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First results on the diet of the young Atlantic sturgeon *Acipenser sturio* L., 1758 in the Gironde estuary

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ABSTRACT

Very little is known about the diet of the European sturgeon *Acipenser sturio* L., 1758 in its natural environment. For juveniles, improved knowledge in this field could lead towards the determination of the species's major feeding habitats in the estuary, in order to then improve their preservation or protection. From May 1998 to March 1999, the stomach contents of 61 juveniles were collected by gastric lavage. The fish were caught during monthly trawling campaigns to monitor sturgeon migration in the Gironde estuary (southwestern France). Specimens were mainly caught during spring and summer in two areas of increased abundance. The gastric lavage method used had been previously tested on Siberian sturgeon *Acipenser baerii* Brandt, 1869 in captivity. Twelve taxa of prey were found. The highest proportions in number identified consisted of polychaetes, mainly represented by *Heteromastus filiformis* (Claparede, 1864) in zone 7 and *Polydora* Bosc, 1802 sp. in zone 1. Crustaceans were the second most abundant group of prey.

Key words: Feeding, juvenile, France, invertebrate fauna.

RESUMEN

Primeros resultados sobre la dieta de los jóvenes esturiones atlánticos* Acipenser sturio *L., 1758 en el estuario del Gironda

Se conoce muy poco sobre la dieta del esturión atlántico Acipenser sturio *L., 1758 en su medio natural. Para los juveniles, un conocimiento mejorado en este campo podía conducir hacia la determinación de los principales hábitats alimentarios de la especie en el estuario, como preámbulo para su mejor preservación y conservación. Entre mayo de 1998 y marzo de 1999 fueron recogidos los contenidos estomacales de 61 juveniles por lavado gástrico. Los peces fueron capturados durante las campañas mensuales de pesca de arrastre para el seguimiento de la migración del esturión en el estuario del Gironda (suroeste de Francia). Los ejemplares fueron capturados principalmente en primavera y verano en dos áreas de alta abundancia. El método de lavado gástrico utilizado fue probado previamente en cautividad con esturión siberiano* Acipenser baerii *Brandt, 1869. Se encontraron presas de doce taxones. Las proporciones más altas en número correspondieron a poliquetos, principalmente representados por* Heteromastus filiformis *(Claparede, 1864) en la zona 7 y* Polydora *Bosc, 1802 sp. en la zona 1. Los crustáceos fueron el segundo grupo de presas más abundante.*

Palabras clave: *Alimentación, juveniles, Francia, fauna de invertebrados.*

INTRODUCTION

Knowledge about the diet of *Acipenser sturio* L., 1758 in its natural environment is very scarce. For juveniles, a better understanding in this field is considered a step towards the assessment of the species's major foraging areas in the estuary. These data would make it possible to protect them from adverse human impact. Additionally, the results could lead to an improvement in the efficiency of the alimentation of *A. sturio* in captivity.

Acipenser oxyrinchus Mitchill, 1815, between 106 and 213 cm (total length, Tl) mainly feed on polychaetes and isopods (Johnson *et al.*, 1997), while subadults of *A. oxyrinchus desotoi* Vladykov, 1955 forage mainly on arthropods, annelids and molluscs (Mason and Clugston, 1993).

The diet of the white sturgeon *Acipenser transmontanus* Richardson, 1836, is based on *Corophium* Latreille, 1806 (crustacean) and *Corbicula fluminea* (Muller, 1774) (mollusc) for individuals less than 80 cm long (McCabe, Emmett and Hinton, 1993; Muir, Emmett and McConnell, 1998). Zolotarev, Shlyakhov and Akselev (1996) show that juvenile Russian sturgeon *Acipenser gueldenstaedtii* Brandt & Ratzeberg, 1833 predominantly feed on molluscs, whereas stellate sturgeon *Acipenser stellatus* Pallas, 1771 consume mainly polychaetes. The diet of the juvenile lake sturgeon *Acipenser fulvescens* Rafinesque, 1817 essentially comprises crustaceans and insect larvae (Nilo, 1996; Beamish, David and Rossiter, 1998) as in *Acipenser brevirostrum* LeSueur, 1818 (Dadswell, 1979; Carlson and Simpson, 1986).

