Sublittoral Macro-infauna of Digdeguash Estuary, New Brunswick, Canada

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SUBLITTORAL MACRO-INFAUNA OF DIGDEGUASH ESTUARY, NEW BRUNSWICK, CANADA

by

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ABSTRACT

Wildish, D. J., A. J. Wilson, and H. M. Akagi. 1980. Sublittoral macro-infauna of Digdeguash estuary, New Brunswick, Canada. Can. MS Rep. Fish. Aquat. Sci. 1568, iii + 8 p.

The Digdeguash River has a total catchment area of 95.8 km^2 and an estuarine area of 6 km^2. Freshwater discharge into the estuary is estimated to vary from 2.6×10^4 to 9.9×10^5 m^3/day. The residual and tidal prism volumes have been calculated and indicate an estuary volume: freshwater discharge ratio of from 39 to >2000:1. Salinity distribution in the estuary is partially mixed and annual maximum/minimum temperatures in the lower estuary are within the range 18 to -1.8 °C. Soft sediments in the estuary are well sorted silts except in three areas where tidal currents cause sediment erosion. Near these modes of maximum shear stress due to tidal currents, the sediment percent volatile solids (Y) are linearly related to the sediment sorting coefficients (X):

$$Y = 0.5650 + 1.4531X$$

This relationship is explained by differential erosion and transport of less dense organic particles away from these stations.

All of the five dominant macrofaunal species at one station in the estuary, which represents 94% of the total biomass, are deposit swallowers. Key dominants are *Casco bigelowi* and *Yoldia sapotilla* both of which actively rework the sediment by their burrowing activities and production of fecal pellets.

Length-frequency data for seasonally sampled amphipods *C. bigelowi*, *Leptocheirus pinguis*, and *Pontoporeia femorata* are presented. Fitted power function constants are given from which wet weight can be substituted for the limb measurements made.

Key words: Digdeguash estuarine benthos, amphipods, sediment characteristics

RÉSUMÉ

Wildish, D. J., A. J. Wilson, and H. M. Akagi. 1980. Sublittoral macro-infauna of Digdeguash estuary, New Brunswick, Canada. Can. MS Rep. Fish. Aquat. Sci. 1568, iii + 8 p.

Le bassin de la rivière Digdeguash a une superficie de 95,8 km^2, son estuaire, 6 km^2. Dans ce dernier, on estime qu'il arrive de $2,6 \times 10^4$ à $9,9 \times 10^5$ m^3 d,eau douce par jour. D'après le calcul des prismes résiduel et des marées, le régime serait de nature estuarienne: l'apport d'eau douce étant de 39 à plus de 2 000 pour 1. Dans l'estuaire, la salinité n'est pas totalement homogène, et les températures maximales et minimales dans sa partie la plus maritime se situent entre 18 et -1,8°C. Les sédiments mous y sont des limons bien triés, sauf dans trois secteurs où les courants de marée sont la cause de leur érosion. Près de ces secteurs où le cisaillement dû aux courants de marée est maximal, le pourcentage (Y) de matières volatiles dans les sédiments est en relation directe avec le coefficient de triage des sédiments (X):

$$Y = 0,565\ 0 + 1,453\ 1\ X$$

Cette relation s'explique par l'érosion et l'exportation différentielles des particules organiques moins denses, de ces stations.

Dans une station de l'estuaire, les cinq espèces dominantes de la macrofaune, qui représentent 94% de la biomasse totale, sont détritivores. Parmi elles, les principales sont *Casco bigelowi* et *Yoldia sapotilla*, qui remanient intensément les sédiments par leur fouissement et par la produciton de boulettes fécales.

Les statistiques de la fréquence des longueurs chez les amphipodes *C. bigelowi*, *Leptocheirus pinguis* et *Pontoporeia femorata* capturés saisonnièrement sont présentées, ainsi que les constantes ajustées de fonctions de puissances à partir desquelles on peut traduire les mesures des membres en poids frais.

