BULLETIN No. 115

Biology of the bloodworm, *Glycera dibranchiata* Ehlers, and its relation to the bloodworm fishery of the Maritime Provinces

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Fisheries Research Board of Canada
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W. E. RICKER
N. M. CARTER
Editors

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ABSTRACT

Commercial bloodworms (*Glycera dibranchiata* Ehlers) are found along both Atlantic and Pacific coasts of North America, from near high-water mark on the beach to a depth of at least 100 fathoms. This study treats only the intertidal populations in southwestern Nova Scotia. The worms are most abundant in soft muds, rich in organic materials, and rare in clear sandy soils. However, abundance in a flat varies, showing long-term trends related to changes in soil condition, or short-term fluctuations of unknown causes. Bloodworms are not confined to single burrows but movements are limited. They seldom crawl on the surface of the mud or travel long distances by swimming, as do sandworms (*Neanthes*). They feed on organic detritus in the soil which helps explain their distribution. The function of their jaws and associated poison glands is in doubt but there is no good evidence that bloodworms are carnivores.

Eggs and sperms begin development in late summer and the worms are sexually mature by early April. The principal spawning occurred in mid-May in 1953 and 1954, although a few "spawners" were still found in early June. Bloodworms die after spawning, resulting in the appearance of "ghost worms" on the flats. These consist of the outer skin and atrophied digestive tract with everted proboscis. There is no evidence for swarming at spawning time.

In aquaria, development from the artificially-fertilized egg to the trochosphere larva followed the pattern characteristic for the group. The trochlear ring formed about thirty-two hours after first cleavage and the larvae alternated short periods of rest with vigorous swimming. They died after about two weeks without further development. Attempts to collect them from plankton and intertidal flats were unsuccessful.

Most of the intertidal population spawns when three years old but a small fraction spawns when four or five years old. Maximum life span appears to be five years. Growth rate is most rapid in the second and third years and decreases sharply thereafter. Maximum size observed was about 34 centimetres (13.5 in.) relaxed length. There is little or no growth in summer.

The catch consists largely of sexually immature three-year-olds. But most bloodworms spawn in the spring at the beginning of their third year and die afterwards. The fishery is, therefore, supported mainly by the smaller fraction of this one age-class which does not spawn in spring, and there is little risk of depleting the stock by fishing. For the same reason catch in one year has little influence on catch in subsequent years so that restrictions on fishing would be useless as conservation measures. However, if the fishery becomes intense, annual catches will fluctuate in response to fluctuations in natural abundance of the stocks. The Nova Scotia stocks are lightly exploited now so such fluctuations are unlikely to interfere seriously with the present annual production of 4,000,000 worms or with expansion to about double the present volume.

INTRODUCTION

The regular rise and fall of the tides, periodically exposing the intertidal zone, invites examination of this small, easily-accessible part of the sea-bottom, and from time immemorial man has entered it to wonder at its many mysteries. Sometimes he has found food or objects useful in other ways. Sometimes he has only satisfied his curiosity.

Among the most common of the creatures he has found are marine worms. Some of these have been of no obvious use. Others were eaten, and even to-day the famed Samoan palolo worm is esteemed as food by the islanders. But for a number of the polychaetous annelids man must early have found a use which has since played an important part in his social and cultural development. That is, a fish-hook baited with a marine worm is spiritedly taken by many fish and provides a ready source of food and recreation. Fish-hooks of various shapes, made of various materials, have been uncovered among remains of the dwellings of pre-historic man and his use of baited hooks for catching fish was certainly widespread. Bait-worms must have been employed in fishing for thousands of years.

In modern times two marine polychaetous worms have a good reputation among salt-water sport fishermen on both the Atlantic and Pacific coasts of North America. Of these the bloodworm, *Glycera dibranchiata* (Ehlers) is the more important but there is also a demand for the sandworm, *Neanthes virens* (Sars), better known to scientists under its formerly accepted name, *Nereis virens*. The demand for these worms has created a small but active bait-worm industry which for the last 20 years has centred in the State of Maine. The landed value there in recent years has averaged about $200,000 annually. After the second world war increased demands for baitworms stimulated interest in potentially productive areas on the Canadian Atlantic coast. As a result the Fisheries Research Board of Canada began explorations for them. This exploratory work, carried out from the Biological Station at St. Andrews, New Brunswick (MacPhail 1954), led to the discovery of several areas where bloodworms were abundant—chiefly in the Wedgeport and Yarmouth districts of Yarmouth County, Nova Scotia. This fostered development of a small bloodworm industry new to Canada. Annual landings of about 4 million worms in 1954 and 1955 were valued at about $40,000 to the diggers.

Little was known about bloodworms when our industry began but information seemed desirable as a basis for judging its prospects and possible need for regulation. Accordingly a two-year biological investigation was undertaken in 1953 as a follow-up of the exploration program. This paper discusses features of the bloodworm's ecology, life-history and population dynamics which were discovered in the course of that study. It concludes that there is no danger of overfishing by the present industry and that landings could be at least doubled without endangering the source of supply.

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Identity of Commercial Bloodworms

The commercial bloodworm has a number of other common names. English-speaking people associated with the industry commonly use the contraction "bloods". This name refers to the reddish fluid in the body cavity which resembles mammalian blood in colour. Another common name is "beak thrower" because of the worm's habit of extruding and retracting the proboscis (forward end of its digestive tract) when handled. French-speaking people of Yarmouth County refer to it by two names. In the Pubnico area it is "le ver". Around Wedgeport it is "la laiche". The derivation of this last name is uncertain.

Relatively few scientists have made a serious study of the bloodworm, and published information on its identification and classification is not great. The proper scientific name is *Glycera dibranchiata*. As is often true in such cases, incorrect references have been made to it but have escaped notice. For example, Sandrof (1946) referred to bloodworms shipped from Maine as *G. americana*. However, Glidden (1951) was unable to collect any *G. americana* from several regions in Maine including Rockland, Wiscasset, Marsh River, Westport Island, Leeds, Searsport, Yarmouth and Georgetown but *G. dibranchiata* was common. The senior author has also examined large numbers of commercial bloodworms from Maine. All proved to be *G. dibranchiata* as described by Ehlers (1868) except for one which was *Glycera robusta* Ehlers. It was supplied by Mr. I. W. Flye, Manager, Maine Bait Company, Newcastle, Maine, who stated that large worms of this type are occasionally brought in by his diggers. This and other evidence indicates that the northern limit of *G. americana* is Cape Cod, Massachusetts. Sandrof must have been mistaken in his identification. Maine's commercial bloodworms are undoubtedly *G. dibranchiata*.

Another example of erroneous identification occurs in the annual Fisheries Statistics for the United States, from 1948 to 1953 inclusive (published 1951-56). Commercial bloodworms are listed there as members of the family "Terebillidae", rather than the family Glyceridae to which they belong. The spelling "Terebillidae" in these publications is probably intended for Terebellidae. One member of this family, *Polycirrus*, is sometimes referred to as a "bloodworm" and occurs on the American east coast but it is quite different from *Glycera* and has no commercial value.

During this investigation several specimens of *G. robusta* were collected. They are reported by E. and C. Berkeley (1954) from specimens submitted to the senior author by diggers in Lunenburg and Sandy Cove in Nova Scotia. The species has also been collected from Boothbay Harbour, Maine (Dr. Marian H. Pettibone, personal communication). It is apparent that its distribution overlaps that of *G. dibranchiata* geographically and that the two may often be found in the same beaches. However, *G. robusta* is most often found in the softer soils, closer to low-water mark, and its burrows are generally deeper than those of *G. dibranchiata*. Furthermore, *G. robusta* commonly attains lengths of up to 80 centimetres (32 in.) and is accordingly more difficult to dig without breaking than *G. dibranchiata*. Since all injured worms are discarded by dealers and packers it appears unlikely that *G. robusta* forms an important part of commercial shipments from the Maritime Provinces and the New England States, even though it may be more abundant than the small number of reported specimens would indicate.

Classification

G. dibranchiata was described by Ehlers (1868) and belongs to the phylum Annelida, class Chaetopoda, order Polychaeta, superfamily Glycerea, family Glyceridae.

Early authors did not agree on the number of genera that should be listed under the family Glyceridae but Hartman (1950) has concluded that only three should be recognized: *Hemipodus* Quatrefages, 1866, *Glycerella* Arwidsson, 1899, and *Glycera* Savigny, 1818 (description in Lamarck 1818). The type species for *Glycera* is *G. unicornis* Savigny. *Glycerella* is a monotypic genus. and *Hemipodus* contains only six species. *Glycera*, according to Hartman (1950), includes 41, A number of synonyms have been used for *Glycera*, including *Rhynchobolus* Claparède, 1868, *Euglycera* Verrill, 1881, *Hemiglycera* Ehlers, 1908, and *Telake* Chamberlin, 1919. The number of specific names is considerable and need for an extensive review and revision was recognized long ago by Arwidsson (1899). Hartman lists 110 species' names but, as already indicated, considers only 41 valid.

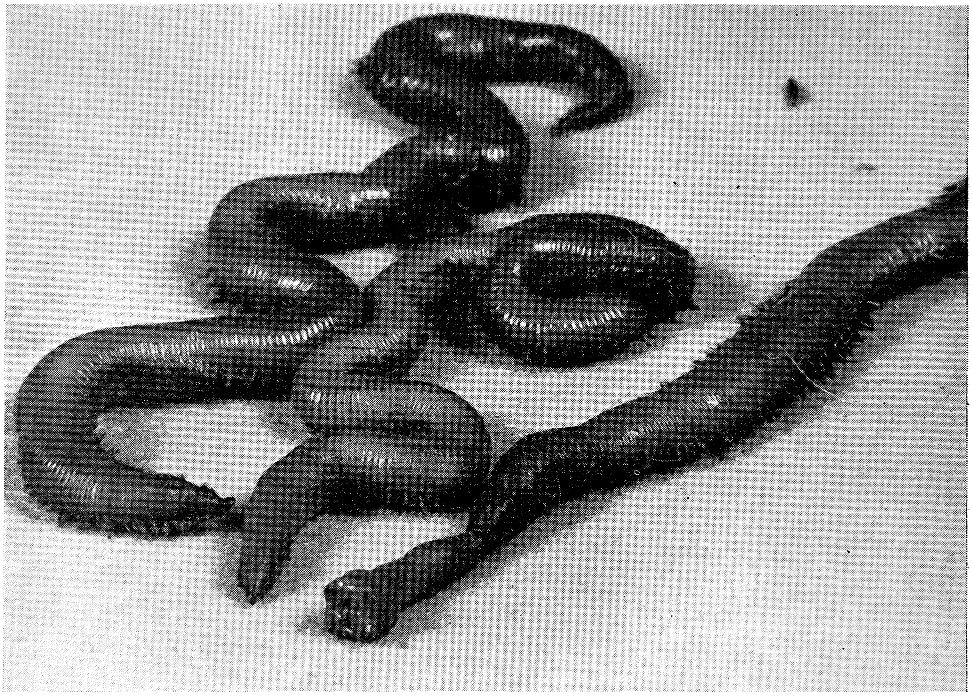

FIGURE 1. Three bloodworms. The anterior (head) end of each is in the foreground. The worm on the right has everted the proboscis with its four terminal jaws. (Photo by I. W. Flye).