These results show that young sturgeons are benthic feeders that prefer small, soft-bodied, benthic prey organisms.

Some preliminary research was conducted on the feeding habits of juvenile *A. sturio* in the Gironde estuary by Magnin (1962). He found that fishes caught in the upper part of the estuary predominantly feed on shrimps *Crangon crangon* (L., 1758) and gammarids. Fishes from the lower part of the estuary were described as mainly consuming polychaetes and mysids. However, those results are very incomplete, and present only few details about the occurrence and proportions of each of the items found in the stomach contents. Therefore, we decided to study more precisely the diet of juvenile *A. sturio* during their initial stay in the Gironde estuary.

MATERIALS AND METHODS

From May 1998 to March 1999, the stomach contents of 61 juveniles were collected by gastric lavage during monthly trawling campaigns primarily aimed at monitoring the spatial distribution of juvenile sturgeons (Rochard *et al.*, 1998). Each trawl lasted for 30 minutes and took place in 12 predefined zones of the estuary (figure 1).

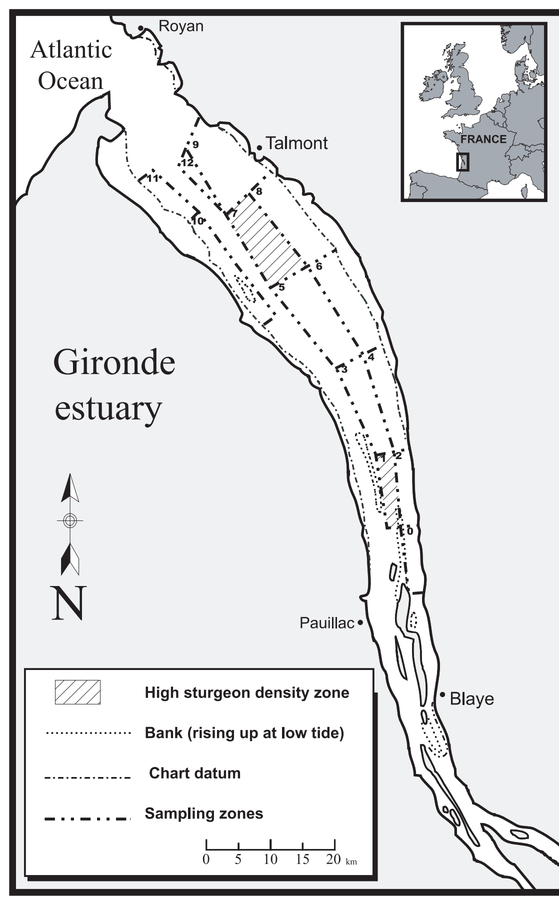

Figure 1. The Gironde estuary, study areas and sampling zones

The gastric lavage method we used is adapted from Nilo (1996). This method has been tested on the Siberian sturgeon *Acipenser baerii* Brandt, 1869 in captivity, and we concluded that it is easy to use, non-traumatic, and permits a good recovery rate of feed-particles. Average recovery rate in *A. baerii* was determined to be between 47 % and 83 %, depending on the prey's shape (Brosse *et al.*, in preparation). Upon their capture, specimens were measured and weighed (two length classes: 63-86 cm and 87-116 cm) before the stomach flushing took place. The gastric lavage device was composed of a garden sprayer equipped with a soft tube (Ø6 mm ext.) for the injection of the water inserted into a bigger one (Ø12 mm ext.) designed to collect the stomach contents (figure 2). Sturgeons were not anaesthetised during this operation because of uncertainties with regard to the efficiency and potential harmful side effects of the clove oil anaesthetic under brackish water conditions for this rare species.

Data were processed using discriminate analysis and the Kruskall-Wallis test to compare for spatial and seasonal variation in the diet. Using the same tests, we checked for differences in numbers or in proportions among the different groups of prey found in the contents.

RESULTS

A. sturio specimens in the Gironde estuary were mainly caught during spring (n = 41) and summer (n = 15) in eight of the 12 sampled zones. However, most of them were collected in two zones (no. 1 and 7, figure 1) of higher sturgeon density (figure 3).