INTRODUCTION

The Digdeguash river and estuary are the least polluted of the three major rivers which enter Passamaquoddy Bay, New Brunswick, the others being the St. Croix and Magaguadavic. The relatively pristine state of the Digdeguash catchment results because little industry and no major human settlements are present. Therefore, the estuary was chosen as suitable for measuring life table data (growth, mortality and reproductive schedules) of the dominant, sublittoral benthic macro-infauna. The original aim was to utilize this information to estimate production in an unpolluted Bay of Fundy estuary. However, because of unresolved sampling problems (insufficient digging depth of the grabs) recognized early in the study, this objective was frustrated and a less demanding one, that of determining life history schedules of dominant amphipods (Wildish, in preparation), was undertaken. The purpose of this report is to present the descriptive biological and physical data obtained as part of the amphipod autecological study.

SAMPLING AND ANALYTICAL METHODS

Physical dimensions of the Digdeguash catchment and its estuary were determined, by divider and planimetry, from the Canadian Hydrographic Service Chart Number 4331. Depths were measured directly, freshwater discharge estimated by the water balance method of Thornthwaite and Mather (see in Wildish et al. 1972) and tidal ranges taken from Canadian Hydrographic Service tide tables (Anon. 1979a).

Benthic macro-infauna were sampled from the anchored research vessel, *Pandulus II*, with a 0.1 m^2 modified Van Veen grab. Ten replicate samples were taken at station 31 (Fig. 1) (45°09.9'N, 66°57.6'W) on 23.9.1976 and 383 replicates at station 32 (45°09.3'N, 66°57.5'W) on 19 separate dates from July 1977 to July 1979. The macrofauna were separated from the sediment matrix by sieving on a 0.8 mm^2 mesh and preserved in buffered 5% formalin. Station 31 replicates were identified by the Biological Station Identification Centre, St. Andrews, and total wet weights determined. Station 32 samples were sorted and amphipods removed for further analysis (Wildish, in preparation). The remaining material was not analyzed further but is preserved at the St. Andrews Identification Centre.

Sediment was obtained by scooping a portion of the top 5 cm of a full Van Veen grab sample. Sediment samples from known locations (1 to 20, see Fig. 1) throughout the estuary were dried in the laboratory. Samples were then analyzed for sediment sorting characteristics by sieving and pipet analysis essentially as in Holme and MacIntyre (1971). Organic carbon was analyzed either by wet oxidation and back titration of unused potassium dichromate, or gravimetrically for volatile solid content after burning at 550°C for 1 h. Redox potentials were determined for sediments which remained undisturbed in the 0.1-m^2 grab, with a combination platinum electrode pushed into the sediment to a depth of 10 cm. Results were recalculated in mV relative to the normal hydrogen electrode.

A gravity, Kajak-type corer weighted to 21.2 kg was also used to study sediment characteristics. The core liner tube was drilled at 1-cm intervals to take a 1 cc cut-off syringe which facilitated sampling at known depths into the sediment. During sampling the holes were covered with electrical tape. Samples (2-7 g wet weight) were stored in stoppered glass vials and analyzed for water content by drying at 105°C to constant weight. Volatile solid content of the dry samples was analyzed as described above.

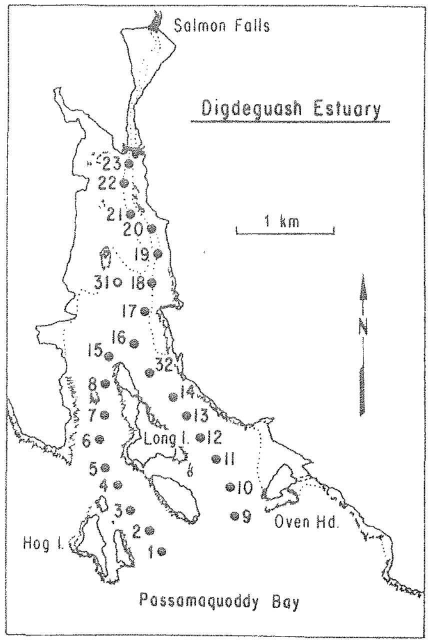

Fig. 1. Map of the Digdeguash estuary showing sampling locations.

