Proceedings of the Nova Scotian Institute of Science (2021)
Volume 51, Part 2, pp. 327-345

THE DISTRIBUTION AND LIFE HISTORY OF *MYSIS GASPENSIS* O.S. TATTERSALL, 1954 (CRUSTACEA, MYSIDA): AN ALMOST ENDEMIC, NEKTONIC COMPONENT OF ATLANTIC CANADA ESTUARINE AND COASTAL ECOSYSTEMS

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ABSTRACT

Mysids (Mysida) or opossum shrimp are nektonic Crustacea found worldwide in freshwater, hypogean, coastal marine or deep-sea habitats. A poorly known, highly localized species *Mysis gaspensis* O.S. Tattersall, 1954 is found only in Atlantic Canada and Maine, USA. During spring to autumn, localized populations form aggregations at low tide in littoral estuarine environments but individuals also occur at littoral coastal sites. In boreal habitats, this mysid has a univoltine, semelparous life cycle. Beginning in March-April, juveniles are released from the female marsupium at 2.0-2.5 mm total length (TL). Growth in TL is linear (r^2 = 0.90), and growth in wet weight is exponential (b = 2.96). Females attain 14.1-16.5 mm TL and males 13.9-25.5 mm TL, by November when they begin maturation. During November-January, penultimate and ultimate males and females migrate seaward where copulation is presumed to occur. Males die after copulation. Development of young during winter results in a mixture of embryo development stages in individual female marsupia by spring. Mean brood size is 59 embryos (range 32-83). Females reoccupy estuarine habitats during March-April and release their young. Females survive after release of young and attain a maximum length of ~20.0 mm TL, but most die or are predated upon by late July. Juveniles and adults of some populations form highly visible aggregations during low tide in the shallow water of estuaries occupying sites with low velocity currents (12-41 cm/s) and near the limit of salinity (0.5-19.0). Aggregations range in size up to 38,000 individuals but the population in some estuaries is often scattered at low tide in small groups or individuals on the down-stream side of rocks or underwater structures.

Keywords: aggregations; brood size; growth; maturation; opossum shrimp; reproduction

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INTRODUCTION

Mysids are a group of small, nektonic, shrimp-like crustaceans with more than 1000 species (Schram 1986, Audzijonyt *et al*. 2005). Approximately 90% of species are found in coastal and deep-sea habitats but others occur in freshwater lakes or hypogean environments (Dadswell 1974, Mauchline 1980, Schram 1986). Their distribution is global, and they are an important component of marine and freshwater food webs, providing nutrition for fishes, seals, and whales (Black 1958, Tyler 1972, Steinansson 1979, Mauchline 1982, Hostens & Mees 1999, Audzijonyt 2006).

Mysids are often referred to as opossum shrimp since females carry developing embryos in a brood pouch or marsupium on the underside of their thorax, which serves to protect her eggs or embryos (Mauchline 1980). Males are sexually dimorphic and when mature have elongated fourth pleopods for transfer of sperm to the female marsupium (Holmquist 1959). After sperm transfer, females release eggs into the marsupium where they are fertilized. Embryos undergo direct development inside the marsupium (Amaratunga & Corey 1979, Mauchline, 1980).

Marine mysids display well developed aggregative behavior and swarms, schools or shoals are often very visible in shallow water (Zelickman 1974, Dadswell 1975, O'Brien 1988). Juveniles and/or adults aggregate together in estuaries and coastal littoral zones around subsurface structures and/or vegetation. Aggregation sites, which are often used daily, appear to be largely in response to environmental conditions such as currents, salinity, or shade (Hulbert 1957, Steven 1961, Dadswell 1975); however, aggregation is also thought to be under intrinsic as well as extrinsic control and is possibly used as a predation defense (O'Brien 1988, Modlin 1990).

Of the three shallow-water *Mysis* species found in the boreal Northwest Atlantic (Brunel 1960, Audzijonyt & Väinölä 2007), *Mysis gaspensis* O.S Tattersall, 1954 is the least studied with few published accounts outside of brief taxonomic, distributional and life history notes (Tattersall 1954, Haefner 1968, Bousfield & Laubitz 1974, Dadswell 1975, Audzijonyt & Väinölä 2007). Known distribution of *M. gaspensis* is in estuaries and coastal habitats from Newfoundland and Quebec to Nova Scotia, New Brunswick, and Maine (Wigley & Burns 1971, Bousfield & Laubitz 1972). The physical similarities between species make mysids difficult to identify but *M. gaspensis* can be distinguished by its unique chromatophore pattern, the most recognizable being four, very large chromatophores on the telson (Tattersall 1954, Brunel 1960, Audzijonyt & Väinölä 2007). A high density of chromatophores also appears on the head, carapace, abdomen, and antennal scales making this species capable of blending into the substrate in shallow water (Fig 1).

