Food and feeding habits of the Caspian marine shad, *Alosa braschnikowi* (Clupeidae) in the southern Caspian Sea

by

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ABSTRACT. - The feeding habits of Caspian marine shad, *Alosa braschnikowi* (Borodin, 1901) in Iranian waters of southern Caspian Sea were investigated by stomach content analysis of 357 fish collected monthly (October 2003 to April 2004) in the commercial catch. The diet consisted mainly of fish dominated by Atherinidae (58%), with *Atherina boyeri* being the dominant prey item based on numerical percentage. The next major food group was Gobiidae (26%), followed by Clupeidae (11%), Cyprinidae (3%), and Mugilidae (1%). Based on frequency of occurrence, *A. boyeri* was the main prey in the stomach of Caspian marine shad (F_i = 57.7%), with an important species index (ISI) of 59.7%. The fish fed on a wider variety of food items during November, December and February than during other months. The lowest feeding activity was recorded in October and January. The gastrosomatic index (GaSI) ranged from 0.3% to 27.7% with monthly variations increase in February and March coincides closely with spawning season and energy preservation for gonadal development.

RÉSUMÉ. - Habitudes alimentaires de *Alosa braschnikowi* (Clupeidae) dans le sud de la mer Caspienne.

Le comportement alimentaire de l'alose marine de la mer Caspienne, *Alosa braschnikowi* (Borodin, 1901) des eaux iraniennes du sud de la mer Caspienne a été étudié par l'examen des contenus stomacaux de 357 individus prélevés mensuellement dans les captures commerciales d'octobre 2003 à avril 2004. L'alimentation est composée de différentes proies, principalement des Atherinidae (58%), *Atherina boyeri* étant l'espèce dominante. Par ordre d'importance décroissante, les autres groupes de proies sont les Gobiidae (26%), les Clupeidae (11%), les Cyprinidae (3%) et les Mugilidae (1%). En terme de fréquence d'occurrence, *A. boyeri* a été la proie principale des aloses (Fi = 57,7%), avec un index d'espèces important (ISI) de 59,7%. En novembre, décembre et février, une plus grande variété de proies a été consommée que pendant les autres mois étudiés. La plus faible activité alimentaire a été enregistrée en octobre et en janvier. L'indice gastrosomatique (GaSI) a varié de 0,3% à 27,7% avec des différences mensuelles ; les valeurs les plus élevées sont observées en février et mars pendant le pic de la période de reproduction.

Key words. - Clupeidae - *Alosa braschnikowi* - Marine shad - Caspian Sea - Iran - Feeding habits.

Caspian marine shad (*Alosa braschnikowi*) are a major component of fish landing in Iranian waters of Caspian Sea, due to their cheap prices and high market demand. They represent about 5% of the total bony fish catch of the southern Caspian Sea (Shilat, 2009).

A. braschnikowi live in pelagic, oceanodromous brackish environments and feed mainly on small clupeids, gobies and atherinids, as well as on crustaceans and occasionally on insects and mollusks (Whitehead, 1985). Spawning patterns vary among the subspecies but spawning occurs mostly in spring and summer after an inshore migration and northward movement (Belyaeva *et al.,* 1989). In winter, *A. braschnikowi* move into deeper water towards the Iranian coast while in March they approached coastal waters including brackish waters, without entering fresh water bodies (Vetchanin, 1984). Spawning and feeding grounds of some populations are located in the northern Caspian, while other populations live permanently in the southern Caspian Sea, and are generally of smaller size. From March to November the diet is dominated by *Clupeonella caspia, Atherina boyeri* and shrimps (Coad, 1999).

