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Exotic sturgeons in the Vistula Lagoon in 2011, their occurrence, diet and parasites, with notes on the fishery background

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Summary

The Siberian sturgeon *Acipenser baerii* and the sterlet *Acipenser ruthenus* were recorded for the first time in the Vistula Lagoon in 2011. Among 66 sturgeons collected between April and December 2011, the Siberian sturgeon was the most numerous species (77%); however, a significant seasonal variability was observed, with sterlet dominating in the catches in late autumn of the same year. The stomach contents of the two species differed widely: Siberian sturgeon (14.9–42.2 cm standard length, SL) fed on crustaceans (*Cercopagis pengoi*, *Oithona* sp., *Neomysis integer*) (10.7% IRI), larvae and pupas of insects (*Chaoborus* sp., *Chironomus* sp., *Polypedilum* sp., *Procladius* sp., *Culex* sp.) (88.9% IRI) and fishes (*Neogobius melanostomus*, *Osmerus eperlanus*) (0.5% IRI), whereas sterlet (24.0–34.4 cm SL) consumed crustaceans (*N. integer*) (64.3% IRI), larvae of insects (*Chironomus* sp., *Polypedilum* sp.) (20.3% IRI) and fish (*N. melanostomus*) (15.4% IRI). Single Siberian sturgeon (4.3%) were found to harbour the parasitic nematode (*Raphidascaris acus*).

1 | INTRODUCTION

Between the 19th and 21st centuries, over 100 non-native (NN) species were recorded for the Baltic Sea (including the Kattegat), posing a potential threat to natural resources (ecosystem services) such as commercially harvested species. That said, some NN fishes, such as rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), peled *Coregonus peled* (Gmelin, 1789) or round goby *Neogobius melanostomus* (Pallas, 1814), can be of interest to local fisheries (Leppäkoski, 2002). Amongst the introduced NN fishes, three sturgeon species have been reported since 1966 in the Polish Baltic waters. In the 1960s, their occurrence resulted from deliberate stocking by the USSR in the Gulf of Finland and the Gulf of Riga (Kairov & Kostrickina, 1970; Paaver, 1999). During the 1990s, increasing numbers of exotic sturgeons were observed, which have been attributed to escapement from fish farms and illegal releases by anglers and aquarists (Arndt, Gessner, & Raymakers, 2002), due to their great value as trophy specimen fish (Hickley & Chare, 2004) and because these species grow to sizes too large for aquaria and garden ponds (Copp, Wesley, & Vilizzi, 2005).

The Siberian sturgeon *Acipenser baerii* Brandt, 1869 has been the most frequently reported non-indigenous sturgeon species in the Polish Marine Areas. The Russian sturgeon *Acipenser gueldenstaedtii* Brandt & Ratzeburg, 1833 has been less common. Neither species was found in the Vistula Lagoon (Gessner et al., 1999; Skóra & Arciszewski, 2013). Since the 1960s the sterlet *Acipenser ruthenus* L., 1758 was observed only once in the Gulf of Gdańsk (Bartel, 1968). Between 1980 and 1997, the catch of NN sturgeons in the Polish Marine Areas was on average 2.2 specimens annually (Gessner et al., 1999). Two other sturgeons species, beluga sturgeon *Huso huso* (L., 1758) and starry sturgeon *Acipenser stellatus* Pallas, 1771, as well as various sturgeon hybrids have been captured in the Baltic waters of neighbouring countries: Germany and Russia - Kaliningrad Oblast (J. Gessner, pers. comm.; Kolman, Lutikov, & Mironov, 2000).