Previous observations of *M. gaspensis* suggest it had a one- or two-year life cycle with mating occurring during winter and young released in the spring (Tattersall 1954, Dadswell 1975). The location of overwintering habitat was also in question and some authors proposed it may be at freshwater sites (Bousfield & Laubitz 1972). New observations presented here combined with those published previously should help clarify numerous aspects of the distribution, life history, and aggregation behavior of this almost Canadian endemic.

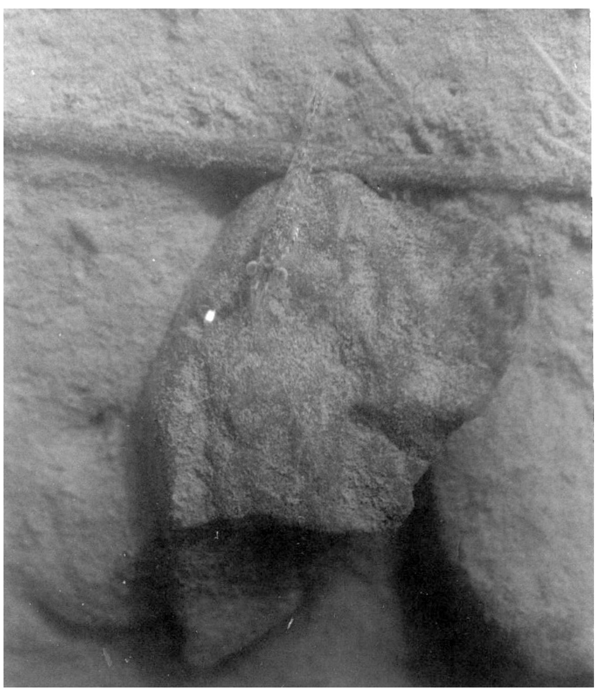

Fig 1 An individual adult *Mysis gaspensis* in a water depth of 20 cm at the Waweig estuary during low tide. Note the density of chromatophores all over its body which serve to camouflage this mysid species.

DISTRIBUTION

Bousfield (1955, 1956, 1962) and Bousfield & Laubitz (1972) carried out extensive faunal surveys for littoral crustaceans that covered the coastlines of Newfoundland, the St. Lawrence estuary, the Gulf of St. Lawrence, Nova Scotia, New Brunswick, and Maine to Massachusetts. A total of 539 sites were sampled between 41° - 50°N and 53° - 71°W at which *Mysis gaspensis* was recorded in 69 locations between 44°40' - 49°35'N and 53°14' - 70°29'W (Fig 2). Haefner (1968) and Larsen & Gilfillan (2004) recorded it from three other locations in Frenchman's and Cobscook Bays, ME, all within the distribution limits previously described by Bousfield & Laubitz (1972). Other studies on mysids along the US Atlantic coast have failed to find *M. gaspensis* south of Maine (Wigley and Burns 1971).

Further Study Sites and Collections

Specimens of *Mysis gaspensis* were collected at a further four study sites in Atlantic Canada (Fig 2): the estuaries of Deer Brook, NL (49°34'N, 57°50'W), the Kouchibouquac River, NB (46°51'N, 64°57'W), Fullers Brook, NS (45°40'N, 60°12'W), and the Waweig River, NB (45°11'N, 67°7'W). Deer Brook and the Kouchibouquac River estuaries are in the Gulf of Saint Lawrence (GSL) and characterized by warm summers, cold winters with extensive ice formation and a tidal range of 0.5-1.0 m (Bousfield 1956). Summer sea surface temperature (SST) in GSL ranged from 18-22 °C (Bousfield 1955, Dadswell 1975). The Fullers Brook and Waweig River estuaries are in the Atlantic coastal region and are characterized by cool summers, ice-free winters, and tidal ranges from 1.5-7.0 m (Bousfield 1956). Summer SST at Waweig ranged from 12-15 °C (Table 1). All study sites were brackish during May to December (0.5-19.0). The January collection site in the outer Waweig estuary was further seaward than the inner estuary site and had a salinity of 28.9. Collections from Deer Brook were from July 4-31, 1969, Kouchibouquac, June 12, 1978, Fullers Brook, September 9, 2012, and the Waweig River from April 16- December 8, 1982, January 24-June 5, 1984, May 4-October 11, 2009, and April 15-18, 2010. A total of 2485 mysids were collected from Deer Brook, one from Kouchibouquac, 14 from Fullers Brook, and 1042 from the Waweig estuary (Table 1).