A. braschnikowi may have been subjected to over fishing in recent years (Coad, 1999) and management has called for more conservative regulations and policies to reduce fishing mortality and target sustainability of this species. Despite its commercial importance, limited information is available on food and feeding habits of *A. braschnikowi* and fisheries in the Iranian waters of the Caspian Sea. Gaining knowledge on the species niche is therefore necessary for stock management. Such information is especially important and timely because of the ecological changes that may have been occurring in southern Caspian Sea as a result of the appearance of the carnivorous ctenophore jellyfish (*Mnemiopsis leidyi*) in 1999 (Shiganova *et al.,* 2001). Consequently, the present study was carried out to investigate the feeding habits of *A. braschnikowi* in the southern Caspian Sea. The main

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objectives of the study were to describe the diet, frequency of occurrence of different food items in the stomach, monthly changes in diet composition, feeding intensity, and feeding habits in relation to fish size.

MATERIALS AND METHODS

Study area

This present study was carried out in the Iranian waters of southern Caspian Sea from October 2003 to April 2004. However, no fish specimen was found in April. From May to September fishing is forbidden in the southern Caspian Sea. Fresh samples of *A. braschnikowi* were collected from commercial beach seine catches (Fig. 1). The beach seine which was hauled by a tractor; it has a 1200 m length and a 10-15 m height, with a 33 mm stretched bag mesh size. The fork length (FL) and somatic wet weight (TW) were measured within 1 cm and 1 g, respectively.

Data analysis

A total of 357 fish measuring 16.2-35.9 cm (FL) and weighing 82.2-588.5 g were collected and examined. Each gut was excised, weighed (g) together with its content, and preserved in 5% formalin for 72 hours and then transferred in 70% ethanol. Afterwards, stomach contents were suspended in water in Petri dishes, and all prey were identified to the lowest possible taxonomical level using standard taxonomic keys (Birschetin *et al.,* 1968). Diet composition was considered in terms of weights and numbers of prey organisms. For these purposes the following indices were applied (Hyslop, 1980):

Weight percentage of prey i: $[\%]W = [W_i / W_\Sigma] \times 100$,

Numerical percentage of prey *i*: $[\%]N = [N_i / N_\Sigma] \times 100$,

Frequency of occurrence: $[\%]F_i = [M_i / M_\Sigma] \times 100$,

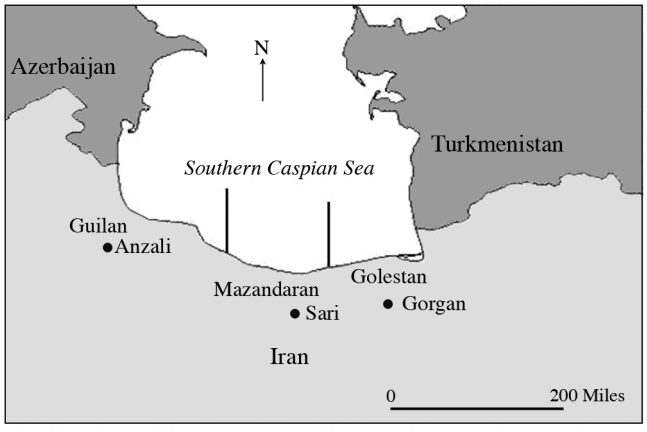

Figure 1. - Map of the Iranian waters of the Caspian Sea, showing the fishing area.

where Wi is the weight (g) of prey group i ; and W_Σ is the total weight (g) of prey detected; N_i is the number of prey specimen of prey group i; N_Σ is total number of prey detected; M_i is the number of stomachs containing prey component i; M the number of stomachs containing food. When Fi > 50%, the prey group is considered the main prey, while 50 > Fi > 10 means that the prey is secondary, and Fi < 10 indicates rare prey (Euzen, 1987).

The main food items were identified using the index of relative importance (IRI) as modified by Hacunda (1981):

$$IRI = \%F \times (\%Cn + \%Cw),$$

where F is the frequency of occurrence, Cn is the numerical percentage composition and Cw is the weight percentage composition of different food items.

The index was expressed as: $\%IRI = (IRI / \Sigma IRI) \times 100$.