MORPHOLOGY

The anatomy of *Glycera dibranchiata* has been thoroughly described (Ehlers 1868, Oppenheimer 1902, Wells 1937). The segmented body (Fig. 1) reaches lengths up to 37 centimetres ($14\frac{1}{2}$ in.), is tapered at both ends and is circular in cross section. The number of segments varies with length, averaging about 300 in a 20-centimetre (8-in.) worm. The parapodia (paddle-feet) along the sides of the body are of more or less uniform size throughout. There are two slender caudal cirri (tail filaments). The anterior (head) end is pointed and equipped with four small tentacles (feelers). There are no eyes.

The anterior end of the digestive tract has powerful muscles which enable the worm to evert it as a large club-shaped proboscis (Fig. 1). It bears four sharp, curved, terminal jaws.

There is no true blood or vascular system. The coelomic (body cavity) fluid takes the place of blood and its circulation is accomplished by contractions of the body wall and ciliated tracts in the gills on the parapodia. The haemoglobin (a red substance) is contained in corpuscles in the coelomic fluid (Lankester 1873 *vide* McIntosh 1910, p. 472). This gives the worm its ordinary reddish colour and makes it appear to "bleed" more than other worms when it is damaged.

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Sexes are separate and eggs and sperms are found free in the coelomic fluid. As the worms mature, these germ cells fill the coelomic cavity, showing through the body wall and changing the colour of the worm. Mature females become pale brown and males cream coloured.

Distribution

Ehlers gave the distribution of *Glycera dibranchiata* as the east coast of North America from Massachusetts to North Carolina. It was found north of this as far as Maine by later investigators (Verrill 1873, 1874, Webster and Benedict 1887) and in the Gulf of St. Lawrence in Canada by Whiteaves (McIntosh 1905). Hartman (1944) described it from the West Indies and the Caribbean Sea. On the Pacific coast it extends from San Mateo County, California, south to Mazatlán, Mexico (Hartman 1950).

Throughout its range the bloodworm is a common member of the intertidal fauna of soft muddy beaches but it is also reported to be abundant below low-water mark in some areas (Verrill 1873). The deepest authentic record is that of McIntosh (1905) between 100 and 220 fathoms (180 and 400 m.). Treadwell (1928) recorded a single immature specimen taken off Long Island, New York, in 633 fathoms (1,160 m.). On the senior author's request this specimen was re-examined by Dr. Olga Hartman and found to be *Goniada quinquelabiata* Augener (personal communication from Dr. Libbie H. Hyman). Treadwell's 1928 deep-water record must, therefore, be discounted.

Recent surveys in the Maritime Provinces (MacPhail 1954) have shown that *G. dibranchiata* is present on many of the intertidal flats. They are common in the Bay of Fundy. They have been taken in Charlotte County, New Brunswick and in Kings County (Minas Basin), Digby County (Sandy Cove), and Yarmouth County, Nova Scotia. Along the Northumberland Strait shore they are found in Shediac Bay, New Brunswick and Hillsborough Bay, Prince Edward Island.

In 1954 an unsuccessful search for bloodworms was made on intertidal flats in the Magdalen Islands, Gulf of St. Lawrence (personal communication from Mr. J. C. Hallam, then summer assistant at the Marine Biological Laboratory, Magdalen Islands, P.Q.).

METHODS OF INVESTIGATION

Measurement

For studying bloodworm populations, length was taken as the most suitable criterion of size. However, living annelid worms normally change their length when handled and must be anaesthetized to obtain a standard length measurement. A 7.5 per cent solution of magnesium chloride in fresh water was found to be a suitable anaesthetic. It is slow in its effects (1 to 2 hours for average-sized worms, less for small) but worms appear to recover from it completely when replaced in sea-water.

A trough, "V"-shaped in cross section, with a centimetre scale attached in the bottom, and filled with the solution was used for measuring. An anaesthetized worm placed in it quickly straightened out in the bottom of the "V" where its length was easily read from the scale.

Measurements of the same worms were found to be reproducible to within ± 2 per cent after successive anaesthetizations. That is, successive measurements of a 25-centimetre (about 10 in.) worm fell within the range 24.5 to 25.5 cm. Measurements with such small errors were quite satisfactory for purposes of this study.

SAMPLING

The standard fork (Fig. 2) and the digging methods of commercial diggers were used for general collecting and for most of the population sampling. The fork is a simple, easily carried, generally available tool with which it is easy to dig relatively large plots quickly. To the investigator it has the advantage that results obtained with it are directly comparable with results of commercial diggers' efforts.

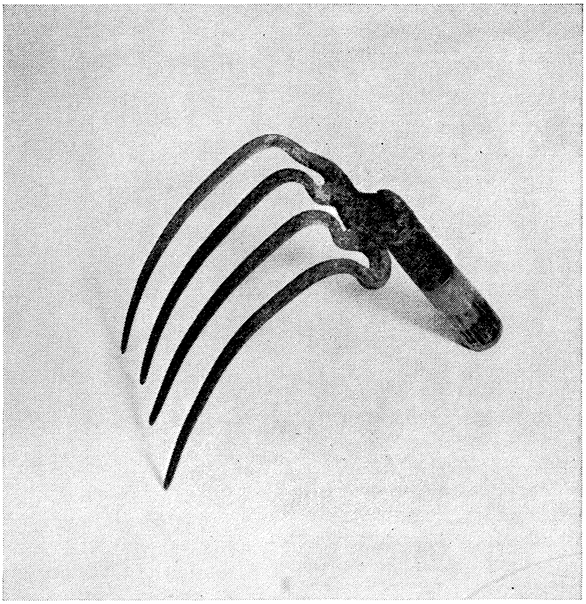


FIGURE 2. Bloodworm fork. The tynes are 9 to $10\frac{1}{2}$ inches long, tapering from $\frac{3}{4}$ inch at the base to $\frac{1}{2}$ inch near the tip. Most diggers have them made from ordinary garden forks. (Photo by P. W. G. McMullon).

A commercial digger, standing half-way to his knees in soft mud (Fig. 3), grasps the fork in one hand and swings it with a quick, chopping motion to dig a trench about 8 inches (20 cm.) deep. Viewed from above, the digger would appear as the centre of a semi-circular trench which lies in front of him with a radius of about 2 or $2\frac{1}{2}$ feet (60 to 75 cm.). Upon completing one trench the digger moves forward a step and digs a new one slicing forkfuls of mud from the new into the old, breaking them up as he works. With his free hand he picks out the exposed worms and places them in a bucket partly filled with sea-water. An experienced digger can maintain this operation at constant speed for long periods of time, making long narrow workings as he advances steadily through the oozy mud. A good digger turns as much as 550 square yards (460 sq. m.) of flats in a tide.

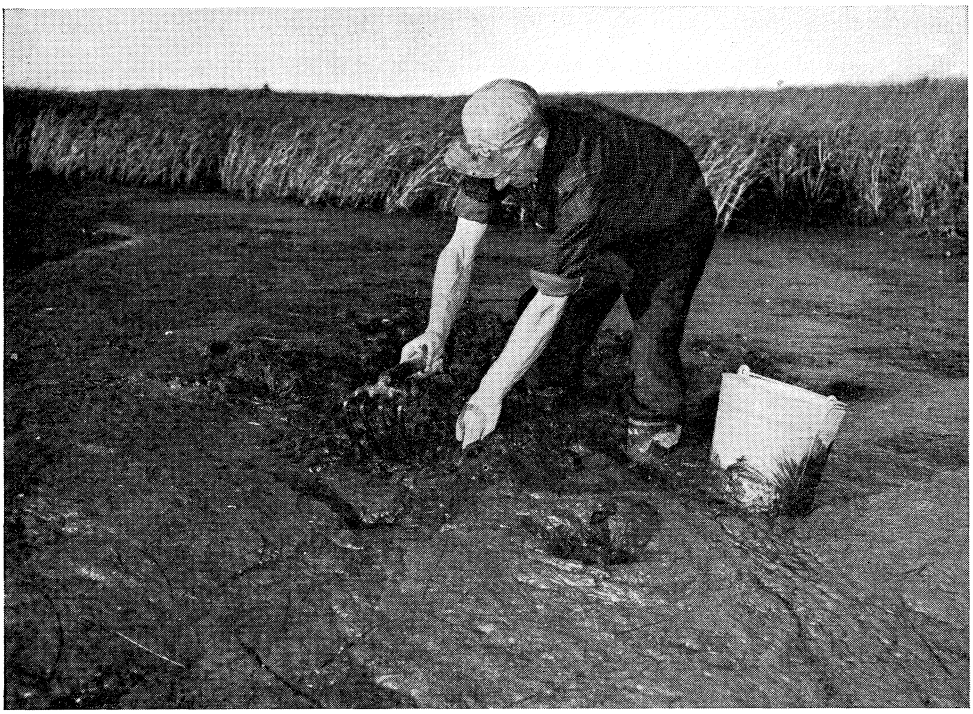


FIGURE 3. Bloodworm digger at work at Wedgeport. The bucket contains worms in sea-water.

The flats at Wedgeport (Fig. 4, 5) are typical of those where bloodworms live in abundance. They are composed of two layers, the upper is a soft dark mud averaging about 12 inches (30 cm.) deep, and the lower a hard, dark gray, mud-sand mixture. Repeated observations showed that bloodworms are confined to the upper layer and are generally found in the upper part of it. Thus, the commercial digging method using a fork with 10-inch tynes samples the entire worm population.

Observations showed that efficiency of digging varied from man to man. This was attributed principally to differences in the speed with which they turned the soil and sizes of the forkfuls they turned but partly to differences in their alertness because partly exposed worms quickly withdraw from sight into their burrows and may not be recovered. To avoid errors introduced by these factors when taking samples for relative abundance studies, an effort was made to standardize digging as much as possible.

On occasion, special detailed samples of all worms present in selected areas were required. At such times a frame of 1/32 inch (approx. 1 mm.) thick galvanized iron which could partition off 1 cubic metre (1.3 cu. yd.) of the upper worm-bearing mud was pushed into the flat. The mud within the frame was scooped out and carefully screened.

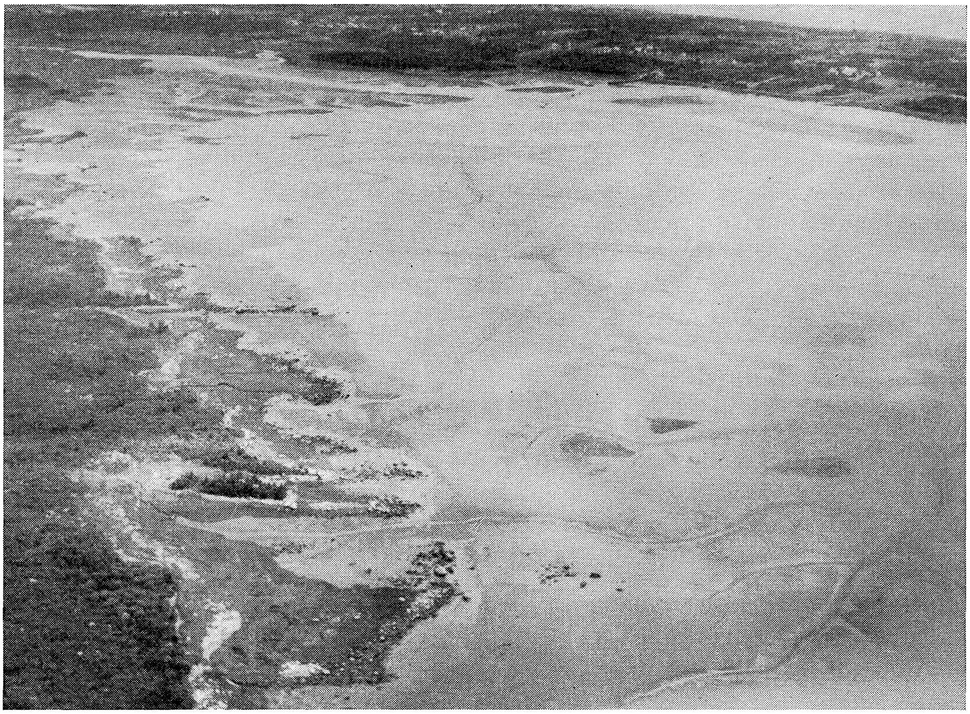


FIGURE 4. Aerial view of about 1 square mile of mud flats in Upper Goose Bay, Wedgeport, at half tide. (Photo by I. W. Flye).

