

## Life Cycle Studies on Arcto-boreal Leeches (Hirudinea)

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**ABSTRACT:** This study provides further information on the life cycles of 6 piscicolid leeches inhabiting the arcto-boreal region of the northwestern Atlantic and northeastern Pacific oceans. Four species including *Platybdella olriki*, *Platybdella anarrhichae*, *Oceanobdella sexoculata*, and *Johanssonia arctica* inhabit the Atlantic primarily, but *Notostomum* (*Notostomobdella*) = *cyclostomum* and *Beringbdella rectangulata* have been recorded only from the Pacific. Some species (*P. olriki*, *J. arctica*, *N. cyclostomum*, and possibly *B. rectangulata*) deposit their cocoons on decapod crustaceans and a pycnogonid, whereas others (*O. sexoculata* and *P. anarrhichae*) utilize the eggs of host fish. Newly hatched leeches can readily locate their hosts that hatch simultaneously. It appears that 3 species, namely, *P. olriki*, *P. anarrhichae*, and *O. sexoculata*, have annual life cycles, whereas others such as *J. arctica*, *N. cyclostomum*, and *B. rectangulata* live more than 1 yr. The life cycle strategies, which include sites of cocoon deposition and host preferences, ensure that their progeny will successfully locate new hosts after emergence.

**KEY WORDS:** marine leeches, Hirudinea, *Platybdella*, *Oceanobdella*, *Johanssonia*, *Notostomum*, *Beringbdella*, northwestern Atlantic Ocean, Bering Sea, Gulf of Alaska.

There is limited information on the life cycles of marine leeches, especially species living in the arcto-boreal region. Some leeches are normally attached to their fish hosts in nature. Others are occasionally associated with decapod crustaceans. Increasing evidence indicates that this relationship is not parasitic but one in which the arthropod provides a hard substrate for cocoon deposition and dispersal (Moore and Meyer, 1951; Meyer and Barden, 1955). This relationship has been confirmed in studies on *Myzobdella lugubris* Leidy, 1851, on the blue crab, *Callinectes sapidus* Rathbun, 1896 (Daniels and Sawyer, 1975); *Johanssonia arctica* (Johansson, 1899) on the spider crab, *Chionocetes opilio* (O. Fabricius, 1788) in the north Atlantic (Meyer and Khan, 1979; Khan, 1982a, b); and *Notostomum cyclostomum* (Johansson, 1898), which attaches to the red king crab, *Paralithodes camtschaticus* (Tilesius, 1815) in North Pacific waters (Moore and Meyer, 1951; Sloan et al., 1984). Some other reports of associations remain speculative, such as that of *Platybdella olriki* Malm, 1865, reported on *Hyas araneus* (Linnaeus, 1758) and on *Sclerocrangon* (= *Crangon*) *boreas* (Phipps, 1774; see Wesenberg-Lund, 1926). Additionally, little is known of the methods used by other leeches to ensure that their progeny will successfully locate new hosts after emergence. The present study provides further information on the life histories of some marine leeches inhabiting the arcto-bo-

real region and their strategies for locating their hosts.

### Materials and Methods

*Platybdella olriki* were obtained from the toad crab, *Hyas araneus*, captured in baited conical traps set at 10–50 m deep in Conception Bay, Newfoundland (47°31'N, 53°05'W). After removal, leeches were held in ambient seawater and subsequently allowed to reattach to toad crabs held in a flow-through aquarium in the laboratory. Species of fish were introduced at 2–5-day intervals to ascertain host preferences. Additionally, a number of fish species inhabiting Logy Bay were examined by SCUBA divers at depths of 5–20 m for *P. olriki*.

Seaspiders, *Nymphon* sp. (Pycnogonidae), were collected by otter trawl off the northeast coast of Newfoundland and Ungava Bay during 1978 and 1982 and held in ambient seawater tanks until their return to the laboratory. Seaspiders harboring cocoons of undetermined leeches were retained until young emerged. Other pycnogonids, without leeches, were exposed to a number of species of leeches to determine which species would attach to deposit their cocoons.

