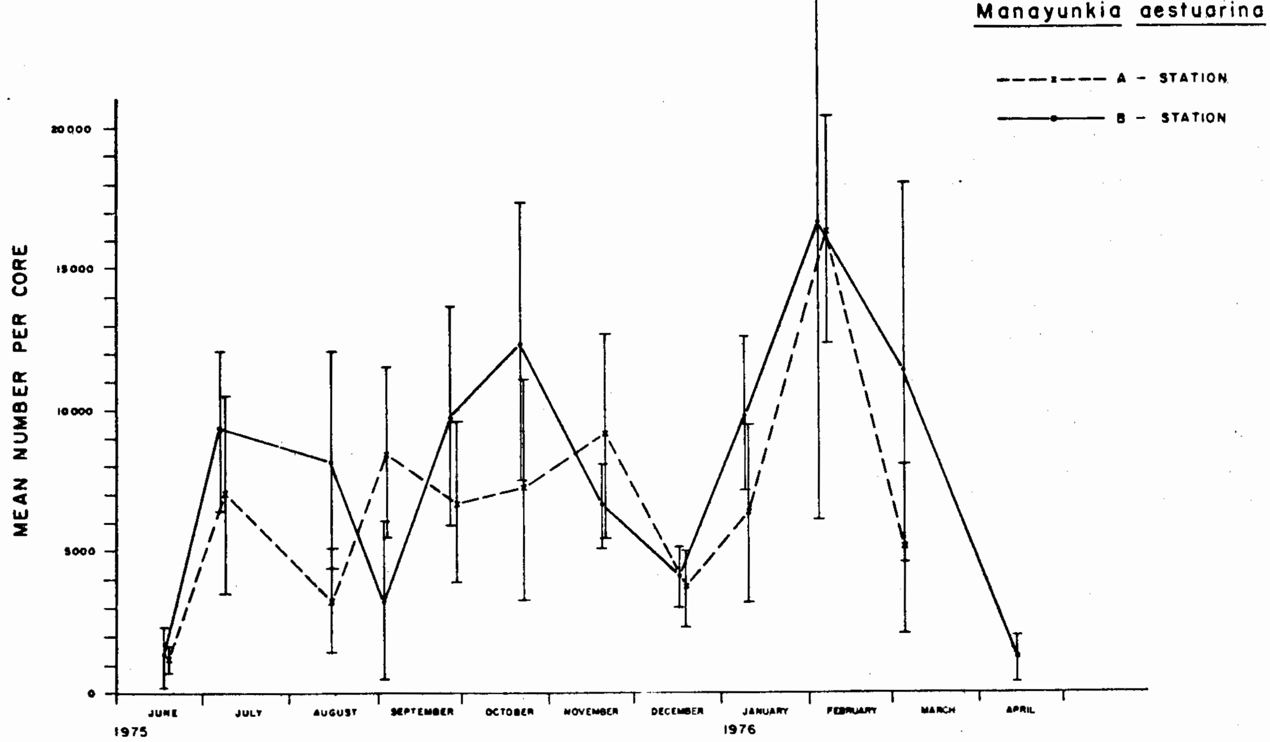


FIG. 6

Corophium insidiosum

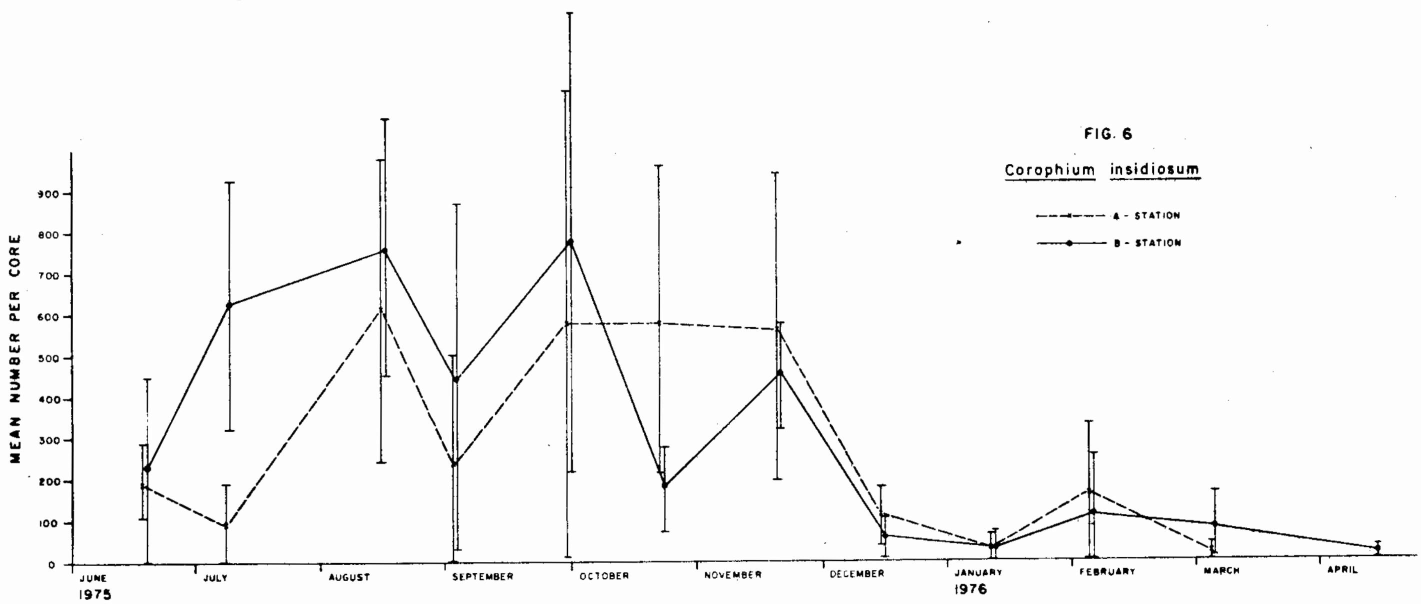
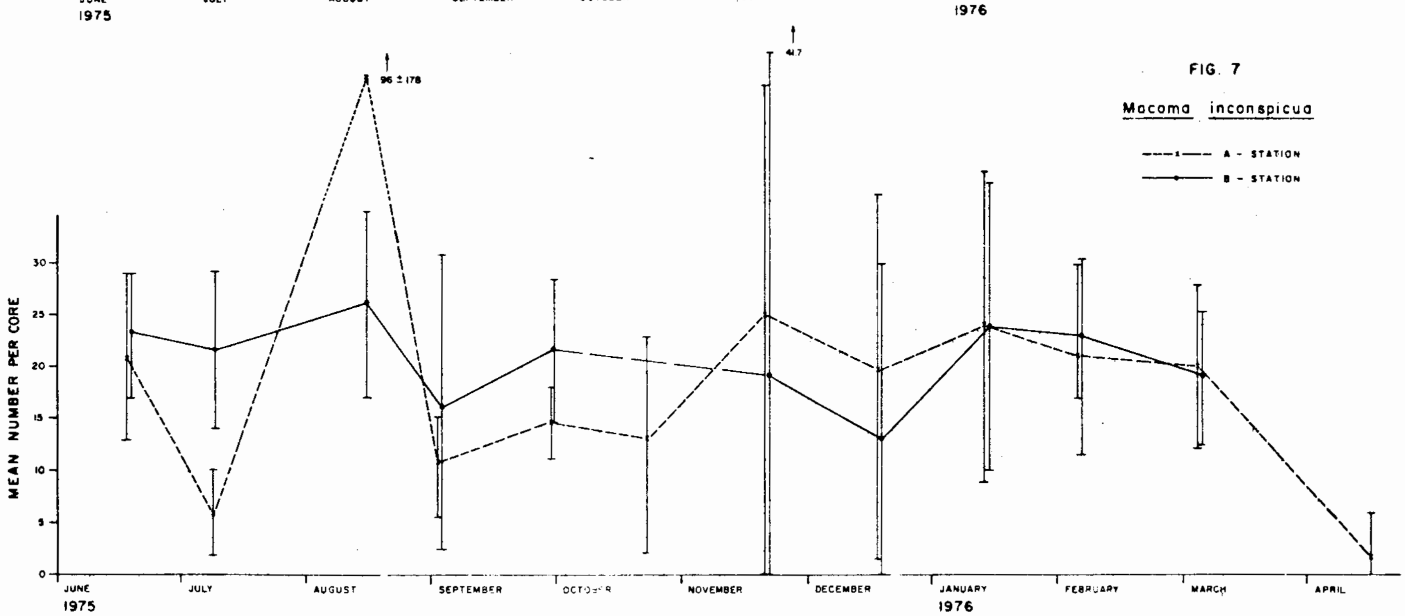