The extent of the diet was calculated using the diversity index of Shannon-Wiener (Ludwig and Rynolds, 1988):

$$H' = - \Sigma P_i \times \log_2 P_i,$$

where H' is the Shannon-Wiener and p_i is the proportion by the number of prey type i.

The gastrosomatic index (GaSI) was calculated to investigate monthly variations in feeding intensity, using the equation (Biswas, 1993):

GaSI = (Fresh weight of stomach/Total fresh weight of fish) x 100.

To determine important species index (ISI) in food items, we used the equation (Rushforth and Brock, 1991):

$$ISI = (f_i) \times (D_i),$$

where f_i is the frequency percentage of prey i, and D_i the mean relative abundance of prey.

The Pearson's correlation coefficient and Jaccard's correlation coefficient were used to determine the association between all food items in stomach contents. The unweighed pair group method with arithmetic mean (UPGMA) (Van Tongeren, 1995) and multivariate statistics package (MVSP) version 3.11(Kerbs, 1989) were used to calculate and construct the dendrogram.

RESULTS

Food items

Three genera of Clupeidae, two genera of Gobiidae, one genus of Atherinidae, Mugilidae, and Gobiidae were identified in *A. braschnikowi* stomach contents in the present study (Tab. I). *Atherina boyeri* was the most frequent prey, constituting 78.6% of the total IRI, followed by *Neogobius fluviatilis* (18.2%), *Clupeonella cultriventris* (1.1%), *Clupeonella engrauliformis* (0.9%), *N. melanostomus* (0.7%) and *Cyprinus carpio* (0.4%). Other food items, including *Liza* spp. and *C. grimmi* were very rare (< 0.01%). The proportion of each prey types is represented in figure 2 and shows the major contribution of Atherinidae (58%).

Table I. - Monthly percentage frequency of occurrence of different prey types in *A. braschnikowi* stomachs from the southern Caspian Sea.

Prey type	Frequency of occurrence (%)					
	Oct. 2004	Nov.	Dec.	Jan. 2005	Feb.	Mar.
Atherinidae						
Atherina boyeri	100.0	40.0	59.6	75.0	63.8	67.9
Gobiidae						
Neogobius fluviatilis	0.0	31.1	32.1	25.0	30.5	28.6
N. melanostomus	0.0	6.7	5.5	50.0	6.7	7.1
Clupeidae						
Clupeonella engrauliformis	0.0	13.3	7.3	0.0	9.5	10.7
C. cultriventris	0.0	28.9	13.8	0.0	3.8	3.6
C. grimmi	0.0	4.4	0.0	0.0	0.0	0.0
Cyprinidae						
Cyprinus carpio	20.0	0.0	11.0	0.0	7.6	0.0
Mugilidae						
Liza spp.	0.0	2.2	0.9	0.0	2.9	0.0
Sample size	10.0	45.0	109.0	4.0	105.0	28.0

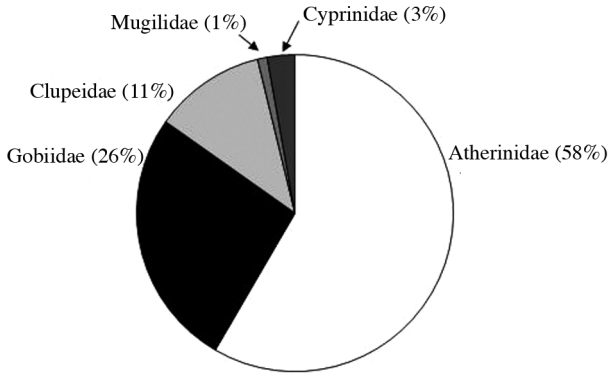

Figure 2. - Numerical percentage of prey in the stomachs of *A. braschnikowi* from the southern Caspian Sea.

