

Aspects of the ecology and life history of Alligatorfish *Aspidophoroides monopterygius*

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Abstract The Alligatorfish (*Aspidophoroides monopterygius*) is one of numerous non-commercial marine fishes for which basic elements of life history and biology are poorly known. More than 200 individuals were collected from the southern Gulf of St. Lawrence, Canada, in September 2000 and 2001, during fisheries-independent surveys. The standard length of Alligatorfish averaged 10.9 cm in 2000 and 9.2 cm in 2001, and putative age ranged between 2 and 7 years. Males possessed significantly longer pelvic fins, relative to body size, than females. We hypothesize that Alligatorfish undergo internal gametic association and that spawning takes place in mid- to late-autumn. Diet was comprised primarily of amphipods and isopods; other diet items included euphausiids, mysids, copepods, pteropods and calcareous algae. Based on analysis of individuals collected in 2000, 6.8% were affected by parasites (nematodes). Our research on the life history and ecology of Alligatorfish contributes to our knowledge of the biodiversity of Canada's sub-Arctic marine fish fauna.

Keywords Reproduction · Diet · Parasites · Age · Growth · Fecundity

Introduction

The Alligatorfish (*Aspidophoroides monopterygius*; Agonidae) is known from the Arctic, northern Pacific and northern Atlantic Oceans. In the North Atlantic, this species is distributed from west Greenland to Cape Cod, along the coasts of Labrador and Nova Scotia, and within the Bay of Fundy and the Gulf of Maine (Bigelow and Schroeder 1953; Backus 1957; Scott and Scott 1988). Alligatorfish are distributed primarily on the continental shelf (Mahon et al. 1998), having been reported from depths typically ranging from 18 m to ~190 m and as deep as 283 m off Newfoundland and 332 m off Greenland, over substrate comprised of pebble, sand, broken shells and occasionally soft mud (Bigelow and Schroeder 1953; Jensen 1942; Snelgrove and Haedrich 1985). Backus (1957) reported this species to have a temperature range of -1.07°C to 2.52°C . Adults are dark to light brown and possess an elongated, slender body which is covered in bony plates that are arranged in longitudinal rows; they possess a single dorsal fin (soft) and reduced pelvic fins (Bigelow and Schroeder 1953).

Exceedingly limited information has been published on the growth, diet, reproduction and parasites of *A. monopterygius* and other Agonids (Scott and Scott 1988; Munehara 1997). Although *A. monopterygius* has been reported to attain a maximum length of 18.0 cm total length (TL), it more typically reaches lengths of between 10 and 15 cm (Backus 1957;

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Robins and Ray 1986; Scott and Scott 1988). Sexual dimorphism has been reported in *A. monopterygius*: Backus (1957) reported the pelvic fin in females to be 5–9% of the standard length (SL) compared to 10–11% of the SL in males. The colour of the pectoral fins has also been reported to differ between sexes (Backus 1957).

From a reproductive perspective, it has been suggested that Agonids undergo internal gametic association, similar to that reported in the closely related Cottids (Munehara 1997). Internal gametic association involves the internal deposition of sperm by the male into the female, a process similar to internal fertilization, but differing in that fertilization and development does not occur until spawning (Munehara et al. 1989; Munehara 1997). Several Agonids, including *Podothecus sachi*, *Alcichthys alcicornis*, and *Brachyopsis rostaratus*, have been reported to undergo internal gametic association (Munehara et al. 1989; Munehara 1997). The only available data on fecundity and egg size for Alligatorfish were reported for a moderately sized female containing 600 eggs approximately 1.25 mm in diameter (Jensen 1942; Scott and Scott 1988). Larvae have been reported in Passamaquoddy Bay, New Brunswick, Canada, from April to June as well as in the Gulf of Maine and Salem Harbour (Massachusetts) during spring, suggesting that spawning takes place in late autumn or early winter (Bigelow and Schroeder 1953; Moore et al. 2003; Fahay 2007). Larvae up to 2.9 cm in length have been caught in demersal sampling gear, suggesting that larvae settle to the bottom from pelagic waters at sizes less than 3 cm (Bigelow and Schroeder 1953). The only reported field densities of Alligatorfish larvae (43 and 60 m⁻³) are those measured in June and July (1990, 1991) in Conception Bay, eastern Newfoundland (NL), Canada (Laprise and Pepin 1995). Little is known about the diet of this species; it has been suggested that Alligatorfish prey on small benthic invertebrates (Coad and Reist 2004; Scott and Scott 1988), although a quantitative analysis has yet to be undertaken. Additionally, little is known about the parasites/diseases affecting this species.