FIG. 7

Macoma inconspicua



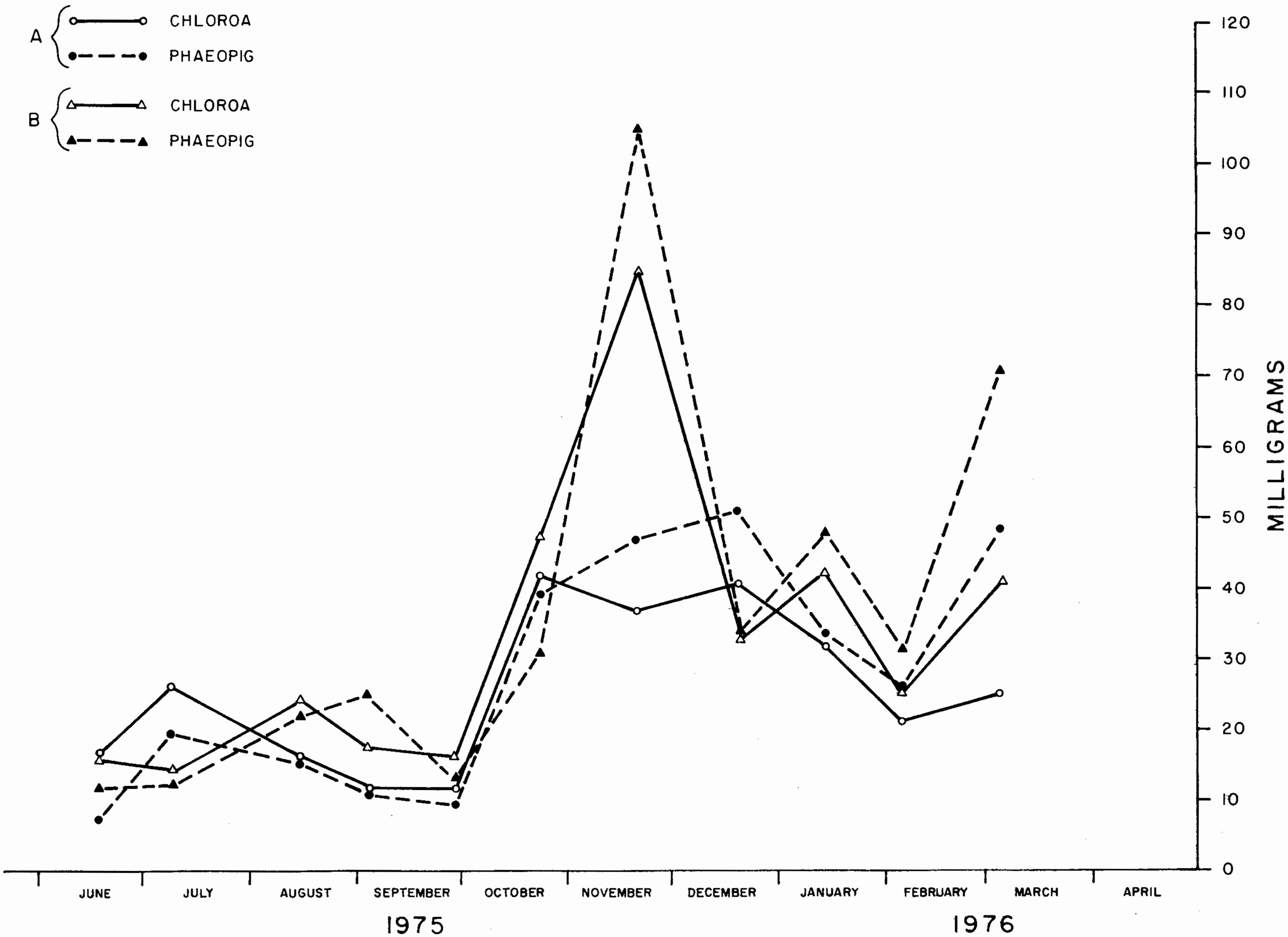


Fig. 8. Temporal change in concentrations of algal pigments (chlorophyll a, phaeopigment) at Station A and B. Mean values are shown.

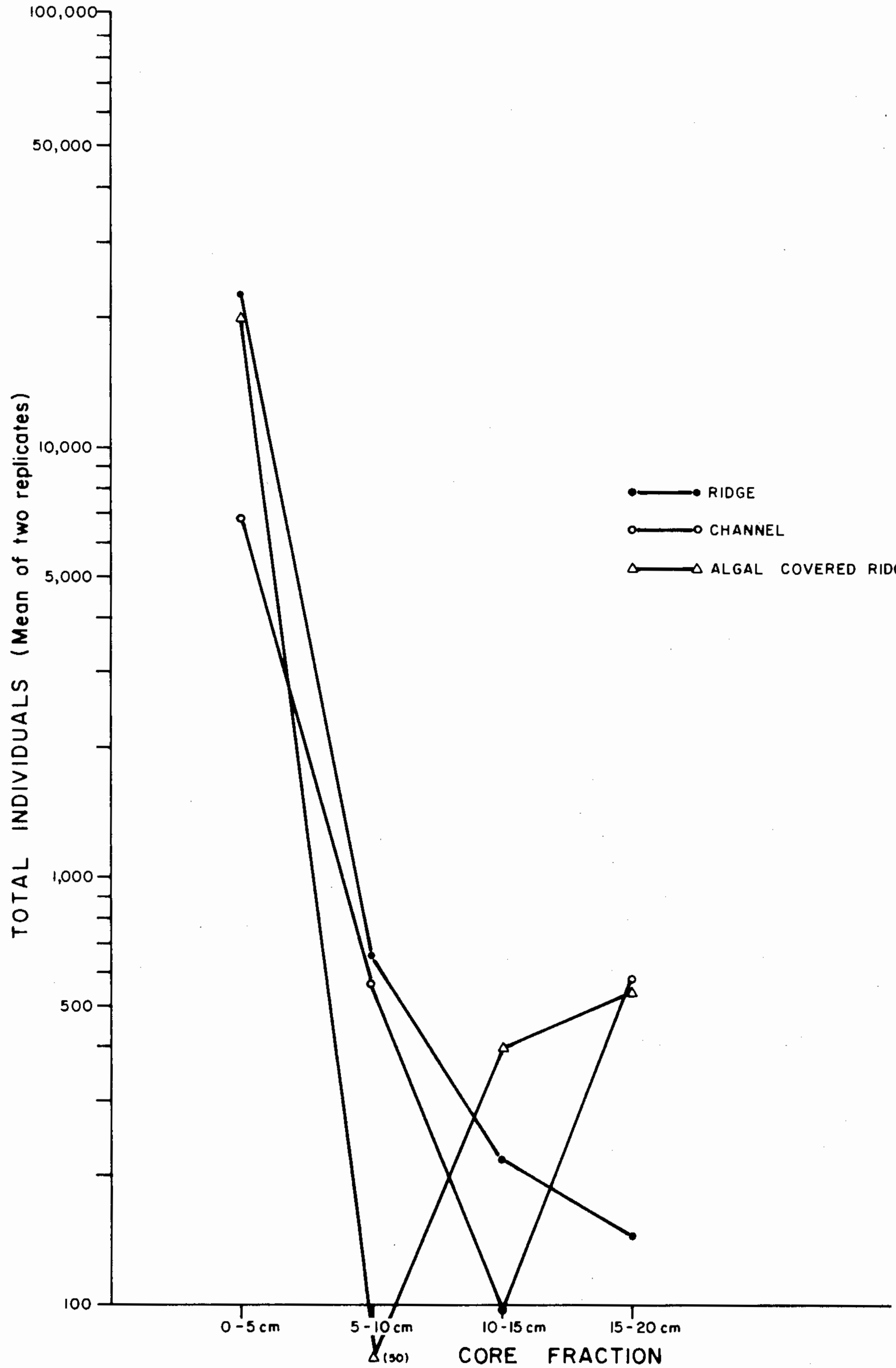


Fig. 9. Vertical distribution of organisms in cores (9800 cm^3) from ridges, channels, and algal-covered ridges. Mean number of individuals are shown for each level in the sediment.

Fig. 10. Photograph of the backhoe used for trenching in the upper intertidal sectors. Photo obtained March 30, 1976.