Egg masses with adhering leech cocoons of an oceanpout, *Macrozoarces americanus* (Schneider, 1801), and an unknown fish were held in aquaria (20 liters) through which ambient seawater (0–4°C) flowed after collection by SCUBA divers and otter trawl, respectively, off the northeastern coast of Newfoundland. After emergence, young leeches were removed and exposed to several fish species to ascertain their host preferences and growth rate.

*Notostomum cyclostomum* were obtained from red king crab and Tanner crab, *Chionoecetes bairdi* Rathbun, 1924, captured in baited traps set at 30–120 m

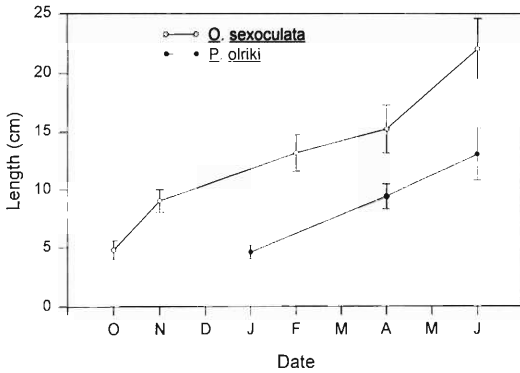


Figure 1. Growth rate of *Platybdella olriki* and *Oceanobdella sexoculata* at the ambient (0–14°C) sea-water temperature. Date refers to months of the year.

in the Gulf of Alaska and the Bering Sea. Live specimens also were obtained from Pacific halibut, *Hippoglossus stenolepis* Schmidt, 1904, captured by hook and line in Resurrection Bay, Alaska (60°06'N, 149°28'W); after transportation to Newfoundland, they were held at 2–4°C in a recirculating water system. Leeches were exposed subsequently in an aquarium to a number of fish species to determine their host specificity.

Several species of fish caught by hook and line in Resurrection Bay, Alaska, were examined for the leech *Beringbdella rectangularata* (Levinsen, 1882). After removal, leeches were placed in 500-ml beakers with seawater at 4°C. The number of cocoons deposited and their dimensions were recorded as well as the period of incubation before young emerged.

## Results and Discussion

### Northwestern Atlantic leeches

*PLATYBDELLA OLRIKI* MALM, 1865: For species description and occurrence, see Meyer and Khan (1979).

This leech was observed on the toad crab, *H. araneus*, taken at 10–50-m depth but not in deeper areas (100–190 m) or on other species of crabs (*Hyas coarctatus* Leach, 1815, and *C. opilio*). Specimens were obtained from January through July; none were observed between August and December. Its prevalence (2.4% of 250 toad crabs examined) and mean intensity ( $0.24 \pm 0.002$ ), although low, were greatest during the months of April (15%;  $\bar{x}$ ,  $0.14 \pm 0.02$ ) and June (25%;  $\bar{x}$ ,  $0.24 \pm 0.3$ ), especially on olive-brown-colored crabs. The leeches were irregularly distributed over the carapace and dorsal and ventral surfaces of the legs. Cocoons were deposited mainly on the ventral surfaces of the legs. Leeches of varying dimensions were collected during May to July mainly from winter flounder, *Pleu-*

*ronectes* (= *Pseudopleuronectes*) *americanus* (Walbaum, 1792), and less often from sea raven, *Hemitrypterus americanus* (Gmelin, 1789), lumpfish, *Cyclopterus lumpus* Linnaeus, 1758, and longhorn sculpin, *Myoxocephalus octodecenspinosus* (Mitchell, 1815). Engorged adults, held in aquaria, each deposited  $14 \pm 4.1$  cocoons between July and September ( $42 \pm 7.2$  days) and died subsequently. Cocoons measured  $0.68 \pm 0.14 \times 0.58 \pm 0.12$  mm. Each produced 1 young that emerged from late December to January, about  $92 \pm 10.4$  days later, coinciding with the time when they appear on toad crabs in nature. Young leeches measured  $4.1 \pm 0.6$  mm in length. They attached and fed readily on winter flounder and ignored other species of fish such as longhorn sculpin and sea raven. Based on the red coloration of recently engorged leeches, about 5 blood meals were required before the leeches deposited cocoons in July (Fig. 1).