Although the Alligatorfish is a non-marketable species and of no direct economic importance (Le Francois et al. 2002), it is vulnerable to incidental catch in bottom-trawl fisheries for groundfish such as Atlantic cod, *Gadus morhua*, and haddock, *Melanog-*

rammus aeglefinus (Bigelow and Schroeder 1953). Alligatorfish are also preyed upon by commercially valuable species, such as cod, haddock, and Atlantic halibut, *Hippoglossus hippoglossus*. Thus, be it from a natural-history perspective, or from the perspective of increasing our knowledge of marine fish biodiversity, there is considerable utility in increasing our knowledge of the life history and ecology of this species, which comprises the primary objective of the present study.

Materials and methods

Fish were collected during the Department of Fisheries and Oceans' (DFO) Autumn Demersal Fish Survey on the *Alfred Needler* in the Southern Gulf of St. Lawrence, Canada, in September of 2000 and 2001 (Cruise Identification Numbers NED-2000-045 and NED-2001-150). The spatial distribution of samples was determined in accordance with that specified by a random stratified survey design (Fig. 1). Specimens were collected using a Western IIA bottom trawl and were frozen after capture, usually within 2 to 3 h.

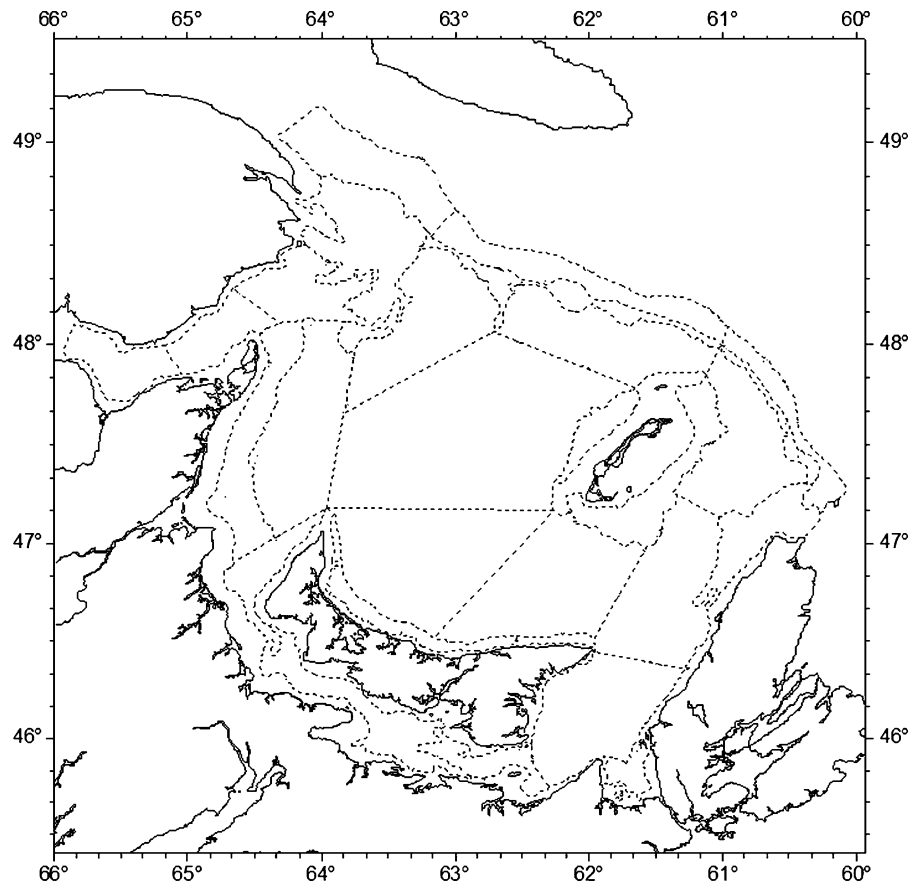
Habitat characteristics

Salinity and temperature were measured at each of the sampling sites at a depth of 5 m (surface conditions) and at the bottom, using a CTD (Conductivity, Temperature, Depth sensor). A Niskin water sampler attached above the CTD was used to collect water samples from the surface and from the bottom, for verification purposes. Differences between 2000 and 2001 were examined using two sample t-tests and where no significant differences occurred data were pooled across years. The bootstrap method was used to estimate the mean and 95% confidence intervals (shown in brackets after the mean) for the habitat characteristics of this species, using the "bootstrap" macro in "Minitab" (1000 iterations).