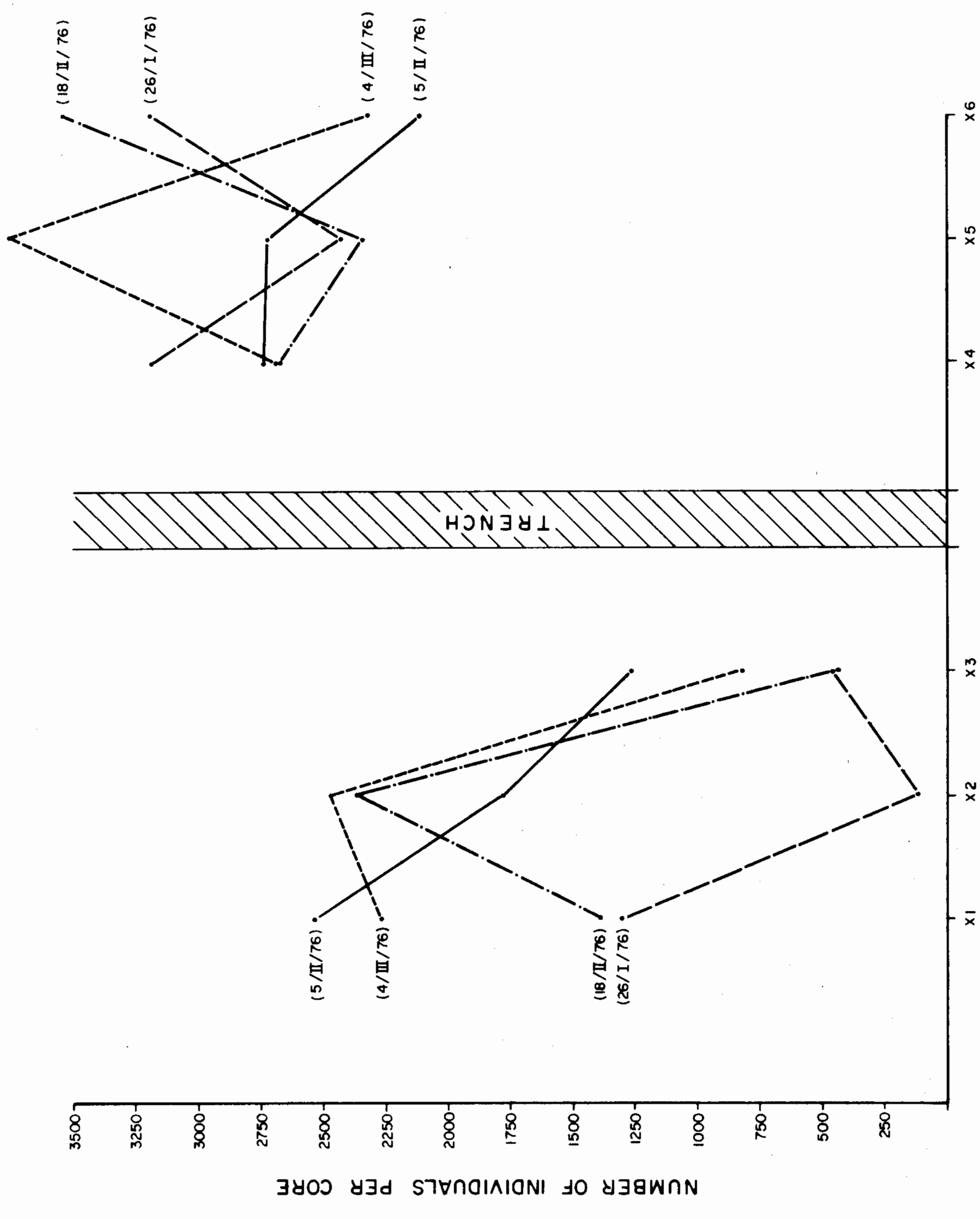


Fig. 11. Differences in abundance of organisms on transect X where hydraulic ditching occurred. Data from the west side of the trench (X1 to X3) are compared to those on the east (X4 to X6). Abundance data are number of individuals per core (283 cm^3).

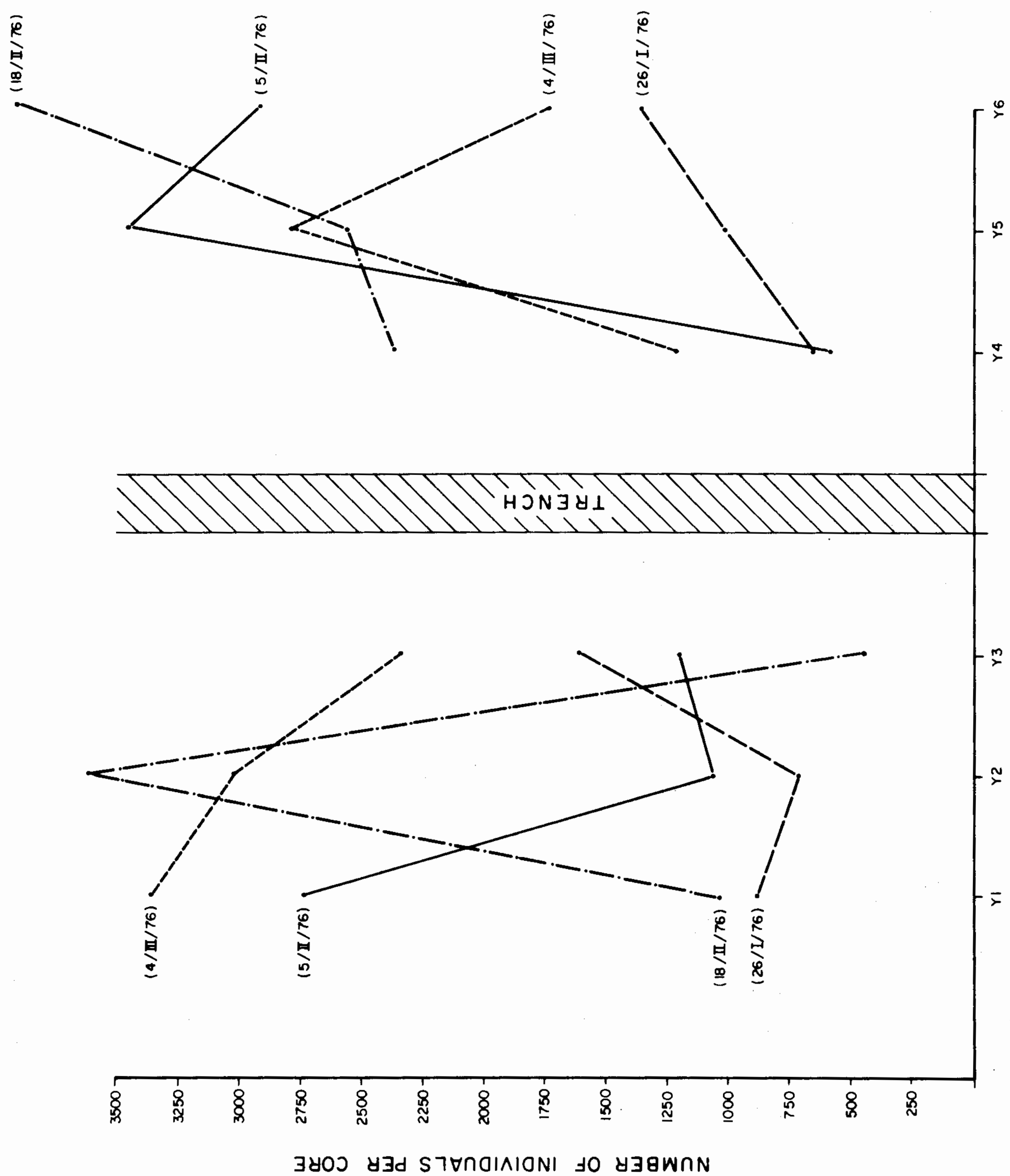


Fig. 12. Differences in abundance of organisms on transect Y where hydraulic ditching occurred. Data from the west side of the trench (Y1 to Y3) are compared to those on the east (Y4 to Y6). Abundance data are number of individuals per core (283 cm^3).