*OCEANOBDELLA SEXOCULATA* (Malm, 1863):

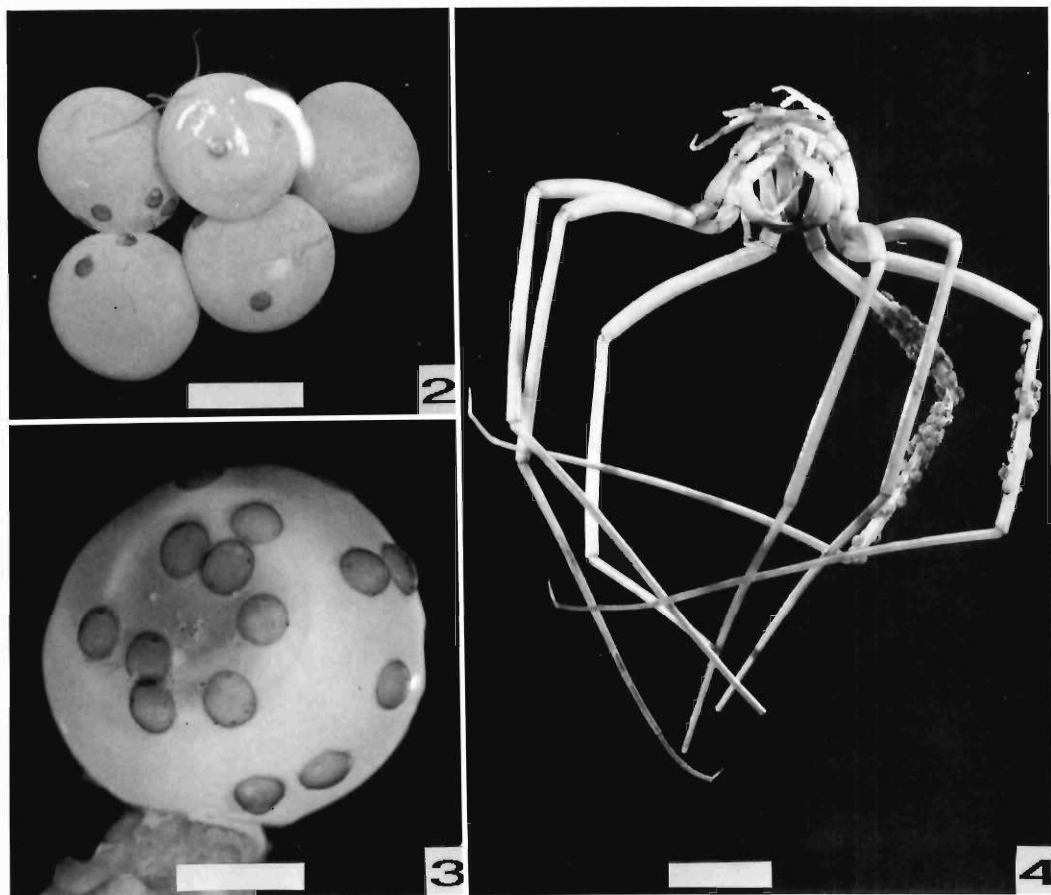
For species description, see Khan and Meyer (1976).

Egg masses collected from oceanpout, *M. americanus*, in November were infested with cocoons of *O. sexoculata* (Fig. 2). Young leeches emerged during February and attached to the cephalic region of larval oceanpout that were hatching concurrently. Blood feeding occurred subsequently and many larvae died. Some leeches on surviving oceanpout larvae were removed at intervals, and their growth rate appeared to be similar in the laboratory (Fig. 1) to that in nature (see Khan and Meyer, 1978). Cocoon deposition, an indicator of maturity, occurred in July and August; by this time, most leeches had died. The natural life cycle appears, therefore, to be annual in nature but bi-annual in the laboratory. Leeches were distributed over the body of oceanpout, but many more occurred in the cephalic region. They appeared to feed continually when attached to their host.

