Zoogeography and Systematics of
Isopoda of the Beaufort Sea

by

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degree of Master of Science in Zoology at
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INTRODUCTION

1.1. General

Isopoda are crustaceans which possess seven pairs of legs of about equal size, are flattened dorsoventrally and have no carapace. The thoracic limbs are without exopodites, pleopods are modified for respiration and the antennual exopodite is absent or minute.

The isopods are a large group and exhibit much variety. They vary in size from two or three millimeters to several centimeters. A giant deep-sea form, *Bathynomus giganteus*, from the Gulf of Mexico and Indian Ocean, attains a length of 30 cm. and width of about 10 cc. The natural habitat of isopods is in salt and fresh water or in moist situations in the case of most terrestrial forms. They have been found in warm springs and subterranean streams (Richardson, 1905).

Isopods usually scavenge for a living, eating whatever is available to them. Other modes of life have, however, made certain members of the group quite important. *Limnoria lignorum* causes considerable damage to pilings by burrowing tunnels; many species are parasitic on fishes, attaching themselves to the skin, gills, or mouth of the host. Others parasitize copepods, ostracods, barnacles, amphipods, schizopods and even other isopods (MacGinitie and MacGinitie, 1949). One of the parasitic isopods, _Olencira praegustator_, attacks the Menhaden (_Brevoortia tyrannus_) in force. Latrobe, who named both species, accurately and fancifully considered the case analogous to that of the ancient chief of state (tyrannus) and the taster (_praegustator_) (Richardson, 1905, p. V111).

The isopods, in turn, are utilized by other marine animals as food. In arctic regions _Mesidothea_ species, for example, are eaten by various fishes, particularly _Cottidae_. They have also been reported in the stomach contents of whales and diving birds such as Loons.

1.2. Literature on _Isopoda_

The bulk of information on isopods deals with taxonomy and distribution. The authority for North American forms is Richardson's "Monograph of the Isopods of North America", 1905. In the U.S.S.R., Gurjanova has been active in taxonomic and zoogeographical considerations of this group and has erected a number of new species and numerous subspecies. Stephensen has worked with collections from the North Atlantic area and makes reference to the work of the above authors. The works of these three scientists summarize the mass of taxonomic work which has been carried out by earlier workers.

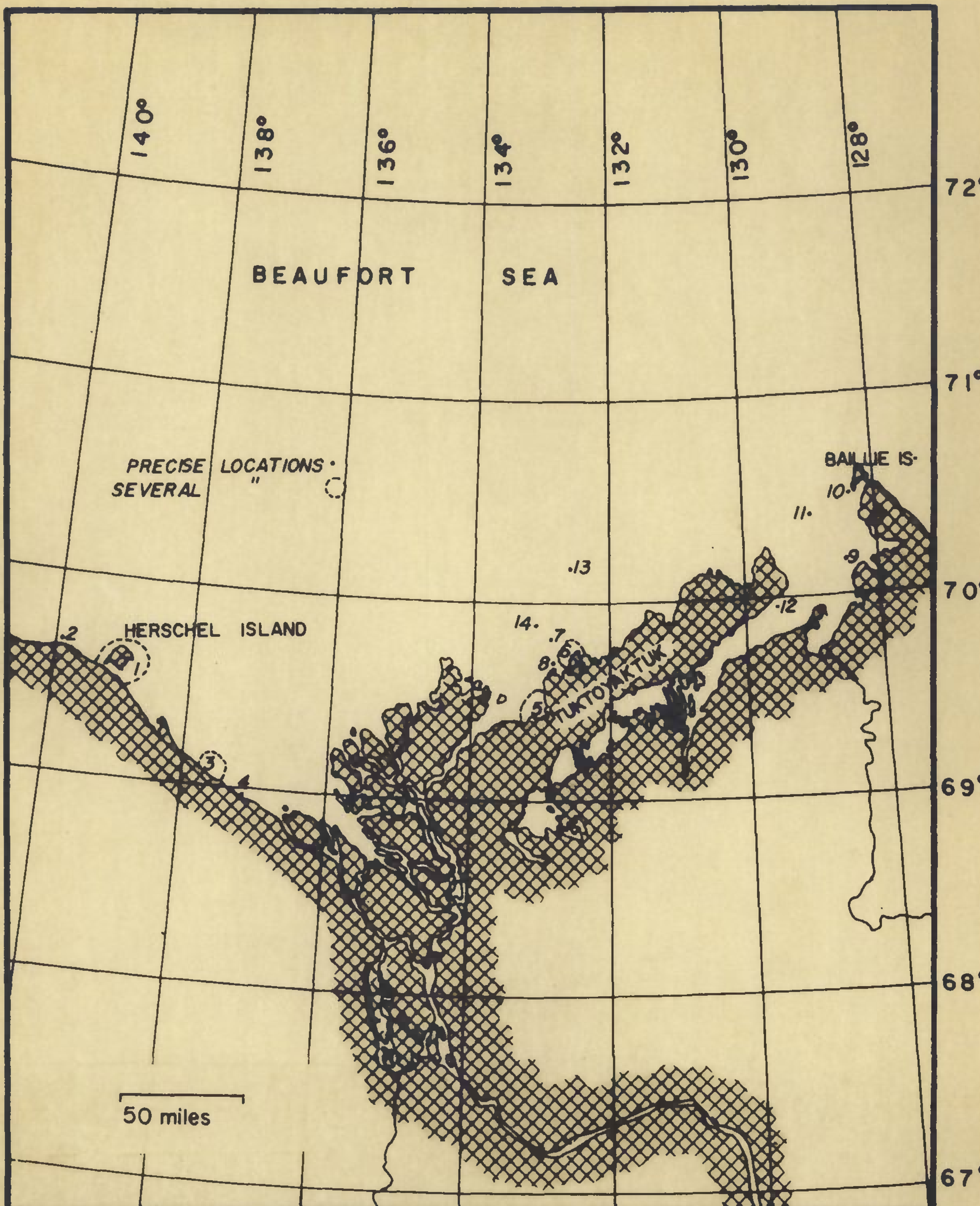
More recently, a considerable volume of work has appeared on the subject of physiology of isopods but there is little information about arctic forms. Waterman (1960), draws examples from the group in his various sections dealing with crustacean physiology.

Ecological work on arctic isopods comprises scanty material but the papers on _Asellus_ species by Steel (1961) and Ellis (1961) have been found of particular interest.

1.3. Scope of Thesis

General zoogeographical considerations are brief because little information has been added since the work of Gurjanova (1934). An attempt has been made to establish the zoogeographic position of the Beaufort Sea. Populations from the areas visited are considered in detail and particular attention is paid to the genus _Mesidothea_.

The taxonomy of the genus _Mesidothea_ (Richardson) is considered in detail because of the confusion of previous work on this group. The species _M. sibirica_ (Birula) is separated from the closely related from _M. entomon_ (L.) on the basis of morphology, body measurements, life history and ecology. Two forms of the species _M. sabini_, geographically separated in the eastern and western arctic, are similarly separated with particular emphasis placed on the subject of relative growth differences between the two forms and the importance of this in dealing with the statistical separation of such closely related animals. The life history and ecology of the various species of _Mesidothea_ are considered in detail.



Findings of Mesidothea species by M.V. SALVELINUS 1960 & 1961

Figure 1

TABLE 1

Locations of Collections of <u>Mesidothea</u> Species "Salvelinus"

1960 and 1961

Location No. (see figure 1)		Area
1		Herschel Island area
2		St. No. 60-1016 near Demarcation Pt., Alaska
3		King Point Harbour, Y.T.
4		Shingle Point, Y.T.
5		Tuktoyaktuk area
6		Warren Point area
7	(see appendices A & D)	St. No. 61-1009
8	" " " "	St. No. 61-1010
9	" " " "	St. No. 61-1015
10	" " " "	St. No. 61-1016
11	" " " "	St. No. 61-1017
12	" " " "	St. No. 61-1021
13	" " " "	St. No. 61-1082
14	" " " "	St. No. 61-1093

2. FIELD INVESTIGATIONS

2.1. Introduction

Material for this thesis was collected from the western Canadian arctic by the use of the research vessel "Salvelinus" and its equipment. The latter vessel was established in the western arctic in August of 1959 by the Fisheries Research Board of Canada, Arctic Unit, in order to carry out investigations into the biological potential of that little-known area. The author took part in the "Salvelinus" investigations of 1960 and 1961 as a student assistant employed by the Fisheries Research Board.

The "Salvelinus" is a working compromise built to meet the varied requirements of the western arctic. The boat has a sufficiently shallow draft to navigate the Mackenzic Delta and is sturdy enough to work in an area where frequent storms occur and ice conditions may be heavy. The vessel itself is 38 feet long, 12 feet wide, has a weight of 15 tons and will accomodate three or four men. In general design, the vessel resembles a British Columbia gill-net boat with hydrographic and trawl winches on deck aft of the cabin. Since its establishment in the area in the fall of 1959, the "Salvelinus" has been wintered at Aklavik., N.W.T. A list of the locations visited is given in table 1. Location numbers correspond with those given in figure 1.

The initial 1960 field season was carried out in the vicinity of Herschel Island, Y.T., and marine work began on July 24th. when ice conditions permitted passage of the vessel along the coast from the Mackenzie Delta. J.G. Hunter of the Fisheries Research Board was in charge of the investigation and D. E. McAllister, curator of fishes for the National Museum of Canada, remained with the group until August 21st. I. G. Gidney, also of the Fisheries Research Board, was the master of the vessel. Frequent storms and foggy conditions during the season made long trips impossible but considerable sampling was carried out in the immediate vicinity of Herschel Island. King Point Harbour and Shingle Point., Y.T., were visited in late August before weather conditions necessitated the termination of the field season on September 1st.

I. G. Gidney again served as the master of the vessel in 1961. The author was in charge of the scientific investigation and assistance was given by H. H. Webber, a student of the University of British Columbia. Ice left the coast early permitting the "Salvelinus" to reach Tuktoyaktuk, N.W.T., on July 1st. Work between Tuktoyaktuk and Warren Point, N.W.T., was interrupted on July 10th. by departure for Liverpool Bay. Investigations of the Eskimo Lakes and

Liverpool Bay continued until mid-August when Tuktoyaktuk was revisited in order to complete survey work in that area. Weather conditions dictated the termination of the season's work on August 29th.

2.2. Methods of Collection

The majority of the collections of isopods from the western arctic were made by means of an otter trawl. The type used in 1960 sampled a width of about 7.6 meters. The mesh size ranged from 32 mm. in the wings to 13 mm. in the cod-end. In 1961 a somewhat smaller trawl was used. This was a type of "balloon trawl" which sampled a width of about 6.5 meters and had a mesh size of about 38 mm. in the wings narrowing to 20 mm. in the cod-end. Such gear is obviously biased toward the collection of larger animals. The quantitative information serves, therefore, as an index of relative abundance only. Collections were also made by means of a trawl dredge having a fine mesh bag but were not treated quantitatively.

2.3. Treatment of Collections

Very large numbers of Mesidothea species were collected in 1960 but at that time M. sibirica was not recognized as distinct from M. entomon. Consequently the quantitative information includes an unknown proportion of these two species. Only one large haul, St. No. 60-1010, was preserved in total and will be discussed later. M. sabini was separated from the other two species and, wherever practicable, numbers and weights of the collections were taken. Mature females were also counted and weighed separately. A number of collections were preserved for special purposes. In 1961, all collections were preserved for examination in the laboratory. All preservations were made in 10% formalin.

2.4. Other Collections

Numerous samples of M. sabini from the collections of the Fisheries Research Board experimental vessel "Calanus" were made available to the author by Dr. E. H. Grainger of the Arctic Unit. These collections, for the most part made by trawl dredge, are itemized in appendix A.

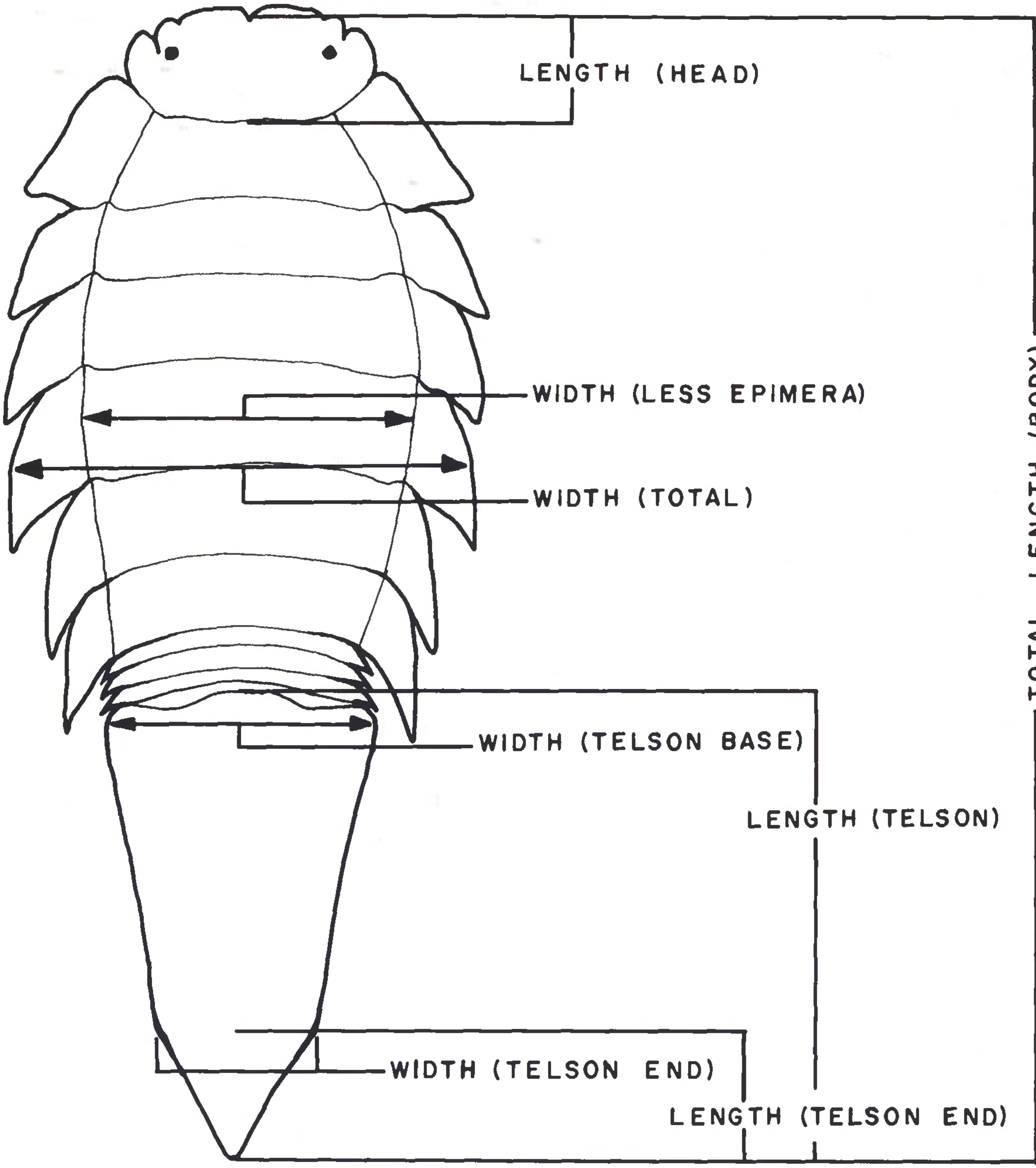
Mr. J. G. Hunter, also of the Fisheries Research Board of Canada, made available collections of M. entomon from Banks Island and the Eskimo Lakes and examples of M. sabini from Frobisher Bay.

Dr. E. L. Bousfield of the National Museum of Canada generously made available all sorted collections of Mesidothea at his disposal. Most of the 30 lots examined were collected by the Canadian Arctic Expedition of 1913 to 1918.

Single specimens of each of M. entomon and

M. sabini from Pelly Bay, N.W.T., were made available by Dr. W. F. Black of Sir George Williams University.

Dr. Lionel Johnson of the Fisheries Research Board loaned a specimen of *M. entomon* taken from fresh water in Greiner Lake, Victoria Island. The existence of this animal as a relict is discussed by Johnson (1962, in press).



MEASUREMENTS ON MESIDOTHEA SPECIES

Figure 2

3. SYSTEMATICS OF GENUS *Mesidothea*

3.1. Introduction

The genus Mesidothea was erected by Richardson (1905) to include the two forms *entomon* and *sabini*. She presents the following reasons for the change (p. 347). The genus differs from *Glyptonotus* (Eights) in having the epimera of all segments of the thorax, with the exception of the first, distinctly separated from the dorsal portion of the segments whereas they are separated on the last three segments only in *Glyptonotus*. *Mesidothea* differs from both *Chiridotea* (Harger) and *Glyptonotus* in having the palp of the maxillipeds composed of five articles instead of three. Modern workers such as Segerstrale (1960) continue to use the name suggested by Richardson.

The following species are recognized under the genus *Mesidothea*: *M. sabini* (Krøyer), *M. entomon* (L.) *M. sibirica* (Birula) and *M. megalura* (G. Sars). The latter is an abyssal form which will not be discussed here because of its absence from North American collections. The two species *M. sabini* and *M. entomon* have been further separated into several subspecies and forms in European areas. Illustrations are included wherever necessary for clarification of involved taxonomic differences.

Distribution of <u>Mesidothea</u> <u>sabini</u> (Krøyer)

Figure 3

3.2. Morphological Treatment

Animals which approximate the typical condition for the various species are given in the figures and descriptions. Similar sizes, wherever possible, are used for comparison of different forms. Drawings have been made by projecting structures onto a flat surface using a low power projecting microscope. In the case of drawings of epimera, these have been removed from the animals and placed flat upon a slide to prevent distortion of the image. Mouthparts have been dissected out and similarly projected but details have been added from observation with a binocular microscope. Articles of periopods were removed and placed inferior side down upon a slide. These were projected and the images outlined. Details of the superior (exterior) surface were drawn from examination with a binocular microscope.

3.3. Body Measurements

Other workers, especially Gurjanova, place particular emphasis on the use of measurement ratios for the subdivision and separation of *Mesidothea* species. Large numbers of specimens were measured for the purposes of this study. The following measurements, illustrated in figure 2, were taken:

Total length (body)

Length head

Length telson - from the end of the telson to its line of fusion with the fourth abdominal segment

WESTERN ARCTIC

Figure 5

HUDSON BAY

Figure 4

<u>Mesidothea sabini</u>

DORSAL VIEWS of MATURE MALES

Width telson base

Width telson end

Length telson end - longitudinal measurement of telson end

Maximum width - greatest width at fourth thoracic segment

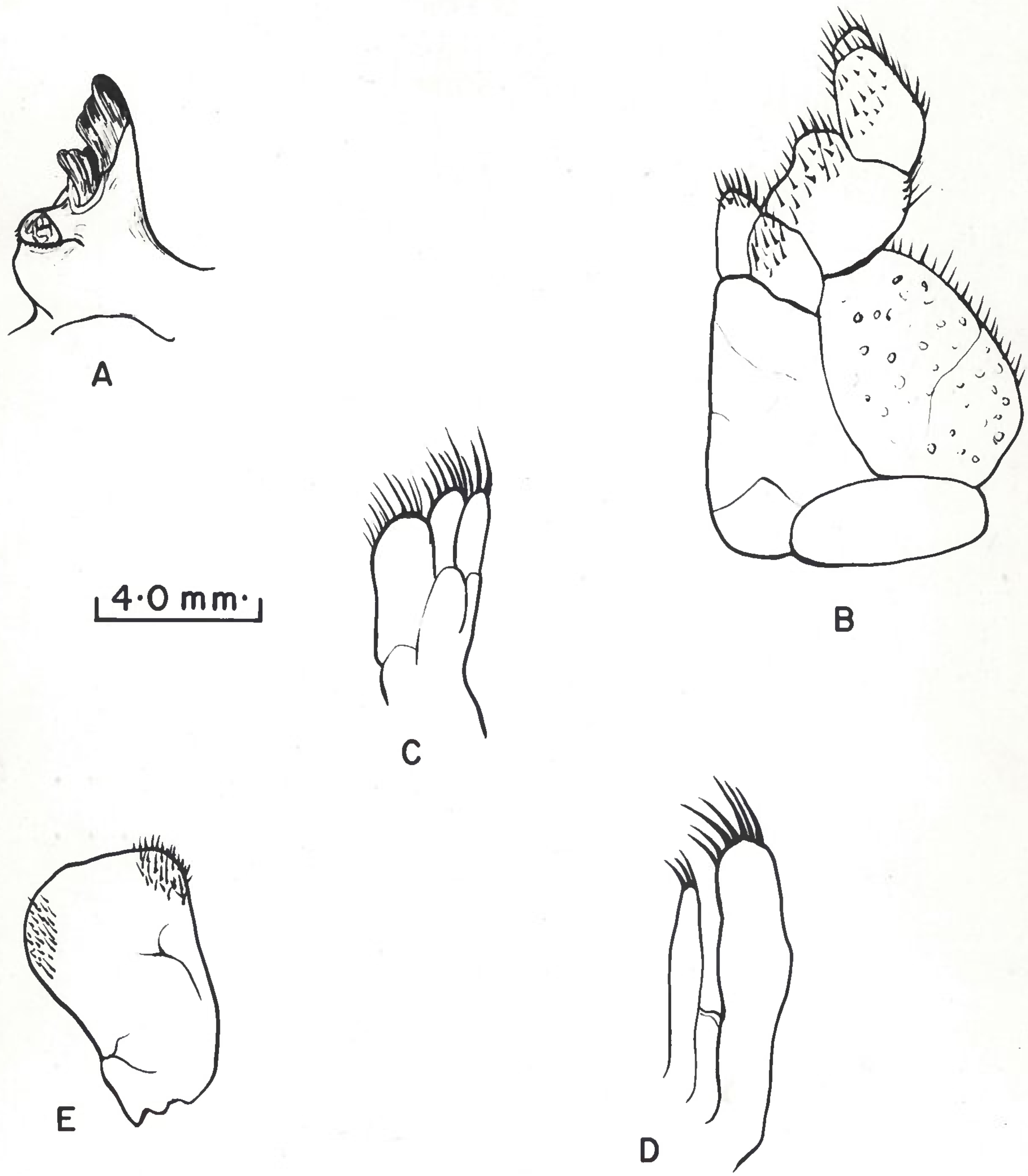
Width less epimera - maximum width of dorsal portion of fourth thoracic segment

Total length (body) was taken to the nearest millimeter in specimens above 40 mm. All other measurements were taken to the nearest o.1 mm. using a vernier caliper. Smaller specimens were measured by the use of a measuring eye-piece in a stereoscopic microscope.