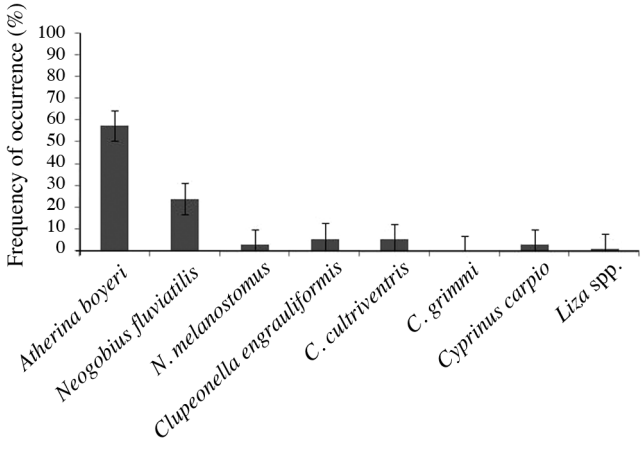

Figure 3. - Frequency of occurrence of different food items in the diet of *A. braschnikowi*.

Frequency of occurrence of different food items

The F_i value of the different food items is represented in figure 3. *A. boyeri* has the highest Fi values (57.7%) followed by *N. fluviatilis* (24.1%). The others food items were rarely and randomly consumed (Fi < 10%).

Monthly variations in diet composition and feeding activity

Significant monthly differences in the diet composition were found during the study span time ($p < 0.05$) while *A. boyeri* was the most frequent prey throughout the study period (Tab. I). Variation in food items was the lowest in October and January and the highest in December. *N. fluviatilis and N. melanostomus* were found from October to March, and *C. engrauliformis* and *C. cultriventris* were found in November, December, February and March. *C. carpio* was found in October, December and February, and *Liza* spp. was found in November, December and February. *A. boyeri* has the highest ISI value (59.7%), followed by *N. fluviatilis* (18.1%), *N. melanostomus* (5.9%), *C. engrauliformis* (3.6%), *C. cultriventris* (2.1%), *C. carpio* (1.2%), *C. grimmi* (0.7%), and *Liza* spp. (0.3%).

GaSI value of *A. braschnikowi* ranged from 0.3% to 27.7% and fluctuated over months (Fig. 4). The GaSI value increased gradually from 3.3 in October to 5.1 in December. A noticeable decrease was observed in January (4.6), followed by an increase in February (5.2) and March (5.5).

Of the 357 stomachs examined, 56 (15.7%) were empty. The proportion of empty stomachs varied significantly among the month ($\chi^2 = 9.3$, $p < 0.05$). The minimum and maximum proportion of empty stomachs occurred in March (4.4%) and November (21.7%), respectively.

The relationship between stomach contents and fish size

The weight of stomach contents of the different size classes of *A. braschnikowi* ranged from 1.96% for the 30-35 cm class, to 4.58% for the size class 15-20 cm, of fish wet TW. The stomach contents were 3.33% and 2.71% of fish wet weight for sizes classes 20-25 cm and 25-30 cm, respectively (Fig. 5). The diet of Caspian marine shad was dominated by Atherinids (*A. boyeri*) (41.5% by weight). Clupeids, mainly *C. engrauliformis*, constituted 8.7% by weight of the food of fishes of 30-35 cm. The cluster analysis separated three groups of food cohorts (Fig. 6). *A. boyeri* and *N. fluviatilis* represented the highest similarity indices of food item composition with the Jaccard's coefficient (~90%), whereas *Liza* spp. and *C. carpio* had the lowest similarity index (~25%). Among the major food groups, *A. boyeri*, *N. fluviatilis* and *C. cultriventris* were recorded in the diet of all fish size classes. Shannon index values ranged from 1.61 for the size class 15-20 cm to 2.11 for size class 30-35 cm.