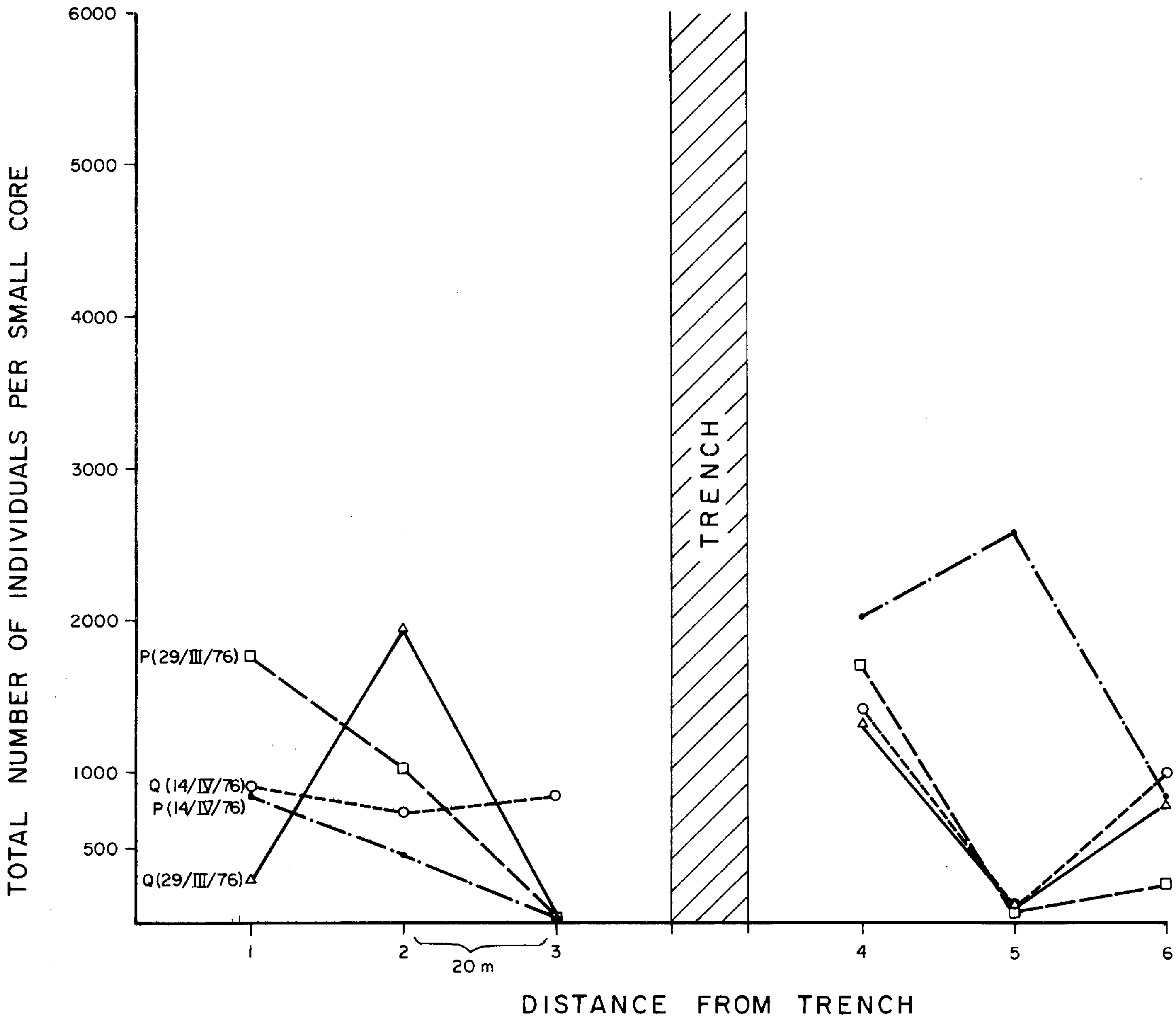


Fig. 13. Differences in abundance of organisms on transect P and Q, where backhoe ditching occurred. Data from the north side of the trench (1 to 3) are compared to those on the south (4 to 6). Abundance data are number of individuals per core 283 cm^3).

Appendix Table 1. Sampling for temporal change at Stations A and B. All data from entire core samples (9820 cm^3), except those labelled AT or BT (15/VIII/75) where upper 3 cm of cores were examined.

SPECIES	A1	A2	A3	A4	A5	18VI75
MACOMA BALTHICA	28	28	16	11	28	
~~OLIGOCHAETA~~	~~0~~	~~22~~	~~0~~	~~0~~	~~0~~	
AMPHICTEIS	32	72	16	0	32	
HETEROMASTUS	0	10	0	0	0	
MANAYUNKIA	978	992	816	1856	1744	
TANAIS	2096	1928	384	288	1968	
C INSIDIOSUM	192	344	112	128	160	
~~C ASCHERUSICUM~~	~~0~~	~~8~~	~~0~~	~~0~~	~~0~~	
GOLFINGIA	0	0	0	0	80	

SPECIES	B1	B2	B3	B4	B5	18VI75
MACOMA BALTHICA	25	23	14	23	31	
MYA	2	1	0	0	1	
VENERUPIS	0	0	0	0	1	
~~OLIGOCHAETA~~	~~16~~	~~0~~	~~0~~	~~0~~	~~0~~	
AMPHICTEIS	32	0	32	80	48	
MANAYUNKIA	464	1664	640	1216	3360	
TANAIS	1984	2240	1120	552	1040	
AMPITHOE	48	0	0	8	0	
C INSIDIOSUM	192	608	112	112	80	
~~C ASCHERUSICUM~~	~~16~~	~~0~~	~~0~~	~~0~~	~~0~~	
GOLFINGIA	0	0	32	8	0	

SPECIES	A1	A2	A3	A4	A5	8VII75
MACOMA BALTHICA	3	10	1	10	8	
OLIGOCHAETA	156	761	44	10	8	
OLIGOCHAETA	156	761	224	806	537	
~~AMPHICTEIS~~	~~0~~	~~0~~	~~0~~	~~0~~	~~32~~	
HETEROMASTUS	67	326	96	346	230	
MANAYUNKIA	4640	12288	5600	8896	3776	
PYGOSPIO	0	64	160	448	96	
EULALIA	0	0	0	0	1	
TANAIS	288	1536	256	1408	416	
~~AMPITHOE~~	~~0~~	~~192~~	~~0~~	~~0~~	~~0~~	
C INSIDIOSUM	0	128	0	196	128	
GOLFINGIA	0	0	0	0	32	
DOLICHOPODIDAE B	160	0	64	64	0	
TIPULIDAE	32	0	0	0	0	

Appendix Table 1 (continued

SPECIES	B1	B2	B3	B4	B5	[illegible]VII7[illegible]
MACOMA BALTHICA	22	29	24	9	23	
PROTOTHACA	0	0	0	0	1	
OLIGOCHAETA	716	1265	1568	313	179	
AMPHICTEIS	64	128	256	64	128	
HETEROMASTUS	307	518	672	134	77	
MANAYUNKIA	6208	9664	12486	11520	7488	
PYGOSPIO	576	1280	704	384	64	
TANAIS	3264	3648	2624	1408	1280	
AMPITHOE	0	64	64	0	256	
C INSIDIOSUM	384	1152	384	576	640	
GOLFINGIA	192	256	0	0	196	

SPECIES	A1	A2	A3	A4	A5	15VIII75
MACOMA BALTHICA	9	23	416	11	23	
MYA	0	1	0	0	0	
OLIGOCHAETA	2374	1232	1036	448	806	
AMPHICTEIS	384	352	192	160	192	
HETEROMASTUS	1018	528	441	192	346	
ETEONE	64	0	0	64	0	
MANAYUNKIA	4800	1696	4736	1440	4252	
PYGOSPIO	448	352	640	256	320	
TANAIS	2048	1472	2624	448	1472	
C INSIDIOSUM	128	960	320	896	768	
GOLFINGIA	0	64	128	96	64	

SPECIES	B1	B2	B3	B4	B5	15VIII75
MACOMA BALTHICA	14	26	36	21	33	
MYA	0	1	0	0	0	
VENERUPIS	0	0	0	1	0	
OLIGOCHAETA	941	1702	2777	2464	719	
AMPHICTEIS	224	128	64	192	128	
HETEROMASTUS	403	729	1190	1056	307	
MANAYUNKIA	3904	7168	10752	13120	5376	
PYGOSPIO	416	576	1600	576	192	
TANAIS	928	3328	5184	5056	2048	
AMPITHOE	0	128	64	0	0	
C INSIDIOSUM	928	480	704	1218	448	
GOLFINGIA	32	64	448	128	0	

SPECIES	AT1	AT2	AT3	AT4	AT5	15VIII75
MACOMA BALTHICA	16	20	10	23	16	
OLIGOCHAETA	3237	2890	761	1500	4592	
AMPHICTEIS	1728	352	192	64	160	
HETEROMASTUS	1387	1238	327	643	1968	
ETEONE	0	64	0	0	0	
MANAYUNKIA	5600	7264	1408	4064	6880	
PYGOSPIO	0	1856	1344	2304	1120	
TANAIS	1586	1632	1056	736	2624	
AMPITHOE	16	0	32	0	0	
C INSIDIOSUM	640	804	1440	608	224	
GOLFINGIA	0	0	192	64	160	