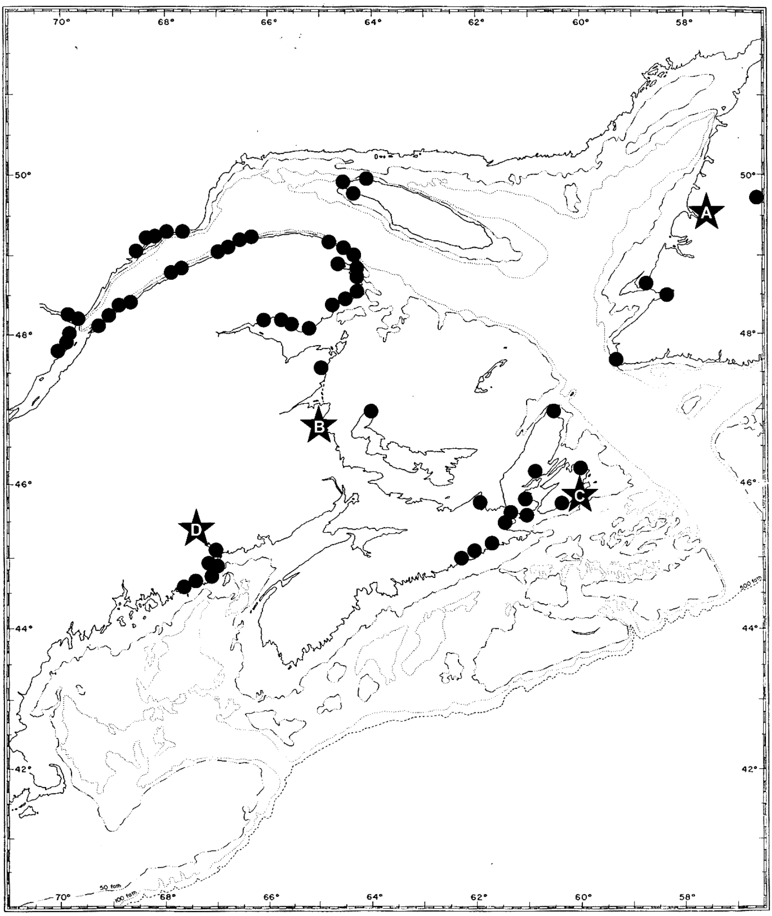

Fig 2 **Known distribution of *Mysis gaspensis* in Atlantic Canada and the US (black dots, after Haefner 1968; Bousfield & Laubitz 1972 Larsen & Gilfillen 2004). Stars indicate further collection sites from this study at (A), Deer Brook estuary, NL, (B), Kouchibouquac estuary, NB, (C), Fullers Brook estuary, NS, and (D), the Waweig River estuary, NB. Locations in the US are from Cobscook Bay, south to Machiasport, Maine, just over the Canada-US border. Additional records not indicated in Newfoundland are one each centrally on either side of the Burin Peninsula, and three sites along the southern coast of the Avalon Peninsula (Bousfield & Laubitz 1972).**

The gap in the distribution of *Mysis gaspesis* apparent in the inner Bay of Fundy (iBoF) and south-west Nova Scotia (SWNS) appears to be a reality and not an artifact of collecting (Fig 2). Bousfield (1962) occupied 26 stations along the coast of iBoF and 20 sites in coastal

Table 1 **Collection dates (D/M/Y), sea surface temperature (SST), salinity (S), current speed (CS), sample size (SS), mean carapace length (CL), mean total length (TL), mean weight (W), and female proportion (%) of *Mysis gaspensis* from the Waweig River estuary, New Brunswick. All samples were collected near the upstream limit of salinity at low tide except the collection on January 24, 1984, which was taken at low tide where the Waweig estuary opens into Passamaquoddy Bay.**

D/M/Y	SST °C	S	CS (cm/sec)	SS #	Mean CL (mm)	Mean TL (mm)	Mean W (g)
5/5/09	12.5	1.9	24.3	155	2.21	6.53	0.002
27/5/09	13.0	0.7	18.5	130	2.66	8.56	0.003
22/6/09	14.0	4.1	19.6	135	3.15	10.30	0.004
18/7/09	15.0	18.0	35.1	98	3.45	10.52	0.009
15/8/09	14.5	15.5	36.2	45	3.52	11.71	0.010
30/8/09	15.5	19.0	25.0	76	3.53	11.56	0.013
7/9/09	15.0	16.0	32.3	58	4.33	11.31	0.012
11/10/09	10.5	2.8	20.7	44	5.60	13.49	0.027
12/11/82	5.0	1.6	22.5	94	5.69	15.24	0.030
8/12/82	3.5	10.0	20.4	111	5.46	15.35	0.037
24/1/84	0.5	28.9	10.1	13	5.42	16.60	0.047
12/4/82	8.0	10.2	24.0	35	5.40	15.27	0.040
15/4/10	9.5	8.4	22.3	21	5.89	18.55	0.044
4/5/09	11.5	2.5	26.8	25	6.02	19.25	0.055
18/5/09	12.0	1.7	18.5	27	5.88	19.14	0.049