3.4. Taxonomy of Mesidothea sabini (Krøyer)

3.4.1. Introduction

Collections made by the experimental vessels "Calanus" and "Salvelinus" of the Fisheries Research Board of Canada have expanded the recorded distribution of M. sabini (see map, figure 3). Specimens from the western and eastern arctic regions, with the exception of deviations noted below, agree with the description given by Richardson (1905) and figures given by Krøyer (1846), Miers (1883), and Weber (1884). The animals from the two areas have been found to differ with regard to morphology and body proportions and will be considered as comprising western arctic



A — MANDIBLE
B — MAXILLIPED
C — SECOND MAXILLA
D — FIRST MAXILLA
E — LABIUM

MESIDOTHEA SABINI

Figure 6

and Hudson Bay forms. The latter form is distributed as shown for "Calanus" collections in figure 3. The western arctic form has been described from "Salvelinus" collections. Dorsal views of mature males of the western arctic and Hudson Bay forms are shown in figures 4 and 5 respectively. The mouthparts of the two forms are similar in appearance (figure 6).

3.4.2. Morphology

The two forms of M. sabini differ from the description given by Richardson (1905) in several ways. The relative length of the first and second antennae was found to be variable whereas Richardson states that the first antenna extends to the third peduncular article of the second. (Figure 377 of her text shows a specimen in which the first antenna extends well beyond the third article.) Specimens less than 40 mm. in length had first antennae which failed to reach the third article of the second whereas those of larger specimens often extended to the end of the fourth article.

Richardson states that the flagellum of the second antenna comprises 6 articles whereas those examined in this study varied from 6 to 11. The western arctic form tends to have a greater number of articles but overlap is considerable. There is an important difference between the

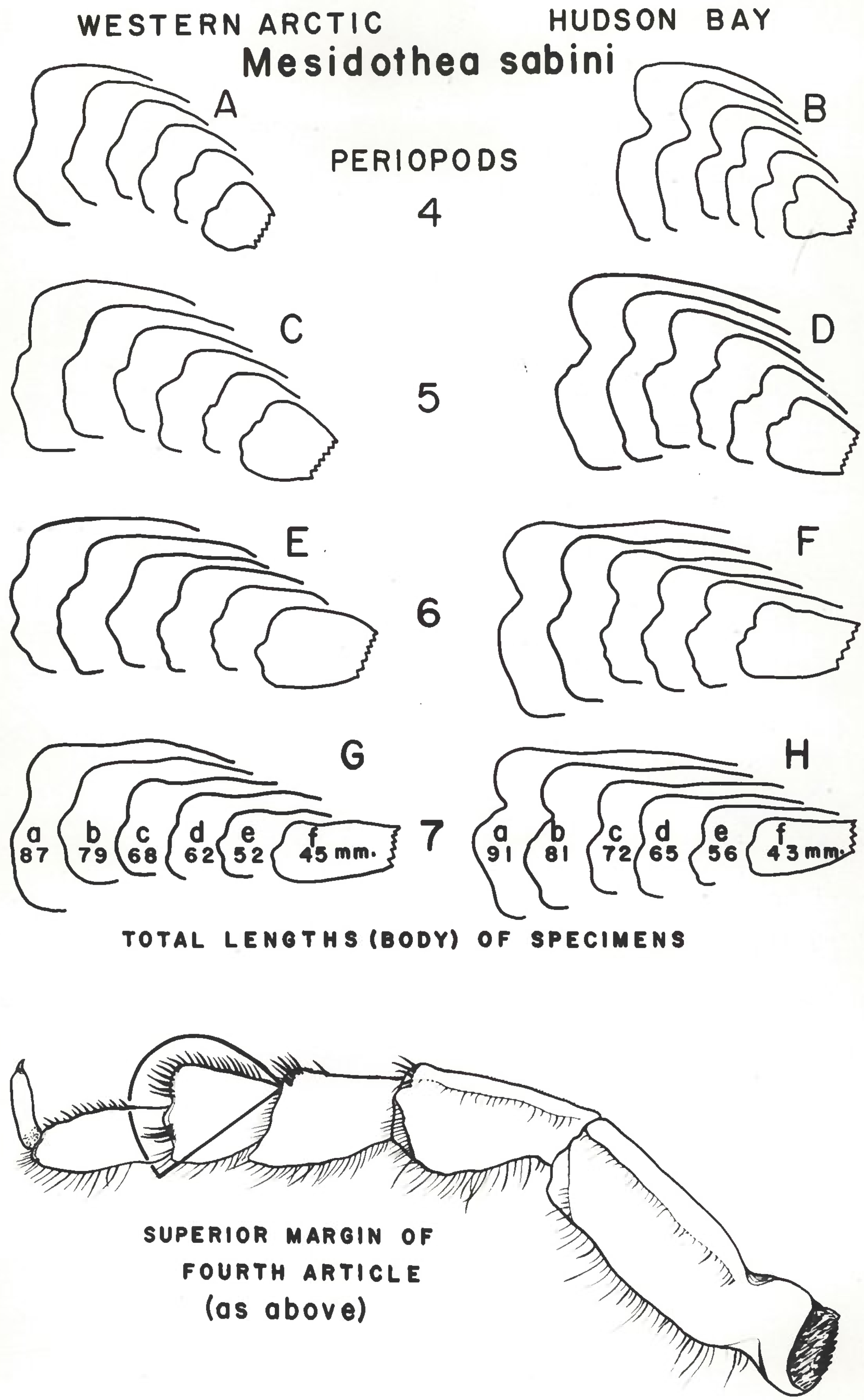

WESTERN ARCTIC
HUDSON BAY
Mesidothea sabini
PERIOPODS
A
B
4
C
D
5
E
F
6
G
H
7
a 87
b 79
c 68
d 62
e 52
f 45 mm.
a 91
b 81
c 72
d 65
e 56
f 43 mm.
TOTAL LENGTHS (BODY) OF SPECIMENS
SUPERIOR MARGIN OF
FOURTH ARTICLE
(as above)

Figure 7

two forms of M. sabini with regard to the length of the second antennae. The second antenna of the western arctic form usually reaches the end of the first thoracic segment whereas it reaches only to the middle of the first segment in specimens from Hudson Bay. The flagellae of the latter tend also to be more truncate in form. These differences may be observed in figures 4 and 5.

Although the question of body proportions will be discussed later, Richardson gives an example having a width to length ratio of 28.5% and the ratio for her figure 379 is 29.5%. These ratios are approximately intermediate between the ratios found for North American forms.

The western arctic and Hudson Bay forms of M. sabini differ with regard to the superior (exterior) margins of the fourth articles of periopods 4 to 7 inclusive. Figure 7 illustrates the margins of the fourth articles from a series of six animals of both forms. The numbers 4, 5, 6, 7, indicate periopod number. A, C, E, G, denote the illustrations for the western arctic form and B, D, F, H, those for the Hudson Bay form. Thus, 4 - A and B, 5 - C and D, should be compared in each case. The letters, a, b, c, d, e, f, denote comparable sizes for the two forms, the total lengths for which are written below the letters in 7 - G and H. The morphological difference is concerned with the degree of indentation occurring in the mid-region of the distal portion of the superior margin of the fourth articles of various periopods. In figure 7, these are the vertical lines in all cases.

Periopod 4 shows the clearest distinction. The western arctic form (A) has little or no indentation throughout the size range whereas the Hudson Bay form (B) shows pronounced indentation. The fourth articles in the latter case are somewhat heart-shaped whereas those of the western arctic form are more rectangular.

A similar distinction may be observed for periopod 5 of the two forms. This difference becomes less distinct for smaller animals, however, and is not altogether clear between the 45 mm. western arctic example and 43 mm. Hudson Bay example (C - f and D - f respectively).

Periopod 6 of the Hudson Bay form (F) is more deeply indented than that of the western arctic example (E). Moreover, the anterior faces of the articles (the horizontal lines in figure 7) of the latter (E) are slightly convex whereas they are slightly concave or straight in the Hudson Bay form (F).

The two forms may be distinguished on the basis of periopod 7 for lengths greater than about 60 mm.

3.4.3. Measurement Ratios

M. sabini may be separated into distinct western

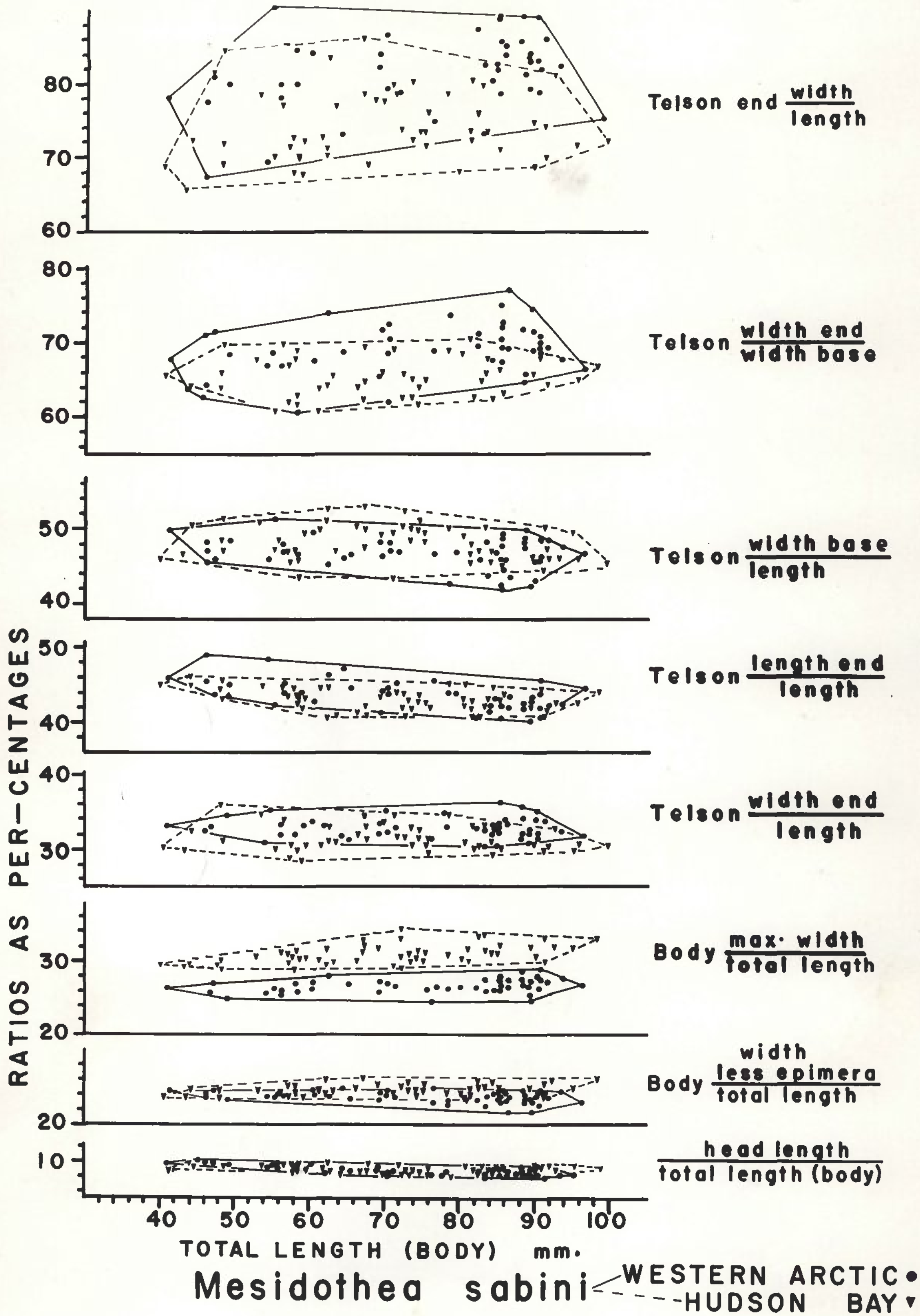

Telson end width / length
Telson width end / width base
Telson width base / length
Telson length end / length
Telson width end / length
Body max· width / total length
Body width less epimera / total length
head length / total length (body)
RATIOS AS PER-CENTAGES
TOTAL LENGTH (BODY) mm.
Mesidothea sabini
WESTERN ARCTIC
HUDSON BAY

Figure 8

arctic and Hudson Bay forms on the basis of measurement ratios. Gurjanova has carried out a study of the European isopods based on this principle. Totals of about fifty specimens from the two areas were measured as described under section 3.3. and shown in figure 2. The following ratios, values for which appear in figure 8, were calculated:

Telson end $\frac{\text{width}}{\text{length}}$

Telson $\frac{\text{width end}}{\text{width base}}$

Telson $\frac{\text{width base}}{\text{length}}$

Telson $\frac{\text{length end}}{\text{length}}$

Telson $\frac{\text{width end}}{\text{length}}$

Body $\frac{\text{maximum width}}{\text{total length}}$

Body $\frac{\text{width less epimera}}{\text{total length}}$

Body $\frac{\text{head length}}{\text{total length}}$

With the exception of maximum width: total length, these ratios were chosen for comparison with the published work of Gurjanova (1933 and 1946). The actual measurements of the specimens are included in Appendices B and C.

The specimens from the western arctic which were measured for comparison were selected from otter trawl collections made by the "Salvelinus" in the Beaufort Sea. Specimens from Hudson Bay were taken by the "Calanus". Table 2, below lists the number of specimens from each general area.

TABLE 2

	No. Measured	Area
WESTERN ARCTIC	36	Tuktoyaktuk, N.W.T.
" "	14	Herschel Island
HUDSON BAY	9	Repulse Bay
" "	2	James Bay
" "	42	Northern Foxe Basin

Only male specimens were measured in each case. This precedent has been established by Gurjanova. Specimens from Hudson Bay appear similar throughout the entire area. Individuals from Frobisher and Ungava Bays did not differ noticeably from those in other areas of the eastern arctic.

In figure 10, individual ratios as percentages are plotted against the total length of the specimen. Due to the methods of collecting, length groups below 40 mm. are poorly represented and so have been omitted from this treatment.

w The relation of maximum width: total length shows no overlap whereas all others overlap considerably. The upper limit for the western arctic form and the lower limit for that of Hudson Bay is 29.5%. The relation of width less epimera: total length shows a 50% overlap. Clearly, the relative greater width of the epimera is largely responsible for the greater width of the Hudson Bay form. The matter of body proportions will be reffered to later when relative growth of the animals has been considered.

3.4.4. Differential Growth

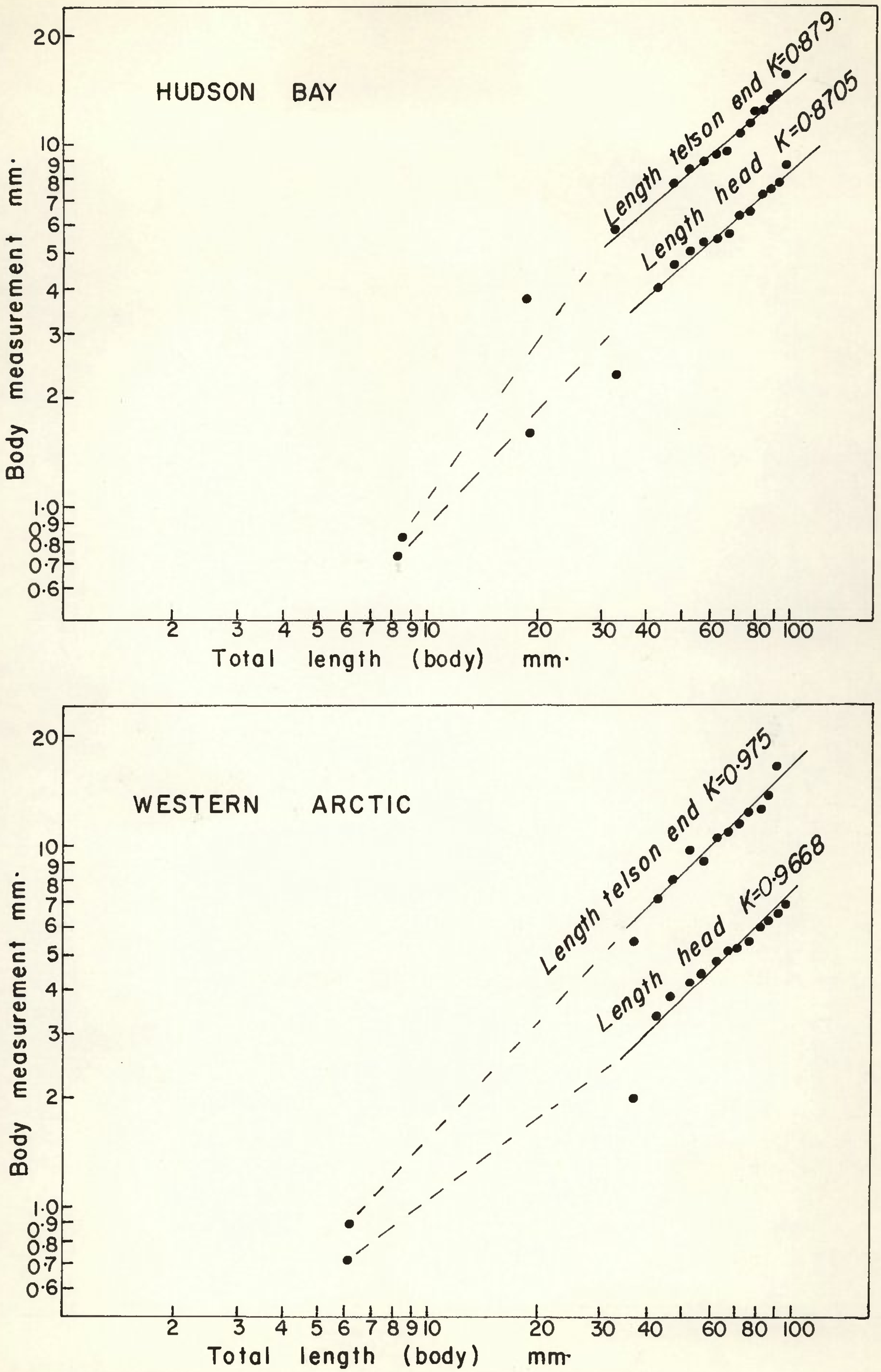
1 Introduction

Gurjanova's work on <u>Mesidothea</u> species is based on the use of mean values of measurement ratios. This procedure is sound only if the various parts of the body grow at a constant rate. If such is the case, then the ratios of these measurements, plotted on a linear scale as in figure 8, will approximate a horizontal line. If the rate of growth of one body part relative to another is differential, however, then the ratios (plotted on a linear grid) will fit a line which is curvilinear in form. In the latter case, the mean value of any measurement ratio would vary throughout the life of the animal and no useful mean could be selected for comparison. Consequently, before the ratios of measurements of the two forms may be compared statistically, each measurement must be checked for differential growth.

The various measurements have been considered relative to total length and telson length as standards of comparison. Miller and Hoy (1939) used width as a standard for Asellus californicus (Miller) but state that body length would be equally useful.

11 Procedure

In order to check for differential growth, the logarithms of various body measurements have been plotted against the logarithms of standards of comparison total length and telson length. Values for the slope, k, were obtained from the equation $\log y = \log b - k \log x$ or $y = b x^{k}$ (Martin, 1949),(Waterman, 1960). Any significant departure from the value of $k = 1$ for one measurement relative to another was interpreted as demonstrating allometric growth according to the definition of Huxley (1932). Growth ratios significantly greater than $k = 1$ show positive allometry and those significantly less than $k = 1$ show negative allometry.



HUDSON BAY
Length telson end K=0·879
Length head K=0·8705
Body measurement mm·
Total length (body) mm·
WESTERN ARCTIC
Length telson end K=0·975
Length head K=0·9668
Body measurement mm·
Total length (body) mm·

Figure 9

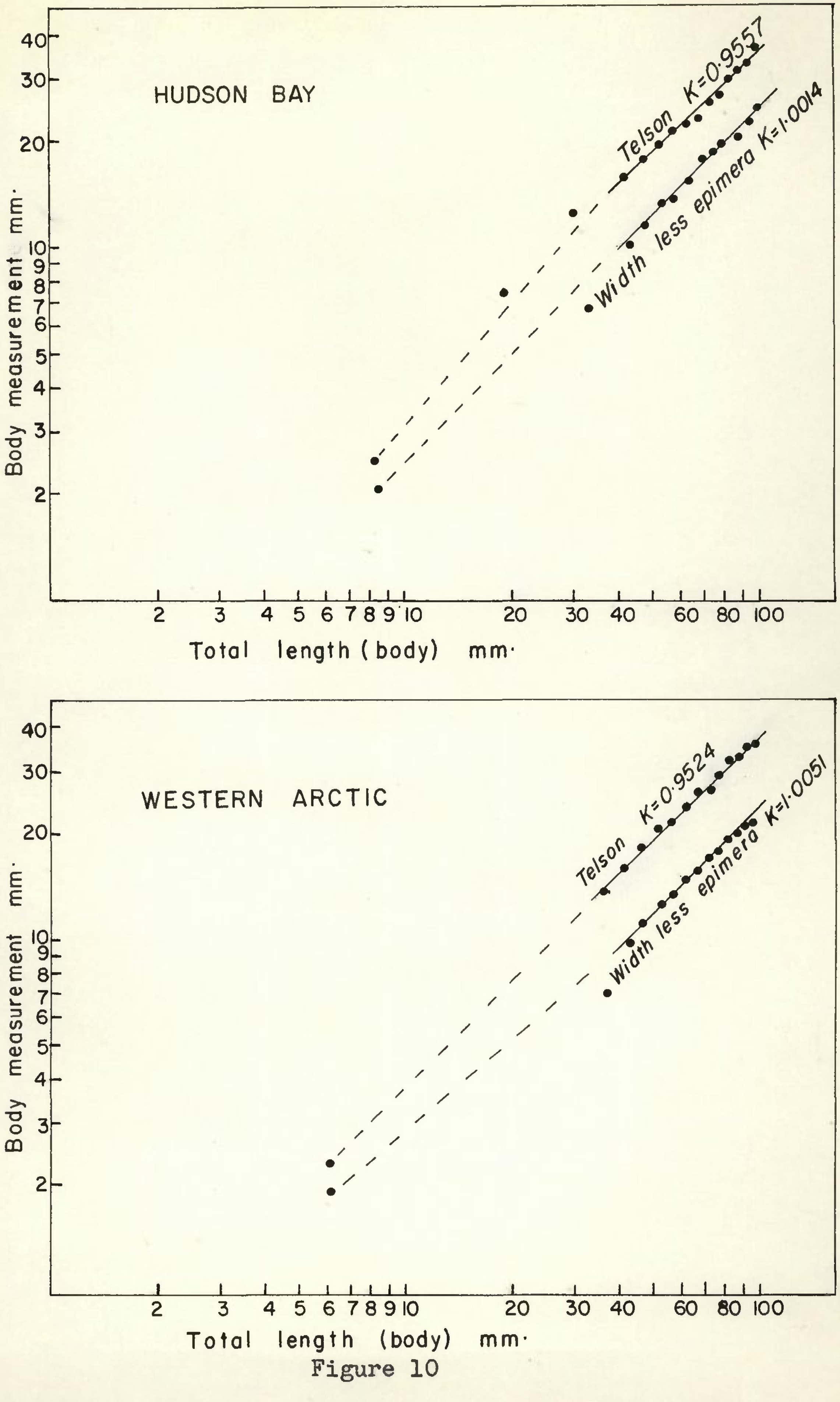

HUDSON BAY
Telson K=0·9557
Width less epimera K=1·0014
Body measurement mm·
Total length (body) mm·
WESTERN ARCTIC
Telson K=0·9524
Width less epimera K=1·0051
Body measurement mm·
Total length (body) mm·