*PLATYBDELLA ANARRHICHAE* (Diesing, 1859):

For species description, see Meyer and Khan (1979).

An ovoid egg mass, ~20 cm in diameter, harbored 7 *P. anarrhichae* and numerous cocoons (Fig. 3) after collection in early December. Cocoons measured  $1.51 \pm 0.12 \times 1.26 \pm 0.15$  mm. Larval wolffish, *Anarrhichas* sp., and young leeches emerged simultaneously in mid-February, approximately 63 days after the egg mass was collected. The young attached immediately to larvae in the head region, including the eyes, and



Figures 2–4. 2. Cocoons and young leeches of *Oceanobdella sexoculata* attached to the eggs of an oceanpout. Scale bar = 4.5 mm. 3. Cocoons of *Platybdella anarrhichae* attached to eggs of an unknown species of wolffish. Scale bar = 3 mm. 4. Cocoons and adults of *Johanssonia arctica* attached to a pycnogonid. Scale bar = 1 cm.

subsequently fed. Young initially measured  $4.5 \pm 0.8$  mm in length and grew rapidly over the following 6 wk ( $8.8 \pm 1.3$  mm in length). During this period, some (~300) were fasted for a 2-wk period and exposed to winter flounder, longhorn sculpin, oceanpout, Atlantic cod, spotted wolffish, *A. minor* Olafsen, 1774, and Atlantic wolffish, *A. lupus* Linnaeus, 1758. The leeches attached only to Atlantic wolffish from which blood was obtained. More than 50% of the leeches attached to the head region of the fish compared to other parts of the body. Most of the leeches left on the wolffish (measuring  $10.8 \pm 1.1$  mm) had died by the end of June without deposition of cocoons. It is likely that growth rate and maturity of *P. anarrhichae* is similar to that of *P. olriki*. Both life cycles in nature appear to be annual. This leech is widely distributed in the

northeast and northwest Atlantic (see Meyer and Khan, 1979).

*JOHANSSONIA ARCTICA* (Johansson, 1899): For species description, see Meyer and Khan (1979).

In the northwestern Atlantic, this leech is normally associated with the spider (queen) crab *C. opilio* and less often on *Hyas coarctatus* and *H. araneus*, on which cocoons also are deposited. Although rarely associated with fish, it can be found in an engorged state primarily on American plaice, *Hippoglossoides platessoides* (Fabricius, 1780), caught in gillnets off the northeastern coast of Newfoundland and Labrador, Ungava Bay, and the Davis Strait. It has been found attached to the pycnogonid, *Nymphon* sp. (Fig. 4), on which cocoons are deposited primarily on the upper 2 segments of the legs. When the seaspiders were held in ambient ( $0$ – $4^{\circ}\text{C}$ ), running seawater,



Figure 5. Cocoons and an adult of *Notostomum cyclostomum* attached to the carapace of a Tanner crab.

small leeches eventually emerged after 201–262 days. These young fed more readily on American plaice than on longhorn sculpin, winter flounder, or Atlantic wolffish.

A group of 7 engorged adult *J. arctica* were allowed to attach and deposit cocoons on a sea-spider that had been collected alive from Ungava Bay. It was held initially at 0°C, and a total of 207 cocoons were deposited over a period of 26 days. Young leeches emerged  $267 \pm 27$  days later, indicating that both crabs (*C. opilio*) and sea-spiders serve as sites for cocoon deposition. The leeches fed approximately 7 times over a 2-yr period before the terminal deposition of cocoons and death. Based on the present and a previous study (Khan, 1982b), the life cycle of *J. arctica* is completed in about 2 yr.