SWNS without encountering *M. gaspensis*. Additionally, 17 sites in iBoF were sampled with small mesh haul seines (5.0 mm; Dadswell *et al.* 1984) and directed efforts to capture *M. gaspensis* in the Martin's and Gold River estuaries and around the shores of Mahone Bay in SWNS were unsuccessful (Dadswell, unpublished data).

LIFE HISTORY

Sampling and Analysis of Further Study Sites

Sea surface temperature and salinity were obtained with a YSI temperature-salinity meter accurate to 0.5 °C calibrated each sampling day with a mercury thermometer. Current velocity was estimated by timing the float of a ping-pong ball over a distance of 5 or 10 m depending on the site (mean of three replicates).

Mysids were captured with a scoop net 0.5 m wide with 1.0 mm mesh. Specimens were fixed with 10% formalin in seawater at the collection site and transferred to 70% ethanol in the laboratory within two days. Gravid females were isolated in individual vials when the specimens were transferred to ethanol.

Specimens were measured under a dissecting microscope to the nearest 0.01 mm using an ocular micrometer. Carapace length was measured from the base of the eyestalk to the posterior lateral edge of the carapace, while total length was measured from the base of the eyestalk to the end of the telson. Individual weights were obtained with a Mettler balance accurate to 0.001 g. Individuals were sexed, when possible, males distinguished by an elongated fourth pleopod and females by the presence of a marsupium. All individuals without distinguishable sex characteristics were considered juveniles.

Male maturity stages of mysids are determined by the length of the fourth pleopod (Holmquist 1959). In Stage 1 of maturing males the exopod of the fourth pleopod extends only to the middle of the last abdominal segment and the last exopod segment is uniramous (Tattersall 1954). In Stage 2 or penultimate males the fourth pleopod extends to the end of the abdomen and the last segment of the exopod becomes biramous (Fig 3). In Stage 3 or ultimate males the fourth pleopod extends to the tip of the telson and the biramous last segment of the exopod becomes further elongated and filamentous (Fig 3, Holmquist 1959).

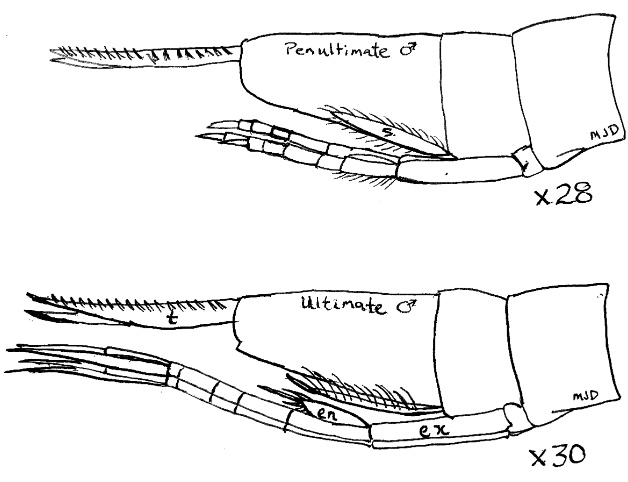

Fig 3 The posterior portion of the abdomen in maturing (upper, penultimate), and mature (lower, ultimate), male *Mysis gaspensis*. The uropod's have been removed to display the relationship between the male fourth pleopod (ex) and the telson (t). Other notations are fifth pleopod or swimmeret (s) and endopod of fourth pleopod (en). Specimens were collected from the Waweig estuary.

Female maturity is determined by the length of the oostegites plates in the marsupium (Holmquist 1959, Amaratunga & Corey 1979). In stage 1 females the oostegites extend only to the base of the fifth swimming legs. In Stage 2 or penultimate females the oostegites extend half the length of the thorax and in Stage 3 or ultimate females the marsupium occupies the entire underside of the thorax.

Eggs and embryos developing inside the female marsupium were staged according to Mauchline (1980), where eggs range between 0.5-0.7 mm in diameter, Stage I embryos are 0.5-1.0 mm TL, Stage II or eyed embryos, 1.5-2.0 mm TL, and Stage III or eyestalk embryos, 2.0-2.5 mm TL. Eggs and embryos were removed from individual female marsupia and counted, measured, and staged at X250 magnification.