Sea water was obtained with a battery-operated induction pump attached to a weighted polyethylene hose. Seawater temperatures were read with a mercury bulb thermometer accurate to 0.1°C and salinity determined by argentometric titration.

RESULTS

PHYSICAL CHARACTERISTICS

The Digdeguash estuary is 6 km long with a freshwater catchment area of 95.8 km^2. No freshwater discharge rates have been measured directly and the values given in Table 1 are based on an estimated water balance for the area (Wildish et al. 1972). The monthly hydrograph includes a peak in April, May and June, resulting from snow melt and a second peak in November when evapotranspiration is low and precipitation is high. Fresh water entering the estuary at Salmon Falls is brownish in colour with a pH range of 4.3 to 7.3 and an average total hardness of 15.8 mg/L as $CaCO_3$ (Anon. 1979b).

Tidal ranges of up to 8.3 m occur at high-water spring tides and at high water salinity distribution in the central channel is partially mixed (Fig. 2). At low water the upper estuary consists of a central channel with wide intertidal mud flats flanked by rock outcrops.

Table 1. Physical characteristics of the Digdeguash estuary.

Catchment area	Total (km^2)	95.8
	Inland wetlands	3
	Lakes	0
Watercourse	Inland (km) main branch	82
	Tidal	6
Estuary area	Total (km^2)	6
	Tidal marshes	0
Estuary depth	Head of tide at MLW (m)	<1
	Mouth at MLW	7
Residual volume	Total estuary at MLW (m^3)	10.4×10^6
Tidal range	Mean tide (m)	5.9
	Spring tide	8.3
Tidal prism	Spring tide (m)	52.0×10^6
	Neap tide	38.9×10^6
Freshwater discharge	Range (m^3/day)	$2.6 \times 10^4 - 9.90 \times 10^5$
Total volume:	Neap tide: highest discharge	39:1
River discharge	Spring tide: lowest discharge	2203:1

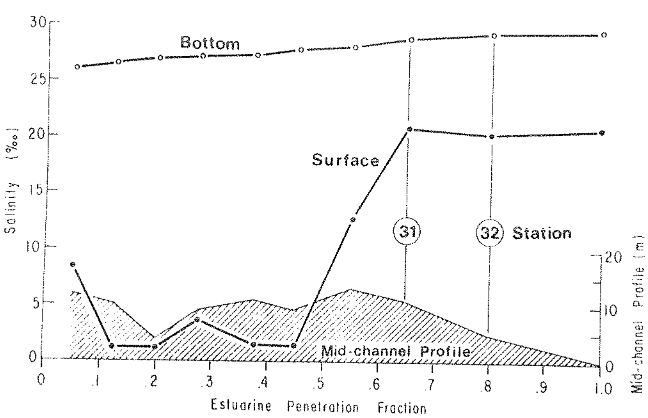

Fig. 2. Mid-channel profile of the Digdeguash estuary on June 7, 1979.

Bottom temperatures observed hourly for 13-h tidal periods at station 32 (Wildish et al. 1977) at different seasons indicate a variation with the tidal cycle of up to 3°C. When superimposed on daily mean seawater temperatures of the surface water at the Biological Station, St. Andrews (Fig. 3 and Appendix 1), the tidal ranges show a reasonably good fit, although the Digdeguash values are slightly more extreme. Annual maximum/minimum temperatures at station 32 should be within 18 to -1.8°C. For comparison, temperature fluctuations at a deeper, more marine location are given (Appendix 2).