In memory of Krzysztof Edward Skóra

Information on the diet of NN sturgeons in the Baltic Sea has focused on the Siberian sturgeon stocked into the Gulf of Finland and the Gulf of Riga (Gerbilskiy, 1970; Kairov & Kostrickina, 1970; Koli, 1966), with data from two specimens captured in the Polish Marine Areas (Keszka & Hesse, 2003; Keszka & Stepanowska, 1997). Neither Siberian sturgeon nor sterlet were reported or studied for the Vistula Lagoon prior to 2011. Indeed, research on sturgeon parasites in Poland has been limited to a few statements, including one observation from the estuary of the River Oder for which acanthocephalans and leeches (without identification to species level) were found in a single specimen of Siberian sturgeon (Keszka & Stepanowska, 1997). Other studies pertain strictly to inland waters, where digeneans *Diplostomum* sp. were found in the Siberian sturgeon 0 + juveniles from fishponds (Dzika, Bielecki, Kolman, & Kolman, 1999; Kolman, Kolman, Dzika, & Bielecki, 2001). The Atlantic sturgeon *Acipenser oxyrinchus* Mitchill, 1815 juveniles after release into the River Drwęca were infected with leeches *Caspiobdella fadejewi* (Epshtein, 1961) (Bielecki, Kapusta, & Cichocka, 2011), whereas the fish in pond conditions were infected by ciliates *Trichodina* sp., *Apiosoma* sp., monogenean *Gyrodactylus* sp., and the copepod *Ergasilus sieboldi* Nordmann, 1832 (Popielarczyk & Kolman, 2013).

The aim of the present study was to provide the first data on the occurrence, diet and parasites of Siberian sturgeon and sterlet in the Vistula Lagoon, with notes on the potential implications for local fisheries.

2 | MATERIALS AND METHODS

The Vistula Lagoon is located on the southern coast of the Baltic Sea. Its width varies between 2 and 11 km, with a mean depth of 2.7 m (max. 5.2 m). It is formed as a part of River Vistula estuary with a single narrow outlet, the Strait of Baltiysk, at its eastern extent. In 1916, flow the Vistula River was redirected to the Baltic Sea, resulting in a reduced discharge (<10% of historic levels) into the Vistula Lagoon via the Nogat tributary. This changed the hydrology of the lagoon, leading to an increase in the sedimentation rate and salinity, on average from nearly 0 to 3.5 PSU (Chumarenko & Margoński, 2008).

Totals of 51 Siberian sturgeon (77% of total), 13 sterlet (20% of total) and two hybrids (3% of total, phenotypically similar to sterlet) were collected from April to December 2011 by Polish fishers operating in the Vistula Lagoon (Figure 1, Table 1). Sturgeons were not collected between 20 April and 10 June, which is a closed season for the gill-net fishery in order to avoid disruption of spawning by the common bream *Abramis brama* (L., 1758) and pikeperch *Sander lucioperca* (L., 1758). A second, regional, closed season occurred between August and September, to reduce fishing pressure on European eel *Anguilla anguilla* (L., 1758) stocks. Sturgeons collected by fishery inspectors originated from inspections (and removal) of unmarked, illegal gill nets (45, 48 or 50 mm mesh sizes), whereas those delivered by fishers to fishery inspectors were captured in 60 mm, square-mesh gill nets.

Fish were stored frozen until arrival at the laboratory, where they were subsequently thawed, measured for standard length (SL) in mm and weighed to 0.1 g accuracy. Specimens were identified according to Hochleitner and Gessner (2001). Stomachs were surgically removed and preserved in 4% buffered formaldehyde solution. The stomach contents were analysed for quality and quantity, then identified to the lowest possible taxonomic level. The food compounds were weighed to 0.1 g accuracy. Specimens with empty stomachs were not considered further.

Index of Relative Importance (*IRI*) (Pinkas, Oliphant, & Iverson, 1971) was calculated based on the relative numerical abundance (*N*),