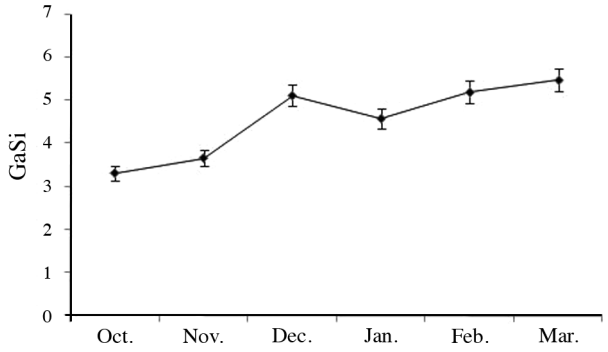

Figure 4. - Monthly variations in the gastrosomatic index of *A. braschnikowi*. Vertical bars indicate standard deviations

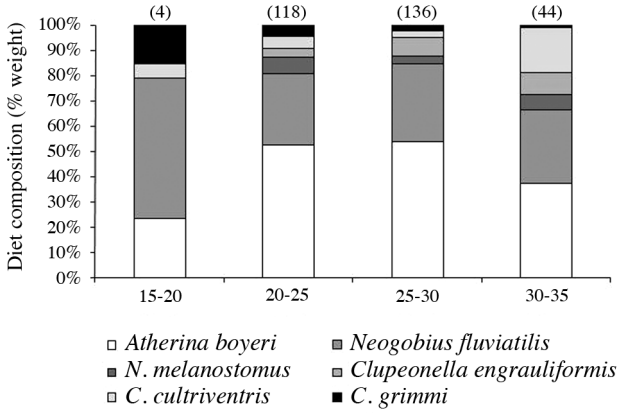

Figure 5. - Composition of *A. braschnikowi* diet with respect to size classes, based on weight percentage of prey. Figures in parentheses indicate number of stomachs examined.

DISCUSSION

Limited information is available on the feeding habits of the Caspian marine shad, *A. braschnikowi*. Generally, this species is classified as omnivore, and unlike other omnivores fishes, it feeds mainly on small Clupeids, gobies, Atherinids and, to a less extent, on crustaceans and occasionally on insects and mollusks (Berg, 1948). Vetchanin (1984) reported that the diet of *A. braschnikowi* in the southeastern Caspian Sea was composed of 85% of anchovy (*C. engrauliformis*) with some gobies (genus *Neogobius*) and shrimps.

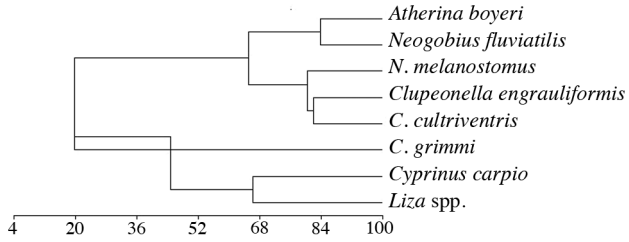

Figure 6. - The dendrogram of cluster analysis of food items in the stomach of *A. braschnikowi* from the southern Caspian Sea.

In the present study, *C. engrauliformis* represented only 10.1% of the food items in stomach of *A. braschnikowi*, whereas atherinid fishes (especially *A. boyeri*) were most dominant. This significant shift in feeding habits of these fish may have been due to the recent sea level rise of the Caspian Sea. Sea level rise has caused displacement in aquatic habitats, and a loss of biodiversity (http://www.caspianenvironment.org). In the mean time, the invasive Ctenophore jellyfish (*Mnemiopsis leidyi*), first reported in 1999 (Ivanov *et al*., 2000) has significantly reduced the abundance and distribution of zooplankton species and their predators, especially *C. engrauliformis* (Kideys and Moghim, 2003). As a result, the catches of *C. engrauliformis* in Iranian waters of the Caspian Sea collapsed from 186000 tons in 1996 to less than 12000 tons in 2004 (Fazli *et al*., 2009).