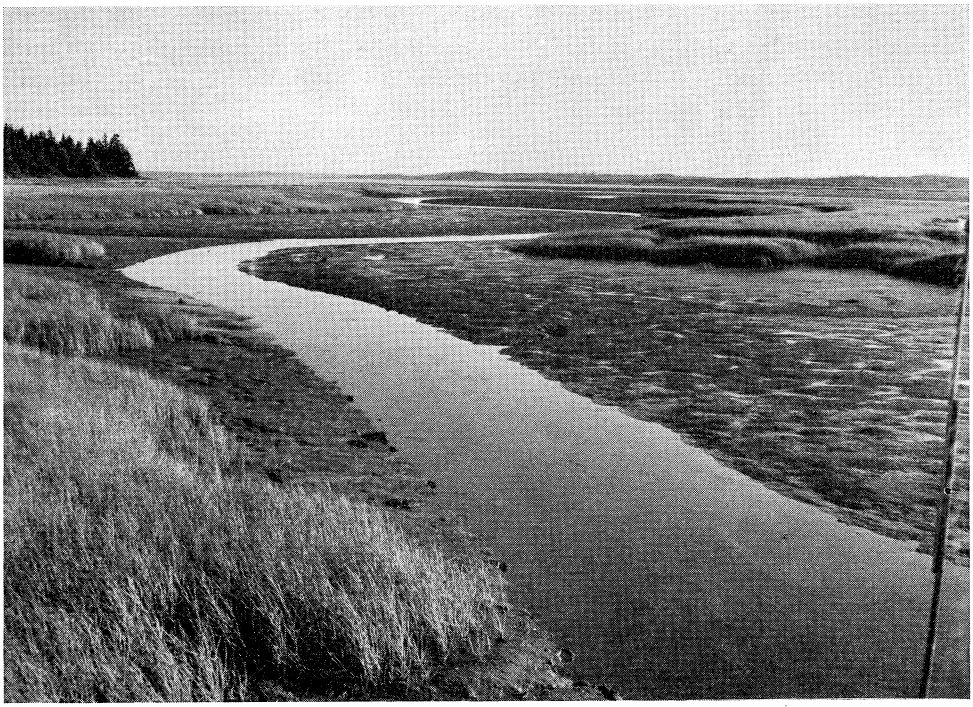


FIGURE 5. Low tide on bloodworm flats at Goose Bay. Sedge banks are characteristic of the whole region.

Marking

For studying movement of worms and for population studies it was necessary to mark bloodworms so that they could be released and recognized in subsequent samples. In various attempts to find a suitable technique the conclusion of Gustafson (1953) was confirmed that vital dyes are generally unsatisfactory either because they are lethal or fail to colour the animals conspicuously for sufficiently long periods of time. It was found, however, that silver nitrate in the form of "caustic pencils", commonly available at drug stores, produced dark marks which remained recognizable for at least a month (Klawe, 1954). This marking method proved satisfactory for our purposes.

ECOLOGICAL OBSERVATIONS

Bloodworms make extensive burrows in mud in both the intertidal zone and below low-water mark but no permanently submerged areas were examined in this study. Observations were made on abundance, movements and habits of the intertidal population.

Distribution in the Intertidal Zone

Numerous sample plots were dug in various parts of the Maritime Provinces at different beach levels and in different types of soils. Bloodworms were commonly found where the beach was composed of soft, dark mud with a high content of organic matter. Relatively few were found in hard soils. In general they were more abundant near low-water mark than higher on the beach. This appears to be related primarily to soil type rather than elevation because soils are generally softer near low-water mark. The relationship between abundance and soil type shows well in records for Sandy Cove, Digby County, N.S., where there is a wide range of soil types (Table I) on an extensive, relatively flat beach.

Table I.—Numbers of worms recovered from 33 10-square-metre plots in different types of soil at Sandy Cove, N.S., June, 1954.

Type of soil	Number of plots examined	Number of worms per plot	
		Range	Average
Sand	8	0 — 2	1.0
Hard clay	1	—	15.0
Dark sand	6	10—27	16.0
Sand and mud	8	10—39	29.0
Soft mud	10	18—71	54.3

There appears to be a limit to the softness of the soil in which bloodworms will live. Very soft, "soupy", mud seldom occurs naturally, but at Wedgeport, areas that have been recently worked through by worm diggers are sometimes in this condition. It may persist for some weeks after the digging. It was impossible to sample these areas systematically but attempts were made to collect bloodworms from them. None were found although they were found in the adjacent areas. Since bloodworms regularly perform local lateral movements (p. 12) some should have entered these areas if they had found them suitable. Their absence suggests that they do not ordinarily live in the softest soils. Apparently bloodworms do not ordinarily enter soils that are so soft as to allow their burrows to collapse behind them.

Fluctuations in Abundance

The number of bloodworms present in any beach varies. Variations may be relatively long-term trends or short-term, year-to-year fluctuations.

Long-term variations in at least some instances are correlated with changes in the physical characteristics of the flats, in accordance with the relationship between abundance and soil-type, just described. For example, in the estuary of the Sissiboo River in St. Mary Bay, Digby County, Nova Scotia, (the northeast neighbour of Yarmouth County) the composition of the flats has changed markedly in recent years and has been accompanied by faunal changes. These changes are quite well known as from about 1931 to 1955 investigators from the Biological Station at St. Andrews carried out field experiments there with soft-shell clams (*Mya arenaria*).

Up until about 1950 the flats were a firm, sand-mud mixture which supported a commercially valuable clam population. An occasional sandworm (*Neanthes*) was also found in the soil but *Glycera* was rare. Starting in the late 1940's, however, clam production declined and at the same time the flats became gradually softer. By 1952, the formerly firm flats had become soft and muddy and the lower two-thirds of the intertidal zone was completely devoid of clams. At the same time bloodworms appeared in abundance. In 1953, seed clams which settled on the soft mud failed to survive more than a few months. By the summer of 1954, the flats were barren of clams except for a narrow, firm strip of beach near high-water mark supporting a sparse population of stunted individuals, but bloodworms had become so abundant that they were being dug commercially. In 1955, commercial bloodworm digging continued but by the summer of 1956 the flat appeared to be firmer and superficial examination indicated that the bloodworms were less abundant. No commercial digging took place that year. It appears that a reversal of the trend of the previous decade has begun.

During 1954, the period when the beach was softest, the junior author observed a bloodworm digger remove a specimen of *Glycera robusta* from the flats. This species, which is characteristic of very soft soils, did not appear to be common even then, but it had never been observed in the Sissiboo area before.

Similar gradual changes in soil composition are known to the writers for several beaches in the Maritime Provinces. In some cases they have been accompanied by obvious changes in the types of animals living in the flats. In general, however, these changes have been less spectacular than those accompanying the shift from commercial clam to commercial bloodworm digging at Sissiboo. Dow and Wallace (1955) believe similar changes may have taken place along the coast of Maine.

The reason for such flat changes is uncertain, but it is thought to be associated with the generally milder winters experienced on this coast since 1945. It is well known that beach ice aids removal of surface deposits of silt and mud (Twenhofel 1950, p. 260) which otherwise may accumulate rapidly in shallow water over intertidal flats or in estuaries (*ibid.*, p. 122). There has been negligible formation of beach ice in the sheltered Sissiboo estuary during recent mild winters and this may have permitted extraordinary silt accumulation.

There is no such ready explanation for short-term fluctuations in bloodworm populations; nevertheless, fisheries statistics of older, well-established fisheries such as those for the State of Maine, provide good evidence of their occurrence. Table II portrays annual bloodworm landings from 1945 to 1954 showing the

TABLE II.—Maine landings of bloodworms (pounds of worms). Taken from "Maine Landings, Annual Summaries for 1945—1954", compiled by United States Fish and Wildlife Service and Maine Department of Sea and Shore Fisheries. (44 bloodworms weigh 1 pound).

Year	Cumberland Co.	Lincoln Co.	Knox Co.	Hancock Co.	Total Maine landings
1945.........	15,000	33,700	—	—	49,100
1946.........	14,019	30,150	—	14,701	59,269
1947.........	89,073	42,523	—	32,037	163,633
1948.........	56,229	438,105	7,722	65,931	567,987
1949.........	129,208	196,469	2,881	69,275	401,716
1950.........	66,502	152,981	1,956	89,965	311,404
1951.........	70,818	86,812	2,000	56,234	215,864
1952.........	15,689	94,043	1,909	98,534	210,175
1953.........	20,757	102,674	27,503	103,286	254,193
1954.........	30,908	42,080	37,444	128,964	239,626

totals for the State and the individual contributions of the four most important counties. Total landings rose steadily to 1948 then dropped and maintained a stable level of about 0.25 million pounds after 1950. But landings from individual counties have undergone considerable variations some of which seem unrelated to their own long-term production trends and to digging effort. For example, the general increases in Cumberland and Lincoln Counties up to 1949, and changes in Knox and Hancock Counties for most of the period of records, are indicative of expansion of areas fished (Dow and Wallace 1955), but the increase has not been steady. Variations in Cumberland and Lincoln

Counties have contributed to the general upward trend in the early years and have continued to occur on a larger scale since these heavily exploited areas reached their full productive capacity. Dow and Wallace consider them as indicative of short-term natural fluctuations in abundance. The records indicate that these fluctuations commonly result in a halving or doubling of the average annual catch.

Apparently both short- and long-term variations in the abundance occur in Maine and it is likely that they occur in the Maritime Provinces as well.

Extent of Movement

The authors have found no account of *G. dibranchiata* swimming to a distance and this study has uncovered no evidence that swimming is an important means of movement. Diggers have never reported seeing bloodworms swimming and they rarely find them on the surface of the flats. They seem to be poor swimmers for when thrown into the water they do not move away in any particular direction as do sandworms (*Neanthes*). Rather they aimlessly perform what is sometimes called "figure-eight" swimming, described for other species of *Glycera* (Støp-Bowitz 1941). Swimming seems to be an "unnatural" means of locomotion.

The scarcity of bloodworms in fish stomachs adds support to the belief that they do not ordinarily leave their burrows either to swim or crawl about. Merriman (1937) seems to have published the only record of their occurrence in fish stomachs. He found whole bloodworms in striped bass stomachs "on rare occasions", although more frequently he found fragments which he believed were baits taken from the hooks of sport fishermen. Similarly, bloodworms are common on the flats near the Biological Station at St. Andrews where the winter flounder, *Pseudopleuronectes americanus*, is also common. Although stomach contents from many flounders caught there have been examined, no investigator has recorded or recalls ever seeing remains of bloodworms in them. By contrast, other invertebrates including young soft-shell clams, siphons of adult clams, and sandworms, which are also common on these flats, are important food items. The habits of these other invertebrates make them readily available as flounder food. Small clams frequently appear on the surface of the soil (Smith 1955) and adult clams when feeding, regularly push their siphons up to or beyond it. Similarly, sandworms commonly appear on the surface of the mud and frequently swim. Since flounders, like striped bass and many other fish, will feed on bloodworms when given an opportunity (otherwise the worms would not be such a popular bait) their scarcity in fish stomachs suggests that their habits do not make them available for food, a conclusion which accords with the observations of poor swimming ability and infrequent appearance at the mud surface. Bloodworms must spend almost all their time in the soil.