Tidal current velocities at station 32 are not sufficient to erode the sediment (Wildish and Kristmanson 1979), although our observations indicate that sediment resuspension due to wave activity does occur. The longest fetch available at station 32 is ≈6 km, in a narrow sector to the southeast, giving wave heights of around 1 m at maximum wind speeds (see in Perkins 1974). McCall (1978) has shown that for waves induced by winds in excess of 20 knots the bottom shear stress developed is sufficient to resuspend sediment at depths up to 10 m, and for a 30-knot wind to depths of 16 m. The effect of biogenic processes on sediment erosion is considered to involve two opposing influences: stabilization by sediment binding of microbial polysaccharides and destabilization by bioturbation inclusive of burrowing and fecal production (Rhoads et al. 1977).

Sorting characteristics of Digdeguash sediments (Table 2) indicate a well-sorted silt uniform throughout the system except in three areas (locations 7, 19 and 23 in Fig. 1). Here the high

Table 2. Sediment sorting characteristics as median phi diameter (MdØ), sorting (QDØ) and skewness (SkqØ) coefficients of Digdeguash estuary sediments with organic carbon and redox values in January-March 1977.

Station	Coordinates (to nearest 1/10 min) North	West	Eh in mV Depth (cm) 0	10	Organic carbon % volatile solids	% potassium dichromate oxidation	MdØ	QDØ	SkqØ
1	45°08.3'	66°57.5'	375	113	8.83	2.37	8.61	0.57	-0.24
2	45°08.4'	66°57.6'	285	113	8.91	2.89	8.39	0.73	-0.28
3	45°08.5'	66°57.8'	376	156	8.71	2.52	8.77	0.52	-0.24
4	45°08.7'	66°57.8'	315	237	8.65	2.47	8.42	0.61	-0.22
5	45°08.8'	66°58.0'	193	-	8.68	3.24	8.39	0.56	-0.18
6	45°08.9'	66°58.0'	285	180	10.48	3.12	8.45	0.57	-0.20
7	45°09.1'	66°58.0'	415	-	4.86	1.28	4.34	3.67	1.77
8	45°09.2'	66°58.0'	205	-	6.66	3.24	7.29	3.37	-2.64
9	45°08.5'	66°56.9'	355	195	8.83	3.24	8.25	0.65	-0.20
10	45°08.7'	66°56.9'	410	225	9.25	2.90	8.35	0.62	-0.25
11	45°08.8'	66°57.0'	474	155	9.34	3.03	8.39	0.62	-0.33
12	45°08.9'	66°57.2'	325	255	9.02	2.74	8.30	0.72	-0.24
13	45°09.0'	66°57.3'	345	175	10.07	3.01	8.37	0.64	-0.28
14	45°09.1'	66°57.4'	355	185	9.31	2.72	8.35	-0.48	-0.56
15	45°09.4'	66°57.9'	395	235	9.49	3.18	8.36	0.64	-0.25
16	45°09.5'	66°57.7'	435	335	8.69	3.16	8.30	0.80	-0.34
17	45°09.7'	66°57.6'	275	215	10.14	3.23	8.17	0.97	-0.48
18	45°09.8'	66°57.5'	455	-	8.60	2.98	7.22	1.30	0.07
19	45°10.0'	66°57.5'	455	-	6.50	1.70	4.45	4.18	-0.76
20	45°10.1'	66°57.5'	465	-	9.66	3.90	7.39	1.38	-0.22
21	45°10.2'	66°57.7'	535	-	6.28	2.08	5.75	3.68	0.95
22	45°10.4'	66°57.7'	455	-	11.30	3.65	8.72	0.24	0.07
23	45°10.5'	66°57.7'	425	-	8.52	1.76	3.03	4.10	+1.19
31	45°09.9'	66°57.6'	-	-	-	3.11	7.94	0.82	-0.13
32	45°09.3'	66°57.5'	-	-	10.60	3.17	-	0.79	-