Figure 10

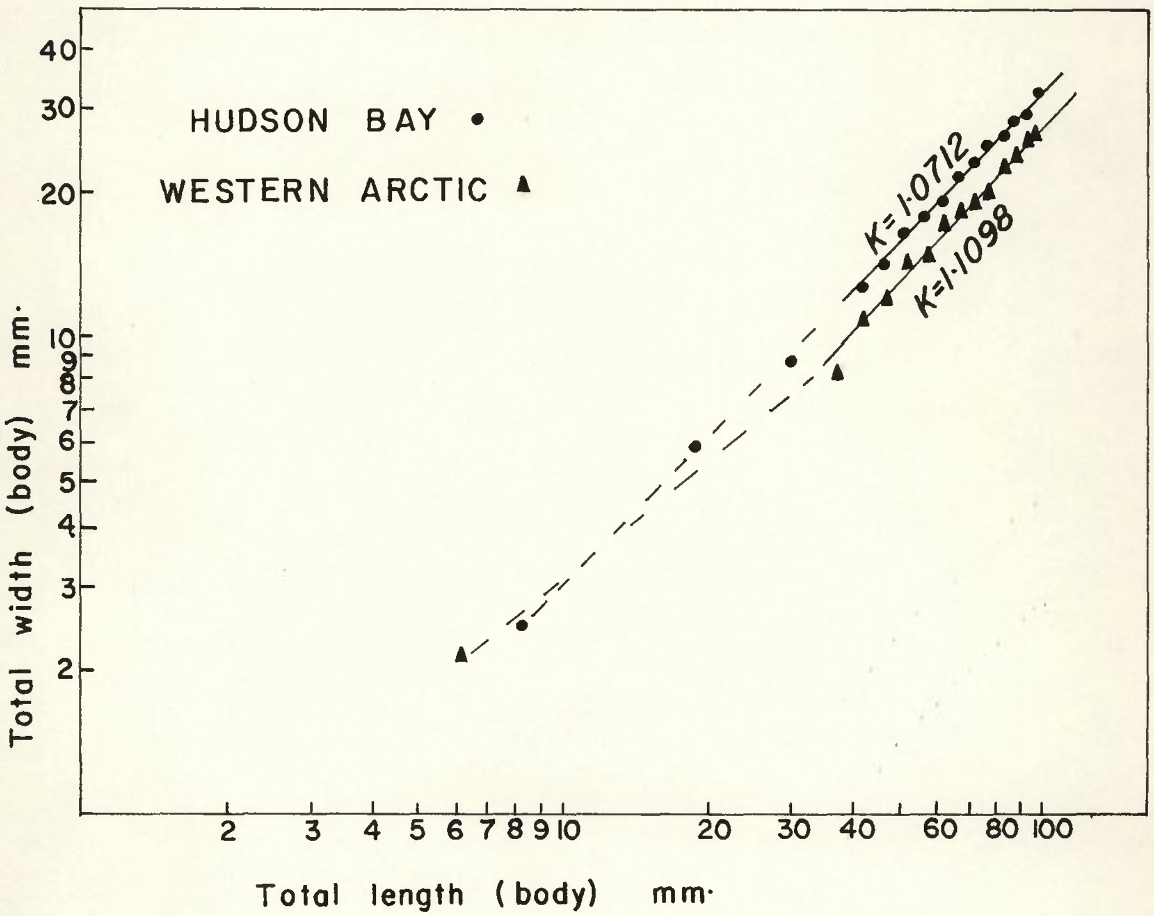

HUDSON BAY
WESTERN ARCTIC
K=1.0712
K=1.1098
Total width (body) mm.
Total length (body) mm.
40
30
20
10
9
8
7
6
5
4
3
2
2
3
4
5
6
7
8
9
10
20
30
40
60
80
100

Figure 11

TABLE 3

M. sabini Measurements Relative to Total Length (Body)

	HUDSON BAY					WESTERN ARCTIC				
	L. Telson	L. Telson end	L. Head	W. less epimera	Maximum W.	L. Telson	L. Telson end	L. Head	W. less epimera	Maximum W.
k (slope)	0.9557	0.8790	0.8705	1.0014	1.0712	0.9524	0.9750	0.9668	1.0051	1.1098
Correlation Coefficient	0.9838	1.0148	1.0344	0.9487	0.9507	0.9803	1.1968	0.9567	0.9623	1.0392
Standard Error of Estimate	0.0173	0.0154	0.0225	0.0324	0.0332	0.0225	0.0791	0.0104	0.0103	0.0372
Standard Dev.	0.0950	0.0877	0.0826	0.1077	0.1050	0.1118	0.1175	0.1200	0.0370	0.1284
Standard Error	0.0247	0.0220	0.0322	0.0463	0.0475	0.0293	0.1029	0.0135	0.0134	0.0484
$t = \frac{k - 1}{S.E.k}$	1.79	5.50	4.02	.302	1.49	1.62	0.24	2.45	0.38	2.27
	(degrees of freedom 49)					(degrees of freedom 43)				
Probability	0.085	0.001	0.001	0.500	0.100	0.100	0.500	0.016	0.500	0.034

TABLE 4

Comparing Slopes (k) for WESTERN ARCTIC and HUDSON BAY

Forms of *M. sabini*

Measurements Relative to Total Length

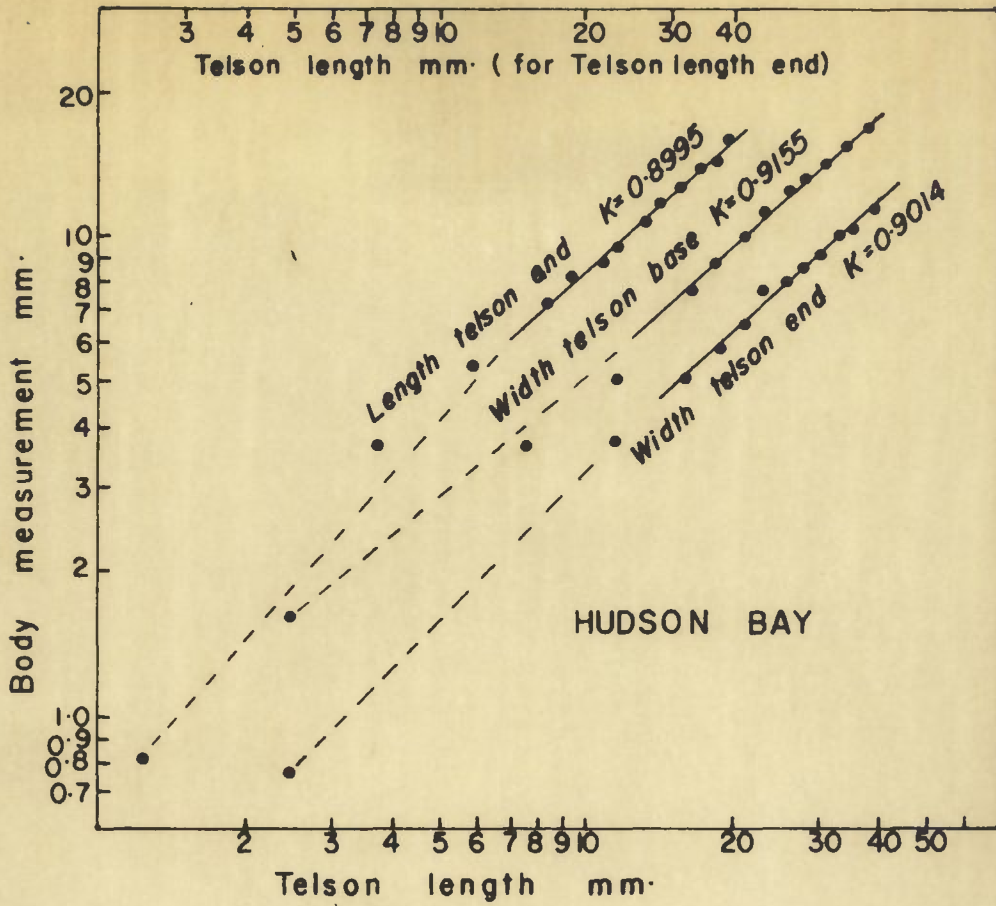
	Difference Between k's	S.E. Diff.	t	Probability
L. Telson	0.0033	0.0186	0.1770	0.500
L. Telson End	0.0960	0.0478	2.008	0.038
L. Head	0.0963	0.0270	3.5600	0.001
W. less Epimera	0.0037	0.0308	0.1201	0.500
W. maximum	0.0386	0.0311	1.241	0.200

The regression lines plotted in this treatment are shown in figures 9, 10, 11, 12. For those measurements relative to total length, Y - values are averaged for each 5 mm. class interval and plotted against the class marks. For measurements relative to telson length, class intervals of 2.5 mm. are employed and mean values are plotted against the median value of each class interval. In all cases, regression lines have been fitted using the technique of weighted least squares. The solid lines in figures 9 to 12 inclusive have been calculated in this way and the k - values are given in each case. The calculated lines are for the length ranges 40 to 99 mm. in the western arctic form and 35 to 99 mm. for the Hudson Bay form. The telson length ranges for both forms (figure 12) are 15.0 - 37. 5 mm.

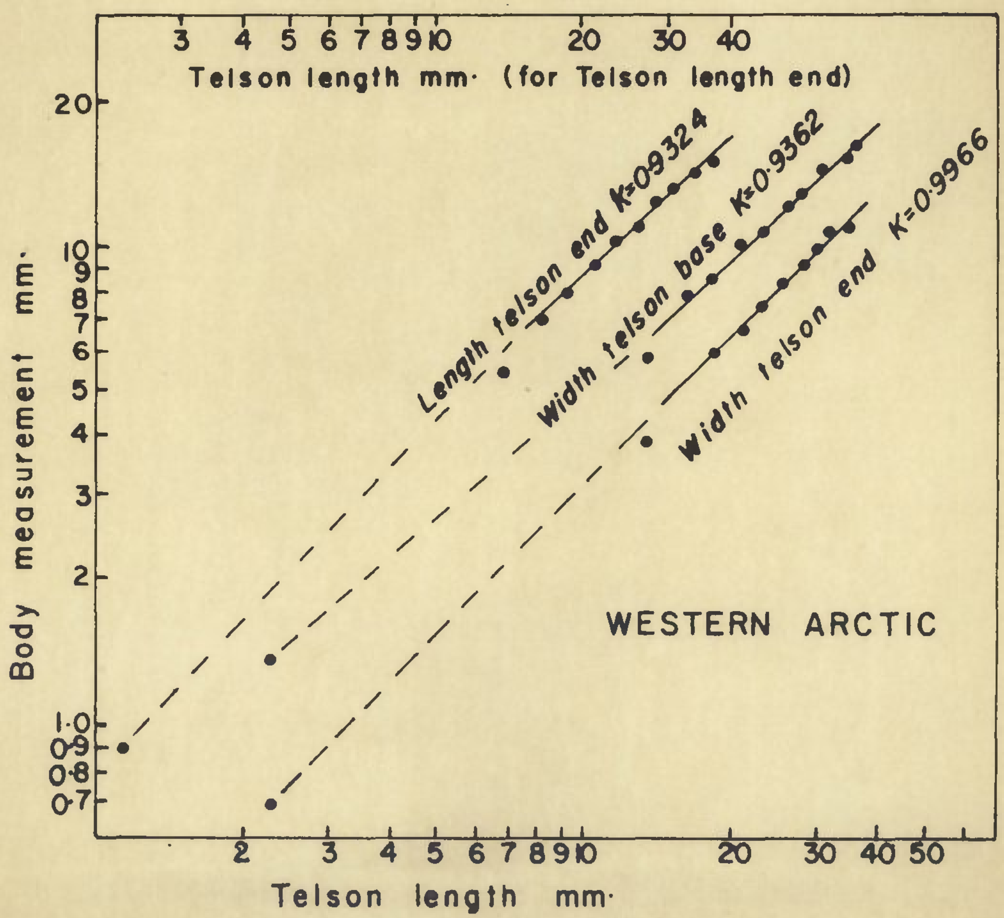
Individual measurements are plotted for smaller individuals but are not treated mathematically. The calculated lines in figures 9 to 12 are joined by broken lines to individual points which represent the mean values for seven juvenile specimens of the western arctic form and five of the Hudson Bay form. The specimens were taken from brood pouches of females but had reached full morphological development.

111 Discussion

It is apparent that the data, transformed to a log-log scale, are adequately described by straight lines.



3 4 5 6 7 8 9 10 20 30 40
Telson length mm· (for Telson length end)
Length telson end K=0·8995
Width telson base K=0·9155
Width telson end K=0·9014
HUDSON BAY
Body measurement mm·
20
10
9
8
7
6
5
4
3
2
1·0
0·9
0·8
0·7
2 3 4 5 6 7 8 9 10 20 30 40 50
Telson length mm·



3 4 5 6 7 8 9 10 20 30 40
Telson length mm· (for Telson length end)
Length telson end K=0·9324
Width telson base K=0·9362
Width telson end K=0·9966
WESTERN ARCTIC
Body measurement mm·
20
10
9
8
7
6
5
4
3
2
1·0
0·9
0·8
0·7
2 3 4 5 6 7 8 9 10 20 30 40 50
Telson length mm·

Figure 12

TABLE 5

M. sabini Measurements of Telson Relative to Telson Length

	HUDSON BAY			WESTERN ARCTIC		
	L. Telson End	W. Telson End	W. Telson Base	L. Telson End	W. Telson End	W. Telson Base
k (slope)	0.8995	0.9014	0.9155	0.9324	0.9966	0.9362
Correlation Coefficient	1.0016	0.9927	0.9876	1.0048	0.9965	0.9902
Standard Error of Estimate	0.0049	0.0016	0.0137	0.0087	0.0080	0.0138
Standard Deviation	0.0829	0.0939	0.0870	0.0877	0.0939	0.0889
Standard Error	0.0075	0.0178	0.0210	0.0135	0.0124	0.0214
$t = \frac{k - 1}{S.E.k}$	13.4	5.54	4.02	5.01	0.27	2.98
	(degrees of freedom 46)			(degrees of freedom 45)		
Probability	0.001	0.001	0.001	0.001	0.500	0.004

TABLE 6

Comparing Slopes (k) for WESTERN ARCTIC and HUDSON BAY

Forms of *M. sabini*

Measurements of Telson Relative to

Telson Length

	Difference between k's	S.E.Diff.	t	Probability
L. Telson End	0.0329	0.0082	4.0120	0.001
W. Telson End	0.0952	0.0080	11.9000	0.001
W. Telson Base	0.0207	0.0155	1.3400	0.10

For groups below 35 mm. total length, information is too scanty to draw rigid condlusions and has not been treated mathematically. The inflections which occur between the dotted lines and the calculated lines suggest that changes in growth rate occur at some stage during the life of the animal in certain cases. Miller and Hoy (1939) observed such changes in growth rate in the subterranean isopod *Asellus californicus* (Miller). They described both periods of growth by straight lines suggesting, as does Martin (1949), that straight lines fit such data adequately. Miller and Hoy observed that changes in growth rate occurred when the animal was about half grown. Lack of information makes it impossible to know where inflections occur in the case of *M. sabini.* More complete data for *M. entomon*, however, show that sharp inflections often occur very early in the growth history of the animal.

Values for the growth ratio, k, were tested for significant differences from a theoretical line having k = 1 with no standard error and an infinite number of degrees of freedom. Expressions of "t" were obtained from the equation:

$$t = \frac{k - 1}{\text{standard error of } k}$$

The values for the growth ratios were tested for significant differences one from another by means of the formula:

$$t = \frac{k\ (\text{Hudson Bay}) - k\ (\text{western arctic})}{\text{standard error of the difference}}$$

The statistical formulae and procedures are carefully outlined by Stanley (1960) and Mather (1949). Tables 3 and 5 give the results of a statistical analysis of data relative to total length and telson length respectively. Those measurements which show significant differences from $k = 1$ (probability (P) 0.05) denote differential or allometric growth.

Figure 9 presents data for length of the telson end and head relative to total length. The growth ratios of these measurements are significantly different (table 4) and only the length of the telson end of the western arctic form fails to show significant allometry (table 3). All measurements are negatively allometric to varying degrees but the head and telson end of the western arctic form grow relatively more rapidly.

The growth of the telson relative to total length for both forms (figure 10) shows a slight but non-significant degree of negative allometry. The growth ratios, furthermore, are not significantly different, one from the other.

Figures 10 and 11 show regression lines for body width measurements relative to total length. The growth ratios of maximum width and width less epimera: total length do not differ significantly between the two forms (table 4). Only the measurement of maximum width of the western arctic form shows significant allometry (table 3).

Figure 12 gives regression lines for telson measurements relative to telson length. All of these measurements show significant allometric growth except the width of the telson end of the western arctic form (table 5). The growth ratio of the width of the base of the telson does not differ significantly from that for the Hudson Bay form (table 6) whereas growth ratios for width and length of the telson end do differ significantly.

All telson measurements show some degree of negative allometry. The base of the telson grows in width at approximately the same rate in the two forms. The telson end of the western arctic form, however, grows in length and width at a significantly more rapid rate.

3.4.5. Comparison of Ratios

It is now possible to return to the subject of growth ratios and to compare the mean values and variances of those measurement ratios of the two forms of M. sabini which do not show significant allometry. Those measurements having growth ratios which are not significantly different are also compared in this way. In view of the fact that the size ranges treated are approximately similar, the latter comparison is valid.

A list of comparable measurements appears in table 7. The means used in the tables are the arithmetic averages

TABLE 7

Statistical Separation of Measurement

Ratios for *M. sabini*

HUDSON BAY - A WESTERN ARCTIC - B

Ratio	Standard Deviation	Mean	Variance	Standard Error	Variance Ratio	Diff. / S.E. Diff.
W. less epimera / L. total	A 1.6826	24.7	2.8310	0.2379	5.9889	5.76
	B 0.6875	23.2	0.4727	0.0972		
W. total / L. total	A 1.4546	30.8	2.1160	0.2053	26.9108	18.29
	B 0.8867	26.4	0.7863	0.1254		
L. Telson / L. total	A 1.0917	38.2	1.1918	0.1543	1.0798	6.74
	B 1.1344	36.7	1.2869	0.1604		
W. Telson Base / L. Telson	A 2.4671	47.9	6.0865	0.3489	1.3938	3.94
	B 2.089	46.1	4.3669	0.2954		

of the data plotted in figure 8. The difference between means has been checked for significance using a normal probability integral table to determine the degree of significance of the following relation:

$$\frac{\text{difference between means (Diff.)}}{\text{Standard error of the difference (S.E. Diff.)}}$$

A "variance ratio" or "F" test has also been used in the treatment of these data.

Width measurements relative to total length show highly significant variance ratios and significant differences between means (table 7). There is a significant difference between means for the ratios of telson length: total length and telson width base: telson length. Both relations have non-significant variance ratios.

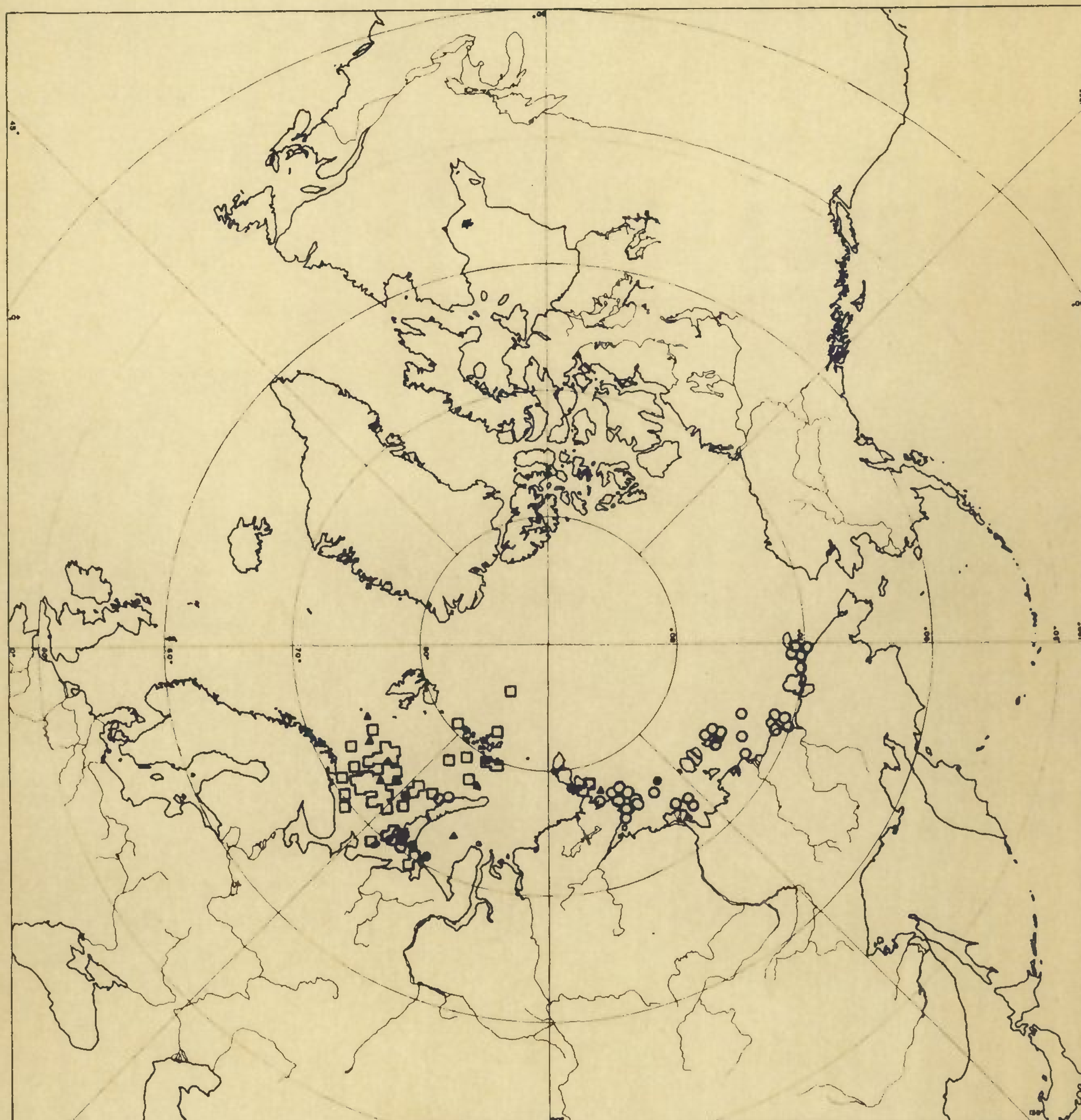
Measurements of body width represent the only clear differences in proportion between the two forms of *M. sabini*. All other relative length proportions show allometry and are therefore not reliable.