Following this conclusion an experiment was carried out to determine the extent to which bloodworms move about through the soil. This was done by measuring the rate at which they repopulate dug-over plots. Eight plots, each with an area of 10 square metres (12 sq. yd.), were dug at Wedgeport in the regular manner and the worms removed from them. After six weeks when the plots were re-dug a catch equal to about 80 per cent of the original catch was obtained. A study of digging efficiency, described later, indicates that upwards of 90 per cent of the commercial-sized population was removed by the first digging. These results, therefore, indicate that bloodworms frequently move about through the mud.

In another Wedgeport experiment to study movement, worms 20 centimetres (8 in.) or more in length were marked with a silver nitrate pencil and released in the centres of four 10-square-metre plots. After twenty to thirty days the plots and surrounding areas were dug and the distances that marked worms had moved from the point of release were recorded (Table III). Of a

TABLE III.—Movements of bloodworms in 20 to 30 day periods, as judged by recoveries of 83 out of 210 worms marked and released in four 10-square-metre plots.

Distance beyond boundary of plot (*metres*)	Number of worms recovered	Percentage of total recoveries
0 (in plot)	47	57
0 — 2	13	16
2 — 4	2	2
4 — 6	5	6
6 — 8	1	1
8 — 10	6	7
10 — 12	0	0
12 — 14	2	2
14 — 16	0	0
16 — 18	0	0
18 — 20	0	0
20 — 22	3	4
22 — 24	0	0
24 — 26	0	0
26 — 28	4	5
28 — 30	0	0
Total	83	100

total of 210 worms released, 83 were recovered. Of these, 57 per cent (47 worms) were found inside the plots, 33 per cent (27 worms) outside but within 10 metres (10.9 yd.) of the plot boundaries, and the other 10 per cent (9 worms) were found at greater distances. The greatest distance travelled was 28 metres (31 yd.) which corresponds to a net movement of about one metre per day away from the plot and into new ground. These observations tell nothing about activity within tunnels already constructed. They accord, however, with the previous observations in suggesting that although bloodworms are active burrowers, their excursions into new territory are slow.

Food Habits

In the course of this study the contents of the gut of 76 bloodworms from Goose Bay, Wedgeport, were examined. Ingested material was always found in the form of food pellets up to three centimètres long. These were regularly present in the anterior part of the intestine but never in the posterior part. Bloodworms kept in laboratory aquaria commonly regurgitated loose, amorphous, pellets through the mouth but were not observed to defecate through the anus. Furthermore, droppings such as are produced by sandworms were never found. These observations are similar to Hartman's (1950). It may be that the posterior part of the intestine acts only as a digestive gland. The function of the anus is obscure.

Different authors hold different opinions on the food habits of worms of this genus. Schmarda (1861) and Ehlers (1868) believed that they are carnivorous, partly because they have a protrusible pharynx, curved jaws and four large associated glands which Ehlers believed were poison glands. McIntosh (1910) described one specimen of *Glycera siphonostoma* with a section of the tube-worm, *Capitella*, in its "stomach" and assumed that this indicated a carnivorous habit, and it is true that bloodworms crowded in an aquarium will grasp and sometimes cut in two or partly swallow one another or other worms such as sandworms. At other times, however, they appear merely to bite and the victim squirms violently but does not die and it is the present authors' view that none of these observations can be taken as proof of carnivorous habits. Crowded bloodworms will grasp and partly cut or swallow almost any objects put near them such as pieces of rock-weed and other algae. We believe that this behaviour is not a feeding activity but merely coincidental with movements of the proboscis in an effort to burrow. Bloodworms regularly do this whenever they are removed from the soil. Furthermore, when bloodworms were held in an uncrowded aquarium they consistently refused to eat animal food offered to them such as bits of softshell clams or sandworms. This corroborates Glidden's findings (1951) and supports Stolte's more careful studies (1928) from which he concluded that bloodworms are detritus feeders.

The food-pellet examinations made during this study lend support to the detritus-feeding theory. The pellets consisted principally of amorphous material containing mud and sand but were mostly of decaying organic material such as would result from indiscriminate ingestion of detritus. In rare cases identifiable pieces of algae were found, but remains of crustaceans or other worms that were common in the flats and which might be expected in the gut of a carnivore were never found.

The conclusion that bloodworms are detritus feeders seems to explain their distribution. They are rare in clear sandy soils that are detritus-poor but common in soft muds, rich in detritus. This correlation suggests that the availability of food in the form of organic detritus largely determines their distribution and abundance.

POISONOUS BITES

There is no doubt that the bloodworm can inflict a painful bite. Sandrof (1946) first described the effects on humans, although he mistakenly identified the worm as *G. americana*. He wrote that the jaws "may fasten onto a finger creating the sensation of a bee sting and producing a painful swelling in persons allergic to the bite . . . ". The senior author was once bitten on the end of a finger by a bloodworm about 18 centimetres (7 in.) long and can testify to the correctness of Sandrof's description. The pain is sharp—quite like that from a bee sting. Judging by the marks left on the finger only two jaws had pierced the skin. The marks were oval-shaped, about 2 millimetres (0.08 in.) long, and white except at their centres where a small red spot indicated the perforation. The whiteness suggested that blood vessels were constricted. The finger began to swell almost at once and was painful and hot to the touch for the rest of the day. On the second day the swelling disappeared but the finger was numb. It itched for most of the third day. Thereafter there were no symptoms.

From statments of other "victims" there appears to be pain and swelling in all cases where the skin is perforated deeply enough. There is probably a true venom involved as Ehlers believed. However, the consistent reaction discounts Sandrof's idea that the only sufferers are those who are "allergic" in the ordinary sense, although there are apparently person-to-person differences in sensitivity to the venom. This may be inferred from a comparison

FIGURE 6. Swelling and inflammation of a digger's hand the second day after a bloodworm bite. (Photo by I. W. Flye).

of the author's reaction, just described, with that of the victim whose hands are shown in Figure 6. In this latter case, however, a secondary infection might have been involved.

Bloodworm diggers and others handling large quantities of bloodworms say that they are rarely bitten. Actually they may be bitten often without realizing it because the epidermis (outer insensitive layer of skin) on their hands is so thick that it may be incompletely pierced by the jaws. Most of the bites that are noticed are on the tender, thin, skin between the fingers where the jaws have a better chance to penetrate to the sensitive layers.

Ehlers, who first described the jaws and "venom" glands, believed bloodworms are carnivorous and probably used these organs to kill the small animals on which they fed. The effects of bites on animals smaller than sandworms or other bloodworms have not been observed. They may be lethal. There was nothing discordant in Ehler's ideas, but since the worm is now believed to be a detritus feeder there is no obvious function for jaws and "poison" glands. Stolte (1928) believed that the jaws were used to grasp objects and may assist the worm in burrowing, which may be true, but he could assign no function to the glands.

In spite of the fact that nearly one hundred years have passed since the glands were first described, it is still not clear that they are indeed the source of the poison in the animal, and the chemical nature of the poison and its use to the worm have still to be explained.

LIFE-HISTORY STUDIES

The life-history of worms of the genus *Glycera* is poorly known and no detailed account of the life-history of *G. dibranchiata* is known to the authors. This paper reports some of the principal features of maturation, spawning, early development, longevity and growth rate which can be deduced from the authors' field observations and from reports of diggers and others associated with the industry.

Sexual Maturation

Bloodworms which are nearly ready to spawn are easily distinguished from sexually immature worms. Their bodies become distended by the fully developed gametes (eggs or sperms) which fill the body cavity and show through the thin body wall. These gametes are responsible for the characteristic colours of matures (females pale brown, males creamy) in contrast to the reddish-brown of immatures.

In the intertidal population, development of mature gametes begins in late summer. Dissections made in late August exposed oocytes (young eggs) about 20μ (0.0008 in.) in diameter free in the coelom of some bloodworms. No observations were made during winter but by the following spring mature worms were common. They contained fully grown oocytes which varied between 180 and 190 μ in diameter (0.0075 in.).

Measurements of a sample of 239 sexually mature worms collected in late May, 1954, are shown in Figure 7. They ranged in length from 13 to 36 centimetres (5 to 14 in.) with most of them between 20 and 30 centimetres (8 to 12 in). There appears to be little difference in the size-frequency distribution of mature males and females. The bi-modality of the distribution is of doubtful significance (p. 26).

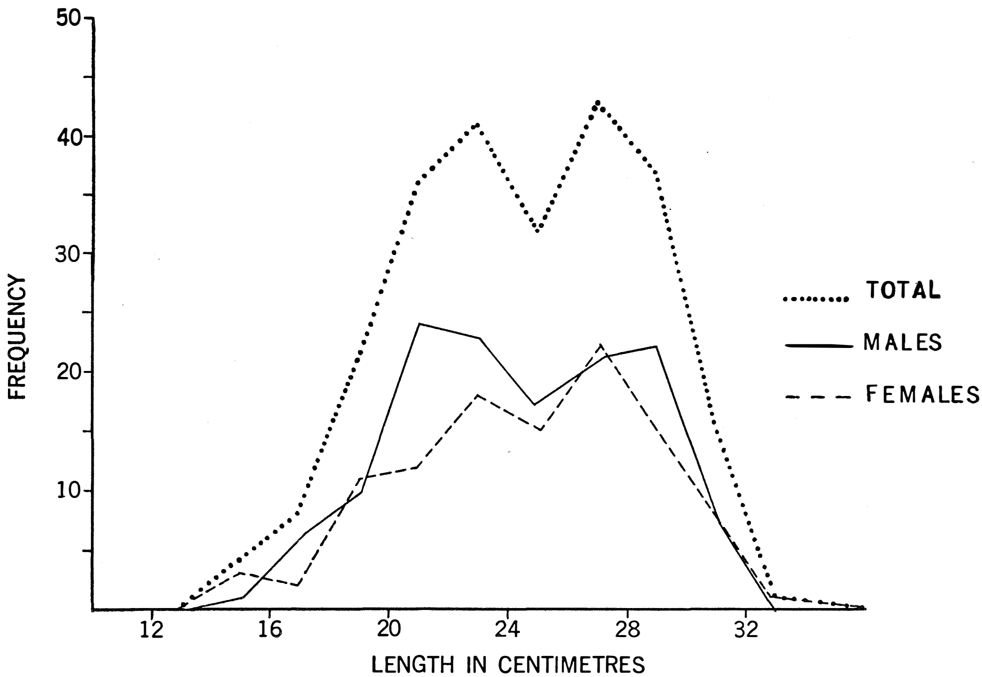


FIGURE 7. Length-frequency distribution of 239 sexually mature bloodworms collected at Goose Bay in May 1954.

SPAWNING SEASON

Diggers report that mature worms, which they call "spawners", are present on the flats in April but are most common in mid-May. The earliest seasonal collections taken during this study were in late May 1954. At that time about 19 per cent of all worms more than 20 centimetres long was sexually mature. Sex ratio of the matures was 1.3 males to 1 female. By early June only about three per cent was mature and all these were females. By mid-June no mature worms could be found.

Although spawning was not observed it appears certain from these records that in the intertidal zone it takes place during early spring. The spawning maximum seems to have been in mid-May in both 1953 and 1954, although the spawning season was spread over a period of at least three or four weeks.