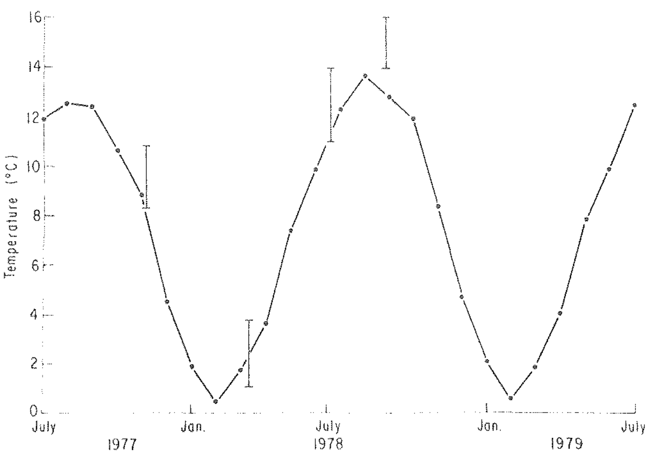

Fig. 3. Temperature curve for surface water near the wharf at St. Andrews Biological Station. Bars indicate range from location #32 during one tidal cycle.

sorting coefficients indicate very poor sorting of a coarser sand with markedly reduced organic carbon values. These areas are interpreted to be where tidal current-caused net sediment erosion leads to selective transport of organic particles with a lower density than the inorganic particles present.

The dependence of % volatile solids on the sorting coefficient (QDØ) previously found in the Musquash estuary (Wildish et al. 1977) also held here for locations 7,8, 19 and 21 which are in areas of the highest shear stress due to tidal currents. Combined data from both estuaries gave the equation:

$$Y = 0.5650 + 1.4531X \quad \text{.............} \quad (1)$$

where $N = 10$, $r = 0.96$, $X = QDØ$ and $Y = \%$ volatile solids.

The relationship between the two measures of organic matter used in Digdeguash work is described by the linear equation:

$$Y = 1.2235 + 2.5934X \quad \text{............} \quad (2)$$

where $r = 0.86$,

and for both Digdeguash and Musquash values:

$$Y = 1.5606 + 2.5251X \quad \text{.............} \quad (3)$$

where N = 34, r = 0.94, and where X is the percentage of dichromate carbon and Y the percentage of volatile solids, both expressed on a dry sediment weight basis.

The two values most poorly represented by equation (2) occur at locations 8 and 20 which are adjacent to areas of high, tidally caused, sediment erosion stress.

Redox conditions at the sediment surface and at 10 cm (Table 2) indicate an aerobic upper sediment layer. One possible contributing factor to the aerobic conditions is the reworking activities of the macrofauna. This interpretation is supported by water content data in sediment cores taken from a few locations in the estuary (Fig. 4). Water content was high near the surface, up to 70%, and declined to 50-55% at 20-25 cm depth, indicative of a reworked zone (Rhoads et al. 1978).

BENTHIC MACROFAUNA AT STATION 31

The list includes 22 species plus a few unidentified individuals (Table 3). The density was 449 individuals/m^2, suggesting that species diversity is low. This is supported by the species/numbers data for each replicate shown in Table 4. The total wet weight biomass, inclusive of shell, is 18.5 g/m^2 and five dominants make up 94% of the total. Biomass dominants include: *Ninoe nigripes* (6.82 g/m^2), *Cerebratulus* sp. (4.76 g/m^2), *Yoldia sapotilla* (2.32 g/m^2), *Nepthys incisca* (1.79 g/m^2), and *Casco bigelowi* (1.75 g/m^2). The dominant species in terms of biomass and numbers are deposit swallowers which move actively through the sediment and rework it by their feeding and locomotory activities. The other species in Table 3 are mostly surface deposit feeders or carnivores.

Similar species composition and densities occur at other stations within the estuary seaward of station 31, for example at station 32. The tidally stressed sediment near stations 7, 19 and 23 were not adequately sampled, although indications were that a very impoverished macrofauna was present.