#### Northeastern Pacific leeches

*NOTOSTOMUM CYCLOSTOMUM* (= *Notostomobdella cyclostoma*) (Johansson, 1898): For species description and occurrence, see Moore and Meyer (1951).

In the Gulf of Alaska and the Bering Sea, leeches were collected more often from the red king crab than from the Tanner crab. The leech was

more prevalent on the Tanner crab taken from the Bering Sea (7% of 101 crabs) than from the Gulf of Alaska (2% of 54). Cocoons also occurred more often on crabs from the Bering Sea (31.2%) than from the Gulf of Alaska (16.3%). Similarly, the mean intensity was greater on crabs taken from the Bering Sea ( $3.2 \pm 1.2$ ) than from the Gulf of Alaska ( $0.6 \pm 0.3$  per crab). Cocoons were deposited primarily on the main body carapace and less often on other parts of the body (Fig. 5). Large individuals were usually associated with crabs, whereas smaller forms were obtained mainly from species of flatfish. In the Gulf of Alaska, small leeches ( $29.2 \pm 2.3$  mm) were collected from yellowfin sole, *Pleuronectes* (= *Limanda*) *asper* (Pallas, 1814), rock sole, *P. bilineata* (Ayres, 1855), flathead sole, *Hippoglossoides elassodon* Jordan and Gilbert, 1880, and Pacific halibut from May to August. This leech is widely distributed in the northeast and northwest Pacific (Moore and Meyer, 1951; Epshtein, 1962; Sloan et al., 1984). According to Moore and Meyer (1951), there is no record of the leech's occurrence in the Arctic Ocean. The same authors (Moore and Meyer, 1951) also reported that most specimens (158 of 161) of *N. cyclos-*

*tomum* were dredged from soft substrate habitats free of their crab or fish hosts and concluded that it is "... a free-ranging predacious hunter which attaches to its prey to satisfy its sanguivorous requirements . . . p. 24." Epshtein (1961, 1962) concluded that *N. cyclostomum* was specific for *P. camtschatica* and *C. opilio*. However, Sloan et al. (1984) noted that although 3 species of crabs, primarily the golden king crab, *Lithodes aequispina* Benedict, 1895, was infested with cocoons of the leech collected from the deep fjords of British Columbia, Canada, gut contents revealed fish blood in various stages of digestion.

Examination of smears (10) of the gastrointestinal contents of leeches removed from crabs in the present study revealed the presence of erythrocytes of fish in all specimens. Five live leeches ( $72 \pm 8.24$  mm) obtained by one of us (A.J.P.) from Tanner crabs were maintained at  $\sim 4^{\circ}\text{C}$  after transportation to Newfoundland. Four of these leeches deposited a total of 35 ( $\bar{x}$ ,  $8.75 \pm 1.1$ ) cocoons over a period of 84 days when held in a 1-liter plastic container. The leeches were subsequently placed in a flow-through seawater aquarium (100 liters), which included Atlantic cod, shorthorn sculpin, *Myoxocephalus scorpius* (Linnaeus, 1758), and winter flounder. They were observed at weekly intervals to ascertain host preferences. The leeches fed only on flounder. Shortly after feeding, 3 of these leeches attached to a toad crab, *H. araneus*, and were subsequently consumed by it. The remaining leech deposited 6 cocoons before it died.

Sixteen young leeches ( $20.0 \pm 2.50$  mm) emerged from cocoons 245–301 days later. Ten individuals fed readily on the blood of winter flounder and 6 on yellow tail, *Pleuronectes (=Limanda) ferrugineus* (Storer, 1839) but not on Atlantic cod or longhorn sculpin. They were maintained at  $\sim 4^{\circ}\text{C}$ , but a sudden change of temperature ( $> 10^{\circ}\text{C}$ ) in the incoming seawater over a period of a week resulted in total mortality. These observations support the view that flatfish species are primarily the source of blood meals of *N. cyclostomum* and the crab exoskeleton as a site for cocoon deposition.