3.4.6. Previous Work

Before any comparison may be made with the work of Gurjanova (1933, 1946) the general outline of her work should be presented. This may be of special interest in view of the fact that translations of the articles have not been published.

Gurjanova recognizes two main subspecies of *Mesidothea sabini* (Krøyer). The typical form is separated from *M. sabini robusta* on the basis of geographical distribution, ecology, and morphology. The morphological distinction between the subspecies in the 60 - 65 mm. range is said to be sharply defined and to become more pronounced as size increases. Specimens in the 20 - 30 mm. length range and smaller are indistinguishable. A third subspecies *M. sabini megaluroides* (Gurjanova), is mentioned by Gurjanova (1946) but will not be included in this comparison because of lack of information. *M. sabini robusta*, which Gurjanova refers to as "Die sibirischen Exemplare" because of its distribution along the Siberian coast, has a more strongly arched dorsal surface; a relatively longer and narrower head; a relatively wider, shorter, and blunter telson; a peculiar form of the epimera and shorter antennae. The second antenna is said to reach scarcely to the end of the first thoracic segment.

M. sabini sabini has a narrow and attenuate telson with a strongly attenuated and cuspidate end. The heas is flat, smooth, and broadened out and the second antenna reaches to the end of the second thoracic segment. This animal turns white or light yellow when preserved in alcohol whereas the former subspecies becomes rather gray in colour.



Mesidothea sabini sabini (Kroyer) ——— □
" " (Kr.) <u>subsp.</u> robusta (Gurjanova) ——— ○
" " " sabini <u>natio</u> barentsi (Gurjanova) ——— ▲
" " " " " petschorica (Gurjanova) ——— ●

DISTRIBUTION of <u>M. sabini</u> ACCORDING to GURJANOVA, 1933

Figure 13

The typical form is further separated into two groups called "natio" _barentsi_ (Gurjanova) and "natio" _petschorica_ (Gurjanova). The latter attains a larger size and has a relatively shorter, wider telson.

The geographical distribution of those several forms, as given by Gurjanova, is shown in figure 13. The subspecies overlap in the Kara and eastern Barents Seas. The _M. s. s. barentsi_ group has a range not dissimilar from the parent subspecies and the _petschorica_ group, although not found as often, is similarly widely distributed.

Gurjanova separates the various forms of _M. sabini_ by means of what she calls "der variations - statistischen Methode" wherein she compares mean values of measurement ratios. The work is based on the measurement of a total of 440 specimens. Of these, 160 were collected from the Barents Sea, 32 from the Kara Sea, and 248 from the East Siberian Sea.

It has already been stated that the second antenna of the wester arctic form of _M. sabini_ reaches the end of the first thoracic segment whereas that of the Hudson Bay form reaches the middle of the first thoracic segment. Gaevskaya (1948) shows figures for Gurjanova's two subspecies in which the second antennae point laterally rather than posteriorly and may not, therefore, be compared.

TABLE 8

Comparison of North American Forms of M. sabini with those given by Gurjanova, 1933

	M. sabini sabini	M.S.S. barentsi	M.S.S. petschorica	M.S. robusta	HUDSON BAY Range for Ratio	HUDSON BAY Mean	WESTERN ARCTIC Range for Ratio	WESTERN ARCTIC Mean
Telson L. end / L.	43.1	42.9	43.2	40.5	39.0-45.1		39.0-47.0	
Telson W. end / L.	29.6	28.7	31.5	34.1	28.2-35.8		29.8-35.7	
Telson W. base / L.	43.0	42.5	43.9	47.9	42.7-53.0	47.9	41.5-51.0	46.1
Telson W. end / W.base	67.8	66.7	70.0	70.7	61.2-70.5		60.5-76.8	
Telson W. end / L. end	67.7	66.3	70.7	84.3	65.6-86.5	74.8	62.3-85.2	76.1
Body W. less epimera / L. total	23.8			23.8	23.2-26.1	24.7	21.1-24.2	23.2

Gaevskaya's text (p. 251) states, however, that the second antenna reaches the middle of the second thoracic segment in the typical form and the middle of the first thoracic segment in *robusta.* The difference between the subspecies on this basis appears to be real but sufficiently confused to make comparison with North American specimens difficult. The illustrations which Gaevskaya presents clearly show the shorter, broader telson of subspecies *robusta* but no other morphological difference is apparent. Her description of telson differences is similar to that given by Gurjanova.

Table 8 lists mean values of the ratios given by Gurjanova. Those considered to be of greatest importance by her are underlined. Maximum and minimum values of the ratios for North American forms (from the data in figure 8) are also given.

Of the various measurements of the telson for North American forms only the width of the telson end of the western arctic form did not show allometry. The width of the base of the telson of the two forms was the only measurement for which there was not a significant difference in growth ratio. Because the size ranges dealt with were similar, it was considered useful to compare the means and variances of these ratios. These values may not be compared with those of Gurjanova, however, because the size ranges and growth patterns of her specimens are not known.

The fact that Gurjanova's forms may not be distinguished until they reach a length between 30 and 60 mm. suggests that allometric growth is responsible for the differences upon which her work is based. The ranges given for North American forms include Gurjanova's values for each of her four groups. The only interesting difference occurring in the work of the latter is with regard to the ratio width telson end: length telson end where there is a 16.6% spread between the values for the typical and robusta forms. As shown in table 8, mean ratios for North American forms are intermediate between the Siberian subspecies on this basis. Measurements of body width, found to be the only reliable measurement proportions for the separation of North American forms, are considered unimportant. The values of width less epimera: total length are given as 23.8% for both forms. These values are intermediate between those given for the western arctic and Hudson Bay forms in table 8. The illustrations given by Gaevskaya (1948) were measured and the ratios calculated. The values of the important ratios are given below:

	M. sabini sabini	M. sabini robusta
telson end $\frac{\text{width}}{\text{length}}$	61.5	86.4
$\frac{\text{width less epimera}}{\text{total length (body)}}$	20.9	22.6
$\frac{\text{maximum width}}{\text{total length(body)}}$	25.1	27.7

These data show the relatively broad separation of the two forms with regard to the measurements of the end of the telson. Width measurements fit within the ranges for the western arctic form.

On the basis of this information, the western arctic form of *M.sabini* is intermediate between the *robusta* and typical subspecies. Width measurements are approximately similar, but the length of the second antenna and the important measurements of the telson end are intermediate. The Hudson Bay form of *M. sabini*, on the other hand, appears to be distinct from all other races on the basis of body width measurements. The zoogeographical implications of this complex situation are considered under section 8.2.

Distribution of < Mesidothea entomon ●
" sibirica ○

M. sibirica formerly called M. entomon in C.A.E. coll. △

Figure 14

3.5. Taxonomy of Mesidothea sibirica (Birula) and Mesidothea entomon (L.)

3.5.1. Introduction

The above species have been confused in both European and North American collections. Richardson's description (1905) is sufficiently broad to include the two forms under the name entomon and only European workers such as Birula (1896), Gaevskaya (1945) and Gurjanova (1933) deal with the separation of the two forms. The two species are clearly distinguished on the basis of morphology, growth patterns, ecology and phsiology. The collections of the Canadian Arctic Expedition have been re-examined and found to contain both species under the name M. entomon. The map, figure 14, gives the distribution of these species. M. sibirica was formerly thought to be distributed only as far east as the Bering Strait (Ekman, 1953).

3.5.2. Morphology

Gurjanova (1933) and Gaevskaya (1946) point out the morphological differences between M. sibirica and M.entomon. Because these works have not been translated, a list of the distinguishing features used is given in table 9.

Mesidothea sibirica

FIGURE 15

Mesidothea entomon

FIGURE 16

DORSAL VIEWS of MATURE MALES

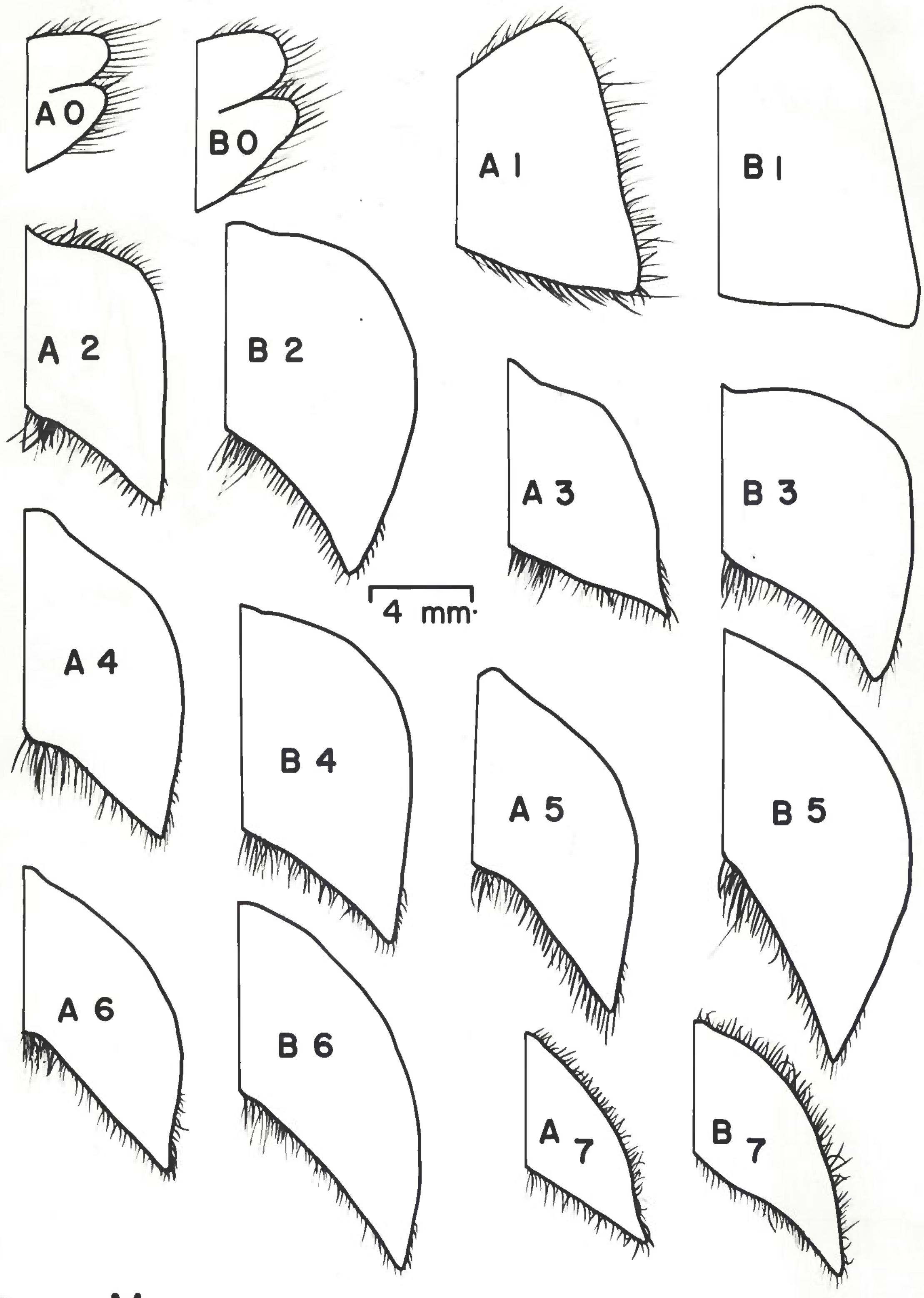
TABLE 9

Morphological Differences Between *M. sibirica* and *M. entomon*

M. sibirica	*M. entomon*
a. forehead strongly arched	a. forehead flat
b. epimera keeled	b. epimera not keeled, rather flat in appearance
c. telson pentagonal	c. telson triangular
d. widest at 3rd. thoracic segment.	d. widest at 4th. thoracic segment
e. antenna 2 - flagellum having 9 articles	e. antenna 2 - flagellum having 12 articles
f. base of telson elevated	f. base of telson flat

Figures 15 and 16 illustrate dorsal views of mature males of *M. sibirica* and *M. entomon* respectively. The various points of separation are commented on below.

The more strongly arched forehead of *M. sibirica* is noticeable in specimens of all sizes but becomes increasingly more pronounced with age. The keeled nature of the epimera of the former, as opposed to the flat condition in *M. entomon*, is especially noticeable in larger specimens. The general appearance of the epimera is different in animals of all sizes. The two species may also be distinguished on the basis of the setation of the epimera of the



MESIDOTHEA ENTOMON — A   MARGIN OF HEAD — O
" SIBIRICA — B   EPIMERA.... 1 — 7
COMPARING EPIMERA (SPECIMENS 80 mm. LENGTH)

Figure 17

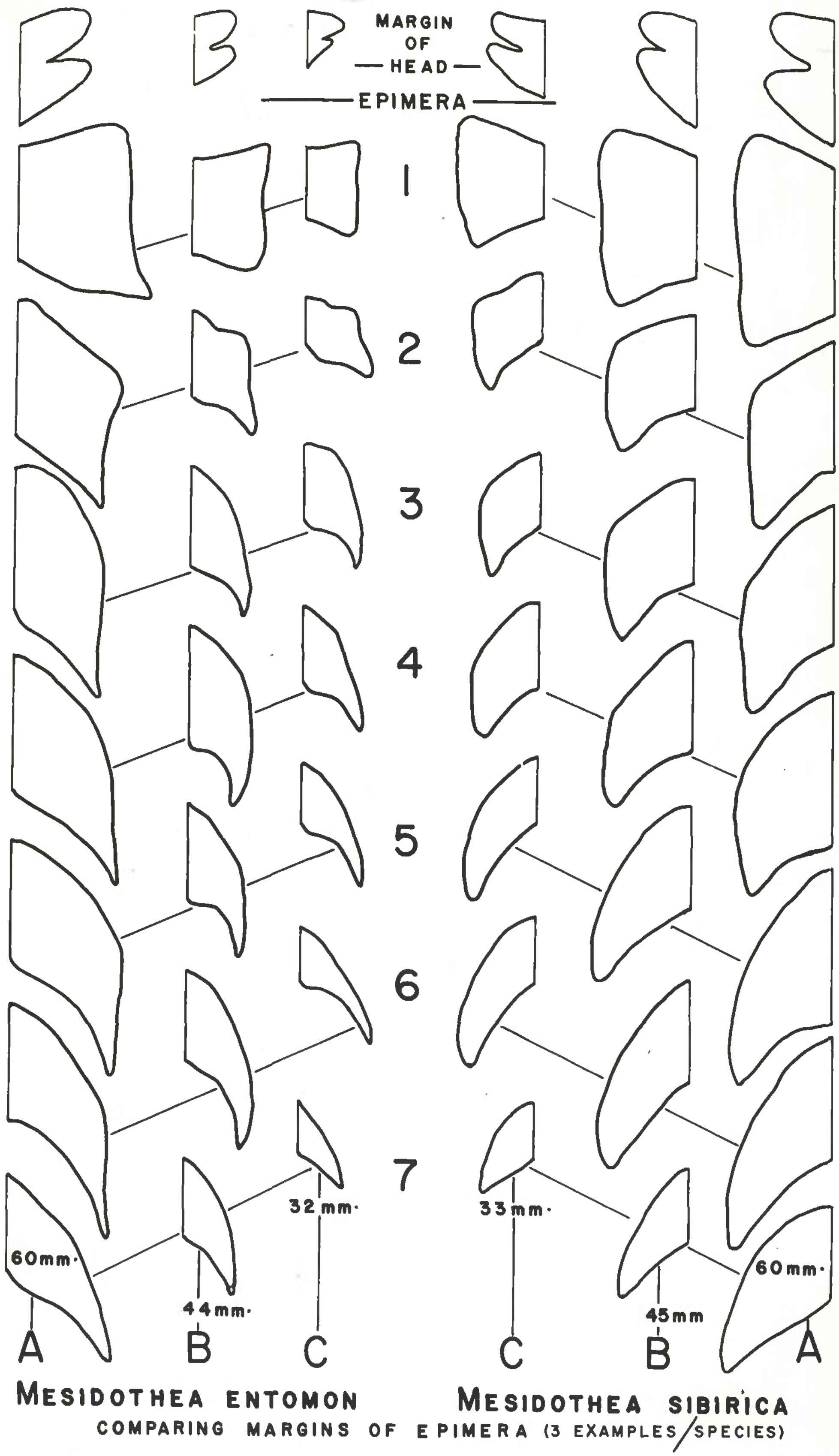

MARGIN
OF
HEAD
EPIMERA
1
2
3
4
5
6
7
60mm.
44mm.
32mm.
33mm.
45mm
60mm.
A
B
C
C
B
A
MESIDOTHEA ENTOMON
MESIDOTHEA SIBIRICA
COMPARING MARGINS OF EPIMERA (3 EXAMPLES/SPECIES)

Figure 18

first thoracic segment (Gaevskaya, 1945). Figure 17 shows a comparison of the general outlines of the sides of the head and epimera 1 to 7 of two 80 mm. specimens. The degree of setation is shown and is consistent for all sizes. The epimeron of the first thoracic segment of M. entomon bears setae along its entire margin (A 1 in figure 17) and the epimeron of the second on anterior and posterior edges (A 2). The first epimeron of M. sibirica (B 1) bears no setae and the second bears setae on the posterior margin only. In general outline, the second to seventh epimera of M. sibirica (B 2 to B 7) are relatively larger, wider, and more rounded on the anterior and lateral margins than epimera of M. entomon from animals of comparable size (A 2 to A 7).

The general outlines of the margins of the epimera of a series of three examples of each species are compared in figure 18. Anterior and lateral margins of epimera 1 to 7 inclusive are more rounded in outline for M. sibirica. Epimera 3 to 7 of M. entomon appear increasingly more pointed as size decreases until the difference between young in the brood pouch becomes very pronounced (figures 39 and 40, 42 and 43).

The pentagonal nature of the telson of M. sibirica as opposed to the triangular nature for that of M. entomon

TABLE 10

Number of Articles of Flagellae of Second Antennae

Length group (mm.)	M. entomon	Number Counted	M. sibirica	Number Counted
5-9	5-6	4	3-4	5
10-14	5-7	2	4	2
15-19	8-9	3	5-6	5
20-24	9	2	5-7	7
25-29			6-7	2
30-34	10	4	6-8	8
35-39	10-11	7	8	2
40-44	11-13	9	8-10	3
45-49	12-14	5		
50-54	12-13	3	8-10	4
55-59	13	1	9-10	2
60-64	15	2	11	4
65-69	13-14	2	11	1
70-74	14	1	10-11	3
75-79	15-17	2	10-11	2
80-84	16	1	10-12	5
85-89	16	2	11	2
90-94			10	1
95-100			10-12	4

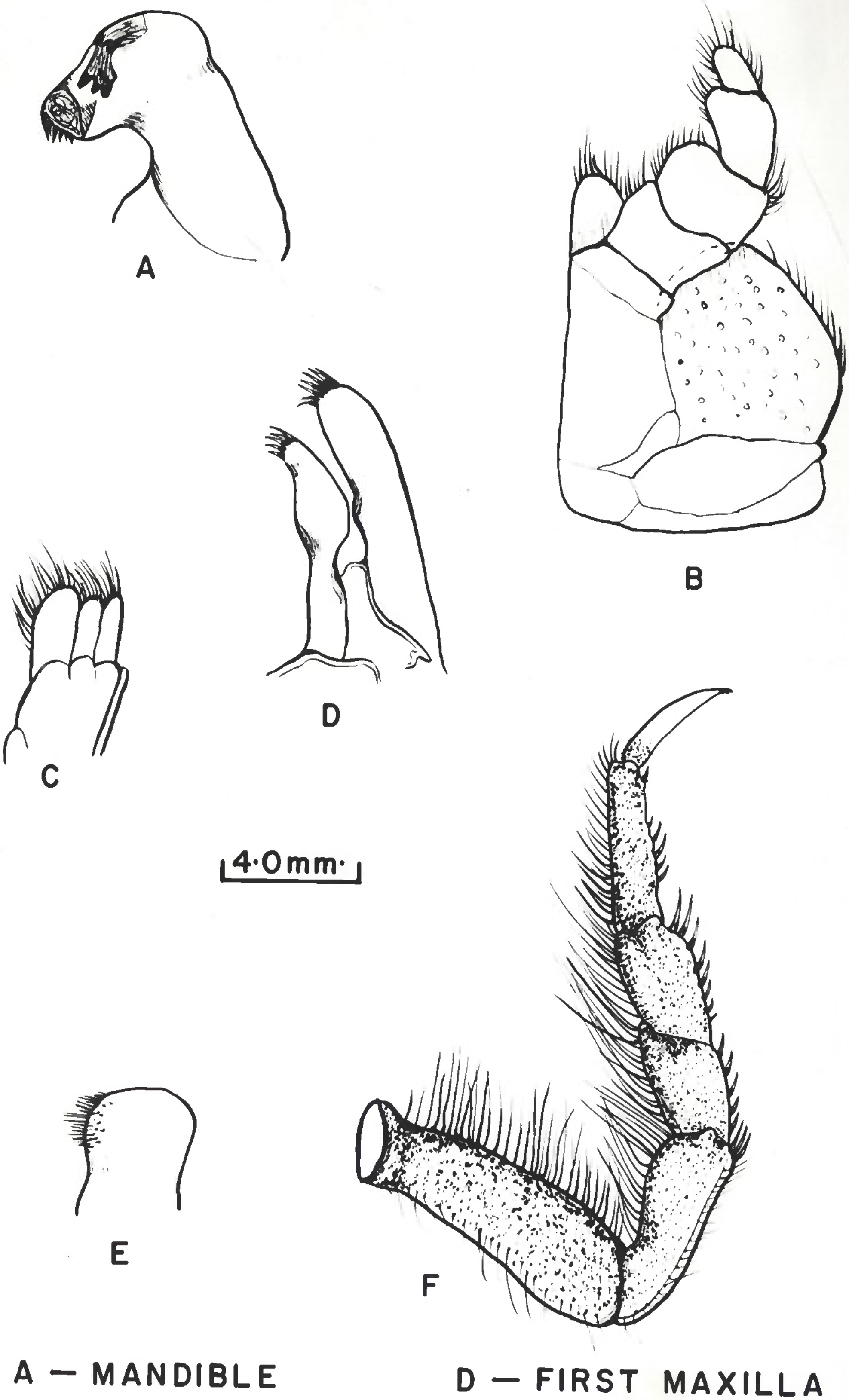
is particularly pronounced in small animals. This will be discussed in the following section on patterns of growth.

The widest body segment shows individual variation for both species. A useful point, however, is that the thoracic region of M. entomon is rather oval in outline whereas M. sibirica is more rectangular.