Age and growth

Total length (TL), standard length (SL) and wet weight (whole specimen after freezing) were determined for each individual. The relationships between TL, SL and weight were examined; where sex did not have a

Fig. 1 Sampling strata for the DFO Demersal Fish Survey of the Southern Gulf of St. Lawrence



significant effect (two sample t-tests of regression coefficients), male and female data were combined. The bootstrap method was used to estimate the mean and 95% confidence intervals for body size, using the “bootstrap” macro in “Minitab” (1000 iterations). Differences in the mean TL, SL and weight (between gender or years) were examined (two sample t-tests), and where differences were not significant, data were combined as applicable. The liver was excised and weighed, and the weight was used to calculate the hepatosomatic index (HSI) as follows: $HSI = \text{liver weight/wet weight} * 100\%$. The sagittal otoliths were excised from the specimens and stored in 95% ethanol. The otoliths were visually examined (in 95% ethanol) against a black background, using a dissecting microscope. The age of each specimen was estimated, following Smith and Gillispie (1988): the number of putative annuli (observed as opaque bands) was recorded and assumed to represent age in years. Asymptotic standard length and growth rate were estimated from von Bertalanffy growth curves, which is expressed as the function below, where: t = time

(years), L_t = length (cm) at time t , L_∞ = asymptotic standard length, k = growth coefficient and t_0 = hypothetical age at a length of 0.

$$L_t = L_\infty \left[1 - e^{-k(t-t_0)} \right]$$

The “Solver” function in Microsoft Excel was used to estimate the three parameters k , t_0 and L_∞ , while minimizing the error sum of squares.

To examine a potential sexual dimorphism, the length of the pelvic fins was measured, using vernier callipers, and compared to the body length separately for females and males. A one-factor ANCOVA was performed on this length of the pelvic fins, with sex as the factor and standard length as the covariates, for each year of data.

Reproduction

Each Alligatorfish was sexed and its reproductive structures examined and measured. Each individual was assigned one of five stages of sexual maturity,

based on the criteria described in Table 1. The gonads were excised from each specimen and weighed. In females, a portion of the gonad was removed, weighed, and preserved in 4% buffered (Borax) formaldehyde. The number of eggs in this portion was used to estimate fecundity. The eggs in this portion of the gonad were measured and egg diameter recorded. The gonadosomatic index (GSI = gonad weight/total body weight, expressed as a percentage) was estimated for each individual.

Diet composition

Stomach contents of each individual were identified to order and, when possible, to family using a dissecting microscope. The abundance of prey items in the stomach contents was recorded, and for each taxon the percentage of the total stomach content was determined. A Feeding Index (FI) was determined for each specimen as $FI = \text{stomach content weight/total weight of fish} \times 100\%$.

Parasites

Each Alligatorfish was examined for parasitic infection. The number of individuals affected, the sex of

the affected individuals, the species of parasite, and the location of the parasite were recorded.

Results

Habitat characteristics

A total of 206 Alligatorfish were collected from the Southern Gulf of St. Lawrence in 2000 (29 males and 74 females) and 2001 (58 males and 45 females). Depth of capture, which ranged from 50 to 200 m, did not differ significantly between 2000 and 2001 ($P=0.27$); the mean depth for both years was 79 m (77 to 81 m). Temperature did vary significantly between 2000 and 2001 ($P<0.001$); temperature ranged from 3.6 to 8.5°C in 2000, with a mean of 6.9°C (6.6 to 7.3°C), and in 2001 temperature ranged from 0.06 to 12.15°C, with a mean of 1.07°C (0.85 to 1.34°C). Salinity also varied between 2000 and 2001 ($P<0.001$); salinity ranged from 29.90 to 30.70‰ in 2000, with a mean of 30.10‰ (30.07 to 30.19‰), and in 2001 salinity ranged from 30.11 and 33.65‰, with a mean of 31.41‰ (31.30 to 31.54‰).