AMPHIPOD SAMPLING AT STATION 32

Seven species of amphipod were taken over the sampling period July 1977 to July 1979. Most of the life-history and reproductive data for the three dominant species are given elsewhere (Wildish, in preparation). The three dominant amphipods were: *Casco bigelowi*, *Leptocheirus pinguis* and *Pontoporeia femorata*. Length-frequency data for each species is given in Appendices 3 to 5. Interpretation of the histograms as annual cohorts was assisted by log probit analysis (Harding 1949). The two peaks of the *Casco* data for November 1977 (Appendix 5) indicate a biannual life history. The more complex pattern for *Leptocheirus*, where at least four cohorts were present in January 1979 (Appendix 4), we interpret as due to a summer or winter hatching for each annual cohort with a relatively long period of reproductive activity. The *Pontoporeia* data indicate a single year-class for the times sampled (Appendix 3) consistent with an annual life history.

Linear limb measurements (X) were related to wet or dry weight (Y) or overall body length (Y) in an exponential fashion. Subsamples from two amphipod collections were made and sets of bivariate data generated which were fitted to the power

Table 3. Species composition at station 31 in the Digdeguash estuary on 23.9.1976 based on ten 0.1 m^2 replicate samples.

Taxa	Number/m^2
Mollusca	
Cylichna alba	1
Oenopota bicarinata	7
Yoldia sapotilla	19
Mya arenaria	2
Polychaeta	
Nepthys incisca	9
Antionella sarsi	3
Ninoe nigripes	255
Lumbrinereis fragilis	1
Brada villosa	2
Ampharete acutifrons	2
Scoloplos armiger	1
Mediomastus ambieseta	10
Unidentifed	8
Arthopoda	
Casco bigelowi	62
Leptocheirus pinguis	2
Pontoporeia femorata	23
Eudorella truncatula	1
Crangon septemspinosa	4
Rhynchocoela	
Cerebratulus sp.	7
Tetrastemma vittatum	1
Lineus socialis	6
Unidentified	4
Aschelminthes	
Priapulus caudatus	4
Sipuncula	
Unidentified	2

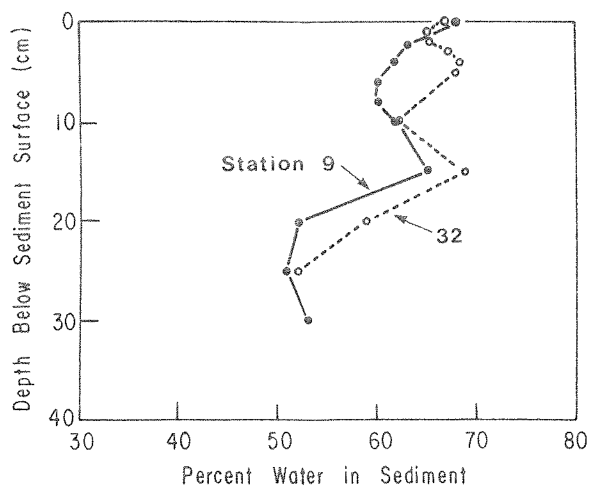

Fig. 4. Water content as a percentage of sediment dry weight in cores from locations 9 and 32 in July, 1979.

Table 4. Cumulative new species (S) and accumulated numbers (N) of individuals at station 31.

Replicate	S	N
1	10	38
2	14	86
3	17	123
4	18	187
5	18	265
6	20	312
7	21	324
8	21	362
9	22	397
10	22	449

function $Y = a \cdot X^b$ (Table 5). The data in Table 5 can be used to substitute wet weight for the limb measurements of Appendices 3 to 5.

DISCUSSION

The sublittoral benthic infauna of the Digdeguash estuary consists almost exclusively of deposit feeders in the soft sediment stations we have examined. A possible exception to this occurs at three stations, 7, 19 and 23, where evidence of tidally caused sediment scour is present but where we have not been able to sample satisfactorily.

Species diversity of the macro-infauna within the Digdeguash is low, consistent with control by unpredictable physical environmental factors. One of these physical factors could be wind/wave caused

Table 5. Regression of the form $Y = a \cdot X^b$ and correlation values relating linear measurements and/or weight. Note that all weight values are in mg, and limb part measurements are all in arbitrary ocular units (divide by 1.6 to give result in mm).