Food items in the stomach of *A. braschnikowi* in the present study were different from the diets of other *Alosa* species in the Caspian Sea as well as other areas. For example, Abbasi and Sabkara (2004) reported that *A. caspia* in the southern Caspian Sea feed mainly on zooplankton (95.0%) and phytoplankton (*Rhizosolenia* and *Sprirogyra*) (4.5%). On the other hand, *C. caspia* makes up 92% of the diet of

Table II. - Food items in the stomachs of different *Alosa* species (Clupeidae) in various areas.

Species	Food items	Location	References
Alosa caspia	98% of zooplankton groups	Southern Caspian Sea	Abdollapour Bereya *et al*. (2007)
A. kessleri	*Clupeonella caspia* (92%), *Sander lucioperca* (6.6%), gammarids (1.0%)	Northern Caspian Sea	Coad (1999)
A. saposchnikowii	kilka, *Atherina*, *Benthophilus*, mysids and gammarids	Southern Caspian Sea	Lönnberg (1900), Chang (1972)
A. pseudoharengus	Zooplanktivorous	Lake Ontario (North America)	Strus and Hurley (1992)
A. fallax	Fish, mysids, shrimp, isopods, insects	River Tagus Estuary, (Portugal)	Assis *et al*. (1992)
A. sapidissima	Copepods (37.7%), Cladocerans (37.4%), Chironomids (43.1%), Ostracods (28.4%)	Susquehanna River (northeastern America)	Johnson and Dropkin (1996)
A. braschnikowi	*Atherina* (57.7%), *Gobius* (34.4%)	Southern Caspian Sea	Present study

A. kessleri in the northern Caspian in May, followed by *Sander lucioperca* (6.6%) and gammarids (1.0%) (Coad, 1999).

Table II provides more details on food and feeding habits of different *Alosa* spp. in different geographic areas.

C. carpio occurred at the highest frequency in the stomachs of *A. braschnikowi* in October. This could be correlated the high abundance and catch of *C. carpio* from the southern Caspian Sea in autumn, as has been reported by Afraei Bandpei (2005). Most of fish analysed in the present study measured more than 15 cm (FL) because of gear selectivity in commercial fishing and were located deeper than 15 m. The presence of the fish may be due to ecological location of fishing area and temperature changes. Wahbeh and Ajiad (1985) and Abdel-Aziz *et al*. (1993) reported also that food consumption appears to be correlated to sea temperature, spawning activity, age, and available food items.

The smallest size class of *A. braschnikowi* contained the highest food mass while the lowest food content was recorded in larger size class. Feeding activity increases during grow out stages and decreases during spawning seasons. Available information (Geetha *et al.,* 1990; Dadzie, 2007; Afraei Bandpei *et al.,* 2009) suggests that the high occurrence of empty stomachs during the spawning season is linked to the decrease in feeding activity because mature gonads take more space in the peritoneal cavity, compressing the stomach and making feeding more difficult. Dadzie *et al*. (2000) also reported that feeding is intensive during the early stages of maturity and decreases as the gonads mature. These results are in agreement with present results, where the GaSI value of *A. braschnikowi* was highest in March (5.5), which coincides closely with spawning season and energy preservation for development of gonads. The feeding migration in Iranian waters of Caspian Sea takes place from October to March, while spawning in the southern Caspian Sea north of Iranian waters occurs from early May to July (Vetchanin, 1984; Coad, 1999). The proportion of empty stomachs was low (15.8%). This could be due to late digestion of preys by the stomach and cannibalism (Whitehead, 1985).

In conclusion, this study showed that *A. braschnikowi* in the southern Caspian Sea has an opportunistic feeding behaviour. *A. braschnikowi* is carnivorous, feeds on a variety of prey items, with changes in diet and feeding behaviour according to the season, month, habitat and fish size. Further research is needed to document *A. braschnikowi* food and feeding habits throughout the whole year.

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