Table 1 The characteristics used to evaluate the stage of sexual maturity for male and female Alligatorfish specimens

Stages of sexual maturity	Characteristics of female specimens	Characteristics of male specimens
Immature	Small ovaries with thin walls, restricted to posterior body cavity, translucent in small fish, opaque in larger fish. Oocytes are irregular and range from 0.02 mm to 0.13 mm.	Testes small, translucent (opaque in larger fish). Testes walls thin and spermatogonia are present in small numbers.
Early Ripening	Ovaries are firm and possess visible blood vessels. Oocytes have begun a major growth phase.	Testes become larger as well as pink in colour. Cysts of spermatocytes are present.
Late Ripening	Ovaries enlarge (occupy ~1/2 body cavity) and are creamy in colour. Eggs are visible within the ovaries and blood vessels are prominent. Yolk droplets appear as inclusions between vesicles and enlarge, restricting the cortical alveoli to the periphery. Oocytes become associated with the ovigenous membrane.	Testes turn white and fill half the ventral cavity. Later during this stage, the proximal testis is white and the distal translucent. All stages of spermatozoa are present with early stages predominating along the distal edge.
Ripe/Spawning	Ovary fills most of the body cavity. Eggs appear translucent to opaque and are easily released from the vent towards the end of the stage. Yolk appears as an even mass, with layers of cortical alveoli visible under the egg membrane.	Testes are white. Spermatozoa are easily released from the vent. Tubules and efferent ducts are filled with spermatozoa.
Spent	Ovary shrinks, softens and becomes whitish. Follicles are empty.	Proximal testis white and soft where as the distal testis develops a translucent border as spermatozoa are released. Few spermatozoa in efferent ducts. Spermatogonia in the distal part of the testis.

Age and growth

The body size (total length, standard length and wet weight) of the Alligatorfish differed significantly between 2000 and 2001 ($P < 0.001$, < 0.001 and 0.05 , respectively) but not between males and females (all $P \geq 0.18$), with the exception of weight in 2001 ($P = 0.04$). The standard length of Alligatorfish in 2000 ranged from 5.1 to 14.4 cm, with a mean of 10.9 cm (10.6 to 11.2 cm). In 2001, SL ranged from 3.9 to 13.9 cm, with a mean of 9.2 cm (8.7 to 9.6 cm). The maximum size observed was 15.7 cm TL (female, early ripening, 2.92 g). Total length was strongly correlated with standard length, with a relationship of $TL = 1.07 * SL + 0.37$ ($R^2 = 0.99$). The relationship between TL and SL did not differ significantly between males and females ($P = 0.72$) or across years ($P = 0.54$). The weight of Alligatorfish ranged between 0.27 and 4.85 g in 2000 with a mean of 2.10 g (1.93 to 2.27 g), and in 2001 ranged between 0.43 and 4.68 g in with a mean of 1.85 g (1.68 to 2.05 g). In 2000, weight was strongly correlated with SL, with a relationship of $W = 0.0025 * SL^{2.8}$ ($R^2 = 0.82$), and this relationship did not differ significantly between males and females. Weight was not strongly correlated with SL in 2001 (Fig. 2). HSI differed between 2000 and 2001 ($P < 0.001$) and was significantly greater in females than males ($P < 0.001$), with females averaging 3.56% (3.27 to 3.89%) in 2000 and 2.83% (2.49 to 3.19%) in 2001. Among males, HSI averaged 2.84% (2.55 to 3.17%) in 2000 and 2.38% (2.12 to 2.65%) in 2001.

Under the assumption that each opaque region on each otolith represented an annulus, age is estimated to have ranged between 2 and 7 years of age (Fig. 3). Maximum age for both males and females was 7 years. From these data, t_0 , k and L_∞ for both years were estimated to be: 2000: $t_0 = -0.866$, $k = 0.231$, $L_\infty = 15.28$ ($R^2 = 0.57$) and 2001: $t_0 = -0.115$, $k = 0.236$, $L_\infty = 15.29$ ($R^2 = 0.50$). The von Bertalanffy growth curves produced from these data are shown in Fig. 3.

The pelvic fins of males, relative to body length, were significantly longer than those of females (ANCOVAs: 2000 - $P < 0.001$; 2001 - $P < 0.001$). Interestingly, the relationship between pelvic fin length and SL was also found to differ between male and female Alligatorfish (Fig. 4), with males showing a stronger and more positive relationship than females.

Reproduction

The stage of sexual maturity differed between males ($n = 91$) and females ($n = 119$) at the time of sampling (Fig. 5). Males were predominantly “ripe/spawning” (86.2% in 2000, 46.6% in 2001), whereas females were predominantly “early ripening” (52% in 2000, 62.2% in 2001), followed by “late ripening” (32% in 2000, 26.7% in 2001). The age of ripe males (age at maturity), which did not differ between 2000 and 2001 ($P = 0.08$), averaged 4.7 years (4.4 to 5.1 years); length of ripe males averaged 10.4 cm (9.9 to 10.9 cm). Although no ripe females were sampled, the age of late ripening females, which differed between 2000 and 2001 ($P = 0.03$), averaged 4.9 years (4.5 to 5.4 years) in 2000 and 4.0 years (3.4 to 4.6 years) in 2001; length averaged 11.2 cm (10.7 to 11.6 cm) in 2000 and 9.5 cm (8.4 to 10.7 cm) in 2001. Egg diameter averaged 0.53 mm (0.47 to 0.59 mm) and ranged from 0.23 to 1.70 mm. Mean fecundity was 1118 (980 to 1260) and ranged between 203 and 3,255 eggs per female. Fecundity was correlated with body size in female Alligatorfish and described by the relationship $F = 1.14 * SL^{2.79}$ ($R^2 = 0.45$).