The number of articles of the flagellum of antenna 2 is variable in both species. To compare the two species on this basis, all of the articles (including the basal and smallest terminal members) were included in the counts. Table 10 lists the range in article number /length group/ species.

The number of articles ranges from 5 to 16 for M. entomon and from 3 to 12 for M. sibirica. It is evident, however, that this is a useful morphological distinction only if the sizes of the animals compared are considered.

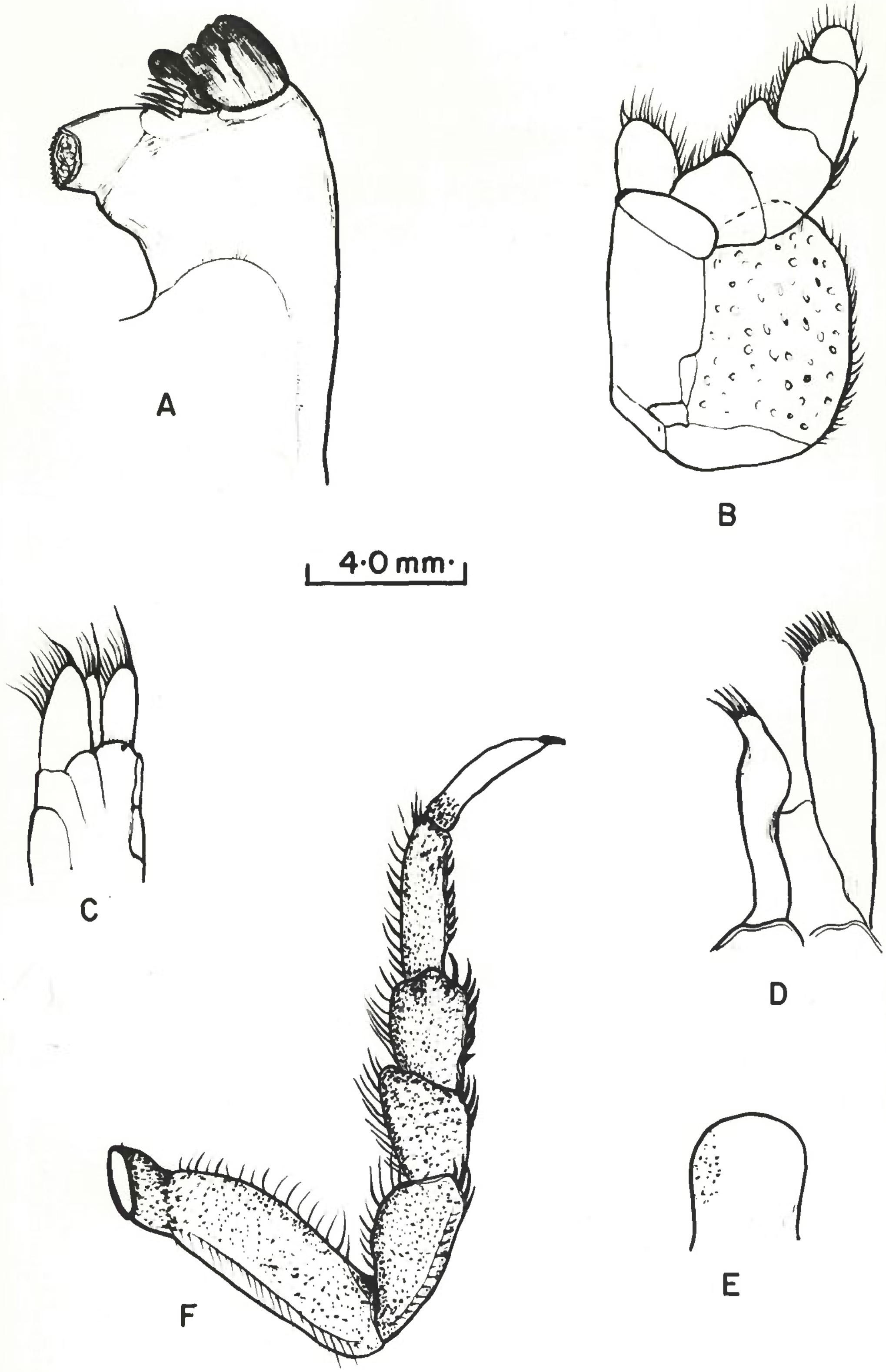
Richardson (1905) describes a 17 mm. specimen of M. entomon as having a flagellum composed of 6 articles. M. sibirica for that length was found to have 5 or 6, M. entomon 8 or 9 articles (table 10). Furthermore, the specimen illustrated in figure 374a has the pentagonal telson and rather rectangular thorax suggestive of M. sibirica. The illustration resembles the latter much more closely than it does M. entomon.



A — MANDIBLE
B — MAXILLIPED
C — SECOND MAXILLA
D — FIRST MAXILLA
E — LABIUM
F — PERIOPOD 5

MESIDOTHEA ENTOMON

Figure 19



A — MANDIBLE
B — MAXILLIPED
C — SECOND MAXILLA
D — FIRST MAXILLA
E — LABIUM
F — PERIOPOD 5

MESIDOTHEA SIBIRICA

Figure 20

Figures 19 and 20 show a comparison of the mouthparts of the species and also of the periopods. A very noticeable difference is apparent in the relatively larger and much heavier mandible of M. sibirica. The tooth of the mandible of M. sibirica is relatively much broader and stronger in appearance.

The periopods of M. entomon bear more numerous, longer setae on their anterior margins. Examples of the fifth periopod are compared in figures 19 and 20 but the remaining periopods differ in the same way.

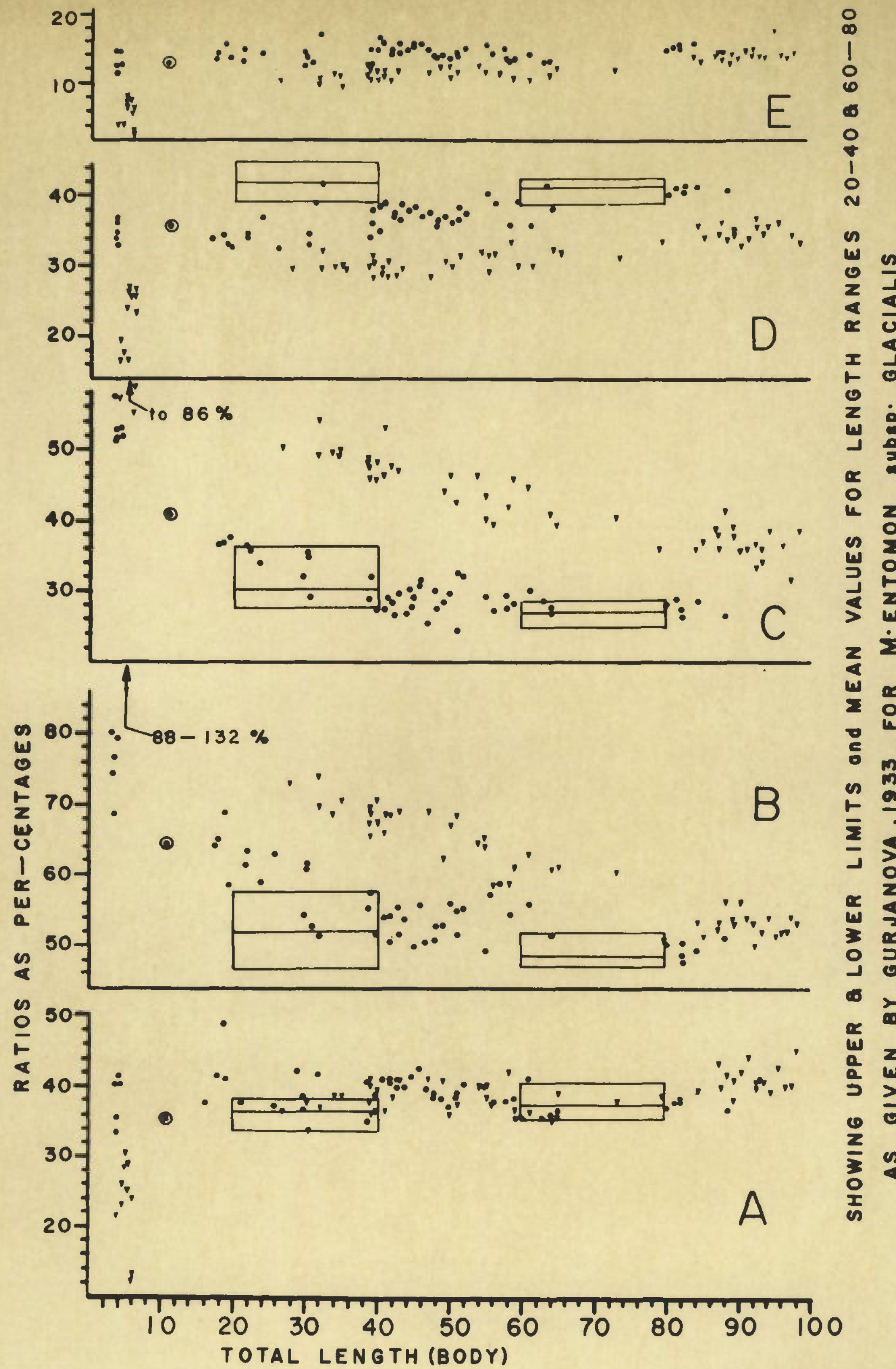
3.5.3. Measurement Ratios

In order to compare the body proportions of *M. sibirica* and *M. entomon* a number of specimens were measured, the ratios of measurement calculated, and the values plotted against total body length in figures 21 and 22. Measurements were made as described in section 3.3. A list of the number of specimens measured and the locations from which they were taken appears in table 11.

TABLE 11

	Number Measured	Locations
M. sibirica	40	Herschel Island area
M. sibirica	13	Tuktoyaktuk area
M. entomon	9	Liverpool Bay
M. entomon	30	Tuktoyaktuk area
M. entomon	5	Herschel Island area
M. entomon	1	Greiner Lake
M. entomon	12	Banks Island

Male specimens only have been measured in all cases except for animals less than 25 mm. in length which were not separated as to sex. This precedent has been established by Gurjanova. Several female specimens were measured and their measurement ratios were found to fit within the ranges



MESIDOTHEA ENTOMON— •   GREINER LAKE — ⊙

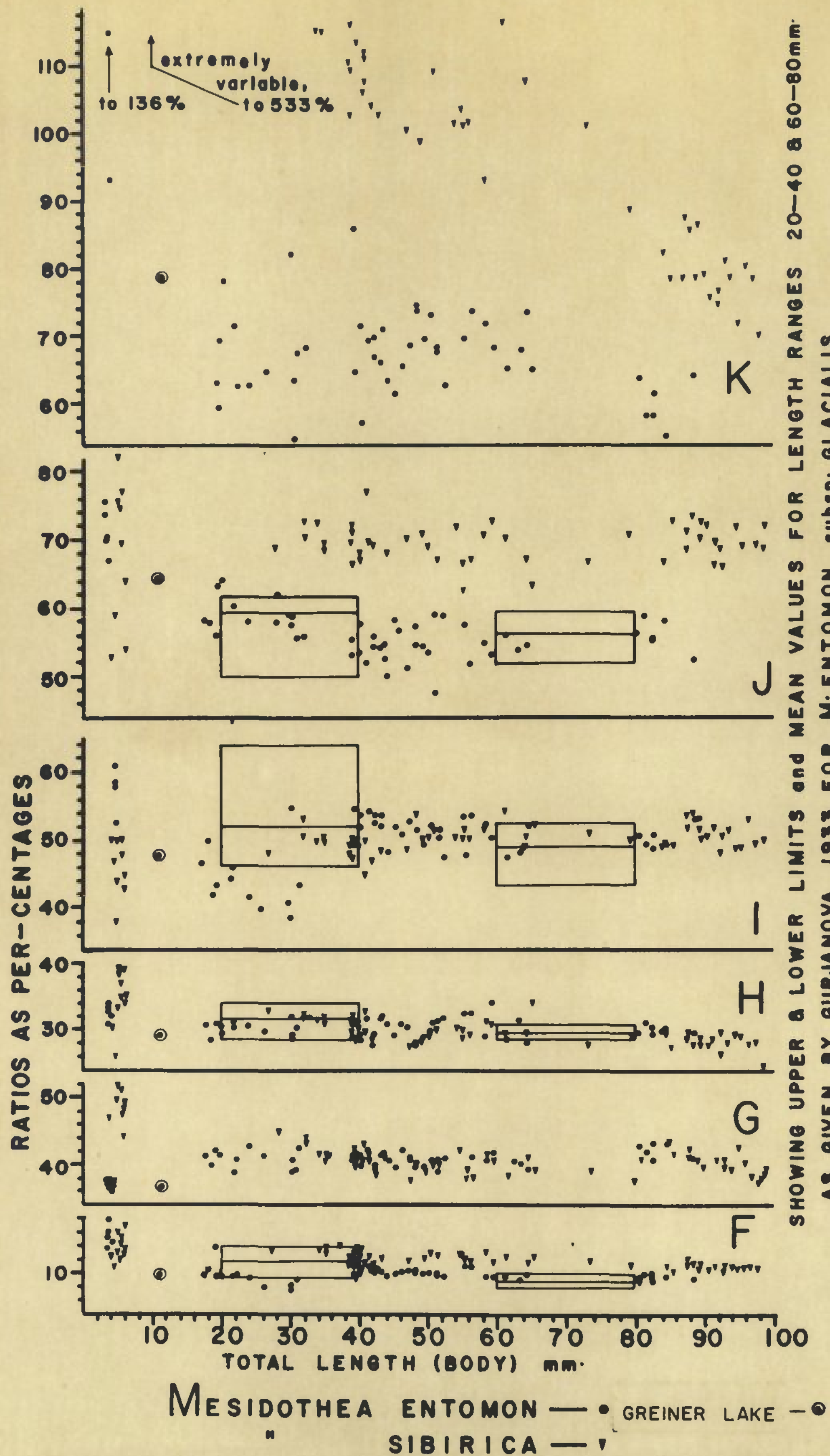
" SIBIRICA— ▼

Figure 21

given for males. The fact that the latter reach a larger size and are usually more numerous in collections is the reason for their use. The following ratios were calculated: A to E appear in figure 21; F to K in figure 22.

A	Telson	$\frac{\text{Length end}}{\text{Length total}}$
B	Telson	$\frac{\text{Width base}}{\text{Length total}}$
C	Telson	$\frac{\text{Width end}}{\text{Length total}}$
D	Body	$\frac{\text{Length telson}}{\text{Total length}}$
E	Body	$\frac{\text{Length Telson end}}{\text{Total length}}$
F	Body	$\frac{\text{Length head}}{\text{Total length}}$
G	Body	$\frac{\text{Maximum width}}{\text{Total length}}$
H	Body	$\frac{\text{Width less epimera}}{\text{Total length}}$
I	Head	$\frac{\text{Length}}{\text{Width}}$
J	Telson	$\frac{\text{Width end}}{\text{Width base}}$
K	Body	$\frac{\text{Length head}}{\text{Length telson end}}$

The measurement of head width, not shown in figure 2, is the maximum width of the cephalic segment.



to 136%
extremely variable, to 533%
RATIOS AS PER-CENTAGES
K
J
I
H
G
F
TOTAL LENGTH (BODY) mm.
SHOWING UPPER & LOWER LIMITS and MEAN VALUES FOR LENGTH RANGES 20—40 & 60—80mm.
AS GIVEN BY GURJANOVA, 1933 FOR M. ENTOMON subsp. GLACIALIS
MESIDOTHEA ENTOMON — •
" SIBIRICA — ▾
GREINER LAKE — ◉

Figure 22

Figures 21 and 22 show that _M_. _sibirica_ and _M_. _entomon_ are clearly distinct on the basis of several measurement ratios. _M_. _sibirica_, for example, has a relatively broader telson at all lengths (B and C, figure 21; J, figure 22). In addition, _M_. _sibirica_ has a relatively shorter telson (D, figure 21) and a shorter telson end (E, figure 21). There is also a marked difference in the growth of the head in length relative to the telson end (K figure 22). The head of _M_. _sibirica_ is longer throughout the lives of the animals. The telson end of _M_. _sibirica_ is relatively shorter than that of _M_. _entomon_ in early life but becomes nearly the same length in large specemens.

The fact that the points plotted in figures 21 and 22 do not follow straight lines in most cases suggests that both species grow at differential rates and that these rates differ markedly between the two species. In other words, both species show pronounced allometric growth for certain measurements. The topic of allometry has been discussed under section 3.4.4. for _M_. _sabini_. There is no particular value in calculating regression lines for the data in figures 21 and 22. _M_. _sibirica_ and _entomon_ are clearly distinguishable by other means.

The measurements of the Greiner Lake specimen refered to in table 11 fall within the ranges plotted for _M_. entomon from the western arctic (figures 21 and 22).

3.5.4. Previous Work

Gurjanova (1933) lists five forms of Mesidothea entomon (L.) as given in tale 12, below:

TABLE 12

Form	Distribution
entomon	Baltic Sea
entomon natio septentrionalis (G.)	White Sea
glacialis (G.)	Estuaries of Rivers, Novaya Zemlya to Bering Strait
glacialis natio caspia (G.)	Caspian Sea
orientalis (G.)	St. Lawrence Island, Bering Strait, to Sea of Okhotsk

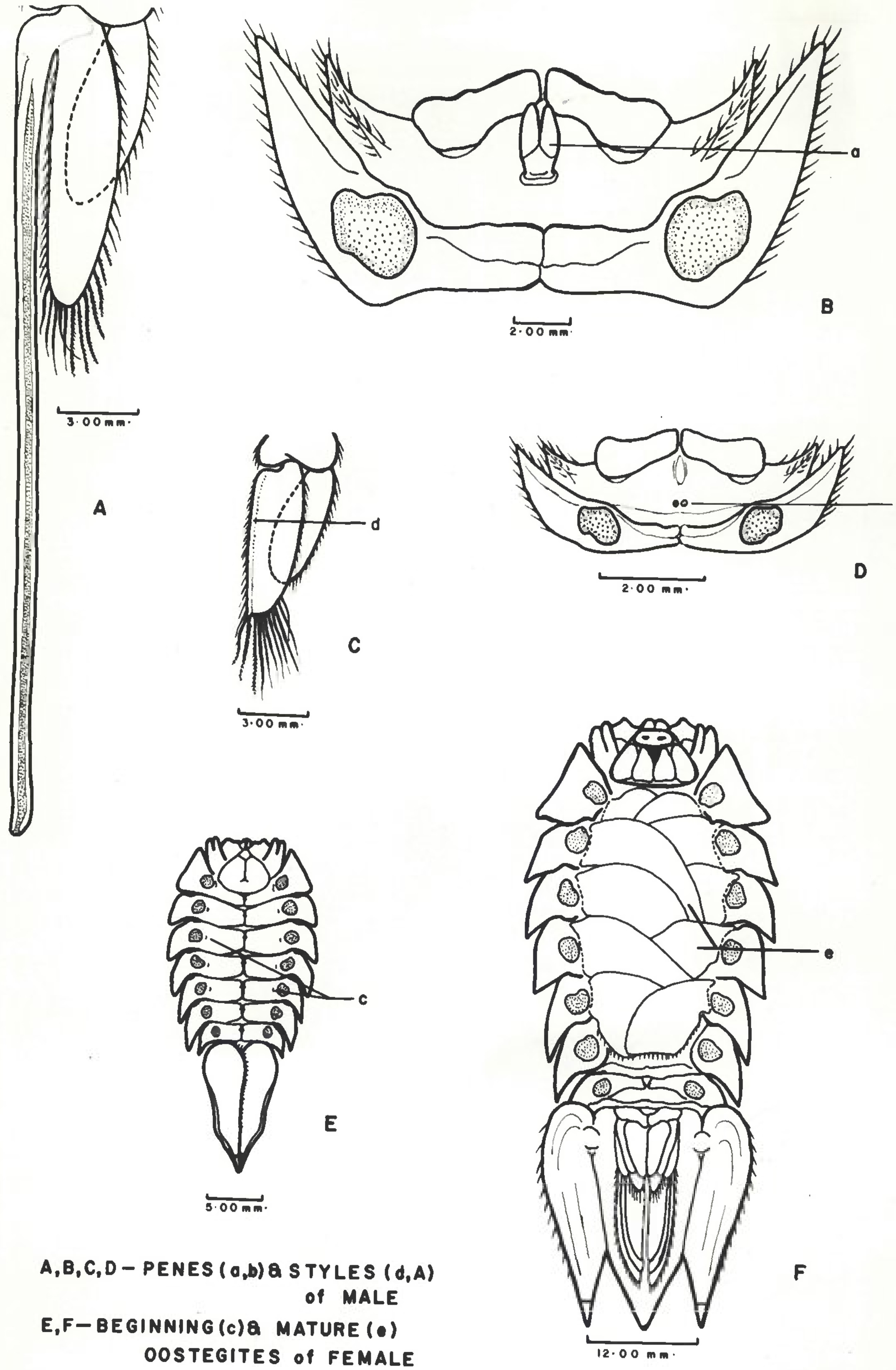
Gurjanova (1946) lists an additional form, M. entomon glacialis natio vetterensis (G.), from the Caspian Sea.

The separation of these forms is based upon geographical distribution and measurement ratios. Gurjanova publishes mean values and extreme values for the length groups which she measured and also includes the number of examples observed. The information which she gives for M. entomon subspecies glacialis (G.) is based on measurements of 20 examples from the 20-40 mm. length group and

10 from the 60-80 mm. length group. The ranges given by Gurjanova for *M. entomon glacialis* include most of the points plotted for *M. entomon* in figures 21 and 22. Data are less complete for the other forms mentioned and do not agree as closely.

It is difficult to compare the data from this study with that given by Gurjanova (1933 and 1946). As has been discussed under part 111 of section 3.4.4. for *M. sabini*, relative length proportions of parts are not taxonomically reliable where allometry exists. Pronounced allometric growth occurs in the population studied here and is probably responsible for the differences in the various European forms.

Gurjanova separates *M. entomon orientalis* from *glacialis* on the basis of measurements of 55 specimens. It is the opinion of the author that the two forms will be nearly similar where their ranges overlap in the Bering Strait and that diversification will take place as geographical separation increases. The forms in the Baltic, Caspian and White Seas have every opportunity to show diversification in view of their historical isolation.



A, B, C, D – PENES (a, b) & STYLES (d, A) of MALE
E, F – BEGINNING (c) & MATURE (e) OOSTEGITES of FEMALE

GENERAL DEVELOPMENT OF SEXUAL STRUCTURES
MESIDOTHEA SPECIES

Figure 23

4. SEXUAL DIMORPHISM IN GENUS *Mesidothea*

4.1. Description

Mesidothea species, similar to other isopods, are sexually dimorphic. Figure 23 illustrates the generalized situation for the genus and a description on the development of sexual structures follows.