*BERINGBDELLA RECTANGULATA* (Levinsen, 1882): For description of the species, see Moore and Meyer (1951).

Three of 12 Pacific cod, *Gadus macrocephalus* Tilesius, 1815, captured in Resurrection Bay at  $\sim 45$  m were parasitized by a leech that occurred more often in the branchial chamber than on the body. As many as 37 leeches infested 1 fish. Pre-

served specimens of 25 leeches from Pacific cod measured  $48.2 \pm 9.4 \times 4.8 \pm 0.8$  mm. Examination of preserved specimens revealed that the leech was *Beringbdella rectangulata* (Levinsen, 1882). The urosome was considerably wider and readily distinguished from the trachelosome. The cephalic sucker was smaller than the posterior sucker and eyes were lacking. This leech was originally described as *Piscicola rectangulata* by Levinsen in 1882, but Vasilev (1939) transferred it to the newly created genus *Levinsenia*. Caballero (1970), however, pointed out that *Levinsenia* resulted in a homonym and proposed *Beringbdella rectangulata* (Levinsen, 1882) comb. n. Epshtein (1962) considered *Ichthyobdella uobir* Oka, 1910, a synonym of *B. rectangulata*.

According to Moore and Meyer (1951), the leech was collected more often from the gills of Pacific cod than from free of its host in Alaskan waters of the eastern Pacific including the Pribilof and Aleutian islands. Levinsen's type material was obtained for the Amur region in the western Pacific. Vasilev (1939) and Epshtein (1962) have recorded it from eastern Kamchatka southward to the Sea of Japan, an area where Oka in 1910 made his collection. According to Burrreson (pers. comm.), the identification of *B. rectangulata* from the great sculpin, *M. polyacanthocephalus* (Pallas, 1814), is incorrect and was confused with *Heptacyclus virgatus* (Oka, 1910). The 2 leeches, namely, *B. rectangula* and *H. virgatus*, are superficially similar in appearance but can be distinguished because *B. rectangulata* has a much stockier body, a more muscular caudal sucker, a smaller oral sucker and lacks eyes (Burrreson, pers. comm.) Measurements of 53 specimens of *H. virgatus* from *M. polyacanthocephalus* captured in the Bering Sea revealed that it is a smaller leech ( $43.7 \pm 9.9 \times 3.6 \pm 0.8$ ) than *B. rectangulata*. It appears, then, that *B. rectangulata* is restricted to gadid fish. Cocoons of this leech, initially opaque in color, become tanned and golden-brown within 48 hr. Three *B. rectangulata*, when held together at  $\sim 4^{\circ}\text{C}$  in a flow-through, ambient seawater system, deposited 15 cocoons over a 26-day period. These, dome-shaped in appearance, measured  $2.71 \pm 0.28 \times 1.79 \pm 0.12$  mm ( $n = 10$ ). A sudden change in the temperature ( $\sim 10^{\circ}$ ) of the incoming seawater caused mortality of the leeches, and the cocoons never hatched. Based on the leech's dimensions, it is likely that its life cycle exceeds 1 yr.