Females possessed a genital duct which ranged from 0.23 to 0.69 mm in length. Females also possessed paired sac-like structures, which were filled with a liquid and located posterior to the ovary, similar to the sperm storage sacs found in *Clinocottus analis* (Cottidae; Hubbs 1966). The length of these structures ranged from 0.10 to 0.48 mm (mean = 0.26 mm) in length, and depth ranged from 0.02 to 0.22 mm (mean = 0.11 mm). Males possessed a urogenital papilla which ranged in length from 0.29 to 0.68 mm, and averaged 0.44 mm.

The average GSI was higher for females (2.80%) than for males (0.60%) in 2000 ($P < 0.001$); however, in 2001, the GSI was slightly higher for males (2.91 vs. 2.27%, $P = 0.04$). Over the course of sexual development, both females and males increased their GSI (except for females in 2000, for which GSI remained constant across development stages). HSI increased in females as they developed from the immature to late ripening stages (3.51 to 3.72% in 2000, 2.01 to 3.94% in 2001), whereas males experienced a decline in HSI during the ripening stage in both 2000 (2.34 to 1.23%) and 2001 (2.58 to 1.97%).

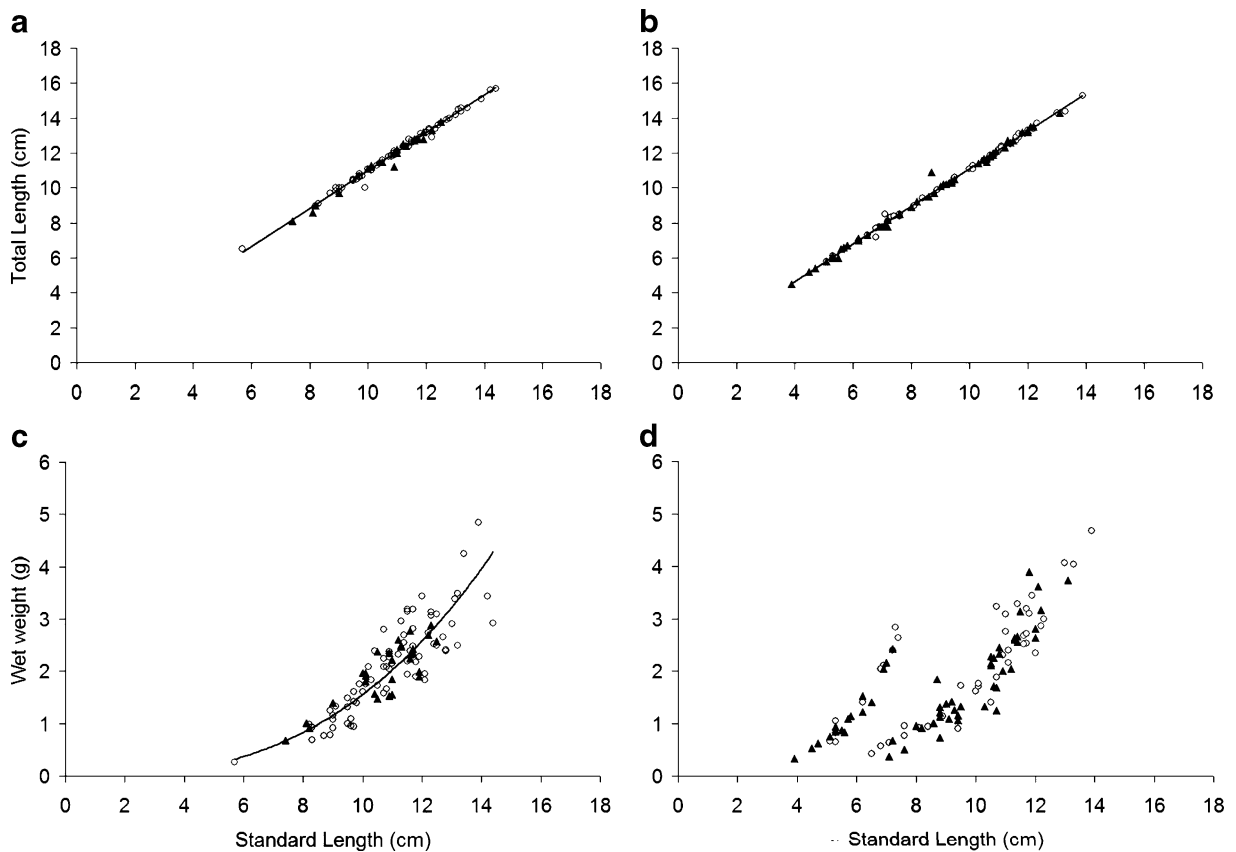


Fig. 2 Total length (cm) as a function of standard length (cm) in Alligatorfish from 2000 (**a**) and 2001 (**b**). Wet weight (g) as a function of standard length (cm) in Alligatorfish from 2000

(**c**) and 2001 (**d**). *Open circles* indicate females and *black triangles* indicate males

Diet composition

In both 2000 and 2001, amphipods comprised a significant proportion of the prey items of Alligatorfish (Table 2). In 2000 the majority of amphipods consumed were caprellids (*Caprella* spp.), whereas in 2001 the majority of amphipods consumed were hyperiids and gammarids. In 2000, isopods comprised the second largest contribution to the diet of this species. In 2001, mysids made up a significant contribution of the diet to both males and females. Euphausiids (mostly *Thysanoessa* spp.) made up a