NOTES

FOOD HABITS AND ALGAL ASSOCIATIONS OF JUVENILE LUMPFISH, *CYCLOPTERUS LUMPUS* L., IN INTERTIDAL WATERS

The lumpfish, *Cyclopterus lumpus* L., occurs in the north Atlantic Ocean, and is economically important in Maritime Canada (roe) and in Iceland, Greenland, and Europe (flesh and roe). Adults spawn in subtidal waters along rocky coasts and occasionally in intertidal waters (Benfey and Methven 1986). The spawning behavior and curious parental care by males was described in the 1800s and early 1900s (Yarrell 1841; Fulton 1907) and recently by Goulet et al. (1986). Juveniles, particularly age 0, have been encountered in pelagic waters (Blacker 1983; Daborn and Gregory 1983), in coastal areas (Bigelow and Schroeder 1953), and in intertidal waters (Proctor 1933; Moring 1985).

Examinations of the food habits of adult lumpfish have shown that the diet includes principally coelenterates, ctenophores, chaetognaths, various crustaceans, small fishes, and some molluscs and polychaetes (Cox and Anderson 1922; Bigelow and Schroeder 1953; Collins 1976; Gregory and Daborn 1982; Able and Irion 1985). Daborn and Gregory (1983), who examined the foods of juveniles in pelagic waters, found that surface-feeding amphipods and copepods were most important in the diet. With that exception, however, the foods consumed by juvenile lumpfish are largely unknown, particularly in intertidal areas.

The Cyclopteridae possess a ventral suction disc with which they adhere to rocks, lobster traps, or other firm objects. Juveniles are often encountered attached to marine algae as well, and in pelagic waters they have been encountered swimming freely and also attached to floating algae (Procter 1933; Forsman 1970; Daborn and Gregory 1983). In tidepools, however, juvenile lumpfish attach primarily to various species of marine algae—associations that have not been documented.

Juvenile lumpfish are seasonally present in Maine tidepools from June to December (Moring, unpubl. data). Occurrences after October are rare—as is typical for most intertidal fishes in Maine. In this study, I examine the foods of juvenile lumpfish during this seasonal period in intertidal areas and document their associations with algae in tidepools.

Materials and Methods

Juvenile lumpfish were collected primarily in three tidal pools: Blueberry, West Pond, and West Side, along Schoodic Peninsula, a portion of Acadia National Park near Winter Harbor, ME. Blueberry Pool, on the eastern side of the Peninsula, is in the middle to upper intertidal zone and is isolated at plus ebb tides <0.5 m. This pool was the deepest of the three (maximum depth averaged 53 cm during collecting trips). Total pool area, measured by compass and tape and computed on circumpolar paper, was 109 m^2 (95 m^2 of exposed pool surface: computed by subtracting area of exposed rocks from total pool area). Direct wave action is from the east, but the pool is effectively protected, being 20 m from open water. The anthophyte, *Zostera marina*, and 13 species of marine algae were identified in the pool during a species composition survey in July 1986.

West Pond Pool, along the southern edge of the Schoodic Peninsula, is the smallest of the three study pools, averaging 41 m^2 of total and exposed pool area. Maximum depth averaged 37 cm. A rock wall forms the eastern boundary of the pool in the lower intertidal zone. Direct wave action is from the southwest, and the pool is formed only during minus (<0.0 m) tides. Eleven species of marine algae were identified in the pool in July 1986, but *Z. marina* was not collected.

West Side Pool is the largest and shallowest of the pools. Total pool area averaged 106 m^2 (104 m^2 of exposed pool), and maximum depth averaged 36 cm during collecting trips. Direct wave action is from the west and pool isolation is less than two hours during ebb tides. *Zostera marina* and 14 species of marine algae were identified in the pool in July 1986.

Juvenile lumpfish were collected with long-handled dip nets during ebb tides and were measured (mm total length), and algal associations (attachments by ventral suction disc) were noted. These associations were noted by direct observation of fish on a species of algae prior to capture or by passing a net through a clump of algae of known species and dislodging fish. Based on unpublished data, samples represent 20–25% of total lumpfish juveniles in pools. Fish were preserved in 10% formalin and stomach contents of 150 fish were analyzed. Total contents of stomachs and total number of each prey taxa were counted and weighed (mg wet weight). Food items were identified to major taxonomic groupings, and occasionally to genus or species. An Index of Relative Importance (Pinkas et al. 1971), which factors percentage frequency, weight, and numbers, was computed for each food item in stomachs.

Algal associations were observed during 43 sampling trips in the seasonal period of lumpfish presence in tidepools, 1979–86, principally in the three study pools. Trips ranged from a low of 2 in December to 10 in June and July during these years. Samples of fish for food analyses were collected from July to November (principally July and August) in 1981, 1984, and 1985. Food habits data were pooled because sample sizes were insufficient for monthly or yearly comparisons. Sampling trips averaged 80 minutes and were made exclusively during daylight ebb tides.

