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Diet composition of adult twaite shad (*Alosa fallax*) in the Aegean Sea (Izmir Bay, Turkey)

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Specimens of twaite shad, Alosa fallax *were sampled from commercial purse seiners and trammel netters in Izmir Bay during November and December 2007. A total of 287 prey items from 14 taxa from 208 stomachs were recorded. The primary food of twaite shad was found to be fish, especially anchovy* Engraulis encrasicolus, *which was the most frequent (%F = 66.11) and abundant (%N = 63.64) prey item, and also had the highest percentage by weight (%W = 81.91). Decapoda, Isopoda, Ostracoda and Copepoda (*Calanus spp., Candocia armata, Temora stylifera *from Calanoida and* Corycaeus spp. *from Cyclopodia), were recorded occasionally with low values for all indices. The study showed that in the Aegean Sea* Alosa fallax *is a predator of small pelagic fish,* E. encrasicolus, A. boyeri, S. pilchardus, *and some crustaceans. Benthopelagic* P. acarne *and demersal* S. hepatus *were first recorded in diet of twaite shad.*

Keywords: twaite shad, *Alosa fallax*, diet composition, Izmir Bay, Aegean Sea

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INTRODUCTION

Twaite shad, *Alosa fallax* (Lacépède, 1803), is an anadromous clupeid species occurring along the coasts and in the rivers of Europe, from southern Norway to the eastern Mediterranean Sea (Lopez *et al.*, 2007). The status of this species in the IUCN Red List is 'least concern' (IUCN, 2010) and it is classified as a focal species under the EU Habitats Directive (Volk *et al.*, 2007).

Twaite shad are strongly migratory and are widely distributed in the Aegean Sea, but rare in the Marmara and Black Seas. They are primarily a marine pelagic species, but also penetrate a short distance up rivers, while some populations are landlocked in lakes (Whitehead, 1986). However, this species is mostly anadromous, entering river mouths in March (Italy) or early June (northern European rivers) to spawn in or above the tidal reaches; eggs are demersal and widely scattered among sand or gravel on the river bed, and adults probably return to sea not long after spawning (Whitehead, 1986). In the River Elbe, *A. fallax* spawns in tidal fresh water where the eggs are maintained in the water column, by the current (Hass, 1968; Thiel *et al.*, 1996). The eggs of the twaite shad have, on an average, diameters of 3.85 mm and may be whirled up to a height of 9.5 m above the bottom by current. The spawning period of the twaite shad stock of the Elbe usually lasts from the beginning of May to the middle of June (Hass, 1968). Golani *et al.* (2006) reported that they spawn in spring and their juveniles return to sea at 14 cm.

Alosa fallax is predominantly ichthyophagous (Taverny & Elie, 2001); their adults feed on crustaceans (i.e. euphosiids, mysids and isopods) and small fish. When young they feed mainly on invertebrates, especially estuarine zooplankton, as well as the fry of sardines, herrings, sprats, anchovies and gobies (Whitehead, 1986; Assis *et al.*, 1992; Maitland & Hotton-Ellis, 2003; Golani *et al.*, 2006; Froese & Pauly, 2008).

Adult twaite shad schools appear from the end of October to early January in Izmir Bay (Aegean Sea), where they are caught by gill nets and/or purse-seines at depths of <50 m. In Turkey, they are of minor commercial importance and are usually sold at a low price in fish markets.

In spite of the fact that the world-wide distribution patterns and some ecological aspects (including diet composition) of *Alosa fallax* species have been described (Whitehead, 1986; Assis *et al.*, 1992; Gerkens & Thiel, 2001; Oesmann & Thiel, 2001; Taverny & Elie, 2001; Aprahamian *et al.*, 2003; Doherty *et al.*, 2004; Maitland & Lyle, 2005; Golani *et al.*, 2006; Froese & Pauly, 2008; Lochet *et al.*, 2009), there is a gap in the knowledge about the ecology of Mediterranean twaite shads. The marine diet of *A. fallax nilotica* has been reported by Canestrini (1885), Zompolas (1939) and Morovic (1959). During the winter months fish feed on the sea bottom at depths of 160 m, on fish (*Cepola rubescens*, *Gobius* spp., *Brachyochirus pellucidus*, *Smaris vulgaris*, *S. alcedo*, *Boops boops*, *Trisopterus capelanus* and *Mullus barbatus*) and Crustacea: Decapoda (*Leander* spp. and *Penaeus* spp.) and Mysidacea (*Gastrosaccus normani* and *Anhialina agilis*) (Morovic, 1959). During the summer months fish feed close to the surface on *Sprattus sprattus*, *Sardina pilchardus*, *Engraulis encrasicholus* and *Atherina* spp. (Canestrini, 1885; Morovic, 1959).