smaller portion of the diet in both 2000 and 2001. Other prey/food items consumed included copepods (predominantly *Temora* spp.), calcareous algae, and pteropods (*Limacina* sp). The feeding index, which did not differ significantly between males and females ($P=0.44$) or between years ($P=0.46$), averaged 1.46% (1.31 to 1.64%).

Parasites

Internal parasites were observed in 7 of 103 specimens of Alligatorfish from 2000, whereas no parasites were observed from individuals sampled in 2001. Only females (7 of 74) were affected, and the parasites were always nematodes. The parasites were observed in the ovaries, gut, body cavity and muscle tissue of the infected specimens. The infected specimens ranged in development from immature to late development, a range in developmental stage similar to that of uninfected females.

Discussion

The primary objective of the present study was to describe and quantify basic information on the ecology and life history of Alligatorfish, one of many

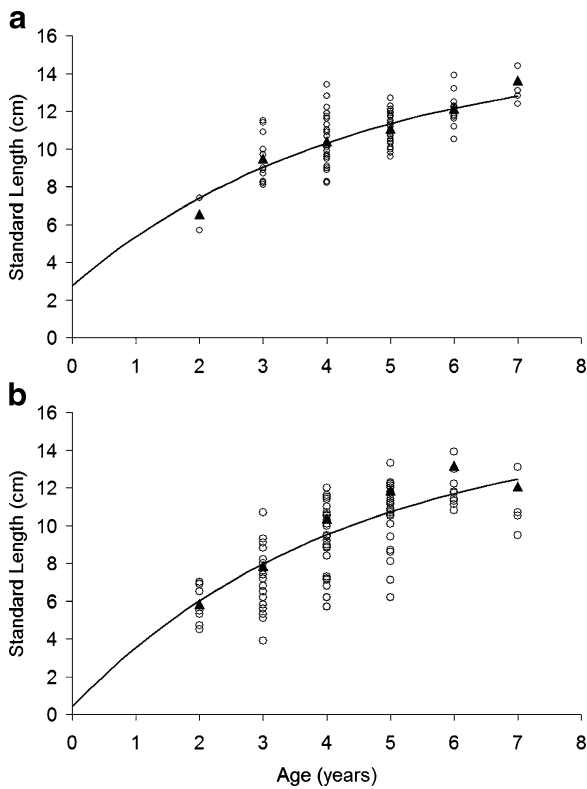


Fig. 3 Length at age curves for Alligatorfish from 2000 (a) and 2001 (b). Triangles indicate the mean length at age. The smooth line indicates the von Bertalanffy growth curve

non-commercial fishes about which exceedingly little is known. One of the primary motivations of the work was to contribute to the empirical basis, and enhance our knowledge, of the biodiversity of marine fishes in the Northwest Atlantic.

The general features of the waters inhabited by Alligatorfish in the Southern Gulf of St. Lawrence, Canada, conform with those previously described for the species. The depths reported here are similar to those reported by Bigelow and Schroeder (1953) and the maximum depth (200 m) was shallower than that observed off Newfoundland (283 m; Snelgrove and Haedrich 1985) and off Greenland (332 m; Jensen 1942). The warmest temperature at which this species was collected (12.15°C) exceeded the previously reported maximum by 2.52°C (Backus 1957).