Summary of Life History Characteristics

During April-November *Mysis gaspensis* populations were largely found in shallow water (0.2-2.0 m), low salinity (0.5-19.0), and low current velocity (12-41 cm/s) estuarine sites that were occupied daily by aggregations or individuals at low tide (Table 1, Dadswell 1975). During high tide mysids dispersed throughout their respective estuaries in higher salinities and became difficult to observe or collect. Individuals of *M. gaspensis* have also been routinely captured during all tide stages at higher salinity sites (29.0-32.0) throughout their range in Atlantic Canada and the US (Tattersall 1954, Heafner 1968, Bousfield & Laubitz 1972).

During November-December estuarine populations migrated seaward to outer estuary or coastal littoral sites with salinities in the range of 28.9-30.0 (Table 1, Heafner 1968). At the low salinity site in the inner Waweig estuary Stage 1, immature males represented 33.4% of the population in November but declined to 6.3% penultimate males during December (Table 2). Heafner (1968) collected only males at a coastal beach in Maine on November 10, 1966. These data suggest maturing males migrated seaward first. When efforts to capture ultimate males were extended seaward at the Waweig estuary during January 1984, collections from a site with salinity of 28.9 at low tide contained 38.5% males (Table 1). No males were captured in samples from the inner Waweig estuary during April and May probably because the adult male mysids die soon after copulation (Mauchline, 1960, Amaratunga & Corey 1975, Astthorsson 1990). Females with broods reoccupied the inner

Table 2 Collection date (D/M/Y), sample proportion of females and males (%), mean total length (TL), TL range, and mean weight (W) of adult *Mysis gaspensis* collected in the Waweig estuary, New Brunswick. Weight of females with broods was determined after embryos were removed.

Date D/M/Y	Gender of Specimens	Sample (%)	Mean TL (mm)	TL Range (mm)	Mean W (g)
12/11/82	Females[a]	66.6	15.22	14.1-16.5	0.035
	Males[a]	33.4	15.25	13.9-17.2	0.026
8/12/82	Penultimate Females[b]	93.7	15.48	14.5-16.7	0.039
	Penultimate Males[b]	6.3	15.00	13.6-15.4	0.029
24/1/84	Ultimate Females[c]	61.5	16.19	15.1-17.5	0.051
	Ultimate Males[c]	38.5	17.01	16.3-18.1	0.037
12/4/82	Females[d] with broods	100	15.27	13.9-16.5	0.040
15/4/10	Spent Females[e]	100	18.55	14.3-20.1	0.044
4/5/09	Spent Females[e]	100	19.25	15.5-19.4	0.055

[a] All females with Stage 1, marsupia oostegites; all males with Stage 1, fourth pleopod.
[b] All females with Stage 2, marsupia oostegites; all males with Stage 2, fourth pleopod.
[c] All females with Stage 3, marsupia oostegites; all males with Stage 3, fourth pleopod, females with eggs
[d] females with broods were 87% of total; with Stage II embryos, 80.6%, Stage III, 29.4%.
[e] females without eggs or embryos in marsupia.

Waweig estuary during late winter and juveniles release occurred either in March or April.

Growth

Stage III, eye-stalk embryos in female marsupia of *Mysis gaspensis* from the Waweig estuary during early April ranged from 2.0-2.5 mm TL. The first free-swimming juveniles captured on May 5 from the Waweig estuary had a mean length of 6.53 mm TL (Table 1). Overall growth in total length of the Waweig population was linear (Fig 4; $r^2 = 0.90$) but the increase in wet weight was exponential ($b = 2.96$; Table 1). By October mean length and weight of juveniles was 13.49 mm TL and 0.027 g (Table 1). Growth of juvenile TL averaged 0.04 mm/d. In the Deer Brook estuary mean TL of juveniles was 8.6 mm during early July compared to 10.52 mm TL during July in the Waweig estuary. Juvenile growth in TL at the Deer Brook estuary during July was also linear and averaged 0.14 mm/d (Dadswell 1975).