Species	Y	X	a	b	N	r
Casco bigelowi	Body wet wt (mg)	Exopod pl[1]	0.04	2.0457	80	0.83
	Body dry wt (mg)	Exopod pl[1]	0.00001238	2.0202	80	0.85
Leptocheirus pinguis	Body length (mm)	a[1] peduncle 2	40.73	0.0717	59	0.86
	Body wet wt (mg)	a[1] peduncle 2	0.1590	2.1253	60	0.89
Pontoporeia femorata	Body length (mm)	Uropod[1] basis	4.159	0.8050	60	0.81
	Body wet wt (mg)	Uropod[1] basis	2.582	1.2868	60	0.53

sediment erosion, particularly near low water in this shallow estuary. Sediment resuspension by wave action in moderate degree is beneficial to microbial activity because the microbial cells reach an area higher in nutrients and oxygen, resulting in increased rates of growth, and are then deposited at or near their original location. However, during storm conditions, severe erosion may result in washout and transport of much of surface sediment plus some of the shallower living benthic animals.

Despite low diversity, the production of benthic animals is believed to be substantial. Estimates of production by the dominant amphipod, *Casco bigelowi*, yield a value of 165-375 mg dry tissue/m^2/yr. The estimate is based on a mean dry weight of 15 mg per animal, mean density of 22-50 animals/m^2 and a production:biomass ratio of 0.5.

Many of the 22 species recorded at station 31 are common in the diet of local fish and the estuary probably provides a good feeding ground for them. The export of energy as living tissue away from the Digdeguash contrasts with the Musquash estuary (Wildish 1977) where export is primarily as non-living particulate and dissolved organic matter derived from a *Spartina* marsh.

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Appendix 1. Long-term average (1921-1967) surface water temperatures in degrees centrigrade at St. Andrews, N. B. (45°05'N, 67°05'W).

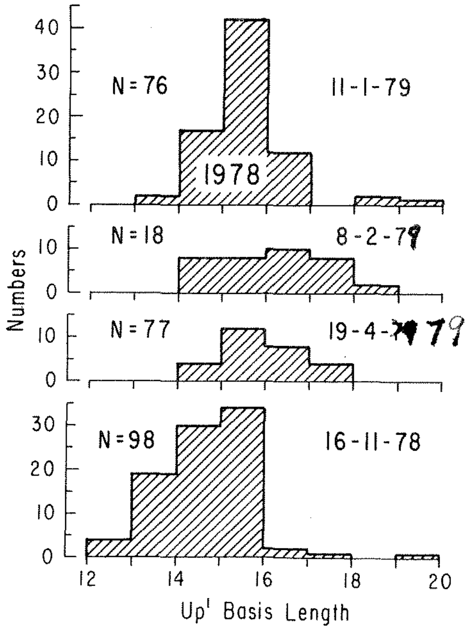
Month	Mean	Std. Dev.	Std. Error	Max.	Min.	Difference
Jan.	1.8	1.15	0.17	3.9	-1.2	5.1
Feb.	0.6	0.96	0.14	2.4	-1.7	4.1
March	1.5	0.97	0.14	3.1	-1.7	1.4
April	3.5	0.94	0.14	5.8	1.0	4.8
May	6.7	0.75	0.11	8.2	5.0	3.2
June	9.4	0.80	0.12	11.1	7.6	3.5
July	11.9	0.85	0.12	13.8	10.2	3.6
Aug.	13.0	0.83	0.12	14.9	10.9	4.0
Sept.	12.6	0.73	0.11	14.3	11.4	2.9
Oct.	10.7	0.75	0.11	12.5	8.6	3.9
Nov.	7.8	0.84	0.12	9.5	5.7	3.8
Dec.	4.2	1.08	0.16	7.0	1.6	5.4

From Lauzier and Hull (1969).