Backus (1957) reported a maximum length of 14.6 cm while Robins and Ray (1986) reported a maximum size for this species of 18.0 cm; we report a maximum length of 15.7 cm. Alligatorfish in the present study ranged from 2 to 7 years with age at maturity averaging 4.7 years for males, and later than

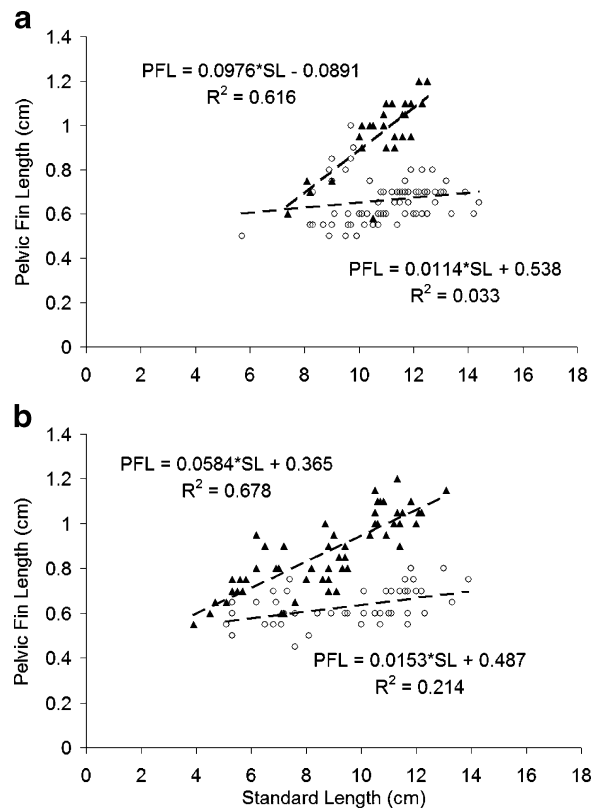
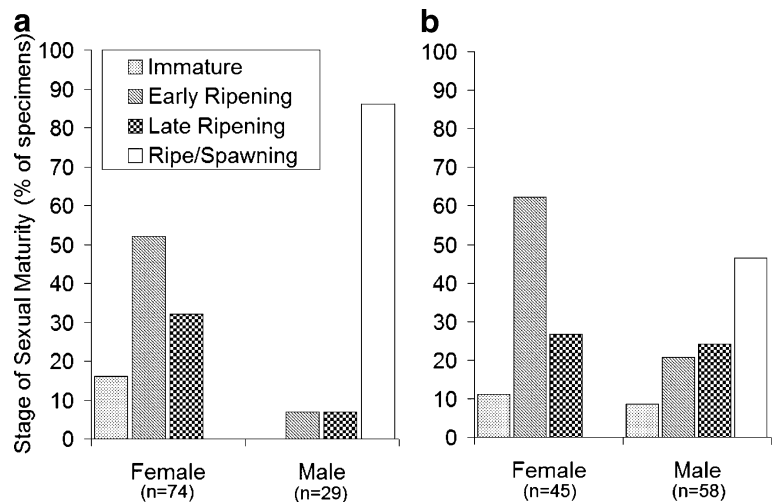


Fig. 4 Pelvic fin length as a function of standard length for male (black triangles) and female (open circles) Alligatorfish observed in 2000 (a) and 2001 (b)

4 years of age in females (based on late ripening individuals). Although there are no published data on longevity in Alligatorfish, other agonids have been reported to live for similar periods of time, e.g., maximum ages for the Bering Poacher, *Ocella dodecaedron*, and Sturgeon Poacher, *Agonus acipenserinus*, have been reported to be 9 and 11 years, respectively (Smith and Gillispie 1988). The conspicuous lack of individuals at 1 year of age may be attributable to the comparatively large size (~3 cm) that larvae can attain prior to settling to the bottom (Bigelow and Schroeder 1953) and thus becoming vulnerable to demersal sampling gear.