Maturation began during November in the Waweig estuary when the first juveniles with discernible sex characteristics were captured. Mean TL of the population in November was 15.24 mm and mean weight was 0.030 g (Table 1). All males and females

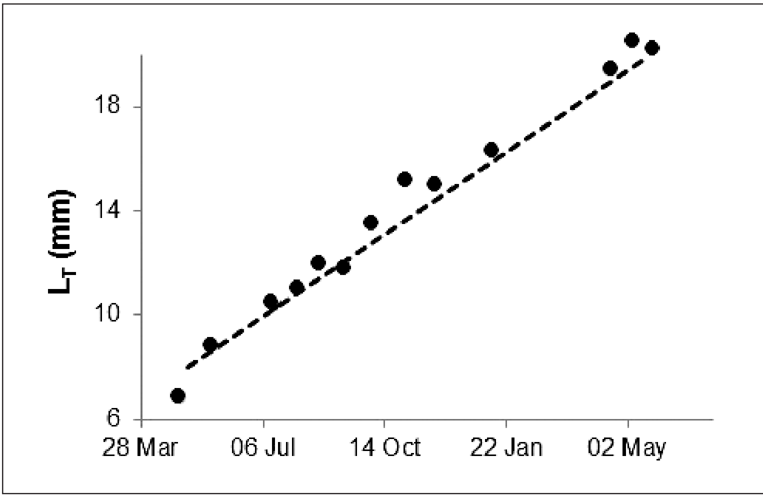

Fig 4 **Growth in mean total length (mm) over 12 months (April to following May) of the *Mysis gaspensis* population in the Waweig estuary, NB (dotted line, r2 = 0.90).**

during November were in Stage 1 of maturation (Table 2, Tattersall 1954, Holmquist 1959). Males and females molted into penultimate, Stage 2 adults during December (Fig 3). Only ultimate, Stage 3 males and females were captured in late January at the outer Waweig estuary by which time mean TL of sampled individuals was 16.60 mm and mean weight was 0.047 g (Table 1). Penultimate and ultimate females were significantly heavier than males (Table 2; t-test, $p<0.05$). Brooding and spent females captured during April and May at the inner Waweig estuary ranged from 13.9-20.1 mm TL (Table 2). Mean daily growth of maturing adults was 0.03 mm. Mature females were not captured in the Waweig estuary after July. Large females (18.6-20.0 mm TL), that were collected at Deer Brook, NL during late July, were survivors from the previous year's cohort (Dadswell 1975). They had Stage 2 oostegites and may have lived long enough to reproduce. All *M. gaspensis* captured at Kouchibouquac and Fullers Brook were juveniles.

Reproduction

Brooding females were collected twice in the Waweig estuary, on January 24, 1984, and April 12, 1982 (Table 2). Collections at Waweig on May 4, 2009, and April 15, 2010 consisted of females with empty marsupia. Five of eight females collected on

January 24, 1984, contained only eggs in their marsupia. Mean egg number was 72 (range 33-98). Individual brooding females captured on April 12, 1982, contained a mixture of Stage II (80.6% of females) and Stage III embryos (29.4% of females) in their marsupia. Most females contained either one embryo stage or the other, but some contained both stages. Mean brood size was 59 embryos (range 32-83). Large females (18.5-20.0 mm TL) collected at Deer Brook, NL during July, contained no eggs or embryos.

Aggregation Behavior

Aggregation behavior was observed at three sites: Deer Brook estuary, Fullers Brook estuary, and the Waweig estuary. Juvenile and adult *Mysis gaspensis* aggregated in either ribbon-like or globular forms.

At Deer Brook, the aggregation that formed at low tide in shallow water (20 cm deep) along the bank of the estuary was approximately 200 m long, 0.1-0.5 m wide, and was estimated to contain 38,000 individuals (Dadswell 1975). At low tide, current velocities in the aggregation site varied from 12-40 cm/s and salinity from 1.4-4.0. The substrate in the aggregation site consisted of sand and small pebbles. Mysids oriented in response to the current with their heads pointing upstream.

At Fullers Brook *M. gaspensis* formed a globular aggregation at low tide just downstream of a bridge abutment surrounded by large boulders. Current velocity was low (10 cm/s) and salinity moderate (18.0). An accurate estimate of mysid abundance was not possible because the water depth was 1-2 m, and the mysids would flee rapidly to deeper water when capture attempts were made. Abundance estimates obtained by counting the mysids while on the bridge above them suggested there were 100-200 individuals in the aggregation. In the slow current at Fullers Brook mysids were less oriented upstream but rather swam back and forth within the aggregation.

At the inner Waweig estuary *M. gaspensis* formed small globular aggregations behind large rocks at the tidal, low-water point, orienting head-first upstream against currents of 19.6-36.2 cm/s and in salinities of 0.7-19.0 (Fig 5, Table 1). Aggregations typically contained 20-40 individuals (visual counts) and were spread out over 200 m of the habitat. Also, at this location single mysids were observed downstream of smaller rocks and were oriented with

Fig 5 **Low tide collection site at the inner Waweig estuary during the lowest water period when individuals or aggregations of *Mysis gaspensis* stationed themselves downstream of rocks.**

head upstream or resting on bottom with no specific orientation (Fig 1). No estimates of the total population were attempted because the bottom substrate was mud and rock and difficult to negotiate. Once the population migrated seaward in late autumn-early winter they were widely dispersed in the lower estuary and coastal habitat, and difficult to observe or capture.