Fish measured between 63 and 116 cm Tl and weighed 1-8 kg. All of the sturgeon captured were in good condition and were released into the estuary after stomach flushing. A total of 12 prey taxa were found (table I).

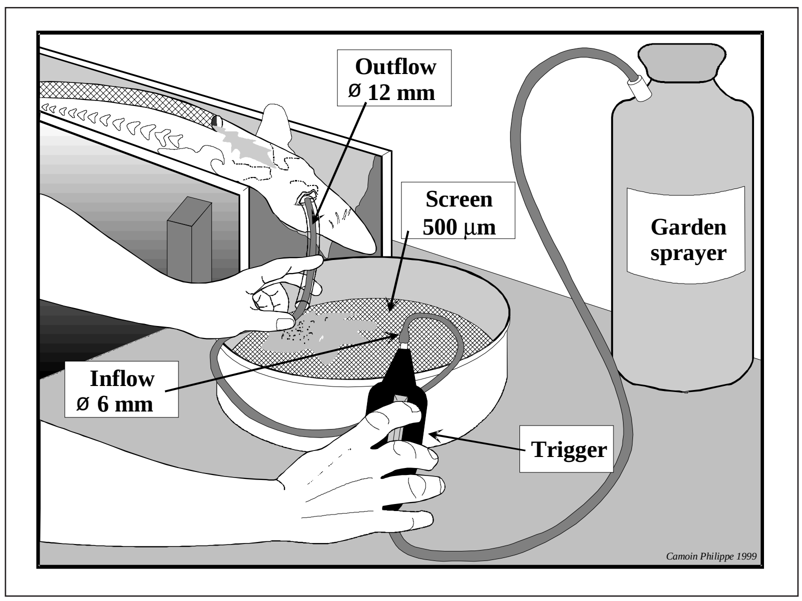

Figure 2. The stomach flushing disposal in place

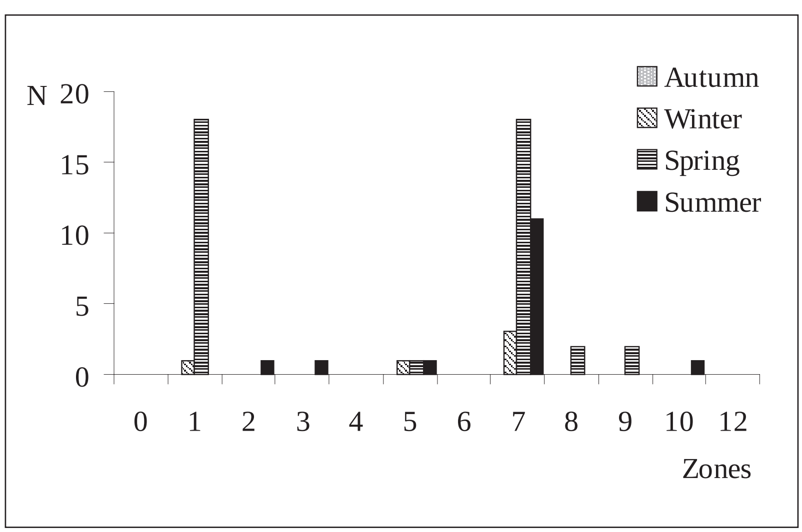

Figure 3. Number (N) of stomach contents of *A. sturio* analysed in the different zones of the esturary during one year (N_{total} = 61)

Table I. Mean number (N), standard deviation (s), and proportion (%), for each taxa encountered in the stomach contents for all the zones and seasons where stomachs were analysed