Our observations of sexual dimorphism are consistent with those reported by Backus (1957) who found that males possessed longer pelvic fins than females, relative to overall body size. What is particularly interesting is our finding that the sexual disparity in fin length increased with body size. Other agonids, such as Bering Poacher and Sturgeon

Fig. 5 Stages of sexual maturity observed in male and female Alligatorfish observed in 2000 (a) and 2001 (b)



Poacher, exhibit a similar sexual dimorphism of the pelvic fins. It has been hypothesised that such a dimorphism may provide a reproductive signal (Smith and Gillispie 1988). One alternative hypothesis is that the mating behaviour of Alligatorfish involves the use of the pelvic fins by the male to grasp the female. Such grasping behaviour is evident during the mating of Atlantic cod, *Gadus morhua*, for example, a species in which males have also been reported to

possess significantly longer pelvic fins than females (Skjæraasen et al. 2006).

The reproductive structures observed in male and female Alligatorfish suggest that this species undergoes internal gametic association, as has been hypothesized for other Agonids and closely related Cottids (Hubbs 1966; Munehara et al. 1989; Munehara 1997). Males possess a urogenital papilla likely involved in copulation and females possess sac-like structures similar to the sperm storage sacs observed in *Clinocottus analis*, a Cottid that undergoes internal gametic association (Hubbs 1966). At the time of the present study (September), the majority of males were described as “ripe/spawning”, and the majority of females were described as “early” or “late ripening”. Males exhibited a greater depletion of their liver reserves (as indicated by HSI) than females during their sexual development (a conclusion subject to the caveat that no ripe females were observed in our samples). It is possible that males are maturing, and copulation occurring, prior to female maturation, and that sperm are stored for later release (e.g., at the time of egg ripening). Larvae have been sampled from April to July in Passamaquoddy Bay, NB, and Conception Bay, NL, which would suggest that spawning takes place in late autumn or early winter (Bigelow and Schroeder 1953; Laprise and Pepin 1995), a hypothesized spawning time consistent with the states of maturity reported here.

Our data on egg size (mean of 0.53 mm) and fecundity (mean of 1,118 eggs per female) repre-

Table 2 Proportional abundance and weight of prey items identified from the stomach contents of Alligatorfish from 2000 and 2001

	2000 ^a % Abundance	2001 % Abundance	%Weight
Females			
Amphipods	61.8	41.4	41.4
Isopods	24.0	0	0
Euphasiids	4.7	0	0
Mysids	0	53.5	53.4
Others	9.4	5.2	5.2
Males			
Amphipods	47.1	62.2	62.1
Isopods	33.3	0	0
Euphasiids	15.7	4.4	4.4
Mysids	0	31.1	31.0
Others	3.9	2.2	2.2

^a% Weight could not be determined for 2000

sents the first quantitative estimates of these life history traits for a sample of Alligatorfish. We caution that egg size may have been under-estimated in the present study because of the slight shrinkage often experienced by tissue samples preserved in formaldehyde.

Previously, no extensive information had been published on the feeding habits of Alligatorfish, although it had been suggested that this species feeds on small invertebrates (Scott and Scott 1988). The present study revealed that amphipods (gammarids, caprellids and hyperiids), euphausiids and mysids comprise the largest components of the Alligatorfish diet. A closely related species, the Arctic Alligatorfish, *Aspidophoroides olriki*, also feeds primarily on amphipods, but also on *Macoma calcaria* (Atkinson and Percy 1992). Smith and Gillispie (1988) reported that two other species of Agonids (Bering Poacher and Sturgeon Poacher) preyed primarily upon gammarids, caprellids, hyperiids, and euphausiids.

Our information on parasites represents the first reported for Alligatorfish (Scott and Scott 1988). Although the incidence of parasitism was low (6.8% among individuals sampled in 2000, 0% among those sampled in 2001), some fish (all females) were infected with parasitic nematodes. The nematodes were not identified; however, it is possible that they could be *Anisakis simplex*, which infects the body cavities, musculature and organs of numerous species of marine fish, including many from the North Atlantic (Hays et al. 1998a). In the Gulf of St. Lawrence, *Anisakis simplex* has been reported to infect euphausiids, an important food source of Alligatorfish, as intermediate hosts, and to infect large fish such as cod, a predator of Alligatorfish, as paratenic hosts (Bigelow and Schroeder 1953; Chandra and Khan 1988; Hays et al. 1998b).

Our work pertains to the basic biology, ecology, and life history of marine fishes that have little or no commercial importance and about which we know exceedingly little. As such, research such as that described here on Alligatorfish has utility from at least three perspectives. In addition to providing previously undocumented information on natural history, it has the potential to contribute to ecosystem-based approaches to fishery management by increasing our basic knowledge of the species with which commercially valuable fishes interact. Arguably, the primary importance of studies such as the present one lies in

their provision of the foundational research upon which our knowledge of marine biodiversity is based.

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