In males, a pair of penes develop in the middle of the ventral surface of the seventh thoracic segment and, at maturity, project caudally (Figure 23, B and D). At an early stage also, a projection appears at the distal end of the endopodite of the second pleopod on the side nearest the mid-line. This projection gradually lengthens and separates from the endopodite until it forms a style hinged to the endopodite at the base only by the time the animal reaches maturity (Figure 23, A and C). The styles appearing on the paired second pleopods adjoin one another along their entire lengths. Because the adjoining styles are grooved, they form a functional tube which in mature specimens, extends to the end of the telson and would appear to have copulatory function. Males with fully-developed copulatory styles were considered to be mature. Photographs of mature males of *Mesidothea sabini*, *sibirica* and *entomon* are given in figures 24, 25 and 26 respectively.

M. sabini

FIGURE 24

M. sibirica

FIGURE 25

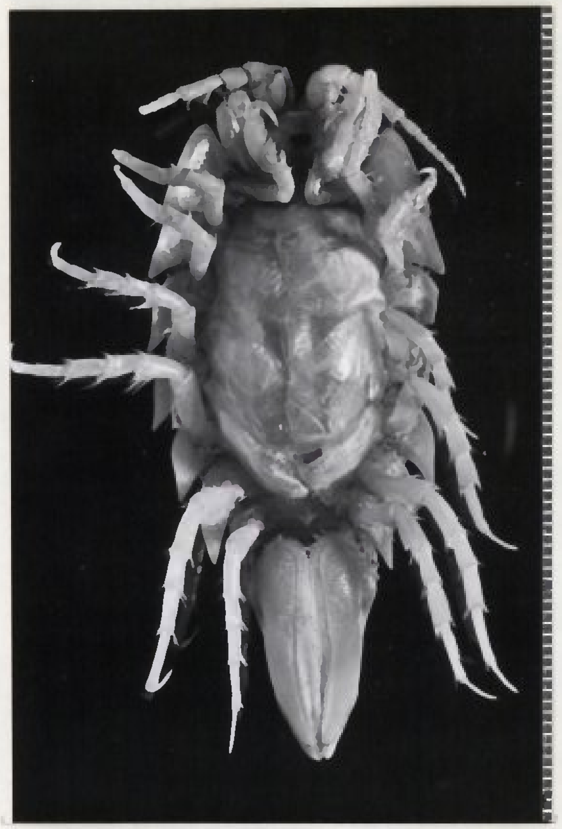
M. entomon

FIGURE 26

VENTRAL VIEWS of MATURE MALES of Mesidothea SPECIES

M. sabini

FIGURE 27



M. sibirica

FIGURE 28

M. entomon

FIGURE 29

VENTRAL VIEWS of MATURE FEMALES of *Mesidothea* SPECIES

Opercular valves have been folded aside to expose styles and penes.

In females tiny projections originating from the mesal margins of the coxae of the first five thoracic segments appear at an early stage in the development of the animal. Accelerated development of these structures takes place when ova are of a mature size and ready for deposition. The large overlapping oostegites formed thereby serve as a brood pouch in which the ova develop (Figure 20, E and F).

The ova pass into the brood pouch through genital ducts which open on the ventral surface of the fifth abdominal segment. These ducts appear on each of the lateral edges of the segment close to the points of attachment of the oostegites. Ova are transported through the ducts and remain unattached within the cavity created between the ventral wall of the abdomen and the overlapping oostegites. Females which had fully-developed oostegites were considered mature. Photographs of mature females of <u>Mesidothea sabini</u>, <u>sibirica</u> and <u>entomon</u> are given in figures 27, 28 and 29 respectively.

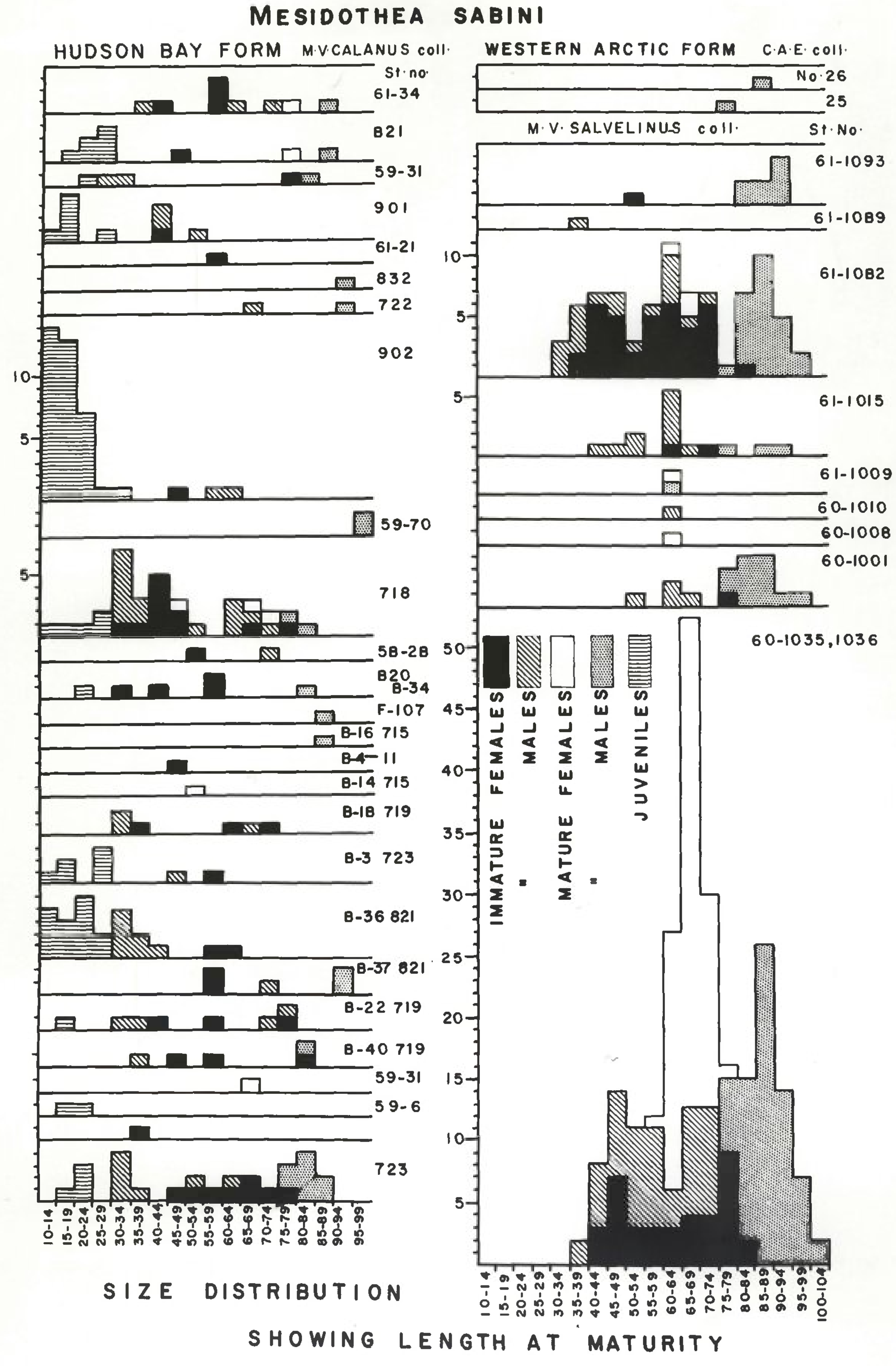

MESIDOTHEA SABINI
HUDSON BAY FORM M·V·CALANUS coll·
WESTERN ARCTIC FORM C·A·E· coll·
M·V· SALVELINUS coll·
St·no·
61-34
821
59-31
901
61-21
832
722
902
59-70
718
58-28
820
B-34
F-107
B-16 715
B-4 11
B-14 715
B-18 719
B-3 723
B-36 821
B-37 821
B-22 719
B-40 719
59-31
59-6
723
No·26
25
61-1093
61-1089
61-1082
61-1015
61-1009
60-1010
60-1008
60-1001
60-1035,1036
IMMATURE FEMALES
" MALES
MATURE FEMALES
" MALES
JUVENILES
SIZE DISTRIBUTION
SHOWING LENGTH AT MATURITY

Figure 30

4.2. Size of Maturity

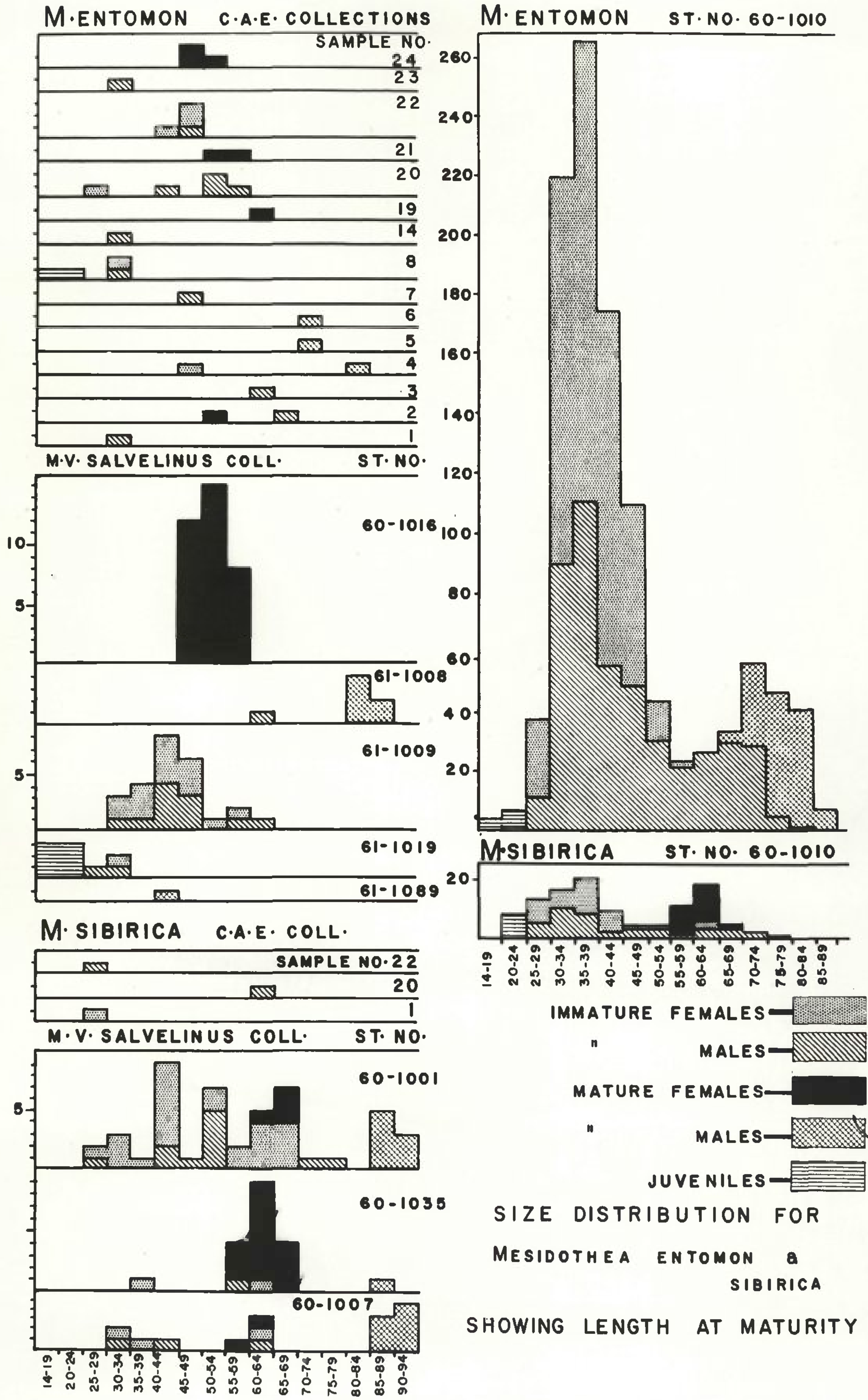
All available collections of Mesidothea were sexed according to the criteria mentioned under section 4.1. Animals greater than about 40 mm. in length could be sexed without any visual aid but smaller specimens were examined under a binocular microscope. The sex of specimens of M. entomon and M. sibirica below about 25 mm. and of M. sabini below 30 mm. could not be determined accurately and such animals were called juveniles.

The size compositions of the various collections examined appear in figure 30 for M. sabini and in figure 31 for entomon and sibirica. Locations are listed in appendices A and D.

The length of mature males of the western arctic form (figure 30) ranged from 75-102 mm. A single specimen from St. No. 61-1009 (area 7, figure 1) was fully matured at 64 mm. Mature females ranged from 55 to 79 mm. in total length.

Mature males of the Hudson Bay form, without exception, ranged in size from 75 to 104 mm. and mature females from 45 to 84 mm. The broader range in size of the latter group is the only difference between the two forms which these data show.

Immature females completely overlap size ranges for mature females in both forms. This situation is mainly



M·ENTOMON C·A·E· COLLECTIONS
SAMPLE NO·
24
23
22
21
20
19
14
8
7
6
5
4
3
2
1
M·V· SALVELINUS COLL· ST· NO·
60-1016
10
5
61-1008
61-1009
5
61-1019
61-1089
M· SIBIRICA C·A·E· COLL·
SAMPLE NO·22
20
1
M·V· SALVELINUS COLL· ST· NO·
60-1001
5
60-1035
60-1007
14-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
M· ENTOMON ST· NO· 60-1010
260
240
220
200
180
160
140
120
100
80
60
40
20
M·SIBIRICA ST· NO· 60-1010
20
IMMATURE FEMALES
" MALES
MATURE FEMALES
" MALES
JUVENILES
SIZE DISTRIBUTION FOR
MESIDOTHEA ENTOMON & SIBIRICA
SHOWING LENGTH AT MATURITY

Figure 31

due to the fact that females develop their brood pouches rapidly, probably during a single moult, and may contain fully-developed ova even though oostegites are rudimentary in form.

Figure 31 indicates that males of *M. sibirica* become mature between 85 and 94 mm. and females between 45 and 80 mm. Males of *M. entomon*, on the other hand, become mature between 65 and 95 mm., females between 45 and 64 mm. The majority of the latter are grouped in the 45 - 59 mm. range whereas females of *M. sibirica* are grouped primarily between 55 and 69 mm. A single male of *M. entomon*, clearly mature and only 43 mm. long, was taken at St. No. 61-1089 (location 5, figure 1). The size ranges of immature and mature males of *M. entomon* overlap but are clearly separated in *M. sibirica*. Mature females of both forms show considerable overlap due, probably, to the explanation given for *M. sabini*.

4.3. Life History

Mesidothea species may produce young throughout the year but such activity appears to be confined mainly to the summer season. Because animals are born at a particular time of the year and presumable grow more slowly in winter because of a reduced food supply, populations are comprised of definite age groups.

The various species appear to spawn once and die. Mature animals of both sexes rarely contained food in their digestive tracts and appeared to be living on fat particles which had been stored within their bodies. The internal organs of spent females and males were observed to have degenerated leaving only the exoskeleton.

The quantitative collections of *Mesidothea* shown in figures 30 and 31 give clues to the life histories of the various species. Because the collections are biased toward larger specimens, the quantitative information does not give an accurate picture of the size distributions for the populations sampled and the data does not lend itself to statistical treatment.

If the size composition of *M. sabini* from St. No. 60-1035, 1036 is considered (figure 30), we see that male specimens have two peaks, one occurring for mature, the other for immature animals. Immature males in the 65 - 75 mm.

length range contribute to the peak for mature animals. These animals may well have been nearly mature; the external manifestations of maturity are not abrupt for males. Immature and mature females, on the other hand, overlap completely but two high points are shown to occur. For St. No. 61-1015, male specimens show three high points whereas females show only two. If each peak represents an age group, and if it is assumed that the smallest age group may have escaped being sampled, then the life cycle of *M. sabini* probably requires 3 or 4 years.

Male specimens of *M. entomon* from St. No. 60-1010 (figure 31) have two peaks. Immature females form one peak only; the absence of mature females from that location is assumed to be due to their tendency to migrate inshore in order to deposit their young. Females of *M. sibirica* for St. No. 60-1010 form two peaks. The fact that no mature males were taken in that collection is not considered significant because of its small size. Again assuming that the smallest age groups of these species may have escaped being sampled, the life cycles of *M. entomon* and *M. sibirica* probably require 2 or 3 years.

5. REPRODUCTION

5.1. Introduction

The reproductive potential of isopods from arctic regions has not been considered in the literature. Counts of ova or embryos for Mesidothea species are given by some authors but are not treated mathematically. The data obtained in this study are deficient but are given mathematical treatment whenever possible. The differences in egg number and diameter have been found to show important differences between these animals.

5.2. Procedure

In the field, the numbers and average weights of ovigerous females were recorded for each station. Animals which had deposited their offspring were said to be in the "spent" condition and counted separately. In most cases, all females carrying brood pouches were preserved.

Collections were re-examined in the laboratory in order to determine the number of progeny each animal carried. The number of undeveloped ova of embryos within the brood pouch of each female was recorded; the abdominal cavity was examined in each case in order to assure that all ova had been transferred into the pouch. Females which did not have brood pouches but were nearing mature size were also examined and ova which were sufficiently developed to be separated were counted. Ten ova from each specimen were measured to the nearest o.l mm. using a measureing eye-piece in a stereoscopic microscope and the mean of these values taken as a measure of egg diameter. Two measurements were taken in each case because the ova were not perfectly round. The various forms of Mesidothea are compared on the basis of means and standard deviations of egg diameters. Correlation coefficients between total length of the parent female and number of offspring were calculated for the various forms.

5.3. Discussion

Loss of offspring from brood pouches before the animals are capable of living in the free state probably occurs during life, during the process of collection, and in storage. Samples have been observed in which numbers of ova had been shaken free from the brood pouch and remained loose within the sample jars.

The question of egg loss from isopod species has been dealt with by other authors. Janke (1924) observed a gradual reduction in brood size as development progressed which amounted to about 45% in Asellus aquaticus (L.). Ellis (1961) considers that such loss may occur in Asellus intermedius (Forbes). Steel (1961) observed a gradual

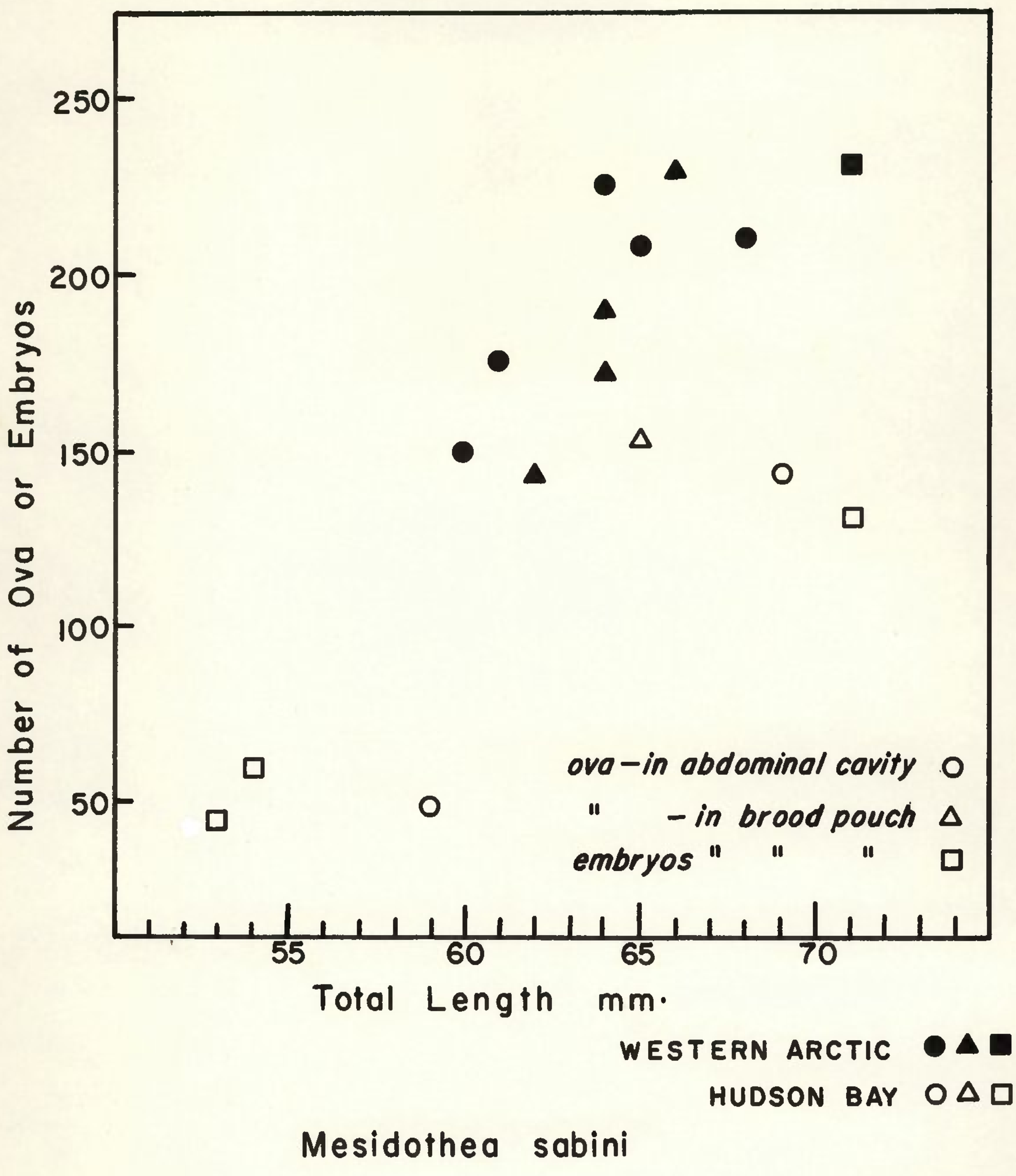

250
200
150
100
50
Number of Ova or Embryos
55
60
65
70
Total Length mm.
ova—in abdominal cavity
" —in brood pouch
embryos " " "
WESTERN ARCTIC
HUDSON BAY
Mesidothea sabini

Figure 32

loss of young, particularly of ova, from the brood pouches of Asellus aquaticus (L.) and Asellus meridianus (Racovitza) under laboratory conditions.

No comment may be made about the probable natural losses of young occurring in these species. Collections have been made, however, by means of trawl dredges and otter trawls, both of which treat specimens somewhat roughly. In this work, counts were made only of those animals which appeared to have lost no young from their brood pouches. Counts of ova from the abdominal cavities were not higher than from brood pouches in most cases; indicating that loss after transfer is not often significant.

Counts of offspring of the two forms of M. sabini appear in figure 32. Both forms become mature at about the same length but few specimens are available for comparison. Numbers of offspring for the Hudson Bay form ranged from 48 to 150 whereas the western arctic form ranged from 145 to 230. The correlation coefficient between number of offspring and total length is 0.45 for the latter and 0.87 for the western arctic form. Regression lines have not been drawn because of lack of material.