SPECIES	BT1	BT2	BT3	BT4	BT5	15VIII75
MYTILUS	0	0	1	1	0	
MACOMA BALTHICA	9	17	26	36	27	
OLIGOCHAETA	649	2061	3338	5062	3853	
AMPHICTEIS	96	64	352	224	256	
HETEROMASTUS	276	883	1430	2170	1651	
MANAYUNKIA	3488	11456	12352	12896	14272	
PYGOSPIO	992	928	2464	2656	2048	
TANAIS	416	1632	3424	3269	4320	
GNORIMOSPHAEROMA	0	32	0	0	0	
AMPITHOE	0	32	32	96	64	
C INSIDIOSUM	704	896	1696	1056	1568	
GOLFINGIA	32	128	224	256	608	

Appendix Table 1 (continued

SPECIES	A1	A2	A3	A4	A5	29IX75
MACOMA BALTHICA	20	13	13	10	16	
MYA	1	1	0	0	0	
PROTOTHACA	0	0	1	0	0	
OLIGOCHAETA	1882	4973	2240	3853	1658	
AMPHICTEIS	320	128	384	0	64	
HETEROMASTUS	806	2131	960	1651	710	
MANAYUNKIA	8192	8128	2560	9088	5248	
PYGOSPIO	1024	960	1856	896	576	
NEREIS	0	0	0	2	0	
CUMELLA	0	64	0	0	0	
TANAIS	1408	1024	1280	1600	1856	
AMPITHOE	64	0	64	64	64	
C INSIDIOSUM	1152	0	1408	192	64	
GOLFINGIA	640	704	704	192	640	

SPECIES	B1	B2	B3	B4	B5	29IX75
MYTILUS	0	0	0	1	0	
MACOMA BALTHICA	16	16	24	31	21	
MYA	0	0	1	0	1	
PROTOTHACA	0	1	0	0	0	
OLIGOCHAETA	2150	3584	3181	2419	3494	
AMPHICTEIS	256	256	384	320	384	
HETEROMASTUS	922	1536	1363	1037	1498	
MANAYUNKIA	3712	11520	7552	13120	12416	
PYGOSPIO	1152	1792	896	1792	1152	
TANAIS	960	2880	2176	1664	2944	
C INSIDIOSUM	1344	448	128	1472	512	
GOLFINGIA	448	320	256	704	448	

SPECIES	A1	A2	A3	A4	A5	23X75
MACOMA BALTHICA	14	20	25	5	1	
MYA	1	1	0	0	0	
OLIGOCHAETA	918	1702	3091	4413	1882	
AMPHICTEIS	96	160	128	128	0	
HETEROMASTUS	394	729	1325	1891	806	
ETEONE	0	0	0	96	0	
MANAYUNKIA	3200	2976	11776	8288	8896	
PYGOSPIO	192	544	1728	448	384	
TANAIS	960	1120	2368	1344	2112	
AMPITHOE	0	32	64	0	0	
C INSIDIOSUM	480	736	1216	96	384	
GOLFINGIA	32	160	768	224	512	

Appendix Table 1 (continued)

SPECIES	B1	B2	B3	B4	B5	23X75
~~OLIGOCHAETA~~	~~1658~~	~~4659~~	~~4166~~	~~5760~~	~~4480~~	
AMPHICTEIS	0	256	128	192	0	
HETEROMASTUS	710	1997	1786	8064	1920	
ETEONE	0	0	0	96	0	
MANAYUNKIA	4544	14720	11520	18720	12096	
PYGOSPIO	320	1536	448	768	64	
~~POLYDORA~~	~~0~~	~~0~~	~~0~~	~~0~~	~~64~~	
HARPACTICOIDA	0	0	128	0	0	
CUMELLA	64	0	0	0	0	
TANAIS	384	768	448	3744	3200	
AMPITHOE	0	64	64	192	64	
C INSIDIOSUM	192	0	256	192	256	
~~GOLFINGIA~~	~~128~~	~~512~~	~~192~~	~~0~~	~~0~~	

~~SPECIES~~	~~A1~~	~~A2~~	~~A3~~	~~A4~~	~~A5~~	~~20XI75~~
MACOMA BALTHICA	0	32	64	0	0	
OLIGOCHAETA	2432	1536	2048	4288	3712	
AMPHICTEIS	256	320	384	480	32	
HETEROMASTUS	1056	672	864	1856	1600	
~~ETEONE~~	~~0~~	~~0~~	~~32~~	~~0~~	~~64~~	
MANAYUNKIA	11488	3808	6496	12704	10784	
PYGOSPIO	576	480	864	640	512	
POLYDORA	32	32	128	256	96	
CUMELLA	32	64	0	0	32	
TANAIS	2112	832	1728	2656	2912	
~~AMPITHOE~~	~~0~~	~~64~~	~~0~~	~~0~~	~~0~~	
C INSIDIOSUM	288	608	1312	416	224	
GOLFINGIA	192	608	416	128	288	

SPECIES	B1	B2	B3	B4	B5	20XI75
MACOMA BALTHICA	0	32	0	0	96	
OLIGOCHAETA	2688	4726	1824	1952	2240	
~~AMPHICTEIS~~	~~224~~	~~32~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	
HETEROMASTUS	1152	2048	800	832	[illegible]	
ETEONE	0	32	0	32	0	
MANAYUNKIA	4672	5248	6688	8032	8032	
PYGOSPIO	640	736	672	640	352	
POLYDORA	96	128	288	128	96	
~~CUMELLA~~	~~32~~	~~0~~	~~64~~	~~0~~	~~32~~	
TANAIS	384	1344	1760	1024	1728	
AMPITHOE	0	0	64	32	32	
C INSIDIOSUM	288	416	608	416	544	
GOLFINGIA	160	64	288	96	160	

Appendix Table 1 (continued)

SPECIES	A1	A2	A3	A4	A5	18XII75
MACOMA BALTHICA	32	0	0	32	32	
OLIGOCHAETA	1344	736	576	512	1216	
AMPHICTEIS	256	288	112	32	64	
HETEROMASTUS	576	352	240	224	480	
ETEONE	64	32	16	0	0	
MANAYUNKIA	4192	2464	2912	2592	5440	
PYGOSPIO	416	480	192	0	0	
POLYDORA	192	160	0	0	0	
TANAIS	832	384	400	512	1152	
AMPITHOE	0	0	0	32	0	
C INSIDIOSUM	160	128	48	160	64	
GOLFINGIA	32	64	80	0	96	

SPECIES	B1	B2	B3	B4	B5	18XII75
MACOMA BALTHICA	0	32	0	0	32	
OLIGOCHAETA	1440	1120	864	1440	571	
AMPHICTEIS	96	128	32	32	32	
HETEROMASTUS	480	224	448	480	245	
MANAYUNKIA	3520	5280	2720	5184	3568	
PYGOSPIO	224	160	160	256	272	
POLYDORA	0	64	0	64	0	
NEREIS	0	0	1	0	0	
TANAIS	1088	1344	512	384	1264	
AMPITHOE	0	32	0	0	16	
C INSIDIOSUM	128	96	0	64	48	
GOLFINGIA	64	0	64	0	48	
CHIRONOMIDAE A	0	0	0	32	0	

SPECIES	A1	A2	A3	A4	A5	13I76
MACOMA BALTHICA	41	26	26	0	29	
OLIGOCHAETA	1685	1482	2201	600	1205	
AMPHICTEIS	493	26	236	60	118	
HETEROMASTUS	699	624	1153	390	500	
ETEONE	41	0	0	30	29	
MANAYUNKIA	7645	4056	11213	4080	4851	
PYGOSPIO	945	312	131	300	59	
NEREIS	164	52	157	0	176	
TANAIS	2384	676	681	900	823	
ANISOGAMMARUS	41	0	0	0	0	
AMPITHOE	0	0	0	0	29	
C INSIDIOSUM	0	26	26	60	29	
GOLFINGIA	0	52	26	60	0	

Appendix Table 1 (continued)

SPECIES	B1	B2	B3	B4	B5	13I76
MACOMA BALTHICA	25	30	31	35	0	
OLIGOCHAETA	2207	1054	1136	2372	2848	
AMPHICTEIS	74	90	62	70	128	
HETEROMASTUS	942	452	491	1027	1216	
ETEONE	50	30	31	70	32	
MANAYUNKIA	14458	9391	8535	10089	6880	
PYGOSPIO	546	331	338	283	448	
POLYDORA	99	90	123	106	96	
TANAIS	2455	1385	737	1274	1888	
ANISOGAMMARUS	25	0	0	0	32	
C INSIDIOSUM	50	0	31	70	32	
GOLFINGIA	149	30	0	35	96	