Spring spawning seems to be general for intertidal populations of *G. dibranchiata*. Messrs. C. Dolloff and I. Flye of the Maine Bait Company have informed the authors that it takes place at approximately the same time in Maine as at Wedgeport. Observations and reports of diggers from other points in Western Nova Scotia indicate that the spawning times are the same as at Wedgeport. Glidden (1951) quoting from an unpublished Manuscript by J. P. Moore entitled "Annelids of Woods Hole" reports that bloodworms near Woods Hole breed during the summer and that mature individuals are rare. From our observations it seems likely that Moore observed only tardy spawners such as were found in Wedgeport in June and missed the spring spawning maximum which probably occurred at the same time as in Maine and Nova Scotia.

Spawning

It is generally believed the *Glycera* normally releases mature gametes through a rupture in the thin walls of the proboscis (Fage and Legendre 1927, Hartman 1950). However, Hartman observed that gametes were often shed through ruptures in the body wall such as might result from abrasion against the substratum. Our observations of *G. dibranchiata* showed that the release often took place at the posterior end, especially in worms which had posterior segments missing. When handled many shed gametes through breaks in the body wall, and could be induced to shed either through the body wall or proboscis by allowing an electric current from a 1.5 volt flashlight cell to flow through water in the dishes containing them. On several occasions worms discharged their gametes through the posterior end, the body wall, or the proboscis without special inducement. There was no clear indication that any one position for the rupture was commoner than others.

"Ghost" Worms

The bloodworm dies after spawning. This results in the appearance of numerous remains of dead worms on the flats at the time that "spawners" are disappearing. The remains, which we shall call "ghost" worms, consist mainly of the cuticle (outer body wall), atrophied digestive tract, and everted proboscis bearing the four prominent jaws (Fig. 8). At Wedgeport they became common in mid-May, then gradually decreased in abundance, disappearing shortly after spawning ceased in mid-June. This cycle of abundance of ghost worms corresponds with the spawning maximum as deduced from the changing abundance of spawners.

Because they persist for a short time after spawning, ghost worms may sometimes be useful in detecting populations of bloodworms and in dating the occurrence of spawnings in places where observations of living worms have not been made. This was true at Sandy Cove, Digby Co., N.S. where a number of ghost worms found on June 12, 1954, indicated a recent spawning, although no mature worms were found.

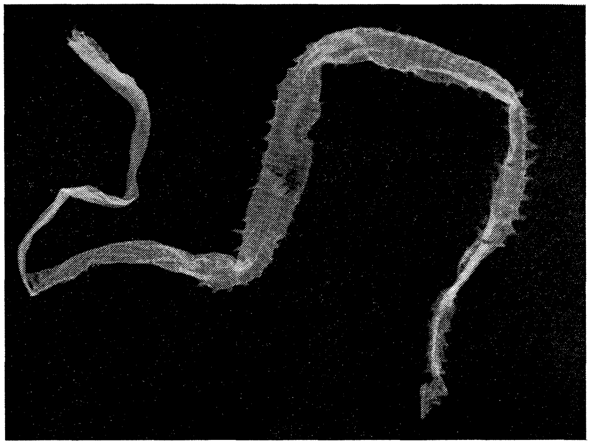


FIGURE 8. "Ghost" (spent) worm found on the beach. Bloodworms die after spawning. (Photo by P. W. G. McMullon).

SWARMING

Swarming at the sea surface at spawning time (epitoky) is known for a number of polychaete worms. This habit, which is accompanied by remarkable morphological changes both external and internal, has been reported for a number of species of *Glycera* (McIntosh 1910, Fage & Legendre 1927) but not for *G. dibranchiata*. During this study the authors observed some internal but no external structural changes preliminary to spawning. Spawning, of course, produces great changes. The body collapses completely as already described leaving only the ghosts. The presence of ghost worms on the flats after spawning indicates that they may come to the surface of the flats at spawning time, but this does not prove swarming. No evidence for such behaviour at spawning time was found.

This is consistent with the evidence that immature bloodworms rarely leave the soil and are generally poor swimmers. However, in most polychaete worms in which swarming occurs, it takes place at night and in some species it is a brief process at a particular season. It therefore regularly escapes notice. This could hold true for the bloodworm as well. Indeed, in one area we thought we had evidence of it. From June to October fishermen driftnetting for herring off Trinity Ledges, Yarmouth Co., N.S., in about 10 fathoms (18.3 m.) of water, frequently observe swarms of marine worms at the surface, apparently attracted by lights used on the boats. In October, 1955 a number of these became entangled in one man's net and dropped onto the deck when he hauled the net in. The remains were later identified by local diggers as bloodworms and were so reported to the junior author. Unfortunately it was impossible to check the identification at that time, but a sample collected on September 10, 1956 was found to consist entirely of *Neanthes pelagica* L. (C. Berkeley, personal communication). It appears, therefore, that the worm diggers' identification was in error. Deliberate observations are needed to establish the spawning habits of bloodworms.

Embryology

The development of *G. dibranchiata* from the egg to the early trochosphere larva was studied in the laboratory. In May 1954, and June 1953 and 1954, mature males and females were selected and kept in separate glass dishes in sea-water. On several occasions the worms released gametes without any special inducement, but failing this it was found that gametes flowed freely through incisions or ruptures in the body wall. It was estimated that a mature female 22 to 24 centimetres (8.5 to 9.5 in.) long contained 1.5 to 2.0 million oocytes.

In addition to oocytes there are black objects of up to 2 millimetres (0.08 in.) in diameter in the coelomic cavities. These are thought to be remains from the break-down of the digestive tract, because this degenerates as the worms become sexually mature. The presence of somewhat similar bodies in *G. capitata* was described by Ehlers. He referred to them as string-like bodies ("strängartige Gebilde"). This description does not suit those of *G. dibranchiata* which are amorphous black masses, not fibrous or string-like.

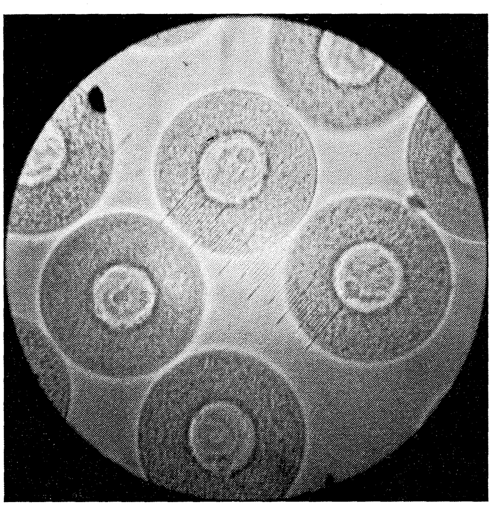


FIGURE 9. Eggs (oocytes) ready to be spawned. Diameter 0.18 mm. Photomicrograph.

The oocytes of *G. dibranchiata* (Fig. 9) are like those of *G. convoluta* which according to Fuchs (1911) are discoidal, granular but rather transparent, with a lighter coloured nucleus. They do not swell in sea-water. Newell (1951) suggests that the flattened shape of the oocytes of many polychaetes facilitates exchange of nutrients and respiratory gases between the oocytes and the coelomic fluid, in which they mature, by providing a greater surface than would a spherical oocyte of the same volume.

Mature oocytes of *G. dibranchiata* are heavier than sea-water and settle to the bottom of containers.

The male gametes are generally observed in platelike masses in the coelomic fluid which may be called sperm plates (Fig. 10). They likely remain attached as plates in all the preliminary stages of development as in other polychaetes and detach only after they mature. A mature spermatozoon is about 70 μ (0.003 in.) long, consisting of an ovoid head and a long flagellum, but without a distinct neck joining them.

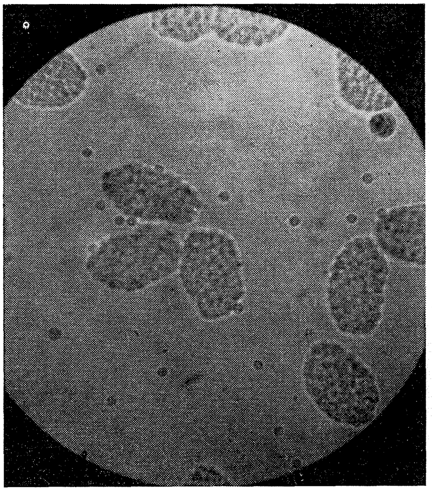


FIGURE 10. Plate-like masses of male germ cells (spermatids) which separate at spawning. Photomicrograph. Each mass is about 0.37 mm. long.

When mature oocytes were exposed to a suspension of motile spermatozoa, a fertilization membrane was usually formed in about five hours. Upon fertilization the eggs changed shape from discoidal to spherical, as reported by Newell (1948 and 1951) for *Arenicola marina* and *Clymenella torquata*. Only large oocytes, 180μ to 190μ, developed the fertilization membrane and a distinct perivitelline space, (Fig. 11) indicating that their maturity is a function of size. In several instances, even large oocytes from certain females could not be fertilized by sperm suspensions that fertilized eggs from other females. In all attempts at artificial fertilization at least some oocytes were left unfertilized.

Starting from the time of formation of the fertilization membrane, the first cleavage took place at about five hours. The two blastomeres were of about the same size. At ten hours some of the eggs had reached the 32-cell

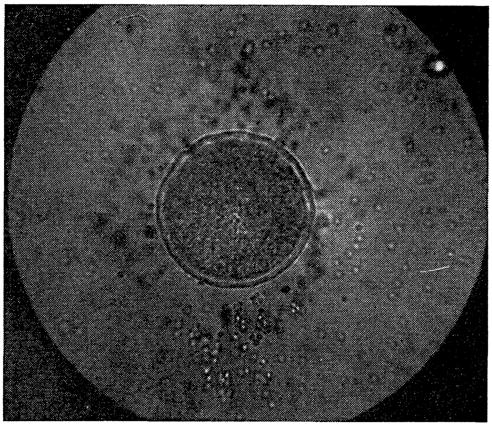


FIGURE 11. Egg (diameter 0.18 mm.) showing fertilization membrance with male germ cells (sperms) nearby. Photomicrograph.

stage but most were in the 4-cell stage. Cleavage appeared to be dexiotropic. Swimming blastulae appeared after about 22 hours and at about 32 hours the trochlear ring was formed (Fig. 12). At this stage the larvae seemed to alternate short periods of rest on bottom with vigorous swimming and swimming larvae could be seen at any level in an undisturbed dish of sea-water. These pelagic larvae soon elongated and the buccal aperature became strongly ciliated (Fig. 13). However, attempts to feed them failed and all died after about two weeks without further signs of development. During the last few days they swam close to the bottom of the container.

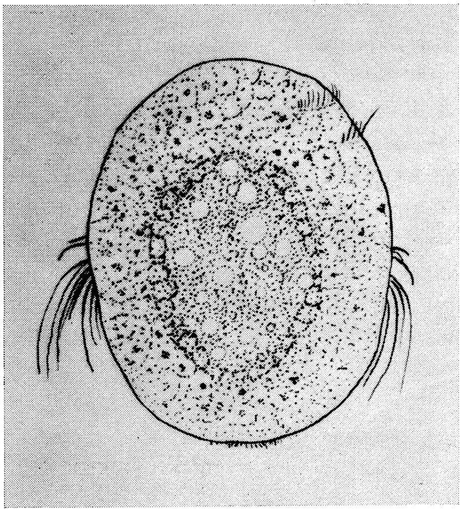


FIGURE 12. Trochosphere larva thirty-two hours after fertilization. Length about 1.3 mm. *Camera lucida* drawing.