Marine leeches inhabiting the arcto-boreal re-

gion utilize different strategies to ensure that their offspring locate new hosts. Adult *J. arctica*, *M. lugubris*, *P. olriki*, and *N. cyclostoma* deposit their cocoons on the legs or carapace of decapod crustaceans and a pycnogonid for dispersal. More piscicolid species deposit cocoons on the legs than on the carapace. Presumably firm substrates are limited or absent in the area frequented by these leeches, but some might utilize rocks when available. Cocoons of *P. olriki*, for example, also were observed by SCUBA divers on rock outcrops frequently used by winter flounder in Logy Bay (Khan, unpubl. data). Other leeches such as *O. sexoculata* and *P. anarrichae* deposit cocoons directly on the egg mass of host fish. Young leeches after emergence can locate their hosts that hatch simultaneously. A third group of leeches, such as *Malmiana scorpii*, *M. brunnea*, *O. microstoma* (Khan and Meyer, 1976), and *O. blenni* (Knight-Jones, 1940) (see Gibson and Tong, 1969) deposit their cocoons in spring on rocks where species of sculpins and blennies, *Blennius pholis* (Linnaeus, 1758), frequent so that the young subsequently can locate their hosts after emergence. The site(s) of cocoon deposition of *B. rectangulata* is unknown, but because the leech feeds on fish that inhabit areas where the substrate is soft, it is likely that a crustacean might also be used for cocoon deposition. Fish leeches that adhere to invertebrates for dispersal and cocoon deposition are less likely to be found in nature feeding on fish except during the period prior to the final blood meal and cocoon deposition. Generally, these leeches have a broader host range than those that attach permanently such as species of *Malmiana* and *Oceanobdella*. The various sites used by these fish-feeding leeches for cocoon deposition and their associated host preferences ensure that their offspring can locate new hosts successfully after emergence.

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#### Literature Cited

- Caballero, E. C.** 1970. Cambio de nomenclatura. Anales del Instituto de Biología Universidad Nacional Autónoma de México Serie Ciencias del Mar y Limnología 1:155-156.
- Daniels, B. A., and R. T. Sawyer.** 1975. The biology of the leech *Myzobdella lugubris* infesting blue crabs and catfish. Biological Bulletin 148:193-198.
- Epshtein, V. M.** 1961. A review of the fish leeches (Hirudinea: Piscicolidae) from the northern seas of USSR. Proceedings of the Academy of Sciences of the USSR 141:1121-1124.
- . 1962. A survey of fish leeches (Hirudinea: Piscicolidae) from the Bering and Okhotsk Seas and from the Sea of Japan. Proceedings of the Academy of Sciences of the U.S.S.R. 144:648-651.
- Gibson, R. N., and L. J. Tong.** 1969. Observations on the biology of the marine leech *Oceanobdella blenni*. Journal of the Marine Biological Association of the U.K. 49:433-438.
- Khan, R. A.** 1982a. Biology of a leech ectocommensal on the spider crab, *Chionoecetes opilio*. Alaska Sea Grant Report 82-10:681-694.
- . 1982b. Biology of the marine piscicolid leech *Johanssonia arctica* (Johansson) from Newfoundland. Proceedings of the Helminthological Society of Washington. 49:266-278.
- , and **M. C. Meyer.** 1976. Taxonomy and biology of some Newfoundland marine leeches (Rhynchobdellae: Piscicolidae). Journal of the Fisheries Research Board of Canada 33:1699-1714.
- , and ———. 1978. Evidence of a bi-annual life cycle in the marine leech *Oceanobdella sexoculata* (Hirudinea: Piscicolidae). Journal of Parasitology 64:766-768.
- Meyer, M. C., and A. A. Barden.** 1955. Leeches symbiotic on Arthropoda, especially decapod crustacea. Wasmann Journal of Biology 13:297-311.
- , and **R. A. Khan.** 1979. Taxonomy, biology, and occurrence of some marine leeches in Newfoundland waters. Proceedings of the Helminthological Society of Washington 46:254-264.
- Moore, J. P., and M. C. Meyer.** 1951. Leeches (Hirudinea) from Alaskan and adjacent waters. Wasmann Journal of Biology 9:11-17.
- Sloan, N. A., S. M. Bower, and S. M. C. Robinson.** 1984. Cocoon deposition on three crab species and fish parasitism by the leech *Notostomum cyclostoma* from deep fjords in northern British Columbia. Marine Ecology Progress Series 20:51-58.
- Vasilev, E. A.** 1939. The Ichthyobdellidae of the Far East. Trudy Karelskogo Gosudarstvennogo Pedagogicheskogo Instituta Serie Biologie 1:25-66.
- Wesenberg-Lund, E.** 1926. Iglar og Oligochaeter. Meddelelser om Grønland. København 23(supplement):93-115.