Zompolas (1939) reported similar findings for *Alosa fallax* from both the east and west coasts of Italy and therefore the samples were likely to have contained both *A. fallax rhodanensis* and *A. fallax nilotica*. The diet was found to consist mainly of fish (*E. encrasicholus*, *S. pilchardus*, *C. rubescens* and *Aphia meridionalis*), Crustacea: Decapoda (*Leander xiphias*, *Crangon spinosus* and *Pasiphae norvegica*), Mysidacea (*Mysis oculata*) and Ampipoda (*Gammarus*

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pulex, *G. rhipidiophorus*, *G. duebeni*, *Sextonia longirostris* and *Hyperoche kroyeri*). The fish were also found to have consumed Uniramia larvae (Chironomidae) and algae. Those fish which were about to enter fresh water for spawning were not found to be feeding actively.

The aim of this study is to examine the diet of adult twaite shad, caught in Izmir Bay (Aegean Sea), with a qualitative and quantitative determination of their prey.

MATERIALS AND METHODS

Twaite shad specimens were sampled from commercial purse seiners and trammel netters in Izmir Bay during November and December 2007, at depths shallower than 50 m. The stretched mesh sizes of the trammel nets and purse seines were 64 mm and 14 mm, respectively. This migratory species leaves the bay at the end of December, and we could not collect fish samples for monthly/seasonal analyses due to their short residence time in the area.

Total and fork lengths to the nearest cm and body weight to the nearest g were recorded for fresh fish. Stomachs were removed immediately from all fish and preserved in 4% formaldehyde for later analysis. In the laboratory, prey were identified to the lowest possible taxonomic level, counted and weighed to the nearest 0.1 g for fish after removal of surface water using blotting paper. Small prey were counted under the microscope and weighed to the nearest 0.0001 g. The total length of whole prey fish (primarily *Engraulis encrasicolus*) were also measured to the nearest cm for expressing the prey–predator length relationship.

The importance of the different prey types was evaluated calculating the frequency of occurrence (%F = number of stomachs containing prey *i*/total number of stomachs containing prey × 100), percentage abundance (%N = number of prey *i*/total number of prey × 100), percentage weight (%W = weight of prey *i*/total weight of all prey × 100) and the index of stomach fullness (SFI = total stomach contents weight/total fish weight × 100) (Hyslop, 1980). Tests of significance for SFI between males and females were performed using the Student's *t*-test (at the 5% probability level). The index of relative importance (IRI) combines the above three quantities into a single numerical index: IRI = (F% × (W% + N%)) and was used to assess the importance of various food items in the diet (Caragitsou & Papaconstantinou, 1988).

RESULTS AND DISCUSSION

Tweny-eight (13.5%) of the 208 adult twaite shad that were examined (fork length-range: 23–39 cm; mean: 30.3 cm ± 0.2) had empty stomachs. The analyses of stomach contents led to the identification of 287 prey items (252 fish and 35 crustaceans) belonging to 14 taxa. Nematode parasites in some stomachs were not considered prey items and were excluded from the analyses.

The results of the stomach content analysis revealed that twaite shad feed mostly on fish, especially anchovy, *Engraulis encrasicolus*. Anchovy was the most frequent (%F = 66.1), abundant prey (%N = 63.6), had the highest percentage by weight (%W = 81.9), and the highest index of relative importance (IRI = 9622.3). Other fish species identified were *Atherina boyeri*, *Pagellus acarne*, *Sardina pilchardus* and *Serranus hepatus* (Table 1). Decapoda, Isopoda, Ostracoda and Copepoda represented by Calanoida and Cyclopodia were recorded occasionally showing low values for all indices. Among the Crustacea, the most important prey was Decapoda (IRI = 44.1).

According to the SFI, male, female and both sexes of twaite shad were calculated as 1.3 ± 0.1, 0.9 ± 0.1 and 1.1 ± 0.1, respectively. There was no statistical difference between males and females ($P > 0.05$).

The relationship between twaite shad length (total length (TL)-range: 31.8–40.9; mean: 35.7 cm ± 0.4) and anchovy length (TL-range: 4.8–11.4 cm; mean: 8.3 cm ± 0.3) was $TL_{prey} = -7.8341 + 0.0134\ TL_{predator}$; $R^2 = 0.0003$ ($P < 0.05$). This result shows that there is no correlation between the TL_{prey} and $TL_{predator}$ relationship (Figure 1). Taverny (1991) reported that prey size, in particular that of *Engraulis encrasicolus*, increased with the size of *A. fallax* and this could be explained by the equation $TL_{prey} = 0.1788\ TL_{predator} + 10.4611$ ($N = 61$; $r^2 = 0.25$; $P < 0.001$). Our result may have been caused by low sample size (N = 28) and the availability of only larger individuals (>31 cm).