SPECIES	A1	A2	A3	A4	A5	6II76
MACOMA BALTHICA	28	14	24	21	30	
MYA	3	0	0	1	1	
VENERUPIS	0	0	1	0	1	
OLIGOCHAETA	896	1030	3763	269	1702	
AMPHICTEIS	192	64	192	64	128	
HETEROMASTUS	384	442	806	115	730	
ETEONE	64	128	0	0	0	
MANAYUNKIA	18880	20480	13760	11008	17280	
PYGOSPIO	512	448	128	256	512	
TANAIS	1024	2240	1280	1408	2304	
AMPITHOE	0	128	0	0	0	
C INSIDIOSUM	384	128	0	64	256	

SPECIES	B1	B2	B3	B4	B5	6II76
MACOMA BALTHICA	7	26	15	25	34	
MYA	0	0	1	0	0	
OLIGOCHAETA	1613	1344	2957	3584	1568	
AMPHICTEIS	0	192	0	64	0	
HETEROMASTUS	691	576	1267	1536	672	
ETEONE	0	0	0	64	672	
MANAYUNKIA	8320	18944	25152	26944	3392	
PYGOSPIO	384	256	512	256	256	
TANAIS	896	2304	1728	1600	1536	
C INSIDIOSUM	256	0	0	256	64	
GOLFINGIA	0	128	128	128	0	

Appendix Table 1 (continued)

SPECIES	A1	A2	A3	A4	A5	4III76
MACOMA BALTHICA	16	12	29	14	27	
MYA	0	0	1	0	0	
OLIGOCHAETA	347	123	246	213	78	
AMPHICTEIS	80	16	96	128	32	
HETEROMASTUS	149	53	106	91	34	
ETEONE	16	8	32	48	64	
MANAYUNKIA	3264	3736	9856	6144	2880	
PYGOSPIO	0	16	0	32	0	
TANAIS	608	200	1728	736	272	
AMPITHOE	0	0	0	32	0	
C INSIDIOSUM	16	16	32	0	48	
GOLFINGIA	0	0	0	16	0	

SPECIES	B1	B2	B3	B4	B5	4III76
MACOMA BALTHICA	16	17	32	16	20	
MYA	0	0	0	0	1	
PROTOTHACA	0	0	0	0	1	
OLIGOCHAETA	403	179	515	616	336	
AMPHICTEIS	96	112	128	80	0	
HETEROMASTUS	173	79	221	264	144	
ETEONE	32	16	48	32	64	
MANAYUNKIA	7296	3392	6032	5136	11264	
PYGOSPIO	0	0	32	16	0	
CUMELLA	32	32	46	0	32	
TANAIS	192	368	78	528	896	
C INSIDIOSUM	0	208	64	32	124	
GOLFINGIA	0	0	0	32	0	

SPECIES	B1	B2	B3	B4	14IV76
MACOMA BALTHICA	0	0	8	0	
OLIGOCHAETA	136	12	118	160	
AMPHICTEIS	0	0	16	8	
HETEROMASTUS	16	0	40	24	
ETEONE	8	0	0	0	
MANAYUNKIA	1080	488	1456	2032	
PYGOSPIO	24	0	64	0	
TANAIS	56	16	48	72	
COROPHIUM SALM	0	0	16	0	
C INSIDIOSUM	16	0	16	0	

Appendix Table 2. Results of post-ditching sampling at transects X and Y (hydraulic ditching). Data are number of individuals per small core (1134 cm^3)

26I76

SPECIES	X1A	X2A	X3A	X4A	X5A	X6A
MACOMA BALTHICA	3	0	2	0	2	2
OLIGOCHAETA	90	17	35	280	140	185
AMPHICTEIS	12	0	12	80	40	8
HETEROMASTUS	38	7	15	120	60	79
MANAYUNKIA	992	64	214	2000	1608	2400
PYGOSPIO	52	16	122	192	96	120
CUMELLA	4	0	8	0	0	0
TANAIS	116	0	22	504	392	256
C INSIDIOSUM	4	4	16	0	8	56
GOLFINGIA	0	4	6	0	32	56
CHIRONOMIDAE A	0	0	0	0	0	8

26I76

SPECIES	Y1A	Y2A	Y3A	Y4A	Y5A	Y6A
MACOMA BALTHICA	1	0	2	1	12	3
OLIGOCHAETA	26	16	62	32	118	73
AMPHICTEIS	6	3	0	4	4	32
HETEROMASTUS	12	7	16	14	50	31
ETEONE	4	6	6	4	12	32
MANAYUNKIA	692	637	1510	540	700	984
PYGOSPIO	98	14	8	34	76	104
NEREIS	0	1	0	0	0	0
TANAIS	16	29	6	22	24	76
C INSIDIOSUM	18	0	6	0	12	28
GOLFINGIA	6	0	0	0	0	0

5I176

SPECIES	X1A	X2A	X3A	X4A	X5A	X6A
MACOMA BALTHICA	2	1	0	5	5	2
PROTOTHACA	1	0	0	0	0	0
OLIGOCHAETA	240	45	120	173	285	129
AMPHICTEIS	16	8	16	16	24	48
HETEROMASTUS	103	19	52	75	123	55
ETEONE	0	0	8	0	16	8
MANAYUNKIA	2032	1544	864	1984	2008	1720
PYGOSPIO	16	24	108	44	112	96
HARPACTICOIDA	0	0	0	0	0	8
TANAIS	112	128	72	440	160	72
AMPITHOE	8	0	0	0	0	0
C INSIDIOSUM	8	4	0	4	0	0
GOLFINGIA	0	0	12	0	0	0

5I176

SPECIES	Y1A	Y2A	Y3A	Y4A	Y5A	Y6A
MACOMA BALTHICA	6	5	0	6	1	2
OLIGOCHAETA	123	157	0	25	252	2
AMPHICTEIS	40	0	0	8	8	0
HETEROMASTUS	53	67	0	11	108	31
ETEONE	0	8	0	4	0	0
MANAYUNKIA	2096	760	1200	480	2912	2640
PYGOSPIO	120	8	0	24	24	64
TANAIS	24	56	0	20	152	96
C INSIDIOSUM	0	0	0	0	0	16
CHIRONOMIDAE A	0	0	0	0	8	0

Appendix Table 2 (continued)

SPECIES	X1A	X2A	1 11 7 X3A	X4A	X5A	X6A
MACOMA BALTHICA	2	2	3	1	3	6
OLIGOCHAETA	64	16	16	0	304	160
AMPHICTEIS	32	0	0	0	0	0
HETEROMASTUS	0	0	0	0	48	0
ETEONE	0	0	8	0	0	0
MANAYUNKIA	2336	3776	420	2394	2160	2736
HARPACTICOIDA	0	16	0	0	0	0
TANAIS	32	96	8	102	480	256
C INSIDIOSUM	0	0	4	0	0	0

SPECIES	X1B	X2B	18II76 X3B	X4B	X5B	X6B
MACOMA BALTHICA	0	1	0	1	2	3
OLIGOCHAETA	64	4	12	32	208	240
AMPHICTEIS	0	0	0	0	0	16
HETEROMASTUS	32	0	4	11	16	32
MANAYUNKIA	3104	772	396	2736	1520	3392
HARPACTICOIDA	0	4	0	0	0	0
TANAIS	86	44	16	112	112	171
C INSIDIOSUM	0	0	0	0	0	32

SPECIES	Y1A	Y2A	13II76 Y3A	Y4A	Y5A	Y6A
MACOMA BALTHICA	8	0	0	3	0	0
OLIGOCHAETA	88	0	6	384	8	0
AMPHICTEIS	0	0	4	8	0	0
HETEROMASTUS	0	0	128	12	32	0
ETEONE	8	0	8	16	0	0
MANAYUNKIA	1024	0	300	3312	1192	5104
NEREIS	0	0	1	0	0	0
HARPACTICOIDA	0	0	0	8	0	0
TANAIS	8	0	2	16	24	24
COROPHIUM SALM	0	0	0	0	8	0
C INSIDIOSUM	0	0	0	0	4	0
COROPHIUM SPP	16	0	0	0	0	0

18II76

SPECIES	Y1B	Y2B	Y3B	Y4B	Y5B	Y6B
MACOMA BALTHICA	0	0	0	6	1	3
OLIGOCHAETA	60	24	2	24	32	160
HETEROMASTUS	24	16	0	0	0	48
ETEONE	8	8	0	8	0	0
MANAYUNKIA	812	3584	306	928	3776	3712
NEREIS	4	0	0	0	0	0
TANAIS	4	72	2	16	32	48
COROPHIUM SALM	4	0	4	0	0	0