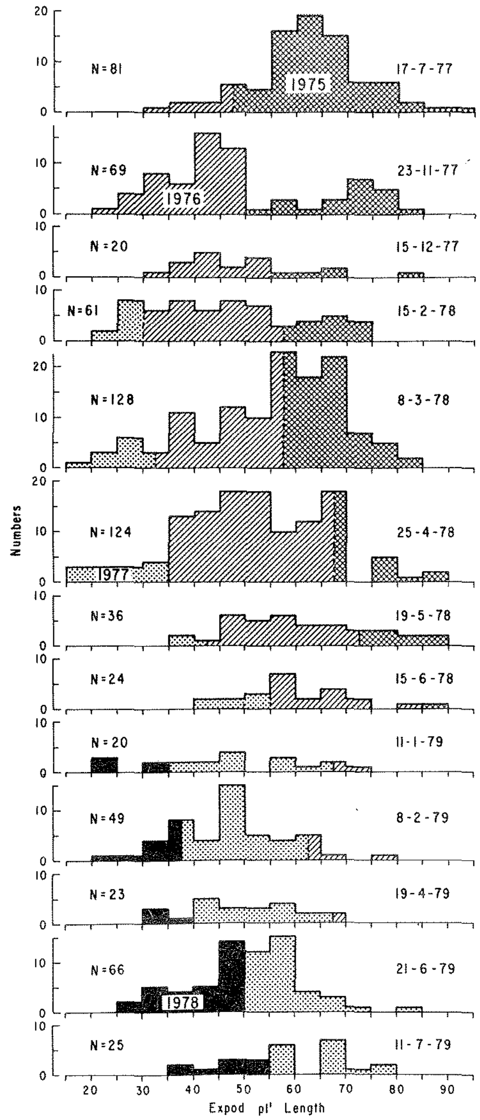
Apendix 2. Long-term (1950-1967) average bottom water temperatures in degrees centrigrade at the Lurcher Light Ship (43°48'N, 66°32'W).

Month	Mean	Std. Dev.	Std. Error	Max.	Min.	Difference
Jan.	5.5	1.13	0.27	6.9	3.6	3.3
Feb.	3.8	1.10	0.26	6.1	2.4	3.7
March	3.1	1.06	0.26	4.8	1.7	3.1
April	3.4	1.00	0.24	5.1	1.8	3.3
May	4.5	1.11	0.28	6.4	2.7	3.7
June	5.9	0.99	0.24	7.7	4.3	3.4
July	7.1	0.96	0.23	8.9	5.6	3.3
Aug.	8.3	1.10	0.26	10.4	6.6	3.8
Sept.	8.5	1.63	0.66	10.9	7.0	3.9
Oct.	8.9	1.07	0.44	9.8	8.7	1.1
Nov.	8.9	1.47	0.38	11.3	5.9	4.4
Dec.	7.4	1.26	0.30	9.7	5.1	4.6

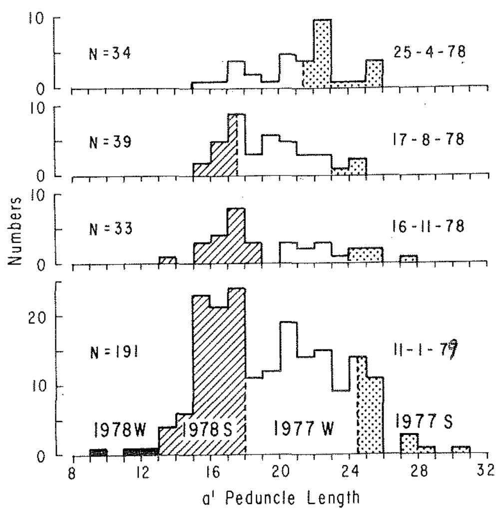
From Lauzier and Hull (1969).



Appendix 3. Frequency histogram of Up^1 basis length (arbitrary units; division by 16 gives result in mm) for *P. femorata.*



Appendix 5. Frequency histogram of Exopod pl^1 length (arbitrary units; division by 16 gives value in mm) for *C. bigelowi.*



Appendix 4. Frequency histogram of a^1 peduncle 2 length (arbitrary units; division by 16 gives result in mm) for *L. pinguis.*