COMPARISON OF *MYSIS* LIFE HISTORIES

The life history of *Mysis gaspensis* is remarkably similar to other *Mysis* species found in the arctic, subarctic and boreal North Atlantic and whose life histories have been described (*Mysis mixta* Lilleborg, 1852; *Mysis nordenskioldi* Audzjonyte & Väinölä, 2007 {as *M. litoralis*}; *Mysis oculata* (Fabricius, 1780); *Mysis relicta* Lovén, 1862; *Mysis stenolepis* S. I. Smith, 1873). All species have a life history where females release young in late winter or early spring, juveniles grow to maturity during summer to autumn, the sexes copulate during early winter after which the males die, the embryos develop in female marsupia until release, and females live a few more months until they disappear, probably because of predation

(Grabe & Hatch 1972, Amaratunga & Corey 1975, Ladurantaye & Lacroix 1980, Salemaa *et al*. 1986, Astthorsson 1990, Rudstrom & Hansson 1990). Only at a 240 m deep site off Newfoundland where a population of *M. mixta* lives year around in temperatures of <0 °C does the life history differ by becoming a two-year life cycle, probably because of temperature effect on growth rate (Richoux *et al*. 2004).

The *Mysis* clade in the boreal Northwest Atlantic, which is based on morphological and molecular data (*M. mixta, M. stenolepis,* and *M. gaspensis,* Audzjonyte *et al*. 2005, Audzjonyte & Väinölä 2007, Audzjonyte *et al*. 2012), forms a distributional gradient from high salinity marine environments to low salinity estuarine habitats similar to the *Mysis* species clade occurring in the arctic (*M. oculata, M. nordenskioldi* {formerly as *M. litoralis*}, and *M. relicta,* Holmquist 1959). In offshore and shallow coastal, high salinity habitats *M. mixta* and *M. stenolepis* are the dominant species (Grabe & Hatch 1972, Amaratunga & Corey 1975, Richoux *et al*. 2005). Dormaar & Corey (1973) demonstrated that *M. stenolepis* is almost an osmoconformer, regulating its internal hemolymph between 1.5-2.5 salinity. It did not survive in salinities below 0.5. On the other hand, *M. relicta* which occurs in low salinity environments in the arctic (Holmquist 1959, Salemaa *et al*. 1986) like those frequented by *M. gaspensis* along the northwest Atlantic coast, is a homeoiosmatic hyperosmoregulator at low salinities maintaining their hemolymph at 1.5-2.2 (Belyayev 1949, Dormaar & Corey 1978). To date, no osmoregulation studies have been carried out with *M. gaspensis* but its osmoregulatory abilities are probably similar to *M. relicta* since it frequents and can survive in salinities as low as 0.05 (Dadswell 1975).

Growth characteristics of *Mysis gaspensis* are also similar to other shallow-water *Mysis* species from the North Atlantic although individuals attained a smaller adult size and grew somewhat slower. At the inner Waweig estuary, young *M. gaspensis* were released from marsupia in March or April when they are 2.0-2.5 mm TL and grew at a daily rate of 0.03-0.04 mm TL until they matured the following January at a of size of 15.1-18.1 mm TL. Maximum size collected was 20.1 mm TL. At coastal habitats off Iceland, *M. oculata* were released during April and grew at a rate of 0.05-0.08 mm/d until they matured at 18.7-20.9 mm TL during January

(Astthorsson 1990). In Passamaquoddy Bay, female *M. stenolepis* released young during April-May at 2.0-2.5 mm TL which then grew at a rate of 0.06 mm/d to a maximum size of 6.82-7.39 mm CL (25.3-26.0 mm TL) when they matured in January and February (Wigley & Burns 1971, Amaratunga & Corey 1975, 1979). At the inner Baltic Sea and off eastern Maine, *M. mixta* juveniles were released during April at 2.0-2.5 mm TL and grew at a rate of 0.05 mm/d to a maximum of 22.0-25.0 mm TL by the following January when they matured (Wigley & Burns 1971, Grabe & Hatch 1972, Rudstrom & Hansson 1990). In the Saguenay fjord, Quebec, *M. nordenskioldi* females released young during April-May which grew from 3.8 mm TL to 15.0 mm TL by September, a rate of 0.06 mm/d (Ladurantaye & Lacroix 1980). Mature individuals of *M. nordenskioldi* range from 22-29 mm TL (Audzjonyte & Väinölä 2007). Greater mean daily growth of *M. gaspensis* in the Deer Brook estuary (0.14 mm/d) compared to the Waweig estuary (0.04 mm/d) during July was probably the result of higher temperatures (18 ^{o}C vs 15 ^{o}C) at the former location (Dadswell *et al.* 1975).