Appendix Table 2 (continued)

SPECIES	X1A	X2A	X3A	X4A	X5A	X6A
			4III76			
MACOMA BALTHICA	1	2	7	5	4	19
OLIGOCHAETA	128	192	51	128	224	80
AMPHICTEIS	104	32	6	48	16	24
HETEROMASTUS	56	112	6	32	144	32
ETEONE	16	0	0	0	16	0
MANAYUNKIA	1656	1712	570	2064	2000	1016
CUMELLA	0	16	0	16	0	0
TANAIS	136	400	96	304	224	88
COROPHIUM SALM	0	0	6	0	0	8
C INSIDIOSUM	0	0	0	64	16	16

SPECIES	X1B	X2B	X3B	X4B	X5B	X6B
			4III76			
MACOMA BALTHICA	17	2	3	9	2	2
OLIGOCHAETA	112	48	64	224	324	146
AMPHICTEIS	80	16	8	80	88	84
HETEROMASTUS	48	48	32	48	256	167
ETEONE	0	0	0	16	0	0
MANAYUNKIA	1792	2048	676	2032	4186	2656
CUMELLA	0	0	0	0	0	21
TANAIS	384	304	168	240	398	251
COROPHIUM SALM	0	0	3	0	60	2
C INSIDIOSUM	0	0	5	32	15	0

SPECIES	Y1A	Y2A	Y3A	Y4A	Y5A	Y6A
			4III76			
MACOMA BALTHICA	0	9	0	5	1	7
OLIGOCHAETA	6	18	0	47	8	151
AMPHICTEIS	0	0	0	16	0	0
HETEROMASTUS	0	0	20	47	0	151
ETEONE	0	0	0	8	0	0
MANAYUNKIA	4397	2568	1294	1253	2172	2767
CUMELLA	0	0	0	8	0	13
TANAIS	13	18	7	24	45	277
COROPHIUM SALM	0	0	0	8	0	13

SPECIES	Y1B	Y2B	Y3B	Y4B	Y5B	Y6B
			4III76			
MACOMA BALTHICA	0	0	0	9	0	0
OLIGOCHAETA	8	0	0	120	0	51
AMPHICTEIS	0	0	0	30	0	0
HETEROMASTUS	0	0	0	37	23	16
ETEONE	0	0	0	15	12	0
MANAYUNKIA	2299	3415	3347	802	3267	0
CUMELLA	0	0	0	7	0	0
TANAIS	24	8	16	52	58	30

Appendix Table 3. Results of post-ditching sampling at transects P and Q (backhoe operation). Data are number of individuals per small core (1134 cm^3)

29III76

SPECIES	P1A	P2A	P3A	P4A	P5A	P6A
MACOMA BALTHICA	1	0	0	1	0	0
OLIGOCHAETA	165	149	1	361	17	23
~~AMPHICTEIS~~	~~33~~	~~42~~	~~0~~	~~34~~	~~5~~	~~6~~
HETEROMASTUS	0	99	0	79	14	16
ETEONE	0	0	0	2	2	1
MANAYUNKIA	1134	1219	4	1556	72	218
PYGOSPIO	0	0	0	22	0	0
CUMELLA	0	7	0	0	0	0
~~TANAIS~~	~~116~~	~~71~~	~~1~~	~~116~~	~~14~~	~~17~~
COROPHIUM SALM	0	0	0	0	0	15
C INSIDIOSUM	16	0	0	0	0	2

29III76

SPECIES	P1B	P2B	P3B	P4B	P5B	P6B
MACOMA BALTHICA	2	0	1	3	0	0
OLIGOCHAETA	66	24	0	181	3	13
~~AMPHICTEIS~~	~~38~~	~~14~~	~~0~~	~~59~~	~~0~~	~~10~~
HETEROMASTUS	85	16	0	54	0	4
ETEONE	0	0	0	0	0	1
MANAYUNKIA	1590	319	4	805	31	168
PYGOSPIO	9	0	0	0	0	16
CUMELLA	0	2	1	0	0	0
~~TANAIS~~	~~66~~	~~20~~	~~0~~	~~39~~	~~2~~	~~24~~
COROPHIUM SALM	0	0	0	10	0	1
C ASCHERUSICUM	0	0	0	20	0	8

29III76

SPECIES	Q1A	Q2A	Q3A	Q4A	Q5A	Q6A
MYTILUS	1	0	0	0	0	0
MACOMA BALTHICA	1	0	0	8	0	0
~~OLIGOCHAETA~~	~~27~~	~~247~~	~~4~~	~~96~~	~~28~~	~~72~~
AMPHICTEIS	23	271	0	16	0	24
HETEROMASTUS	0	58	0	32	0	20
ETEONE	1	0	1	0	0	8
MANAYUNKIA	76	2285	9	1088	84	364
PYGOSPIO	0	24	0	56	4	24
~~CUMELLA~~	~~1~~	~~0~~	~~1~~	~~6~~	~~0~~	~~0~~
TANAIS	23	222	3	16	20	88
ANISOGAMMARUS	1	0	0	0	0	0
C INSIDIOSUM	13	8	0	0	0	2
COROPHIUM SPP	0	0	1	0	0	0

Appendix Table 3 (continued)

2[illegible]III76

SPECIES	Q1B	Q2B	Q3B	Q4B	Q5B	Q6B
~~OLIGOCHAETA~~	~~98~~	~~76~~	~~0~~	~~120~~	~~6~~	~~96~~
AMPHICTEIS	72	36	0	32	2	40
HETEROMASTUS	0	12	0	0	0	40
ETEONE	0	4	0	24	0	8
MANAYUNKIA	220	544	16	1032	34	552
PYGOSPIO	8	44	0	24	0	88
~~POLYDORA~~	~~0~~	~~0~~	~~0~~	~~0~~	~~32~~	~~88~~
TANAIS	40	28	0	88	4	32
COROPHIUM SALM	12	0	0	8	0	8
C INSIDIOSUM	0	4	0	0	0	0

14IV76

SPECIES	P1A	P2A	P3A	P4A	P5A	P6A
OLIGOCHAETA	56	8	32	128	260	184
~~AMPHICTEIS~~	~~40~~	~~16~~	~~0~~	~~72~~	~~20~~	~~32~~
HETEROMASTUS	0	24	0	56	100	40
ETEONE	8	0	0	0	0	8
MANAYUNKIA	432	200	56	2040	3600	416
PYGOSPIO	8	0	0	8	0	24
TANAIS	72	8	0	32	20	120
~~COROPHIUM SALM~~	~~8~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
C INSIDIOSUM	32	0	0	0	0	0

14IV76

SPECIES	P1B	P2B	P3B	P4B	P5B	P6B
MACOMA BALTHICA	0	0	0	0	0	4
OLIGOCHAETA	168	224	4	136	164	148
AMPHICTEIS	48	96	12	16	36	32
~~HETEROMASTUS~~	~~8~~	~~48~~	~~0~~	~~0~~	~~8~~	~~16~~
ETEONE	0	0	0	0	8	0
MANAYUNKIA	576	240	48	1504	508	384
PYGOSPIO	48	0	0	0	4	36
POLYDORA	0	0	0	0	0	8
CUMELLA	0	0	0	0	0	4
~~TANAIS~~	~~56~~	~~0~~	~~0~~	~~8~~	~~0~~	~~72~~
C INSIDIOSUM	0	0	0	0	0	12

Appendix Table 3 (continued)

	14IV76					
SPECIES	Q1A	Q2A	Q3A	Q4A	Q5A	Q6A
OLIGOCHAETA	60	40	112	8	0	28
AMPHICTEIS	4	8	16	8	0	28
HETEROMASTUS	8	4	48	0	0	0
MANAYUNKIA	712	80	688	1072	12	1060
PYGOSPIO	0	4	0	0	0	4
TANAIS	4	20	16	160	20	96
C INSIDIOSUM	0	0	0	8	4	96

	14IV76					
SPECIES	Q1B	Q2B	Q3B	Q4B	Q5B	Q6B
OLIGOCHAETA	136	152	80	46	0	16
~~AMPHICTEIS~~	~~0~~	~~88~~	~~0~~	~~0~~	~~0~~	~~1~~
HETEROMASTUS	4	40	0	16	0	0
MANAYUNKIA	812	960	608	1304	16	620
PYGOSPIO	0	16	0	0	0	0
CUMELLA	0	0	0	8	0	0
TANAIS	0	48	40	48	12	64
C INSIDIOSUM	0	16	0	0	0	0
CHIRONOMIDAE A	4	0	0	0	0	0
DOLICHOPODIDAE B	4	0	0	0	0	0

Appendix Table 4. Results of sampling to investigate vertical distribution of organisms in sediments. Samples were obtained at Station A and B, then fractioned horizontally at 5 cm intervals. The surface area of the cove was 491 cm^2.