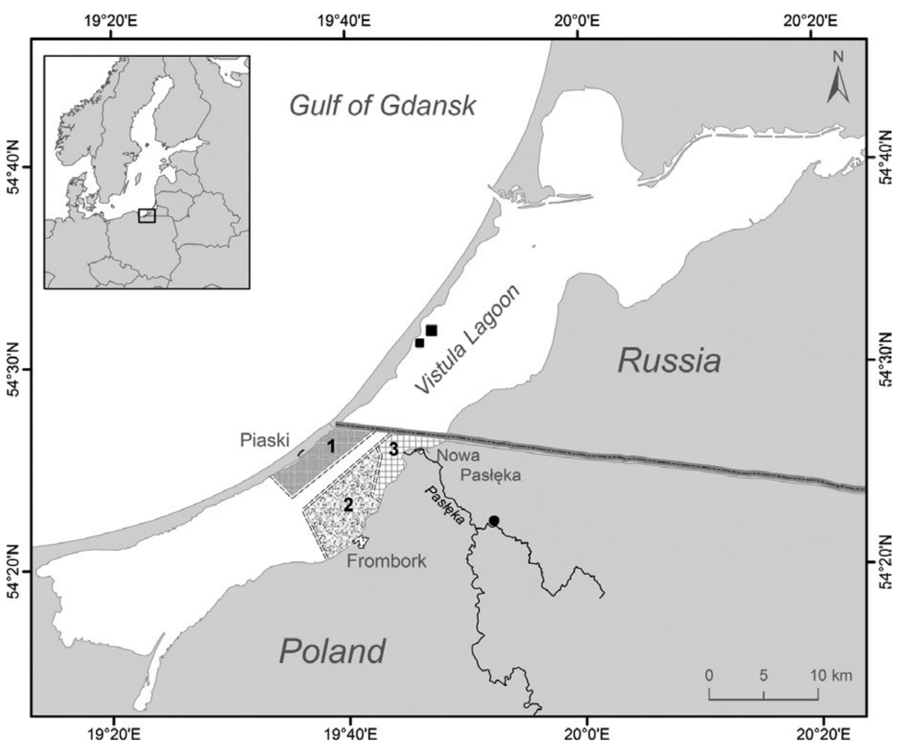

FIGURE 1 Fishing grounds in Poland of fish collected for the present study (1 - Piaski, 2 - Frombork, 3 - Nowa Pasłęka), ■ - capture sites in Russian portion of Vistula Lagoon; ● – location of the sturgeon farm as a potential source of escapement

TABLE 1 Date of capture (dd/mm), sample name (SN), number of fish (*n*), percentage of Siberian sturgeon (% *Ab*), fishery harbour, total number of boats (TBN), number of boats involved (NIB), and collector (S = scientist, FI = fishery inspector) for non-native sturgeons collected in the Vistula Lagoon, Poland, in 2011

Date	SN	*n*	% *Ab*	Harbour	TBN	NIB	Collector
08/04	A	1	100.0	Nowa Pasłęka	23	1	S
05/05	B	1	100.0	Piaski	17	1	S
20/05	C	6	100.0	Piaski	17	1	S
25/07	D	7	100.0	Piaski	17	1	S
25–28/07	E	22	90.9	Frombork	12	2	FI
01/10–10/11	F	18	61.1	Frombork, Nowa Pasłęka	12 23	4 2	FI
11/11–05/12	G	11	45.5	Frombork	12	2	FI

weight (*W*) (rather than volume), and frequency of occurrence of each food compound (*F*) using the equations:

$$\mathrm{IRI} = (\%N + \%W) \times \%F$$

$$\%N, \%W = \frac{\sum S_i}{\sum S_t} \times 100$$

$$\%F = \frac{F_i}{F_t} \times 100$$

where:

%*N* - numerical percentage of a food item in all stomachs,

%*W* - percentage by weight of a food item in all stomachs,

%*F* - percentage occurrence of each food compound in all stomachs,

S_i - stomach content (number or weight) composition of food items (*i*),

S_t - total stomach contents (number or weight) of all stomachs,

F_i - number of stomachs with food items (*i*),

F_t - total number of analysed stomachs with food contents.

The percentage of IRI was calculated according to Cortés (1997).

Approximately 65% of the specimens (23 Siberian sturgeon, 13 sterlet, 1 hybrid) were subjected to standard parasitological examination, with a focus on the body cavity, stomach with pyloric caeca, intestine, and swim bladder. Nematodes found in these samples were fixed in 70% ethanol, and cleared in lactophenol (Rolbiecki, 2002).

The program Statistica 12 (StatSof Inc. USA) was used for statistical analysis of the data. The Mann–Whitney *U* test was used to compare the standard lengths of Siberian sturgeon and sterlet. Statistical differences in diet composition with respect to sturgeon species was assessed by a Pearson's chi-square test (χ^2).

3 | RESULTS

The proportion of Siberian sturgeon captured decreased during the study period (Table 1, Figure 2). The mean SL of Siberian sturgeon and sterlet did not differ significantly (Mann–Whitney *U* test, $p > .05$). All sturgeons collected directly from fishers ($n = 15$) had full stomachs, whereas most of the 51 sturgeons (91.7% of Siberian, 73.3% sterlet) obtained from fishery inspectors had empty stomachs. Three main groups of prey were consumed: crustaceans, insect larvae, and fishes. The most important food items for Siberian sturgeon ($n = 17$) were insects (Table 2), whereas the sterlet ($n = 4$) preferred crustaceans. The main difference in diet composition between Siberian sturgeon and sterlet was the presence of *Neomysis integer* (Leach, 1814) and chironomids (χ^2 test, $p < .001$).