Reproduction in *Mysis gaspensis* conforms to the univoltine, semelparous reproductive cycle common to other North Atlantic *Mysis* species. Juveniles begin maturation in autumn and proceed through penultimate and ultimate molts to sexual maturity during January. Like *M. stenolepis*, *M. gaspensis* adults migrate to more oceanic sites with higher salinity for copulation and males died soon after (Haefner 1968, Amaratunga & Corey 1975, Mauchline 1980). Female *M. gaspensis* brood an average of 59 young which is similar to the brood size of both *M. mixta* (mean 60; Grabe & Hatch 1972) and *M. oculata* (mean 52; Astthorsson 1990) but only about a third the number carried by *M. stenolepis* females (mean 157; Amaratunga & Corey 1975). Broods of *M. gaspensis* developed over a period of approximately 110-120 days from eggs during January to Stage II and Stage III embryos by April with release of free-swimming young during late March to mid-April. The development duration for embryos was similar to that found for both *M. stenolepis* (Amaratunga & Corey 1979) and *M. oculata* (Astthorsson 1990).

Females survive after the release of young but whether any live to reproduce a second time is unknown. Like other females in populations of North Atlantic *Mysis* species, none were encountered after July (Grabe & Hatch 1972, Amaratunga & Corey 1975, Astthorsson

1990). The univoltine, semelparous life cycle appears to be dominant among North Atlantic *Mysis*.

Aggregation during low tide is well developed among *Mysis gaspensis* populations. Studies to date suggest these aggregations are largely in response to environmental stimuli probably including current direction and velocity, and salinity. Formation of aggregations is well-known among other mysids, but researchers disagree about whether these are schools, swarms or shoals, the latter definition implying social interaction (Steven 1961, Zelickman 1974, O'Brien 1988, Modlin 1990). Among species of *Mysis* in the boreal North Atlantic only *M. gaspensis* is known to form aggregations in the environment at consistent locations (Dadswell 1975, this study). Amaratunga & Corey (1975) describe *M. stenolepis* forming small groups around seaweed fronds but there were no consistent groupings or orientation. Prouse (1986) observed that *M. stenolepis* occurred pelagically in Cumberland Basin, iBoF but sampling results appeared to indicate no aggregation behavior. Dadswell (unpublished data) has observed swarms/shoals of many thousands of newly released juveniles of *M. mixta* (4.0 mm TL) around large filamentous macroalgae at a depth of 15 m in Mahone Bay, NS during late March. Astthorsson (1990) makes no mention of *M. oculata* forming aggregations in coastal habitat at Iceland, but Holmquist (1959) reported an aggregation of this species numbering in the thousands, in a depth of 0.5-1.0 m at the harbor of Hunds Ejland, Greenland. Whether these aggregations are true shoals awaits further research.

COMMENTS ON FURTHER RESEARCH

Further research on the distribution, biology, and physiology of *Mysis gaspensis* is needed. The species range probably extends north of latitude 50N in Quebec, Newfoundland, and Labrador. There are undoubtedly more populations in Atlantic Canada that form aggregations at low tide and their occurrence begs locating. We know nothing about the feeding and diet of *M. gaspensis*. Other *Mysis* species are known to feed on detritus, zooplankton, and each other (Pavlyulin & Kovalchuk 1982, Griffin *et al*. 2020) and *M. stenolepis* can digest cellulose obtained from feeding on macroalgae detritus (Foulds & Mann 1978). At the aggregation sites in estuaries investigated in this study few other organisms accompanied *M. gaspensis*. The amphipods *Gammarus oceanicus* Segerstråle, 1947 and *Gammarus lawrencianus* Bousfield, 1956 were found at Deer Brook, *Gammarus setosus* Dementieva, 1931 in the Waweig estuary, and the mysid, *Neomysis americana* S. I. Smith, 1873 at the Kouchibouquac site. Further studies on the life history are also needed, including the survival duration of males during winter, better information on the timing for release of young, and whether mature females survive long enough to reproduce a second time.

Acknowledgements Justine Barry, Tina Moore, Leslie Linkletter, Daphne Themelis, and Gary Melvin assisted with the collection of samples and analysis of biological characteristics of specimens. Aaron Spares prepared figures. The late Edward Bousfield and Charlotte Holmquist stimulated my interest in the taxonomy, distribution, and life history of mysids.

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