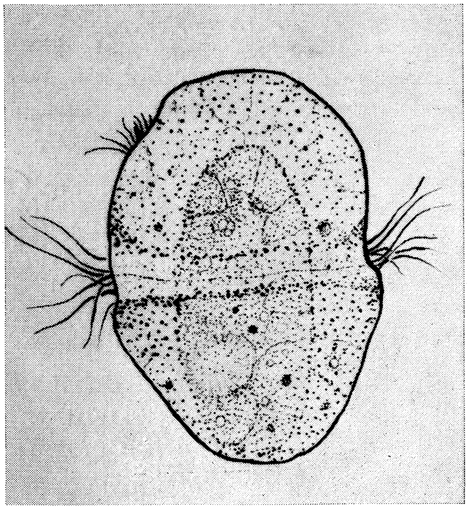


FIGURE 13. Seven-day trochosphere larva 1.3 mm. long. *Camera lucida* drawing.

Facilities for maintaining cultures of early stages at constant temperatures were not available so the influence of temperature on rate of development was not determined. A maximum-minimum thermometer kept in the laboratory showed a range from 12 to 20° C. (54 to 68° F.) during the period of study, although, during most of it the temperature remained in the upper part of this range.

Late Larval and Post-larval Development

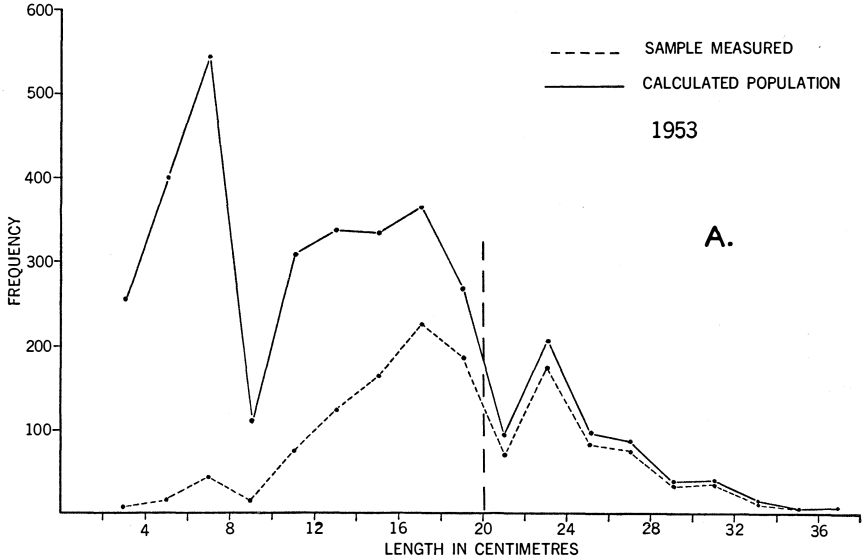
There is little information available on late larval and post-larval development. Laboratory observation on behaviour of trochosphere larvae indicated that they may be pelagic, at least in early stages. Such pelagic stages have been described for other species of Glycerids by Fuchs (1911), Aiyar (1933), and Thorson (1946), and Fuchs and Thorson have described older pelagic stages. However, although Glycerids are common members of the bottom fauna, their larvae are reported as generally uncommon in the plankton. They were rare in Aiyar's collections. Thorson (p. 76) reported that they "seem never to occur in large numbers"; of three species of *Glycera* known to occur in Danish waters, two of them commonly, he found larvae which could be ascribed to only one. It is not surprising, therefore, that attempts to collect larvae of *G. dibranchiata*, using a no. 5 plankton net over the Wedgeport flats at high water, were unsuccessful, even though this netting is fine enough (mesh size 0.28 mm.) to retain the glycerid larvae described by Thorson (1946). All evidence considered, it does not seem likely that bloodworm larvae are pelagic during much of their development.

A few attempts to collect larvae which might have settled on the intertidal flats were also unsuccessful. Following a method described by Newell (1949) small pits were made in the flats exposed at low water, and channels dug to drain surface water into them from the surrounding 10 to 20 square metres (12 to 24 sq. yd.). The water from the pits was stirred and strained through screens, the finest of which was again no. 5 plankton netting. No larvae were found which could be ascribed to *G. dibranchiata*.

The smallest bloodworms found in the mud-flats at any time were about 3 centimetres (1.2 in.) long. As they were common at the time of the earliest seasonal collections in late May and early June when spawning was still in progress it is unlikely that they had developed from larvae of that year but were probably one year old. As in other groups of invertebrates, it appears that information on the late larval and post-larval stages cannot be obtained without special study.

Size- and Age-Composition of Intertidal Populations

The size-frequency distributions of samples of bloodworms taken during the summers of 1953 (June 20 to Aug. 27) and 1954 (June 18 to Aug. 14) are shown in Figure 14. The samples were taken from undisturbed plots near commercial diggings. Abnormal worms such as those with recent injuries



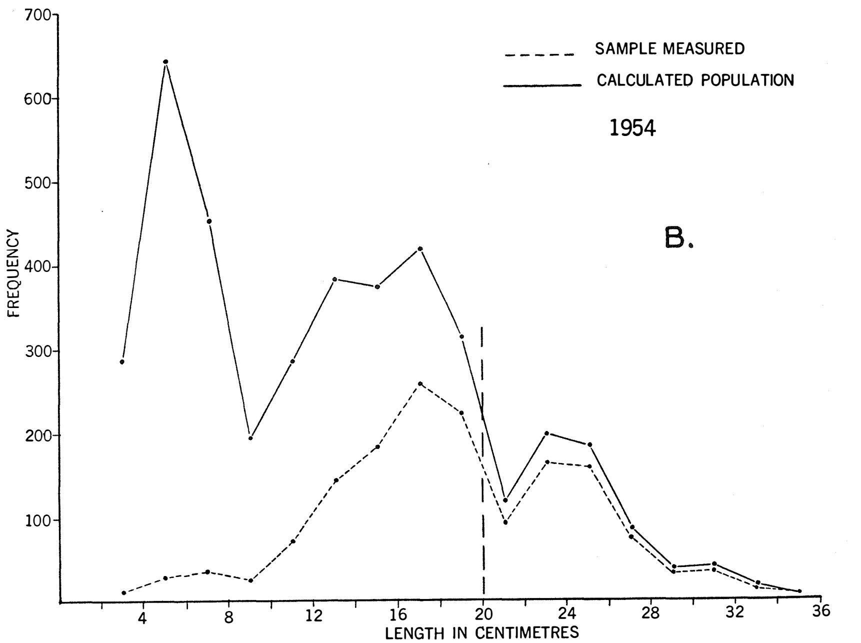


FIGURE 14. Length-frequency distributions of actual samples of Goose Bay bloodworm populations and calculated distributions developed from them by allowing for difference in the efficiency of sampling of various-sized worms (See figure 15). The broken vertical lines at 20 cm. mark the average minimum acceptable commercial size. A.—June 20 to August 17, 1953, samples totalling 1,429 worms. B.—June 18 to August 14, 1954, samples totalling 1,566 worms.

or newly regenerated tail segments were discarded before measuring. They made up only about 1.5 per cent of the samples. All worms in the samples were immatures.

These samples were taken using the commercial digging method which is not equally efficient for capturing all sizes of worms, and even misses some of the largest. To derive an estimate of the true abundance of worms of different sizes from the numbers of them actually taken in the samples a test of digging efficiency was undertaken. Bloodworms of various sizes were marked and released in a 10-square-metre plot (12 sq. yd.). To ensure that they stayed within the plot it was surrounded by a ditch about 50 centimetres (20 in.) deep. After allowing about an hour for the released worms to distribute themselves, the plot was redug in the usual manner. Records of numbers released and recovered are given in Table IV and a curve relating percentage recovery to size is shown in Figure 15.

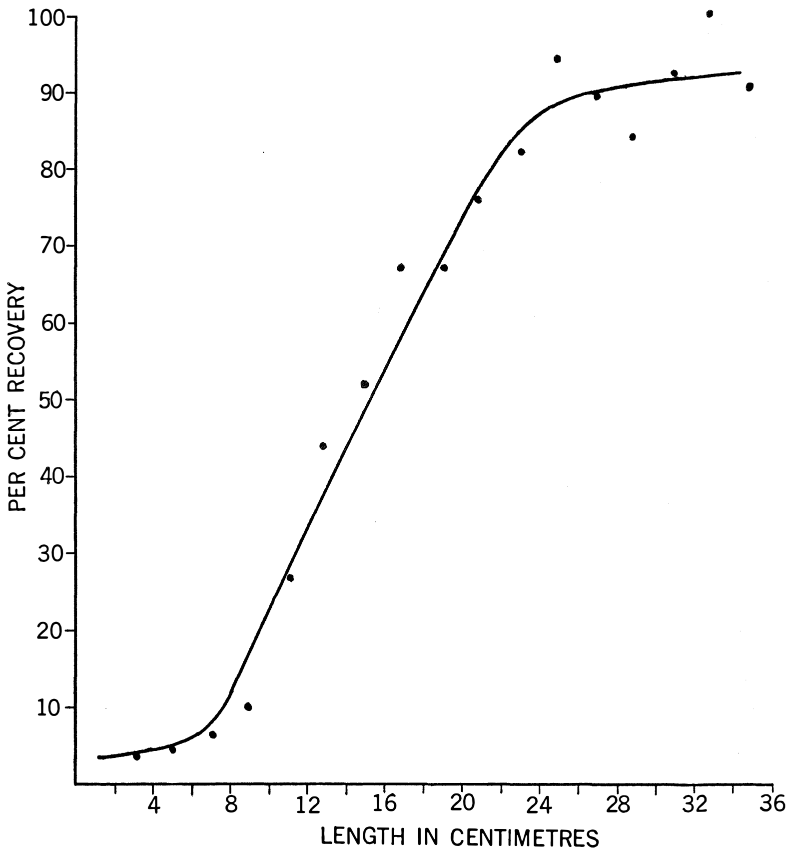


FIGURE 15. The efficiency of sampling bloodworms by commercial digging methods, judged from percentage recoveries of different sizes of marked worms. Curve drawn by inspection.

TABLE IV.—How digging efficiency is affected by the size of worms; based on recoveries of marked worms released in 10-square-metre plots and dug one hour later.

Length of worms (*centimetres*)	Number marked	Number recovered	Percentage recovery
2 — 4	96	4	4.2
4 — 6	66	3	4.5
6 — 8	45	3	6.7
8 — 10	48	5	10.4
10 — 12	67	18	26.9
12 — 14	75	33	44.0
14 — 16	73	38	52.1
16 — 18	70	47	67.1
18 — 20	58	39	67.2
20 — 22	50	38	76.0
22 — 24	50	41	82.0
24 — 26	50	47	94.0
26 — 28	49	44	89.7
28 — 30	50	42	84.0
30 — 32	50	46	92.0
32 — 34	23	23	100.0
34 — 36	21	19	90.5
Total	941	490	

On the assumption that these results are typical of the regular sampling, they have been used to reconstruct relative size-frequency distributions of the populations from the samples (Fig. 14, calculated population). The most striking feature of the resulting size-distribution curves is the presence of distinct modes at about 5, 16 and 23 centimetres (2, 6.5, 9.1 in.) and a less distinct fourth mode at about 31 centimetres (13 in.). The appearance of these modes in two successive years is strongly suggestive of successive year-classes.

If there were a differential growth rate between sexes a possible alternative to the year-class hypothesis is that some modes represent females and others males. Such a size-sex differential is difficult to detect because it is impossible to distinguish immature males and females in superficial field examinations. However, the sex of mature worms is readily distinguished and Figure 7 indicates that there is no such difference between them. Sexual dimorphism in size among immatures is therefore unlikely.