Previous feeding studies for *Alosa fallax* in other areas also reported that twaite shads are mainly ichthyophagous and that they feed on small fish and some crustaceans (Whitehead, 1986; Assis *et al.*, 1992; Oesmann & Thiel, 2001; Doherty *et al.*, 2004; Maitland & Lyle, 2005; Golani *et al.*, 2006). However, the main diet of twaite shad may vary depending on the abundance of available food in their habitat. Assis *et al.* (1992) identified that the twaite shad diet in the Tagus Estuary (Portugal) was dominated by the fish *S. pilchardus*, *E. encrasicolus*, *Pomatoschistus minutus*, *P. microps* and *A. boyeri*. Oesmann & Thiel (2001) reported that juvenile twaite shads fed on fish (*Sprattus sprattus*, *Osmerus aperlanus* and *Pomatoschistus* sp.) and mysids, malacostracas, cladocerans, copepods, insects, unidentified eggs, plants and detritus in the Elbe Estuary, Germany. In the Gulf of Gascogne, adult twaite shad fed preferentially on anchovy (*E. encrasicolus*)

Table 1. Percentage frequency of occurrence (%F), percentage abundance (%N), percentage by weight (%W) and index of relative importance (IRI) for prey types of *Alosa fallax*.

Prey items	%F	%N	%W	IRI
Crustacea				
Copepoda				
Calanoida	1.67	1.05	0.0014	1.76
Calanus spp.	1.11	0.70	0.0016	0.78
Candocia armata	1.11	0.70	0.0033	0.78
Temora stylifera	1.67	1.05	0.0011	1.76
Cyclopodai	0.56	0.35	0.0011	0.20
Corycaeus spp.	0.56	0.35	0.0013	0.20
Decapoda	8.33	5.24	0.0573	44.13
Isopoda	3.89	2.45	0.0182	9.60
Ostracoda	0.56	0.35	0.0054	0.20
Teleostei				
Atherina boyeri	1.11	2.80	2.74	6.15
Engraulis encrasicolus	66.11	63.64	81.91	9622.31
Pagellus acarne	0.56	0.35	0.25	0.34
Sardina pilchardus	0.56	0.35	0.84	0.67
Serranus hepatus	1.11	1.05	0.47	1.69
Digested fish	30.55	19.93	13.70	1027.40
No. of stomachs	208			
No. of empty stomachs	28			
% of empty stomachs	13.46			

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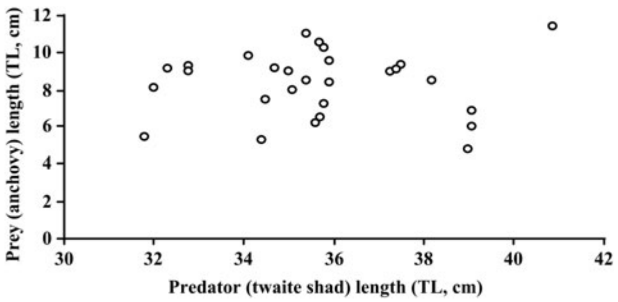

Fig. 1. Predator length–anchovy prey length relationship (N = 28).

year around and euphausids were only secondary prey (Taverny & Elie, 2001). In British waters, adults feed to an appreciable extent on other fish, especially the young of some members of the clupeid family, such as sprat and herring (Maitland & Hotton-Ellis, 2003). While they mainly fed on small sprats, *Sprattus sprattus* and marine mysids, they also include *Praunus neglectus* in their diet in Ireland (Doherty *et al.*, 2004). In the Solway, Scotland, the food of twaite shad included primarily unidentified fish (some were small clupeids) and secondarily Malacostraca, while Copepoda were relatively unimportant in the diet (Maitland & Lyle, 2005).

In conclusion, this study showed that in the Aegean Sea *Alosa fallax* is a predator of small pelagic fish (*E. encrasicolus*, *A. boyeri* and *S. pilchardus*), and some crustaceans. Benthopelagic *P. acarne* and demersal *S. hepatus* were recorded for the first time in the diet of twaite shad. However, there is need for further seasonal feeding habit studies of both adult and juvenile twaite shad.

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