Table 13, below, compares the egg diameters of the two forms of M. sabini and gives correlation coefficients (r) between total length of the parent female and number of offspring.

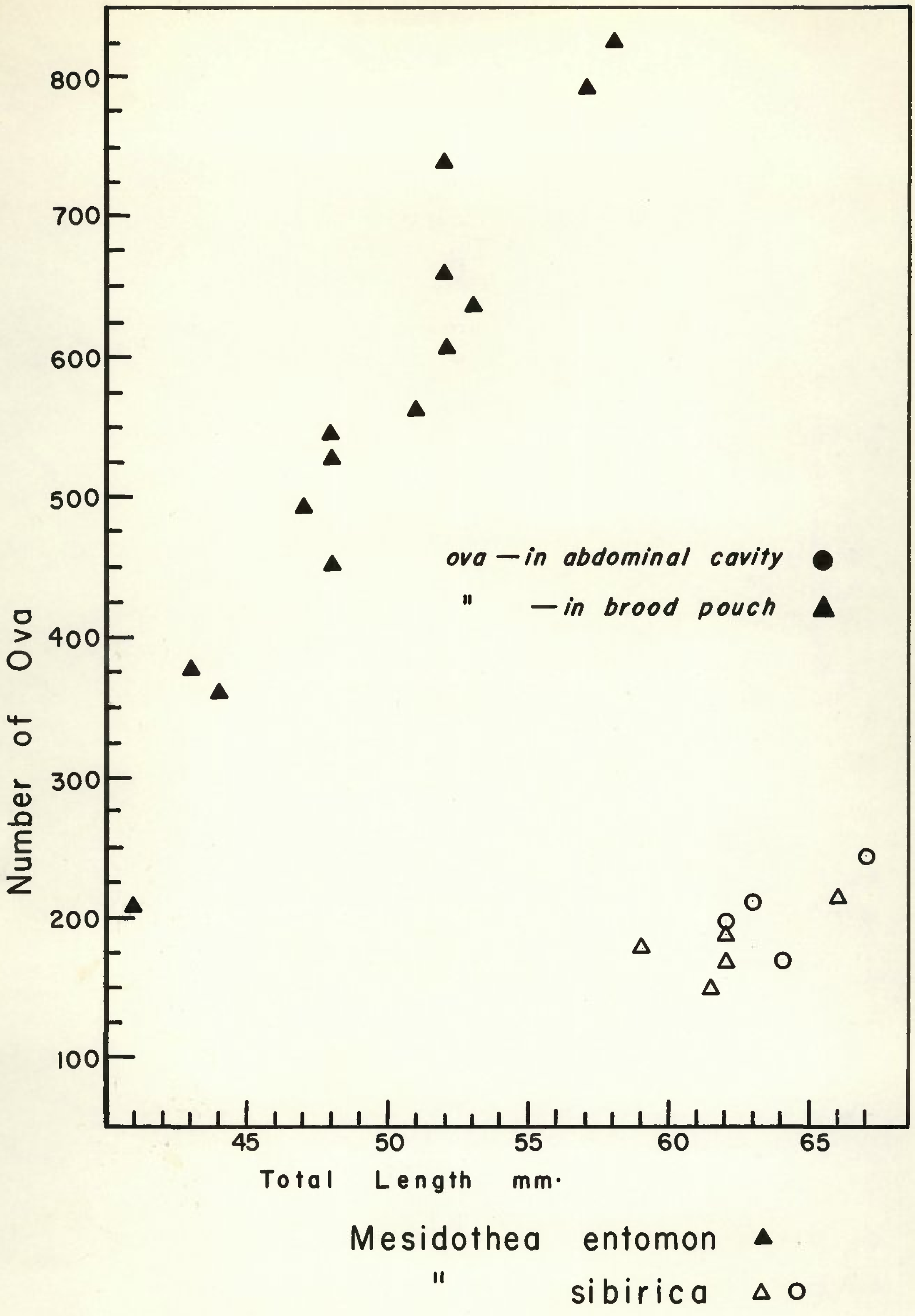
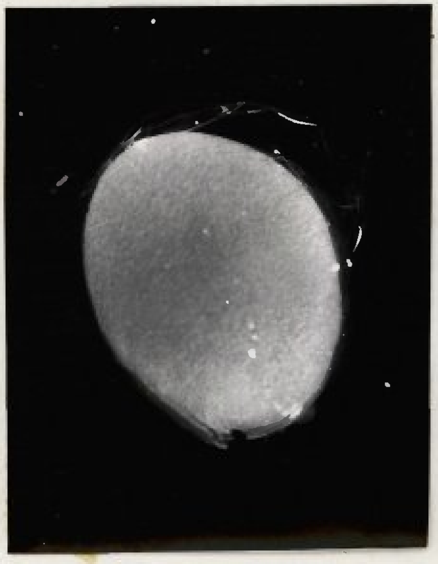

Number of Ova
800
700
600
500
400
300
200
100
45
50
55
60
65
Total Length mm.
ova — in abdominal cavity
" — in brood pouch
Mesidothea entomon
" sibirica

Figure 33



HUDSON BAY
Figure 34

WESTERN ARCTIC
Figure 35

M. sabini

M. sibirica

Figure 36

M. entomon

Figure 37

UNDEVELOPED OVA of Mesidothea SPECIES

TABLE 13

WESTERN ARCTIC	Mean Diameter	Size Range	No. Specimens	Standard Deviation	(r)
Brood Pouch	2.21	1.89-2.72	4	0.3102	0.87
Abdominal Cavity	1.22	0.98-1.43	5	0.1472	
HUDSON BAY					
Brood Pouch	3.30		1		0.45
Abdominal Cavity	1.93	1.78-2.07	2		

The Hudson Bay form produces fewer offspring which are, however, larger at all comparable stages of development. Egg diameter of the western arctic form averaged 2.21 mm. and ranged from 1.89 to 2.72 mm. for the four specimens carrying ova within their brood pouches. Ova within the abdominal cavity (5 specimens) averaged 1.22 mm. and ranged from 0.98 to 1.43 mm. The egg diameter of a single specimen from Hudson Bay carrying ova within the brood pouch was 3.30 mm. Two specimens had ova within their abdominal cavities which measured 2.07 and 1.78 mm. Undeveloped ova of the Hudson Bay and western arctic forms are compared in figures 34 and 35 respectively.

Because more information is available for M. entomon and M. sibirica, no counts of embryos are included in figure 33, resulting in more reliable information. The coefficient of correlation (r) between egg number and total length is 0.96 for M. entomon and 0.71 for M. sibirica. The points which have been plotted for the former approximate a straight line. A regression line, determined by logarithms for these data, was found to have a slope of 3.32. There is a probability of less than 0.02 that this slope differs from a theoretical line having a slope of 3 and no standard error. This suggests that egg number may be a function of body volume. A similar situation has been demonstrated by Ellis (1961) for Asellus intermedius (Forbes).

M. sibirica, on the other hand, has a regression line with a slope of 2.19. The spread of values is so great, however, that this value does not differ from a slope of 1.00 at 0.100 probability or from 3.00 at 0.200 probability.

Table 14 gives a comparison of egg sizes for M. sibirica and M. entomon and lists correlation coefficients (r) between total length of the parent female and number of offspring.

TABLE 14

	Mean Diameter	Size Range	No. Specimens	Standard Deviation	(r)
M. sibirica	2.83	2.44-3.10	9	0.2324	0.71
M. entomon	1.14	1.02-1.25	11	0.0734	0.96

Egg sizes of the two species are compared in figures 36 and 37. Ova from brood pouches have been measured for both species. Five of the examples of *M. sibirica* are given in figure 33. The remaining ova were measured from specimens which had apparently lost ova from their brood pouches and could not be included in the graph.

Embryos of all stages of development were observed but no distinction was made between the various stages. There is no evidence that young feed before they leave the brood pouch; no traces of food were noted in digestive tracts of young which had reached full morphological development.

M. entomon leave the brood pouch when they are 3 to 4 mm. long and *M. sibirica* when they are 4 to 6 mm. long. *M. sabini*, on the other hand, are incubated until they reach a length of 9 to 11 mm. No distinction may be made between Hudson Bay and western arctic forms because animals at comparable stages of development were not available.

M. sabini

FIGURE 38

M. sibirica

FIGURE 39

M. entomon

FIGURE 40

DORSAL VIEWS of YOUNG of *Mesidothea* SPECIES

The Hudson Bay form would, in all probability, be somewhat larger.

Embryos which have reached approximate full development are compared in figures 38 to 43 inclusive as given below:

	Dorsal		Ventral	
M. sabini	Figure	38	Figure	41
M. sibirica	"	39	"	42
M. entomon				

It is believed that animals in arctic environments require longer to mature, often reaching a larger size than in warmer regions. These animals usually produce fewer but larger offspring which are thereby better equipped to withstand the adverse environmental conditions.

In the genus Mesidothea, M. entomon is found in the least saline, warmest waters. This species also has the smallest ova and the greatest reproductive potential. Where the three species exist together in the wesstern arctic, M. entomon is by far the most abundant.

The information on the ecology of M. sibirica and sabini shows no definite differences for the western arctic. Egg size and number are approximately similar for these species.

<u>M</u>. <u>sabini</u>

FIGURE 41

<u>M</u>. <u>sibirica</u>

FIGURE 42

<u>M</u>. <u>entomon</u>

FIGURE 43

VENTRAL VIEWS of YOUNG of <u>MESIDOTHEA</u> SPECIES

The ecological information about M. sabini shows that the western arctic form may come from less saline situations. The animal has been taken under somewhat warmer conditions in Hudson Bay but the latter work is based upon many observations and does not suggest anything about the usual conditions to which the species is subjected. It is probable, however, that the fewer, larger ova of the Hudson Bay form result from colder conditions in that area. The work carried out by Dunbar (1951a, 1953, 1954) shows that planktonic animals in Hudson Bay are subjected to colder conditions than in the western arctic. The situation for benthonic forms must remain unknown until more work has been carried out.

6. ECOLOGY and ABUNDANCE

6.1. Introduction

The environmental conditions to which marine animals are subjected are likely to vary considerably in the vicinity of a large river like the Mackenzie. The river spreads out into a fan-shaped delta of channels and islands which, at its outer limit, has a width of about 90 miles. During the summer, a vast volume of silt-laden water flows out of the Mackenzie and affects the surrounding coastline. Under the influence of easterly winds Mackenzie water (11°C.) was noted at Herschel Island in 1960 for days at a time and in July of 1961, after flood conditions had ceased, muddy water was observed as far east as Atkinson Point, sixty miles from the most easterly branch of the Mackenzie. Such changes affect the fauna of the region to a depth of several meters. In the winter, the flow of the Mackenzie subsides by a considerable degree, the river carries no silt, and the ice cover prevents movement of the water mass by wind. Winter conditions are therefore more stable but colder and more saline.

TABLE 15

Data on Quantitative Collections of Mesidothea

1960 and 1961

Station Number	Water Depth (meters)	%of Total weight	Bottom Temp.°C	0/00 Salinity	Bottom Type	M.entomon Number	M.sibirica Number	M.sabini Number	Total Density (gm/m^2)
60-1009	17-25	75%	-1.2	-	mud	740	?	-	0.46
60-1010	7-10	60%	-0.5	26.78	mud	1043	103	2	0.75
60-1014	3.5	65%	4.1	-	gravel	859	?	-	0.21
60-1015	3.5	60%	7.6	-	gravel	466	?	-	0.18
60-1016	12	35%	0.9	-	gravel &stone	268	?	-	0.09
60-1021	5-9	72%	1.6	21.44	gravel & sand	1515	?	1	0.38
60-1035	20-41	75%	-1.3	31.62	mud	2517	?	307	0.96
60-1036	33-35	80%	-1.3	31.62	mud	1228	?	73	0.66
61-1008	3.5	2%	-0.2	-	sand	7	-	-	0.02
61-1009	6	3%	-0.5	20.48	sand	25	-	-	0.01
61-1015	10	5%	-1.4	32.47	sand& mud	-	-	14	0.01
61-1082	28	1%	-1.2	32.88	mud	-	-	82	0.09
61-1093	13	15%	-	-	hard mud	-	9	-	0.03

6.2. Quantitative Abundance

Methods of quantitative sampling are described under section 2.2 and it is pointed out that the data are useful only as a measure of relative abundance because of the gear employed. Table 15 lists those collections which were considered to be of interest. Values of salinity throughout this work have been determined by the Atlantic Oceanographic Group, Halifax, Nova Scotia.

An unknown proportion of *M. sibirica* is included in the 1960 values for *M. entomon*. The two species were separated only for St. No. 60-1010. Locations may be checked by referring to figures 1 and 44. Data on individual locations are given in appendices A and D.

Quantitative collections were made with similar gear handled in the same way upon each occasion. Consequently, although the information may not be a good approximation of the actual biomass of *Mesidothea*, the hauls are comparable one with another and serve as measurements of relative abundance. Population densities of *Mesidothea* were found to be highest in mud-bottomed areas (0.46-0.93 g./m^2), and lowest in sand and gravel areas (0.38 g./m^2). Population levels east of the Mackenzie Delta were found to be very much lower than those in its immediate vicinity or to the west (table 15). Whereas *Mesidothea* species comprised

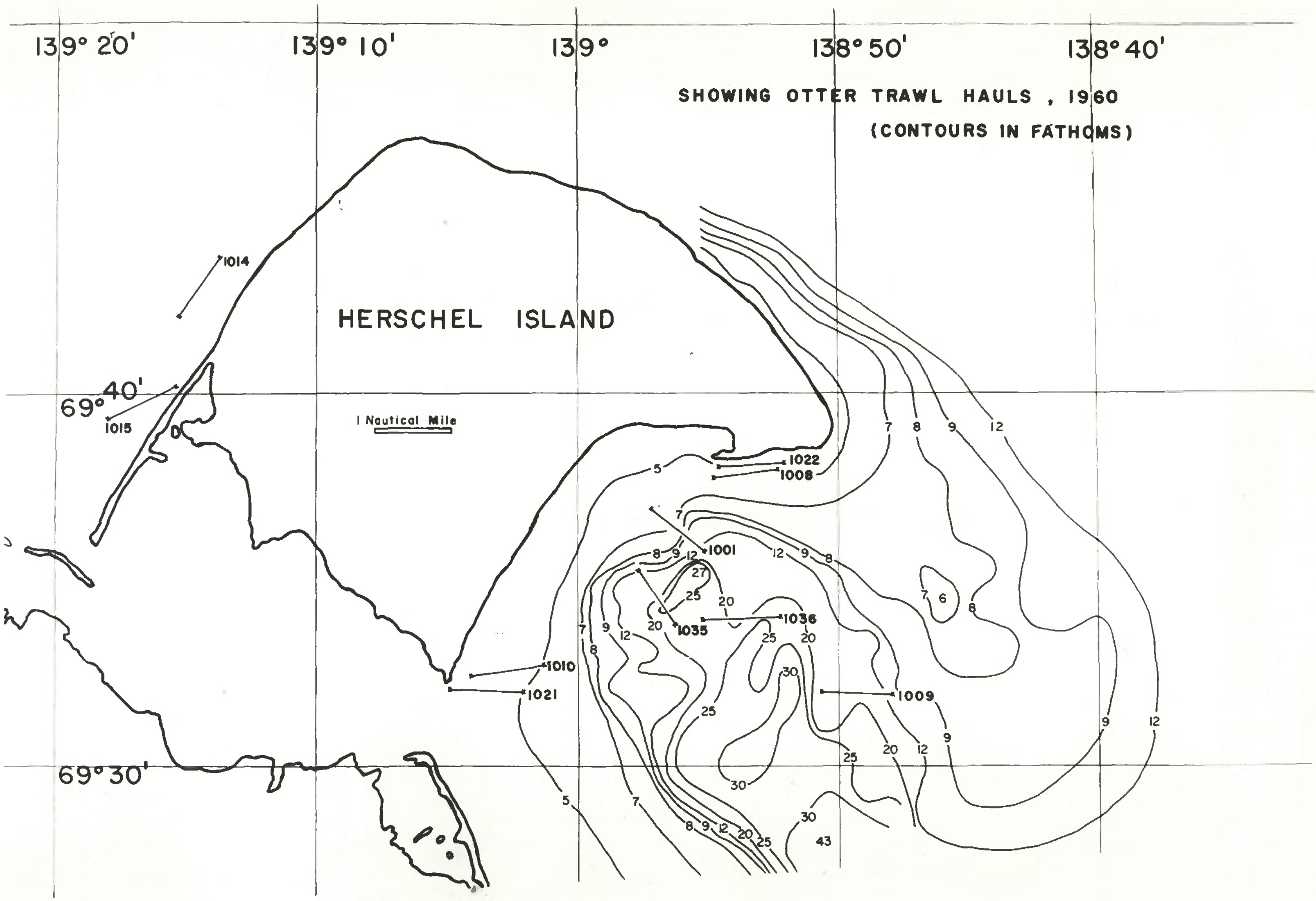

SHOWING OTTER TRAWL HAULS , 1960
(CONTOURS IN FATHOMS)
HERSCHEL ISLAND
1 Nautical Mile
139° 20'
139° 10'
139°
138° 50'
138° 40'
69° 40'
69° 30'
1014
1015
1022
1008
1001
1035
1036
1010
1021
1009

Figure 44

from 35 to 92%, by weight, of hauls in the vicinity of Herschel Island, they accounted only for from 1 to 5% of hauls along Tuktoyaktuk Peninsula and in Liverpool Bay. A single haul in the vicinity of the Delta, St. No. 61-1093, was 15% Mesidothea.

Gurjanova (1934) describes the Laptev Sea as supporting very large numbers of Mesidothea in coastal areas. The Herschel Island area is probably very similar, having mud bottom, shallow depths and the influence of a large river. The area along Tuktoyaktuk Peninsula and Liverpool Bay, on the other hand, differs by having a hard sand bottom and by being influenced to a lesser extent by the Mackenzie. These factors appear to be responsible for the smaller numbers of Mesidothea. Temperatures and salinities are approximately the same for the two areas and the total biomass is similar. On the gravel substratum to the west of Herschel Island (St. No.'s 60-1014, 1015, 1016) population levels were only slightly higher than in Liverpool Bay. The mud bottom which parallels Tuktoyaktuk Peninsula some 25 miles offshore supported a greater biomass than the hard sand in inshore areas (note St. No. 61-1082).

Quantitative sampling in the Baltic Sea has been described by Demel and Mulicki (1958). Careful sampling showed densities of M. entomon as high as 28.64 g./m.^{2} The western arctic populations are very much more sparse even when biased sampling is taken into account.

6.3 Environmental Conditions

Table 16, below, lists the range of conditions under which <u>Mesidothea</u> species have been taken.

TABLE 16

Species	Depth (meters)	Salinity o/OO	Temperature ^{o}C
<u>M</u>. <u>sabini</u>			
(WESTERN ARCTIC)	6-81	20.48-32.88	-1.41 to -0.50
(HUDSON BAY)	12-145	26.18-33.30	-1.79 to 1.10
<u>M</u>. <u>sibirica</u>	9-80	26.78-30.62	-1.32 to -0.51
<u>M</u>. <u>entomon</u>	0.75	fresh-31.62	-1.41 to 11.00

<u>M</u>. <u>entomon</u> tolerates the widest range in conditions. The species has been found crawling along the shoreline and has been collected at depths of 75 meters. It has been taken from fresh water and from water of 31.62 $^{o}/oo$ salinity. The highest temperature recorded for the species was 11.00^{o}C., the lowest - 1.41^{o}C.

Waterman (1960) deals with the salinity tolerances of <u>M</u>. <u>entomon</u>. Baltic Sea animals were found to tolerate 25% Baltic Sea water but to die within four days when placed into fresh water. He further considers that those animals found in the fresh water of Swedish and Russian lakes must be a distinct physiological strain.

M. sibirica is considered to exist under conditions of higher salinity and lower temperature than *M. entomon*. It also lives at greater depths in Siberian waters. The animal has been recored from temperatures of -1.32°C. to -0.51°C. and from salinities of 26.78 o/oo to 30.62 °/oo. This shows that although the animal may not be able to tolerate colder, more saline situations, it is much less likely to be taken under the warmer, brackish conditions which *M. entomon* seems to prefer.

In the western arctic, *M. sabini* is often found separate from *M. entomon* in colder, relatively more saline situations (table 16). The Hudson Bay form of this species has been taken from a wider temperature range than animals from the western arctic: -1.79 to 1.10 compared with -1.41 to 0.50. The Hudson Bay form exists under relatively more saline situations: 26.18 to 33.30 °/oo compared with 20.48 to 32.88 o/oo. The animal is found to depths of 145 meters whereas western arctic specimens have been taken only to depths of 81 meters. Trawling operations have been carried out to depths of 150 meters in the western arctic.

6.4. Food

Mesidothea species, as a group, scavenge for a living. Their digestive tracts usually contain large proportions of mud mixed with algae. Animal remains will also be attacked if such is available and the flesh of dead animals, placed on the sea bottom, is usually devoured within a few hours. The various species have not been observed to prey upon other marine animals or to attack one another.

7. BEHAVIOR and MOVEMENTS

7.1. Introduction

Experiments on the behavior of Mesidothea were conducted in the field in 1960. M. entomon and M. sibirica were used for these experiments but were not considered separately. M. sabini, the eyeless species, was not considered.

7.2. Swimming

Mesidothea species are not active swimmers and usually settle down on the bottom after travelling a short distance. In swimming, an animal keeps its ventral side upwards and folds aside the opercular valves which cover the five pairs of foliaceous pleopods. The pleopods are raised at right-angles to the telson and are then brought quickly downward in order to deliver a propulsive thrust. By such rhythmic movements of the pleopods, the animal propels itself through the water but usually in a circular direction. If dropped at the surface of the water, an individual will swim in spirals toward the bottom. The animals had poor control of their swimming movements and showed little or no ability to avoid objects placed in their paths. Measured over short distances in aquaria, specimens were observed to swim at rates ranging from 5 to 10 cm. a second.

Johansen's notes in the Report of the Canadian Arctic Expedition of 1913 - 1918 (Boone 1920) include the statement that young of Mesidothea are pelagic and that they swim on their backs by means of movements of the periopods. Specimens were taken in bottom samples only in the western arctic, Stramin and plankton nets failing to secure isopods of any size. The periopods are held close to the sides of the body during swimming and play no part in such movements.

7.3. Crawling

Mesidothea species crawl along the sea bottom and M. entomon has been observed to travel out of the water onto the beach upon occasion. Crawling movements were observed for animals out of water and the following serves to describe these movements. Periopods 1 to 3 serve mainly to elevate the cephalic portion of the body. When the head has been elevated, periopods 4 to 7 are drawn anteriorly and from that position thrust the animal forward. Periopods 4 and 5 lag 6 and 7 slightly in delivering the propulsive thrust. The animal, having been thrust forward literally upon its face, raises the head by means of periopods 1 to 3 and repeats the cycle.