Modes of this type may also be observed in populations which have more than one spawning season. In this case each year-class might be represented by two modes. The possibility that there is more than one spawning each year was suggested by the 1955 report of an October deep-water swarming. As pointed out above, however, this report was almost certainly mistaken and there is no indication that spawning in other areas takes place more frequently or at times different from that deduced for Wedgeport. The weight of evidence at the present time favours the hypothesis that each mode represents a separate year-class and it has been adopted here.

With this hypothesis it is possible to derive the principal features of the life span and growth of intertidal bloodworm populations from the samples. The smallest worms taken in the samples and represented by the first mode (5 cm.) were already abundant at spawning time. It is reasonable to assume that they were one-year-olds. The remaining three modes of Figure 14 represent successively older year-classes. Since all worms in the samples were immatures, the four modes indicate a life span of four years as immatures.

Because bloodworms die after spawning, the great reduction in number of immatures from two to three years of age (compare areas under the sections of the calculated curves from 9 to 21 and 21 to 29 cm., Fig. 14) suggests that many of them become sexually mature and spawn as three-year-olds. This conclusion is supported by measurements of mature worms in Figure 7. The size-distribution of the total sample of matures in this figure comprehends the last two modes for immatures in Figure 14, but the majority of them correspond in size to immatures in their third year. Apparently most bloodworms spawn in the spring as they reach three years of age and then die. The surviving three-year-olds that fail to spawn are a small minority.

A comparison of Figures 7 and 14 gives further information about the relationship between age and size at sexual maturity. From Figure 14, three-year-olds range in size from 21 to 29 centimetres (8.3 to 11.4 in.) although those over 25 centimetres (9.8 in.) are only half as common as smaller sizes. From Figure 7, however, mature three-year-olds are about equally abundant throughout their size range. It appears, therefore, that it is principally the larger three-year-olds which become mature, spawn and die, and the smaller which live on to four years.

The break in the size-distribution of matures in Figure 7, indicating a relative scarcity of the 25-centimetre group, and suggesting the possibility of two distinct groups of matures, is of doubtful significance. The total sample consisted of only 239 worms, and the distribution of surviving immatures for the same year (Fig. 14B) taken from a much larger sample (1,566 worms), shows no similar break. However, the Figure 7 samples included worms as large as 34 centimetres (13.4 in.) which must have been more than three years old. This combination of year-classes may explain the bi-modality of the curves.

The suggestion of a fourth age-class averaging 31 centimetres (12 in.) in length (Fig. 14) indicates that some worms fail to spawn even as four-year-olds and live through their fourth summer to spawn the next spring as five-year-olds. They were, however, too scarce in 1954 to be detected in the sample of matures represented by Figure 7. Five years appears to be the maximum life span of the bloodworm.

Growth Rates

Deductions from these population studies and observations made during 1953 and 1954 give some information on growth rates of the intertidal bloodworm population. The growth curve shown in Figure 16 has been constructed from a consideration of apparent maximum and minimum sizes of the worms and the modes in Figure 14. Growth rate appears to be most rapid during the third year and to decrease thereafter towards a maximum size of about 35 centimetres (14 in.)

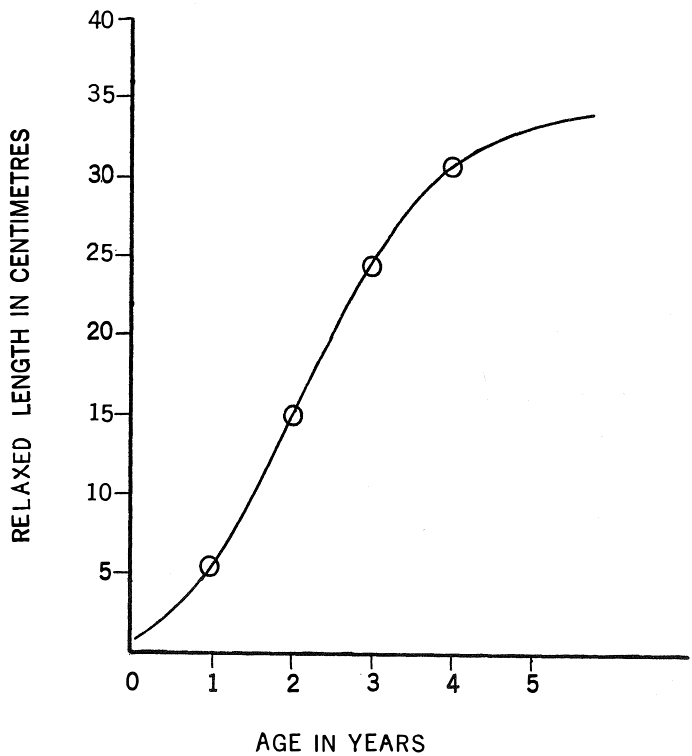


Figure 16. Growth rate of bloodworms from the intertidal zone at Goose Bay, as judged from modes in the size-frequency distribution of samples taken during the summers of 1953 and 1954 (Figure 14). Curve drawn by inspection.

The several samples taken in 1954, which were pooled to plot the single curve shown as Figure 14B, have been separated according to the month of collection and plotted separately in Figure 17 to show percentage size-frequency distributions. The most striking feature of these curves is the close correspondence of their modes, despite the fact that they represent collections made in three different summer months. It appears from this that bloodworms did not grow during the warm summer period—June to August.

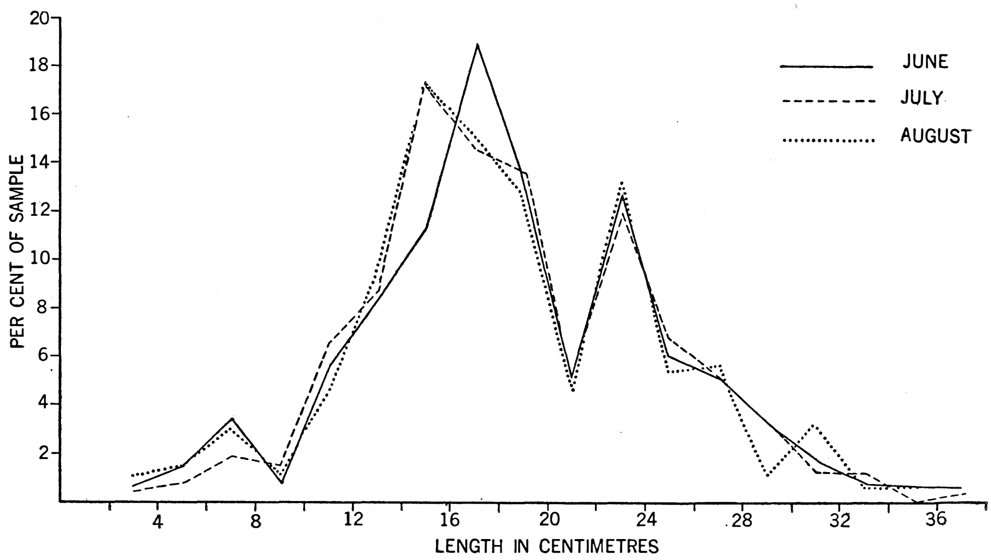


FIGURE 17. Percentage length-frequency distribution of 1954 samples of bloodworms taken from Goose Bay in June (366 worms), July (362 worms), and August (701 worms).

This conclusion is in accord with other observations of bloodworms. During the summers of 1953 and 1954 numbers of them were kept in the laboratory in jars of sea-water for periods of up to two months. There was no apparent body growth. It was also pointed out earlier that small oocytes were not found in the coeloms of bloodworms until late August. These apparently develop and grow between then and May of the following year when spawning takes place. That is, both body growth and maturation of sex products goes on chiefly in the colder months.

A cessation of growth in summer seems almost unique among invertebrates of the eastern Canadian coast. Food conditions and temperatures, which are thought to influence growth rate in most invertebrates, are generally considered ideal during the summer in this area and most molluscs appear to grow most vigorously during that season (Stevenson and Dickie 1954). As far as can be ascertained, the Wedgeport area is, climatically speaking, near the northern part of the range of bloodworms and it was, therefore, reasonable to suppose that summer conditions should be ideal for their growth as well as for that of molluscs. The evidence that they did not grow during the summer suggests a need for careful study of conditions controlling growth rates and geographic distribution in bloodworms and related species.

THE FISHERY AND ITS EFFECTS

Production, Labour Force and Income

The history of the Canadian bait-worm fishery has been briefly reviewed by MacPhail (1954). Bloodworms are by far the more important of the two species landed, although the commercial fishery for them is small. Almost all digging takes place in Yarmouth County. The entire catch is exported for sale to salt-water sport fishermen in the United States. Landings were first made in 1952 and totalled 2.6 million worms (Table V). They subsequently increased, and in 1954 and 1955 exceeded 4 million worms worth one cent each or about $40,000 to the diggers. Our annual production is therefore less than half that of Maine (Table II).

Table V.—Monthly landings of bloodworms in Canada.

Year	March	April	May	June	July	Aug.	Sept.	Oct.	Total
				thousands of worms					
1952	—	—	123	350	844	781	454	50	2,602
1953	12	351	583	702	877	433	541	—	3,499
1954	—	—	680	706	1,267	767	580	228	4,228
1955	—	225	778	899	1,020	518	367	200	4,007

There are no records to show the digging force employed but it is possible to estimate it as a basis for judging the relative importance of the fishery in the local economy. The average daily catch by a good digger is 500 to 600 worms for which he is paid between $5 and $6. Using the lower catch estimate, the 1954 landing of 4.2 million worms required the equivalent of 8,400 days' digging by one man. Since the digging season that year lasted for about 22 weeks (Table V) and since each digger averages about 4 digging days per week, the catch must have been landed by about 95 diggers. This is undoubtedly an over-estimate of the diggers regularly employed as the force is augmented in summer by school children, a fact reflected in the virtual doubling of the monthly catch from May to July. However, similar variations affect the landings of our soft-shell clam fishery. The bloodworm digging force of 95 employed for about half the year may be compared with the average of 112 diggers employed throughout 1954 for soft-shell clam digging in Charlotte County, N.B., one of the most important clam-producing areas in the Maritime Provinces. Clam diggers' incomes average about $6 per digging day. Taking into account both the digging forces and the lengths of seasons, the comparison shows that where conditions have favoured development of the bloodworm fishery, it has become about half as important as a source of income to diggers as the clam fishery is elsewhere.

Without precise information on the digging force it is impossible to calculate catch per unit effort as a measure of relative abundance in examining the past history of the fishery or predicting trends. However, general enquiry indicates that there has been an increase in the number of regular diggers paralleling the increase in landings, and that there has been no appreciable change in the diggers' daily catches even though the same flats have been dug over each year. This suggests that there has been little diminution in the supply of worms available. Examination of the character of the fishery and consideration of the information on general ecology and life-history given above, provide an explanation for this and a basis for judging the prospects of the fishery.