Results

Food

Amphipods were the principal item in the diet of 150 juvenile *C. lumpus* examined that ranged in length from 9 to 50 mm; peak length frequency was 15 mm. Copepods, isopods, cumaceans, and marine mites (Acarina) were also numerically important (Table 1). Two lumpfish had consumed larval fishes: one a smaller lumpfish and the other an unidentified species. Seven stomachs (4.7%) were empty. Amphipoda were also most important in weight. The Index of Relative Importance (IRI) indicates Amphipoda (IRI = 6,732) and Copepoda (IRI = 2,650) and, to a lesser extent, Isopoda (IRI = 798) were the most important items in the diet. Other foods were of only minor importance.

There was no significant difference in the diets of lumpfish between locations along Schoodic Peninsula (Table 1; χ^2 = 16.93, 0.10 > P < 0.05), except that Polychaeta were consumed in higher numbers at Blueberry Pool. More Cumacea and Copepoda were consumed by fish in West Side Pool, but this trend at West Side Pool may be a reflection of fish size and the presence of *Z. marina*—excellent microhabitat for Copepoda and Cumacea. These organisms were significantly more important in the diet of fish <15 mm (χ^2 = 32.0; P < 0.05), while Amphipoda, Isopoda, and Polychaeta were more significant (χ^2 = 51.0; P < 0.01) in the diet of juveniles ≥15 mm TL than in the diet of smaller fish.

Algal Associations

Juvenile lumpfish observed were from 6 to 50 mm long and included primarily fish of age 0, but also age 1, as judged by length-frequency graphs and other work of Cox and Anderson (1922) and Daborn and Gregory (1983). One juvenile, 80 mm TL (apparently from an older year class), was also collected. From 328 observations of algal attachments of lumpfish during daylight hours, definite patterns emerged. *Zostera marina* and 18 species of marine algae were identified from the three pools during a survey in July 1986. Juvenile lumpfish were also found attached to an additional species, *Rhodymenia*

TABLE 1.—Percent occurrence and percent of total weight of food items in the diet of juvenile *Cyclopterus lumpus*, and foods by pool location and size (percent occurrence). West Pond data were not sufficient for inclusion in site comparisons, but are used in length comparisons; n = 150 for all three pools. Seven stomachs were empty (4.7%) and are not included in food data. Fish size range was 9–50 mm, with a length frequency peak of 15 mm.

Item	Occurrence %	Weight %	Pool: Blueberry (n = 78)	Pool: West Side (n = 62)	Total length of fish (mm): <15 (n = 60)	Total length of fish (mm): ≥15 (n = 83)
Amphipoda	68	68	71	61	45	84
Copepoda	53	6	49	61	73	40
Isopoda	38	14	41	32	20	51
Cumacea	35	3	27	47	42	30
Acarina	20	1	18	23	20	19
Polychaeta	15	3	24	2	5	23
Mysidacea	3	1	3	5	3	4
Other items	[1]<3	4	—	—	—	—

[1]Other items, in order of decreasing percentage occurrence: Cladocera, fish eggs, Diptera, *Littorina* spp. (Gastropoda), *Mytilus edulis*, algae, fish larvae, Caprellidea, dinoflagellates, cypris larval stages, megalops larval stages.

palmata, in a different intertidal locale on the Maine coast. Fish were found attached to 12 of these species of algae, *Zostera marina*, and 1 invertebrate—the blue mussel, *Mytilus edulis*. Only two lumpfish were encountered free-swimming, without a substrate or algal association, during these daylight observations. In 39% of the observations, juveniles were primarily associated with one of three species of *Laminaria*. In areas without *Laminaria*, but with *Zostera marina*, however, fish were frequently associated with *Z. marina* (Table 2).

Associations with *Laminaria* were significantly higher ($\chi^2 = 251.4$; $P < 0.01$) than with *Z. marina* but, because algal species composition varies with locale, associations were also analyzed by location (Table 2). In West Side Pool, which contained almost no *Laminaria* spp., 76% of the associations were with *Zostera marina*. No one algal species was dominant in West Pond Pool. In Blueberry Pool, *Laminaria* is much more abundant (but <50% of algal surface area), and 67% of the associations were with that genus.

As juvenile lumpfish increase in size, fewer were associated with *Z. marina* and more with *Ascophyllum nodosum* (Table 2). The difference was significantly in favor of attachments to *Z. marina* for fish <19 mm, but significantly in favor of attachments to *A. nodosum* for lumpfish over 26 mm ($P < 0.05$, paired comparison t tests and chi-square tests). Areas containing *Z. marina* may thus be extremely important to juveniles <20 mm long, but the protective function of the plant decreases as fish size increases.