	Winter		Spring		Summer	
Preys	N(s)	%	N(s)	%	N(s)	%
Amphipoda						
Bathyporeia pelagica Bate, 1857					0.5 (2.0)	0.1
Corophium volutator Pallas, 1766					9.5 (35.7)	1.1
Gammarus sp.	0.6 (0.8)	0.3	12.9 (52.9)	1.2		
Isopoda						
Cyathura carinata (Krøyer, 1847)	3.8 (2.8)	2.0	2.6 (4.5)	0.2	0.5 (0.7)	0.1
Syntidotea sp.	4.2 (4.8)	2.2	0.3 (1.9)	0.0	0.4 (1.0)	0.0
Mysidacean						
Mysids			1.8 (3.9)	0.2	3.3 (9.6)	0.4
Decapoda						
Carcinus maenas (L., 1758)	0.2 (0.4)	0.1				
Crangon crangon (L., 1758)	7.2 (10.6)	3.8	0.5 (1.1)	0.1	2.4 (4.2)	0.3
Polychaeta						
Heteromastus filiformis (Claparede, 1864)	170.4 (184.7)	90.7	721.6 (1 522.9)	67.9	878.8 (1 166.2)	98.0
Nereide sp.	1.4 (1.0)	0.7	7.8 (28.5)	0.7	0.8 (1.2)	0.1
Polydora sp.			314.4 (669.5)	29.6		
Pisces						
Pomatoschistus minutus (Pallas, 1770)			0.0 (0.2)	0.0	0.3 (1.0)	0.0

Table I (continued)

	Zone 1		Zone 2		Zone 3		Zone 5		Zone 7		Zone 8		Zone 9		Zone 10	
Preys	N(s)	%	N(s)	%	N(s)	%	N(s)	%	N(s)	%	N(s)	%	N(s)	%	N(s)	%
Amphipoda																
Bathyporeia pelagica															8.0	16.7
Corophium volutator							47.7 (67.4)	58.6								
Gammarus sp.	0.5 (1.8)	0.1					18.3 (25.9)	22.5	0.3 (1.1)	0.0	1 (0.0)	0.1	227 (87.0)	96.2		
Isopoda																
Cyathura carinata	4.6 (5.9)	0.7	1.0	25.0	1.0	10.0	1.3 (25.9)	1.6	1.2 (1.8)	0.1	1.5 (0.5)	0.2				
Syntidotea sp	0.1 (0.2)	0.0					4.3 (3.7)	5.3	0.4 (1.9)	0.0			6 (6.0)	2.5		
Mysidacean																
Mysids	0.1 (0.3)	0.0	3.0	75.0			4.7 (6.6)	5.7	1.8 (3.8)	0.1	2 (1.0)	0.2	2.5 (2.5)	1.1	39.0	81.3
Decapoda																
Carcinus maenas	0.1 (0.2)	0.0														
Crangon crangon	1.6 (6.2)	0.2			6.0	60.0	3.3 (2.9)	4.1	1.4 (3.0)	0.1	1 (1.0)	0.1				
Polychaeta																
Heteromastus filiformis					3.0	30.0			1 304.8 (1 692.0)	98.8	932 (676.0)	99.4	0.5 (0.5)	0.2		
Nereide sp.	0.2 (0.5)	0.0					0.3 (0.5)	0.4	10.4 (31.8)	0.8	0.5 (0.5)	0.1			1.0	2.1
Polydora sp.	678.4 (848.6)	99.0														
Pisces																
Pomatoschistus minutus	0.1 (0.2)	0.0					1.3 (1.9)	1.6	0.0 (0.2)	0.0						

The rate of empty stomachs was very low (2.5 % in spring and 0 % in summer and winter). The gut contents mainly consisted of polychaetes, with a strong dominance in number. The species present in the gut contents were dominated by *Polydora* Bosc, 1802 sp. (Spionidae) in zone 1 and *Heteromastus filiformis* (Claparede, 1864) (Capitellidae) in zone 7.

The juvenile sturgeon diet varied according to sampling season (spring compared to summer: $H = 4.767$; $p = 0.0052$) and sampling zone (zone 1 vs. 7: $H = 9.803$; $p < 0.001$) but not according to fish length ($H = 1.591$; $p = 0.126$).

DISCUSSION

The diet of the *A. sturio* juveniles mainly consisted of polychaetes and benthic crustaceans (table I). All of these items are small, and seem to have a limited ability to escape. The strong dominance of the polychaetes in the diet may be due to the very high densities of these organisms in the substrate (Bachelet, Bouchet and Lissalde, 1981).