Commercial Catches and Spawning Stock

The spawning stock is in no danger of destruction by the fishery. Each adult female has been shown to have a high reproductive potential, so it probably

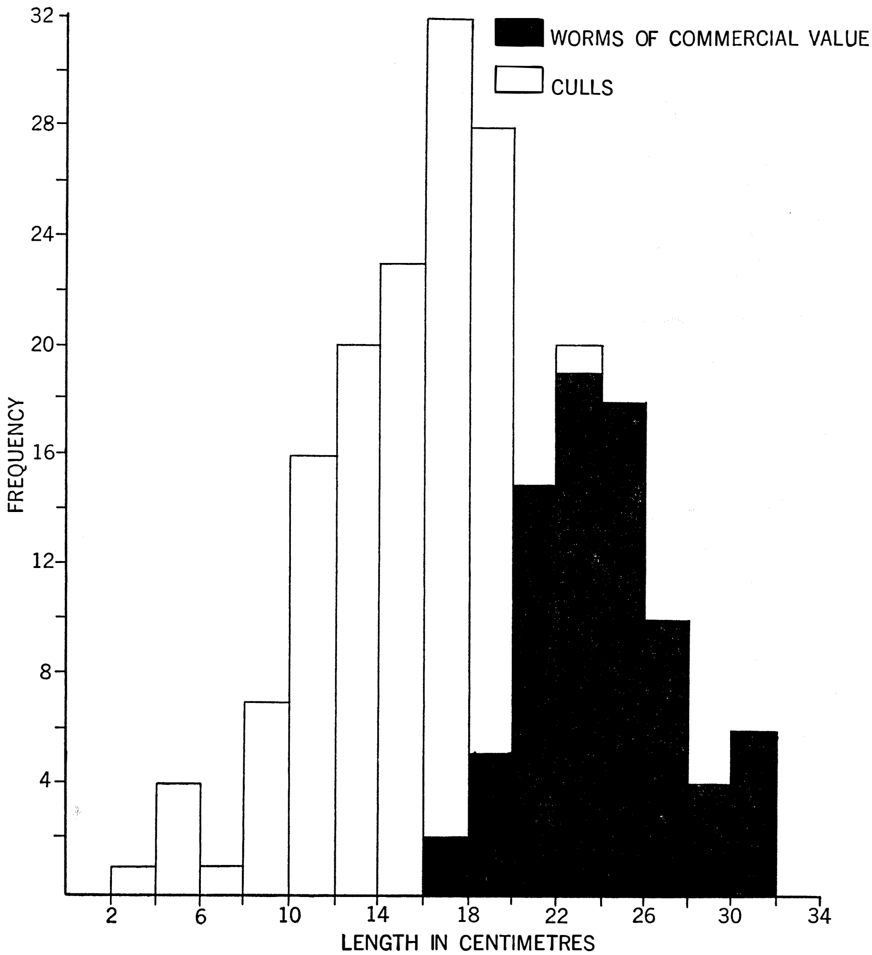


Figure 18. Length-frequency distribution of a sample of bloodworms dug by the senior author at Goose Bay in June 1953 and culled by a buyer for commercial sizes.

requires relatively few spawners in an area to maintain the population. Furthermore, the intertidal population is only a part of the total stock so there may be some recruitment to it through settlement of pelagic larvae of deep-water parentage or through actual movement of adult worms themselves from deep water. But even if there were no recruitment from deep water there would seem to be little risk of the fishery endangering the survival of an adequate spawning population. This seems likely because the fishery is so highly selective of the sizes of worms taken, because it removes only 50 per cent of the worms from the beach soil worked through and because little damage is done to all sizes of worms that are left in the soil.

Figure 18 shows the size-distribution of a sample of bloodworms dug by the senior author at Wedgeport in 1953 and culled for commercially valuable sizes by a buyer. He selected worms which averaged greater than 20 centimetres (8 in.) relaxed length, and this limit has been marked on the size-distribution graph of population in Figure 14. Since diggers ordinarily bring in only worms more than 20 centimetres long, Figure 14 shows that the fishery, which is active from late spring to mid-autumn, probably takes a few two- and four-year-old worms, but depends chiefly on three-year-olds. But it was shown earlier that the majority of bloodworms spawn in early spring when they reach three years of age, and die afterwards. Since the fishery takes only immatures, the bulk of its catches must be composed of that minority group of three-year-olds which fail to spawn and die in the spring. It can only be concluded that the fishery has too little influence on the abundance of the spawning stock to constitute a threat to continued industrial prosperity.

Relationship between Catch and Abundance

The evidence that bloodworm catches consist largely of three-year-olds indicates that landings in any one year are not appreciably influenced by the previous fishing history. That is, each year-class contributes importantly to the fishery only once and it matters little to catches in future years whether the fishery in any particular season captures a small or large proportion of the stock of worms of useful sizes. It follows that as long as the present commercial practices of size and age-selection are continued, restrictions of the rate of digging would be both ineffective and unnecessary as conservation measures.

This does not mean that the industry will be stable. Catches which depend so heavily upon the abundance of a single age-group are likely to change remarkably with changes in the natural abundance of this age-group in the stock. That is, if any one year-class is a particularly good one, catches will be high, and vice versa. Changes in natural abundance of stocks were described earlier. Long-term abundance trends have been detected in some Maritime waters and short-term fluctuations have been detected from the more heavily fished areas of Maine. Although short-term fluctuations have yet to be detected in the Maritimes, it is to be expected that abundance changes of both types occur. A preliminary assessment of their probable importance to the fishery may be made from the information now at hand.

Effects of Long-term Fluctuations. When they occur, long-term changes in abundance of bloodworms seem likely to have a profound effect on the fishery. In beaches, like those at Sissiboo, which appear to have become suitable for bloodworms as a result of the recent succession of mild winters, it is almost certain that the days of commercial bloodworm digging are numbered. This follows from the fact that meteorologists, climatologists and oceanographers alike predict a long-term change in our climate. They forecast temperatures of about present levels for another four or five years, then a gradual return to the colder conditions of the early 1940's. By 1960 we may expect colder, icy winters. If the winters do get colder it is likely that the now soft Sissiboo flats will revert to their former firm condition and that their bloodworm populations and the bait-worm fishery they supported will completely disappear.

Flat conditions in Yarmouth County appear to have been suitable for bloodworms for many years and are likely to remain so for years to come, independent of climatic changes. There seems, therefore, to be little danger of adverse long-term changes in the worm populations on which the main part of the industry depends.

Effect of Short-term Fluctuations. Although there is as yet no evidence that out main fishery is affected by shorter-term fluctuations in the abundance of worms, the history of the Maine fishery indicates that they do occur here. The degree to which they will show up as fluctuations in catch will depend on how they affect local distribution and concentration of worms, and on the intensity of the fishery.

From information on the Maine fishery it appears that short-term fluctuations in abundance are localized so that different flats or even different parts of the same flat may vary independently from year to year in their suitability for digging worms. For example, the records of landings for individual counties of Maine indicate that fluctuations in the supply from any one county have little relation to the fluctuations in supply from other counties. If short-term variations in abundance operate in this way generally, their effects on total landings will be small as long as the fishing intensity is low but will increase as the fishery becomes more intense. That is if there are few diggers, and one of them finds that worms in one flat or part of a flat are scarce, he will be able to find an undug spot not far away where digging is better. With many diggers, however, he may have to satisfy himself with poor digging.

Calculations based on available information indicate that fishing intensity in Yarmouth County is low. To make a daily catch of 500 to 600 worms, a digger from the Goose Bay area generally turns about 425 to 550 square yards (350 to 460 sq. m.) of flats. Few of our flats are turned more than once a year so for a total 1954 landing of 4.2 million worms, diggers turned about 3.8 million square yards (3.2 million sq. m.). In Goose Bay alone there is a total of about 8.5 million square yards (7.1 million sq. m.) of flats exposed at low tide, most of which appears suitable for bloodworms (Figs. 4 and 5). It is evident that if only half of it had contained bloodworms it could have supplied the total 1954 landing by itself. But there are at least three other areas of Yarmouth County now being exploited: Yarmouth Harbour, Chebogue River and Little River, each with an area comparable to Goose Bay. It, therefore, appears that considerably less than one-quarter of the worm-bearing flats of Yarmouth County is being dug annually and that diggers should still have a wide selection of spots in which to dig. In the present situation, then, our industry is protected from the full effects of short-term fluctuations in abundance.

There are also other ways in which our industry is protected. Worm diggers do not take all the commercial-sized worms in the flats they dig. Using marking experiments the senior author estimated that by careful digging he removed about 95 per cent of them. But this is not characteristic of industrial operations. General observations indicated that poor diggers take less than 40 per cent of the commercial-sized stock in the soil. The average for most diggers is about 50 per cent. Combining this with the low digging intensity it appears that removals by the present fishery amount to only 10 to 15 per cent of available population each year. Thus if worms are abundant in only a few places in any particular year, these could be dug over more than once a year and maintain production at satisfactorily high levels.

From the above considerations it is not surprising that to date Canadian bloodworm landings from the only important region have shown little variation which can be ascribed to either long-term or short-term fluctuations in abundance. Long-term fluctuations do not seem to have occurred there and when short-term fluctuations have occurred there has always been an adequate number of digging spots from which diggers could choose thereby obscuring their effects on catch. It is important, however, to consider how far our industry could expand before it would be adversely affected by short-term abundance changes.

Maine landings regularly fluctuate about 50 per cent above or below the average, and because of the heavy exploitation there, this probably reflects corresponding fluctuations in abundance. If this holds generally it means that roughly half of the digging area is seriously affected during times of worm scarcity or unusual abundance. From this we might theorize that if the fishery were to dig only half the flats or less each year, its average landings would be little affected at times of even greatest scarcity. Diggers encountering poor digging in one area would still have a good chance of finding average digging by moving to other undug ground or by re-digging good areas already exploited that year.

Applying this deduction to Nova Scotia areas where less than one-quarter of available area is now dug, it would seem that in the absence of long-term trends, digging intensity could be doubled before the fishery would be exposed to the full effects of short-term fluctuations in abundance. That is, if past landings represent average production for the dug-over ground, digging intensity could be more than doubled before competition among diggers for average digging spots would expose them to a serious risk of very low catches resulting from short-term periods of low abundance. With such stable catches by individual diggers, appropriate business management should be able to maintain total production at satisfactory levels.

Prospects

This study shows that the bloodworm fishery of the Yarmouth County area of Nova Scotia is still literally only "scratching the surface". Apparently it could be doubled, which would make it its production comparable with that of Maine.

Consideration of the growth rate and life-history of bloodworms in relation to commercial practices suggests that such a fishery could have no appreciable effects on either the natural abundance of the spawning stock or on its own future yields. Its prosperity would depend on natural abundance and because the present rate of exploitation is so low, it is capable of marked expansion without adversely affecting the catch per unit effort by the diggers.

Long-term fluctuations in abundance, related to changes in soil-type, seem likely to soon lead to drastic reductions in catch in a few marginal areas, but there is no indication that they will affect our main fishing areas in the near future. However, short-term fluctuations in natural abundance of stock might limit expansion, and if the fishery should become intense, could lead to low catches in some years. Should this occur, it might give diggers and dealers a false impression of a need for restrictions on digging effort. All evidence from this study indicates, however, that such restrictions would be unnecessary and ineffective as conservation measures, and that the stocks are capable of maintaining a satisfactorily stable total production at about double the present average annual landing. Beyond this, short-term fluctuations may lead to occasional periods of poor catches from which the fishery might choose to protect itself by digging restrictions. However, the need for such restriction must be based on economic considerations, and cannot be considered as conservation of the bloodworm population. If these were applied they should be short-term, probably no more than a year, because the conditions they would be designed to correct would be short-term. If they were long-term they would likely interfere with potential production and be damaging to the fishery.

With increasing human populations with more leisure time to indulge in the popular salt-water sport fishery, it also seems likely that the demand for bait-worms will increase. This is likely to lead to expansion of the Yarmouth County fishery in the near future, and if prices for worms increase it could favour development of similar fisheries in other parts of the Maritime Provinces where digging is not commercially attractive now. Readers are therefore urged to report local concentrations of large bloodworms to the Director, Biological Station, St. Andrews, N.B., who will be pleased to advise them on the possibility of commercial development.

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