Discussion

Juvenile lumpfish in Maine appear to use intertidal areas seasonally during more than one year of life. An array of sizes of *C. lumpus* can be taken within a single tidepool (e.g., lengths of 9–49 mm from a single pool in August). Although most juveniles in intertidal areas were age 0, fish of age 1 were not rare, and one fish collected was probably age 2. An adult was also observed guarding a nest in a deep tidepool near Blueberry Pool in 1982.

The food of juveniles is less diverse than that of adults (as reported by others), probably because the younger fish have smaller mouths and less ability to capture prey. The availability of larger prey items may also be limited in tidepools; ctenophores and coelenterates are generally uncommon in such waters. However, the consumption of copepods and amphipods by more than half the juveniles examined in this study coincides well with the studies of Daborn and Gregory (1983) of juvenile lumpfish in surface waters offshore. Although it is commonly believed that adult lumpfish feed only during winter (Cox and Anderson 1922; Collins 1976), the juveniles assuredly feed in summer: <5% of the stomachs that I examined were empty.

The information presented here dealing with juvenile lumpfish and algae are field observations of in situ associations. Given a choice between several genera or species of algae, the algal preference might be different. However, data from Blueberry Pool, where *Z. marina* and at least 13 species of algae were present, showed that 67% of the juvenile lumpfish were encountered with *Laminaria* spp., even though those three species made up less than one half of the submerged algal surface area (visual estimation).

Because juvenile lumpfish are typically observed attached to marine algae or to *Z. marina*, the question remains why associations are with specific algae? There may be several possible explanations, including functional morphology of the fish species, coloration, hydraulics, and adhesion.

TABLE 2.—Algal and plant associations by *Cyclopterus lumpus* (%) by pool and total length.

Site or size (n)	Taxon: *Laminaria* spp. (3 species)	*Fucus vesiculosus*	*Ascophyllum nodosum*	*Agarum cribrosum*	*Zostera marina*	Others
Pool						
West Side (76)	0	13	5	0	76	6
West Pond (17)	29	29	24	0	2	16
Blueberry (150)	67	12	10	6	1	4
Total length (mm)						
≤12 (72)	34	13	4	5	33	11
13–18 (84)	47	11	8	4	27	3
19–24 (54)	43	15	11	6	20	5
≥25 (38)	49	13	18	0	8	12

Marine algae serve as arractants for invertebrates (Hicks 1986). Juvenile lumpfish are not rapid or efficient swimmers, and thus cannot effectively pursue active prey. It would seem advantageous for such fish to live in concentrations of algae near concentrations of invertebrates.

Second, unlike some species of tidepool fishes (e.g., *Oligocottus snyderi* and *Xererpes fucorum* of the Pacific coast), juvenile lumpfish show only limited variations in color. The brown-orange coloration of juveniles may explain why they prefer algal genera and species of similar coloration, such as *Laminaria*. This explanation does not hold for the large number of juveniles associating with *Z. marina*, which is green. However, the strong association with *Z. marina* apparently holds only for small lumpfish which feed heavily on small crustaceans (Tables 1, 2). Brown (1986) recently found that small juveniles (about 10 mm long) spent more time attached to structures than was spent swimming. Algae of any type or color may thus be especially important to the smallest fish, particularly if availability of brown algae is reduced in a particular locale (e.g., West Side Pool, where 60% of the fish were 15 mm, compared with 41% in Blueberry Pool). As lumpfish size increases, there appear to be increasing associations with brown algae and decreasing associations with green-colored *Z. marina*, even when both types are present (Table 2).

Third, *Laminaria* spp. can provide some protection for fish from direct wave action, perhaps more than from other genera or algal species present (for general concepts, see Wieser 1952, O'Connor et al. 1979, and Seed 1986). *Laminaria* often occurs in clusters, resulting in a diffusing of wave action that would otherwise displace fishes. The distribution of *L. saccharina* has been shown to be independent of exposure (Sze 1982). Lumpfish associated with this functional type of alga may be effectively protected at flood tides from full wave action, and at ebb tides from avian or terrestrial predators.

Finally, the ability of lumpfish to attach to objects has been well documented; juveniles of the sizes collected in the tidepools of Schoodic Peninsula, ME can adhere to objects and withstand water speeds of up to 170 cm/s (Gibson 1969). Lumpfish use this attachment ability to avoid the adverse impacts of wave action (Alexander 1967). Suction efficiency would be improved by adherence to a flat, somewhat rigid surface. though several species of marine algae have smooth, nonrippled fronds, species of *Laminaria* provide the most surface area of this type in the pools examined.

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