The removal of any one pair of periopods from living individuals seemed not to impede their crawling ability. However, if any two pairs were removed, the animals were rendered practically incapable of movement. The size of an animal has no apparent connection with crawling speed. This is due to the fact that animals perform differently under different circumstances.

To obtain information on this, animals were placed within the centre of a circle having a 15 cm. radius and the time required to reach the periphery was recorded. This was found essential because of the failure of specimens to travel in any pre-determined direction. Crawling speeds varied from 2 to 8 mm. a second.

7.4. Protective Behavior

Mesidothea species, when molested, arch their bodies until the head almost touches the end of the telson. This is, presumabley, a means of protection and is more often noted among smaller animals. If large animals were physically hurt, such as by the removal of a periopod, they also arched their bodies.

7.5. Spawning Migrations

Females of M. entomon appear to migrate inshore toward shallow water in order to deposit their young whereas other species do not. Evidence for this is noted in the greater incidence of ovigerous females in inshore collections. Hauls with a fine mesh trawl in Pauline Cove, Herschel Island, netted large numbers of tiny M. entomon but none in deeper water offshore.

8. ZOOGEOGRAPHY

8.1. Introduction

The zoogeographical consideration of the arctic isopods has been dealt with in detail by Gurjanova (1934). Little additional information has been made available for North America since that time. MacGinitie (1955) lists several species taken at Point Barrow, Alaska, during the years 1948 to 1950 inclusive. The present work lists the findings of the research vessel "Salvelinus" along the western arctic coastline from Herschel Island, Y.T., to Baillie Island, N.W.T., during the summers of 1960 and 1961. Collections from the wastern arctic, particularly those made by the research vessel "Calanus", have been examined by the author for specimens of the genus Mesidothea. Collections from the National Musem of Canada have been similarly examined.

The contribution to zoogeography of this recent work may be summed up as follows. The ranges of the high-arctic species Mesidothea sibirica and Synidothea bicuspida have been extended eastward to the area of the Mackenzie River in western Canada. The former species, not previously recognized for North America, was formerly considered to extend to 171° west longitude on the Siberian Coast (Ekman, 1953). The most easterly location formerly recorded for


KARA SEA
BARENTS SEA
LAPTEV SEA
NORWEGIAN SEA
E. SIBERIAN SEA
BERING SEA
CHUKCHEE SEA
Pt Barrow
BEAUFORT SEA
Davis Strait
Hudson Bay

Figure 45

Synidothea bicuspida was Point Barrow, Alaska. The species *Mesidothea sabini* has been found to be widely distributed throughout Foxe Basin, Hudson and James Bays, and Hudson Strait.

Boone (1920), Gurjanova (1934), and Stephensen (1937, 1943) present zoogeographical information for *Isopoda* species. Table 17 summarizes the work of these authors and includes additional information from recent collections. The various areas referred to are shown in figure 45. The Point Barrow collections described by MacGinitie (1955), the Canadian Arctic Expedition collections and those from "Salvelinus" work are included separately in table 17 but all belong to the Beaufort Sea area. Findings in the central arctic region of Canada include those collections made between 90o and 120° west longitude. Only those species reported by Gurjanova to exist in the Beaufort Sea are considered here.

It should be emphasized that the central arctic region of Canada has been poorly collected whereas collections from the Hudson Bay area have not been described. As a result, the reported absence of any species from these areas is meaningless.

8.2. Discussion

Gurjanova (1934) clearly shows the gradual reduction in the number of isopod species which occurs as one travels

TABLE 17

	BARENTS SEA	KARA SEA	LAPTEV SEA	EAST SIBERIAN SEA	BERING & CHUKCHEE SEAS	BEAUFORT SEA (Gurjanova, 1933)	POINT BARROW, 1955	C.A.E., 1913-1918	SALVELINUS -1960,61	CENTRAL ARCTIC	E.ARCTIC &W.GREEN-LAND	NORWEGIAN SEA
Janira alascensis (Benedict)					X	X						
Eurycope mutica (G. Sars)	X					X					X	X
Munnopsis typica (Sars)	X	X	X			X			X	X	X	X
Mesidothea entomon (L.)		X	X	X	X	X	X	X	X	X	X	
Mesidothea sibirica (Birula)	X	X	X	X	X	X		X	X			
Mesidothea sabini (Krøyer)	X	X	X	X	X	X	X	X	X		X	
Synidothea bicuspida (Owen)	X	X	X	X	X	X	X	X	X			
Synidothea laevis (Benedict)					X	X						
Synidothea muricata (Harford)		X			X	X						
Synidothea picta (Benedict)					X	X						
Pleuroprion murdochi (Benedict)					X	X	X					
Areturus baffini(typica)(Sabine)						X		X		X	X	X
Rocinella belliceps (Stimpson)					X	X						
Phryxus abdominalis (Krøyer)	X	X	X		X	X	X				X	X
Dajus mysidis (Krøyer)	X	X	X			X					X	X

to the east and to the west of the Davis Strait region. The numbers of species for the various areas are given below:

Eastern arctic	107
Norwegian Sea	85
Barents Sea	41
Kara Sea	24
East Siberian Sea	5
Beaufort Sea	15

The East Siberian Sea has an impoverished fauna described by Gurjanova as being typically arctic. The shallow depths, low temperatures and brackish conditions along that coast prevent most species from inhabiting or crossing that marine area.

The Beaufort Sea would appear to have been colonized from three directions:

1. The Bering Strait and northern Pacific
2. The North Atlantic region to the east
3. Siberian waters to the west

The following seven species presumably penetrate into Beaufort Sea from the Bering Strait and north Pacific where they have their centres of distribution:
Janira alascensis, Synidothea laevis, muricata and picta, Pleuroprion murdochi, Rocinela belliceps, Eurycope mutica.

of these, Synidothea muricata and Eurycope mutica exist in the Kara Sea and Barents and Norwegian Seas respectively. The latter two areas, the south-western part of the Kara Sea and southern areas of the Beaufort Sea are described by Dunbar (1953) as belonging to the subarctic marine environment. The animals may, therefore, live under similar environmental conditions in spite of their wide geographical separation.

MacGinitie (1953) lists one species, Pleuroprion murdochi, which reaches Point Barrow from more southerly areas and which is not found elsewhere in higher latitudes. Several other species are mentioned (but not identified) which may show a similar pattern of distribution. The existence of this subarctic animal at Point Barrow may be indicative of conditions there. However, no such invasion of the Canadian western arctic has been noted, suggesting that conditions there are more arctic.

Four of the species existing in the Beaufort Sea: Munnopsis typica, Eurycope mutica, Phryxus abdominalis and Dajus mysidis, appear to have arrived there from regions to the east. These species are distributed throughout North Atlantic regions but are absent from Siberian waters west of the Beaufort Sea.

The remaining four species: Synidothea bicuspida and Mesidothea entomon, sibirica and sabini, occur in Siberian water but are absent from certain areas of the North Atlantic. There is a strong suggestion that these species reached the Beaufort Sea from the west.

The zoogeographical situation of _M. sabini_ is very complex. Two distict forms have been found in North America, distributions for which are given in figure 3. The absence of the species between 92° and 128° west longitude probably has no significance. If _M. sabini_ reached North America from the west, then the western arctic form should resemble _M. sabini robusta_ more closely than _M. sabini sabini_. However, the animal resembles both forms and is rather intermediate between the two. The Hudson Bay form appears to be distinct from all other races of the species but resembles the western arctic population more closely than the typical subspecies from the Barents Sea. There appear to be three possible explanations for the situation which appears:

1. _M. sabini_ reached North America by travelling to the east from the Barents Sea area.
2. The species originated in North America and travelled to the east and to the west to colonize European waters.
3. The species became more sedentary after an original rapid colonization, resulting in the appearance of different forms.

Each of these possibilities has certain disadvantages. The absence of *M. sabini* from Jan Mayen, Iceland, The Faroes and northern Norway suggests that the species has never traversed that region of the North Atlantic. On the other hand, it is not reasonable to suppose that the western arctic form could have originated from the *robusta* subspecies to develop characteristics intermediate between the latter and the typical form. This problem must remain unresolved until the European collections have been examined and samples from the central arctic have been obtained.

9. SUMMARY

Material for this thesis was collected during the "Salvelinus" investigations of 1960 and 1961. Quantitative and qualitative collections of isopods were made along the western arctic coastline from near Demarcation Point, Alaska, to Baillie Island, N.W.T. Material from Hudson Bay was obtained from the "Calanus" collections of 1947 to 1961. Other material came from the Canadian Arctic Expedition of 1913 to 1918 and from individual collections. The work has been carried out with the following purposes in mind:

1. To study the taxonomy of the genus *Mesidothea*.
2. To deal with the life histories and reproductive potentials of *Mesidothea* species.
3. To discuss the quantitative abundance and ecological requirements of the various forms.
4. To determine the zoogeographic position of the Beaufort Sea in terms of the distribution of the Isopoda.

The morphology of various species of the genus *Mesidothea* is considered in detail and figures are drawn to illustrate important points. The various species and forms of the genus may be separated by means of the

following key which summarizes the morphological work in this thesis:

A_1 — eyes present

B_1 — forehead flat, margin of epimera of first thoracic segment with setae, telson rather triangular, mandible and tooth weak, setae of periopods long and numerous . . . . . .
. . . _Mesidothea_ _entomon_

B_2 — forehead strongly arched, margin of epimera of first thoracic segment without setae, telson pentagonal, mandible and tooth strong, fewer and shorter setae on periopods . . .
. . . _Mesidothea_ _sibirica_

A_2 — eyes absent . . . . _Mesidothea_ _sabini_

B_1 — ratio of maximum width to total length greater than 29.5%, superior margins of fourth articles of periopods 4 to 7 strongly indented, antenna 2 extending to middle of first thoracic segment . . . . .
. . . HUDSON BAY

B_2 — ratio of maximum width to total length less than 29.5%, superior margins of fourth articles of periopods 4 to 7 weakly indented, antenna 2 extending to end of first thoracic segment . . . . WESTERN ARCTIC

The species M. sibirica has previously been included under M. entomon in North American collections. M. sabini has been found to contain two races which differ in the eastern and western arctic regions and are called "Hudson Bay" and western arctic" forms.

A series of about 50 examples of each species have been measured and measurement ratios calculated. The ratios are plotted and M. entomon and M. sibirica are shown to differ on this basis. The forms of M. sabini are similarly compared and found to differ with regard to measurements of body width.

The various measurements for M. sabini are plotted on log - log scales against total length and telson length as standards of comparison. The data are considered to be adequately described by straight lines and regression lines are calculated for each measurement. The information is analyzed statistically for the occurrence of allometric growth and differences in rate of growth between the two forms. Significant allometric growth was found for the majority of measurements of both forms of M. sabini. The length and width of the telson end and head length of the western arctic form grow at a significantly more rapid rate than for specimens from Hudson Bay. In most cases, growth of various body parts is negatively allometric with respect to the growth of the body in length.

It is pointed out that relative length proportions are not reliable for taxonomic work where allometry may exist. Consequently, only the measurements of body width of the forms of *M. sabini* may be compared as ratios since these alone grow isometrically. This points to the inadequacy of the European work in which several forms of *M. entomon* and *M. sabini* are recognized on the basis of measurement ratios. The differences between the various forms result from unknown degrees of allometry occuring throughout their growth histories.

Size distribution graphs of quantitative hauls of the various collections show that the life cycles of *M. entomon* and *sibirica* probably require two or three years, *M. sabini* three or four years. The peak of reproduction occurs during the summer. The various species reproduce once and die shortly thereafter.

M. entomon lives under the warmest, least saline conditions and produces the greatest number as well as the smallest ova. A regression analysis shows that egg number is approximately the cube of body length and therefore probably a function of body volume. *M. sabini* and

M. sibirica live under nearly similar conditions in the western arctic and have similar reproductive potentials and egg sizes. The Hudson Bay form of *M. sabini* produces fewer, larger offspring than the western arctic form. This corroborates the suggestion that conditions in the greater part of Hudson Bay are more arctic than along the western arctic coastline.

The behavior, movements, abundance and feeding habits of *Mesidothea* are considered. The animals were found to be quantitatively most abundant in mud-bottomed areas in the region of Herschel Island. Females of *M. entomon* migrate inshore in order to deposit their young whereas other species do not. All forms live as scavengers, feeding upon such things as detritus, algae, and animal remains.

Fifteen isopod species have been recorded from the Beaufort Sea. Of these, seven species are distributed in the Bering Strait and north Pacific and appear to have reached the Beaufort Sea from that area. Four species are found in the North Atlantic region but are absent from eastern Siberian waters suggesting that they reached the Beaufort Sea from the east. The remaining four species are absent from North Atlantic regions and appear to have penetrated into the Beaufort Sea from the west.

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APPENDIX A

COLLECTIONS OF Mesidothea sabini (Kroyer)

"Calanus" Collections (Hudson Bay area)

Specimens Corresponding to "HUDSON BAY" Form

St. No.	Coll. No.	Depth. (meters)	Temp. °C	Salinity °/oo	Bottom	Date	Number	Latitude	Longitude
11	B- 4	46	-1.18	30.95	stone & sand	12/7/47	1		66° 35'
715	B-14	14-15	1.10	31.60	sand & mud	19/9/55	1	69° 34'	80° 17'
715	B-16	12	-	-	Lamin-aria	21/9/55	1	69° 34'	80° 17'
718	B-17	75	-0.56	31.60	smooth mud	25/9/55	35	69° 18.5'	81° 35.5'
719	B-18	50	-0.44	31.55	mud	29/9/55	6	69° 20.5'	81° 43.5'
722	B-19	36-45	-0.39	31.44	mud	29/9/55	2	69° 20'	82° 00'
723	B- 1	22	-1.70	-	mud	18/1/56	2	69° 22.7'	81° 44.3'
723	B- 3	22	-1.79	-	mud	1/3/56	8	69° 22.7'	81° 44.3'
723	-	20	-	-	mud	2/6/56	1	69° 22.7'	81° 44.3'
719	B-22	50	-1.11	32.09	mud & stones	11/8/56	8	69° 22.7'	81° 44.3'
820	B-34	73	-1.38	32.50	mud	28/8/56	6	69° 55.7'	80° 19'
821	B-35	13	-	-	mud	29/8/56	9	70° 00.5'	80° 12'
821	B-36	30	-	-	mud	29/8/56	21	"	"

APPENDIX A (continued)

St. No.	Coll. No.	Depth. (meters)	Temp. °C.	Salinity o/oo	Bottom	Date	Number	Latitude	Longitude
821	B-37	13-30	-	-	mud	29/8/56	5	70° 00.5'	80° 12'
719	B-40	50	-0.24	31.67	mud	2/9/56	5	"	"
723	B-41	20	-	-	mud	4/9/56	6	"	"
723	B-42	20	-	-	mud	4/9/56	27	"	"
832	B-44	80-90	-1.37	33.30	sand & stones	8/9/56	1	69° 44'	77° 38.2'
901	B-46	15	-	-	sandy mud	24/8/57	10	69° 06'	79° 11'
901	B-62	15-20	-0.85	31.04	mud	8/9/57	39	69° 06'	79° 11'
58-28	B-19	115	-1.24	32.74	mud & stones	10/9/58	2	59° 04'	80° 27'
59- 6	B- 6	65	-1.33	26.18	sand & rocks	23/6/59	1	52° 55'	79° 58'
59-31	B-32	100	-1.32	32.63	mud & rock	3/8/59	5	55° 28'	81° 22'
59-70	B-52	140	-1.37	33.04	mud	1/9/59	2	56° 15'	81° 14'
59-64	B-48	26	0.68	28.71	gravel	31/8/59	2	55° 05'	83° 40'
61-21	B-18	79	0.74	32.92	rocky	7/8/61	1	64° 43'	86° 57'
61-32	B-24	145	-0.92	-	mud & rock	14/8/61	2	66° 11'	84° 12'
61-34	B-25	125	-	-	rock & sand	23/8/61	9	66° 28'	86° 16'

APPENDIX A (continued)

"Salvelinus" Collections (Beaufort Sea)

Specimens Corresponding to "WESTERN ARCTIC" Form

St. No.	Depth (meters)	Temp. °C	Salinity o/oo	Bottom	Date	Number	Latitude	Longitude
60-1001	12-34	-	-	mud	27/7/60	17	69° 32'	138° 55'
60-1008	5-10	-	-	mud	2/8/60	1	69° 33'	138° 55'
60-1010	3- 8	-0.51	26.78	mud	3/8/60	1	69° 31.2'	139° 04.5'
60-1035,36	20-33	-1.32	31.83	mud	25/8/60	238	69° 32'	138° 57'
61-1009	6	-0.50	20.43	sand	6/6/61	2	69° 43.5'	132° 48'
61-1015	12	-1.41	32.47	sand	10/6/61	15	70° 11'	128° 35'
61-1082	28	-1.19	32.88	mud	19/8/61	72	70° 13'	132° 36'

APPENDIX A (continued)

Miscellaneous Collections

W. A. - "WESTERN ARCTIC" Form

H. B. - "HUDSON BAY" Form

St. No.	Date	Number	Form	Location
-	2/8/48	1	H.B.	Port Burwell (Ungava)
-	?/8/48	3	H.B.	Koksoak River (Ungava)
F-11	3/8/49	2	H.B.	Ungava Bay (area)
-	2/9/51	1	H.B.	Frobisher Bay
F-107	?/?/47	1	H.B.	George River (Ungava)
45	21/7/56	1	H.B.	Pelly Bay (Collected by W. F. Black)

Collections of "Canadian Arctic Expedition," 1913–1918

Catalogued in National Museum of Canada, Ottawa.

Reference Number — given in Figure 30.

Ref. No.	Catalog No.	Date	Number	Form	Location
25	1189	?/9/04	1	H.B.	Cape Fulkrton, Hudson Bay
26	1282	3/10/13	1	W.A.	Collinson Point, Alaska

APPENDIX D

COLLECTIONS of *Mesidothea entomon* (L.) and *Mesidothea sibirica* (Krøyer)

(Quantitative Collections Given in Table 15)

Mixed collections of *M. entomon* and *M. sibirica* (not separated)

numerous = over 100 specimens
few = less than 100 specimens

St. No.	Depth (meters)	Bottom	Date	Number	Latitude	Longitude
60-1001	12-34	mud	27/7/60	numerous	69° 32'	138° 55'
60-1007	10	mud	2/8/60	"	69° 33'	138° 55'
60-1008	5-10	mud	2/8/60	"	"	"
60-1011	2-3	mud	4/8/60	"	69° 33'	138° 51'
60-1012	2-4	mud	5/8/60	"	69° 30'	138° 51'
60-1022	5-7	mud	10/8/60	"	69° 34'	138° 51'
60-1023	2-3	mud	10/8/60	"	69° 33'	138° 51'
60-1025	3	mud	14/8/60	"	"	"
60-1027	3	mud	16/8/60	"	"	"
60-1029	7-8	mud	17/8/60	"	"	"

APPENDIX D (continued)

St. No.	Depth (meters)	Bottom	Date	Number	Latitude	Longitude
60-1042	2-3	mud	30/8/60	few	69° 06'	137° 55'
60-1043	17	mud	31/8/60	"	69° 08'	137° 55'
60-1044	15-18	mud	31/8/60	"	69° 00'	137° 23'

"Salvelinus" Collections of *M. entomon*

St. No.	Depth (meters)	Temp. $^{\circ}C$	Salinity o/oo	Bottom	Date	Number	Latitude	Longitude
61-1004	2	10.5	-	mud	2/6/61	4	69° 26.5'	133° 01.8'
61-1010	4	-	-	mud	6/6/61	10	69° 39'	132° 48'
61-1016	7.5	-1.25	-	mud	11/6/61	1	70° 29.5'	128° 19'
61-1017	4	7.12	15.07	sand	12/6/61	8	69° 58.7'	129° 30'

Miscellaneous Collections

Collections of "Canadian Arctic Expedition" 1913 - 1918,

Catalogued in National Museum of Canada, Ottawa. Reference Number — given in Figure 31.

Ref. No.	Catalog No.	Number	Station	Date	Location
1	1284	1	24	22/8/13	Point Barrow, Alaska
2	1541	2	-	?/?/04	Herschel Island, Yukon Territory

APPENDIX D (continued)

Ref. No.	Catalog No.	Number	Station	Date	Location
3		1	27a.	18/9/13	Collinson Point, Alaska
4	1294	2	28a.	14/10/13	Collinson Point, Alaska
5	1301	1	30b.	9/5/14	Demarcation Point, Alaska
6	1297	1	28b.	18/9/13	Collinson Point, Alaska
7	1298	1	28m.	?/6/14	Collinson Point, Alaska
8		4	20b-C.	30/6/13	Grantley Harbour, Alaska
7		6		8/6/14	Collinson Point, Alaska
10		2		8/10/13	Collinson Point, Alaska
11		1	20a.	14/8/13	Port Clarence Bay, Alaska
12	1290	13	27i.	18/9/13	Collinson Point, Alaska
13		2	27i.	7/9/13	Collinson Point, Alaska
14		1		?/6/13	Grantley Harbour, Alaska
15		1	28r.	24/6/14	Collinson Point, Alaska
16		2	417	29/8/15	Bernard Harbour, N.W.T.
17		2		15/9/13	Collinson Point, Alaska
18		7		14/8/15	Bernard Harbour, N.W.T.

APPENDIX D (continued)

Ref. No.	Catalog No.	Number	Station	Date	Location
19	1303		53c.	26/6/16	Cape Bathurst, N.W.T.
20	1296	5		18/10/13	Collinson Point, Alaska
21	1286	2	31b.	30/ 5/14	Konganevik,Alaska
22	1287	4	27a.	7/ 9/13	Collinson Point, Alaska
23	1306	1	53c.	26/ 6/16	Cape Bathurst, N.W.T.
	1308	1	48b.	18/ 5/16	Banks Peninsula, Bathurst Inlet
		2	48a.	?/ 5/16	Bathurst Inlet
		2	58c.	10/ 8/18	Bartier Island, Alaska
	1304	1	40a.	?/ ?/15	Bernard Harbour
			Collected by E. A. Porsild		
24		3		?/ 6/47	East of Mackenzie River

Collections of M. entomon Made by J. G. Hunter in Eskino Lakes, Northwest Territories

Coll. No.	Date	Number	Location
9	3/9/55	6	Camp Lagoon, Eskimo Lakes
57	9/9/55	1	Eskimo Lakes
69	11/9/55	12	Eskimo Lakes
79	12/9/55	1	Eskino Lakes

APPENDIX D (continued)

Collections of _M. entomon_ from Banks Island, Northwest Territories

Date	Number	Location
21/7/58	7	north-west of Kellett Mouth, Banks Island

M. sibirica Previously Called _M. entomon_ in "Canadia Arctic Expeditition" Collections, Boone (1920)

Ref. No.	Catalog No.	Number	Station	Date	Location
1	1284	1	24	22/8/13	Point Barrow, Alaska
20	1296	1		18/10/13	Collinson, Point, Alaska
22	1287	1	27a.	7/9/13	Collinson Point, Alaska