There are some differences between our results and those from Magnin (1962), mainly concerning the diet of sturgeons caught in the upper part of the estuary. Magnin found that sturgeons eat primarily shrimps and gammarids, while we found that they mainly consume polychaetes. Magnin only indicated what he occasionally observed in the gut contents of sturgeons, but he did not perform a special study on this aspect.

Our differences could be explained using two hypotheses:

- The sturgeons in Magnin's study were younger than those used in ours and it is possible that their diet changed during their stay in the estuary.
- The benthic fauna in this part of the estuary has significantly changed between the two studies, and the sturgeons have modified their diet in order to stay in this part of the estuary.

Both studies describe young *A. sturio* as benthic feeders, which consume small soft-bodied prey organisms. Compared to data on other sturgeon species, it is apparent that all are feeding on invertebrates, mainly arthropods and annelids (Dadswell, 1979; Carlson and Simpson, 1986; Mason and Clugston, 1993; McCabe, Emmett and Hinton, 1993; Zolotarev, Shlyakhov and Akselev, 1996; Nilo, 1996; Johnson *et al.*, 1997; Beamish, David and Rossiter, 1998, and Muir, Emmett and MacConnell, 1998).

Sturgeons are mainly bottom feeders, as can be concluded from the ventral position of their mouth and the way they collect their food using a projection of their oropharyngian cavity. Therefore, all of the sturgeons did not consume exactly the same taxa. There are three main groups of prey: arthropods (insect larvae and crustaceans), annelids (oligochaetes and polychaetes) and molluscs (bivalves and gastropods). *A. sturio* mainly feeds on annelids and arthropods, as does *A. oxyrinchus* (Mason and Clugston, 1993; Johnson *et al.,* 1997) and *A. stellatus* (Zolotarev, Shlyakhov and Akselev, 1996). Some, such as *A. fulvescens,* (Nilo, 1996; Beamish, David and Rossiter, 1998) or *A. brevirostum* (Dadswell, 1979; Carlson and Simpson, 1986), mainly feed on arthropods. Others, such as *A. gueldenstaedtii* (Zolotarev, Shlyakhov and Akselev, 1996), essentially consume molluscs. The differences in predominant food may be linked to the main fauna of the habitats where these sturgeons live. For example, the benthic fauna in the rivers is dominated by arthropods and annelids, while it is mainly composed of annelids, molluscs, and arthropods in the estuaries.

The temporal variation in the young sturgeons' diet may be linked with their seasonal migrations, as described previously (Rochard *et al.*, 1998). However, the fact that there were no sturgeons caught in the zone 1 during summer may be sufficient to influence the results of our statistical tests.

Thus, the migrations observed may be due to changes in the benthic fauna composition. We can neither accept nor reject this theory at present, because we lack information on the composition and spatio-temporal distribution of the benthic fauna in the estuary channels.

Because of these uncertainties, we cannot draw conclusions on this temporal variation in sturgeon abundance until more information on the benthic fauna (repartition, dynamics, etc.) becomes available.

The spatial differences in food composition are stronger than the temporal ones. These differences essentially result from the predominant consumption of two different polychaete taxa (*Polydora* sp. and *Heteromastus filiformis*) in the main upstream and downstream capture zones. We can formulate two hypotheses to explain this segregation between those two species:

- These two polychaetes have different ecological requirements and do not live under the same conditions. Therefore, it should be realistic to think that *Polydora* sp. is present in high densities in zone 1 and *Heteromastus filiformis* in zone 7. In that case, young sturgeons would consume the most abundant prey and have an opportunistic feeding behaviour.
- The two polychaetes are found in high densities throughout the entire estuary because of their wide ecological spectrum. This leads to the conclusion that young sturgeons are selecting *Polydora* sp. in the upper estuary and *Heteromastus filiformis* in the downstream area of the estuary, indicating a specialist feeder behaviour.

Because we have no quantitative data on the benthic fauna found in the channels of the

Gironde estuary, future studies and subsequent comparisons with dietary changes in *A. sturio* are to be carried out.

This work has collected quantitative and qualitative data on the *A. sturio*'s diet, and its spatial and temporal variability. The present study shows that there are dietary differences among sturgeon species living in different water bodies, such as rivers and estuaries.

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