SPECIES	A1(5)	A2(5)	A3(5)	A4(5)	A5(5)	31X75
MACOMA BALTHICA	16	5	10	18	11	
OLIGOCHAETA	2822	3718	1792	3584	2374	
AMPHICTEIS	128	192	256	256	64	
HETEROMASTUS	1209	1594	768	1536	1018	
MANAYUNKIA	7806	13952	6784	6912	6720	
PYGOSPIO	960	1152	1024	1344	704	
TANAIS	1920	2368	1344	3712	1024	
AMPITHOE	0	128	0	128	0	
C INSIDIOSUM	704	192	128	128	64	
GOLFINGIA	384	320	256	576	256	

SPECIES	A1(10)	A2(10)	A3(10)	A4(10)	A5(10)	31X75
MACOMA BALTHICA	1	0	2	3	0	
OLIGOCHAETA	0	0	0	64	0	
HETEROMASTUS	0	0	0	17	0	
ETEONE	0	0	1	0	0	
MANAYUNKIA	32	32	224	256	32	
PYGOSPIO	0	32	96	0	0	
NEREIS	0	0	1	0	0	
GLYCINDE	0	0	1	0	0	
TANAIS	64	64	288	32	32	
C INSIDIOSUM	0	0	64	32	32	
GOLFINGIA	32	64	64	32	0	

SPECIES	A1(15)	A2(15)	A3(15)	A4(15)	A5(15)	31X75
MACOMA BALTHICA	0	0	0	0	32	
OLIGOCHAETA	45	22	22	0	0	
HETEROMASTUS	19	10	10	0	0	
MANAYUNKIA	288	32	352	64	160	
PYGOSPIO	0	0	128	0	0	
TANAIS	0	32	32	32	32	
C INSIDIOSUM	0	32	32	64	32	

SPECIES	A1(20)	A2(20)	A3(20)	A4(20)	A5(20)	31X75
MYA	3	0	0	0	0	
OLIGOCHAETA	45	112	45	112	22	
AMPHICTEIS	0	0	0	32	0	
HETEROMASTUS	19	48	9	48	10	
MANAYUNKIA	256	448	64	736	64	
PYGOSPIO	0	0	0	64	16	
TANAIS	32	224	64	64	512	
C INSIDIOSUM	0	32	0	32	32	

Appendix Table 4 (continued)

SPECIES	B1(5)	B2(5)	B3(5)	B4(5)	B5(5)	3IX75
MACOMA BALTHICA	21	21	21	36	2	
OLIGOCHAETA	3136	2195	3002	672	269	
AMPHICTEIS	64	384	128	256	0	
HETEROMASTUS	1344	941	1288	288	115	
MANAYUNKIA	6784	4800	32	3520	960	
PYGOSPIO	832	2176	1536	640	448	
EULALIA	0	0	0	0	64	
TANAIS	1216	2304	1856	384	192	
AMPITHOE	0	0	0	0	64	
C INSIDIOSUM	128	448	128	1152	384	
GOLFINGIA	192	64	192	1088	128	

SPECIES	B1(10)	B2(10)	B3(10)	B4(10)	B5(10)	3IX75
MACOMA BALTHICA	0	0	0	1	0	
OLIGOCHAETA	134	0	134	403	0	
HETEROMASTUS	58	0	10	172	0	
MANAYUNKIA	160	96	32	192	0	
PYGOSPIO	32	0	0	0	0	
TANAIS	160	32	64	32	64	
C INSIDIOSUM	0	0	0	96	32	

SPECIES	B1(15)	B2(15)	B3(15)	B4(15)	B5(15)	3IX75
OLIGOCHAETA	32	32	32	32	0	
MANAYUNKIA	64	96	256	224	32	
PYGOSPIO	0	32	0	32	0	
TANAIS	0	64	32	288	0	
C INSIDIOSUM	32	32	0	224	0	

SPECIES	B1(20)	B2(20)	B3(20)	B4(20)	B5(20)	3IX75
MACOMA BALTHICA	0	0	2	4	0	
MYA	0	1	1	0	0	
OLIGOCHAETA	45	32	0	112	0	
HETEROMASTUS	19	0	0	48	0	
MANAYUNKIA	352	160	256	192	96	
TANAIS	160	32	64	96	0	
C INSIDIOSUM	0	0	0	32	32	
GOLFINGIA	0	0	32	64	32	

TOP

Appendix Table 5. Results of investigations to determine differences in abundance between channels (prefix C), algae-covered ridges (prefix A), and algae-free ridges (prefix R). Samples were obtained with a small core (surface area = 57 cm^2), and horizontal fractions obtained at 5 cm intervals.

SPECIES	ZC1(5)	ZA1(5)	ZR1(5)	15X 75
MACOMA BALTHICA	23	0	32	
OLIGOCHAETA	560	5622	5645	
AMPHICTEIS	192	0	0	
HETEROMASTUS	240	2410	2419	
MANAYUNKIA	966	16256	24320	
PYGOSPIO	448	128	95	
HARPACTICOIDA	32	32	0	
TANAIS	64	192	352	
AMPITHOE	0	0	192	
C INSIDIOSUM	704	0	96	
GOLFINGIA	160	96	128	

SPECIES	ZC1/10	ZA1/10	ZR1/10	15 X75
OLIGOCHAETA	168	5	17	
HETEROMASTUS	72	3	7	
MANAYUNKIA	144	6	268	
NEREIS	0	1	0	
GLYCINDE	16	0	0	
TANAIS	48	0	72	
AMPITHOE	0	0	16	
C INSIDIOSUM	48	24	48	
GOLFINGIA	32	8	8	

SPECIES	ZC1/15	ZA1/15	ZR1/15	15 X75
OLIGOCHAETA	0	17	11	
AMPHICTEIS	5	6	8	
HETEROMASTUS	0	7	5	
NEREIS	0	1	1	
TANAIS	40	8	24	
C INSIDIOSUM	5	0	0	
GOLFINGIA	5	0	8	

SPECIES	ZC1/20	ZA1/20	ZR1/20	15 X75
OLIGOCHAETA	0	78	0	
AMPHICTEIS	0	16	0	
HETEROMASTUS	0	34	0	
MANAYUNKIA	16	424	56	
PYGOSPIO	0	16	0	
TANAIS	16	56	24	
AMPITHOE	8	8	0	
C INSIDIOSUM	0	112	8	
GOLFINGIA	0	48	16	

Appendix Table 5. (continued)

SPECIES	ZC2(5)	ZA2(5)	ZR2(5)	15 X75
MACOMA BALTHICA	17	32	14	
OLIGOCHAETA	1389	3494	2352	
AMPHICTEIS	480	0	192	
HETEROMASTUS	595	1496	1008	
MANAYUNKIA	3584	10144	5664	
PYGOSPIO	1760	0	864	
TANAIS	352	448	1792	
AMPITHOE	0	0	128	
C INSIDIOSUM	2016	0	224	
GOLFINGIA	320	32	256	

SPECIES	ZC2/10	ZA2/10	ZR2/10	15 X75
MACOMA BALTHICA	16	1	9	
OLIGOCHAETA	168	0	280	
AMPHICTEIS	16	0	48	
HETEROMASTUS	72	0	120	
MANAYUNKIA	208	32	160	
PYGOSPIO	48	0	112	
TANAIS	16	0	80	
C INSIDIOSUM	0	16	80	
GOLFINGIA	16	0	8	

SPECIES	ZC2/15	ZA2/15	ZR2/15	15 X75
OLIGOCHAETA	28	160	22	
AMPHICTEIS	8	0	0	
HETEROMASTUS	12	0	10	
ETEONE	0	8	0	
MANAYUNKIA	24	528	176	
TANAIS	0	80	80	
AMPITHOE	8	8	0	
C INSIDIOSUM	0	0	8	
GOLFINGIA	0	8	0	

SPECIES	ZC2/20	ZA2/20	ZR2/20	15 X75
OLIGOCHAETA	50	39	28	
HETEROMASTUS	14	17	12	
ETEONE	8	0	8	
MANAYUNKIA	1024	200	80	
CUMELLA	0	0	8	
TANAIS	32	24	32	
C INSIDIOSUM	8	8	16	