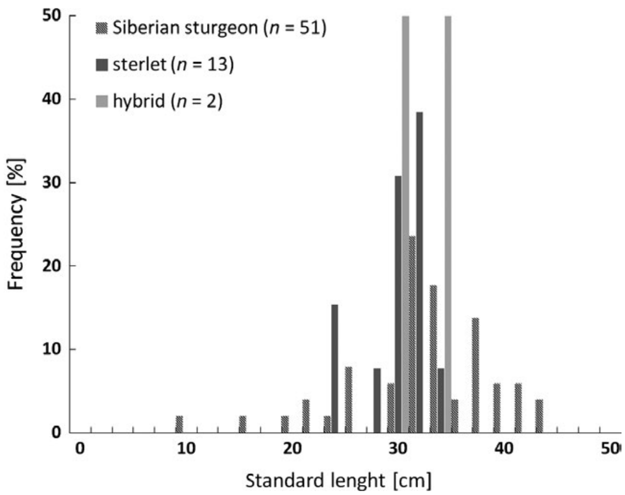

FIGURE 2 Length–frequency distribution (2 cm classes) of Siberian sturgeon, sterlet, and hybrid caught in the Vistula Lagoon (Poland) in 2011

Three adult individuals (one female with developed eggs, and two males) of the parasitic nematode *Raphidascaris acus* (Bloch, 1779) were noted in an intestine of a single Siberian sturgeon (43.3 cm, 338 g).

4 | DISCUSSION

There are several documented escapes and reports of the occurrence of non-native sturgeon species such as Siberian sturgeon, Russian sturgeon and sterlet from European seas and their tributaries (e.g. Britton & Davies, 2006; Gessner et al., 1999; Keszka & Hesse, 2003; Maury-Brachet, Rochard, Durrieu, & Boudou, 2008; Paaver, 1999; Skóra, 2012; Skóra & Arciszewski, 2013). Potentially harmful consequences of their co-occurrence are often mentioned in the literature and include competition for food, transfer of new parasites and diseases (Grabda, 1991; Gessner et al., 1999 after Pavlov,

TABLE 2 Diet of the Siberian sturgeon and sterlet caught in the Vistula Lagoon from April to December 2011

Family	Species	Developmental stage	%N	%W	%F	IRI	% IRI
Siberian sturgeon							
Crustaceans			11.4	24.1	53.3	1892.7	10.7
Cyclopoida	*Oithona* sp.	Adult	<0.1	<<0.1	6.7	0.4	0.1
Cercopagididae	*C. pengoi*	Adult	1.2	0.1	6.7	8.9	0.1
Mysidae	*N. integer*	Adult	10.1	24.0	46.7	1592.5	14.5
Insects			88.0	69.9	100.0	15792.0	88.9
Chaoboridae	*Chaoborus* sp.	Larvae	1.0	0.4	6.7	9.6	0.1
Chironomidae	*Chironomidae*	Pupae	48.2	63.6	66.7	7459.7	67.9
	Chironomus sp.	Larvae	0.3	0.3	6.7	3.9	<0.1
	Polypedilum sp.	Larvae	16.7	2.0	73.3	1364.1	12.4
Culicidae	*Procladius* sp.	Larvae	21.5	3.6	20.0	501.2	4.6
	Culex sp.	Larvae	0.4	<0.1	20.0	8.0	0.1
Fishes			0.6	6.0	13.3	87.8	0.5
Gobiidae	*N. melanostomus*	Juvenile	0.6	5.1	6.7	38.1	0.4
Osmeridae	*O. eperlanus*	Juvenile	<0.1	0.9	6.7	6.1	0.1
No. of all stomachs/with food items		50/17					
% of empty stomachs		66.0%					
Sterlet							
Crustaceans			59.6	75.9	75.0	10163.3	64.3
Mysidae	*N. integer*	Adult	59.6	75.9	75.0	10163.3	67.6
Insects			28.8	3.2	100	3205.0	20.3
Chironomidae	*Chironomus* sp.	Larvae	12.8	2.5	50.0	765.5	5.1
	Polypedilum sp.	Larvae	16.0	0.7	100.0	1674.0	11.1
Fishes			11.5	20.9	75.0	2433.0	15.4
Gobiidae	*N. melanostomus*	Juvenile	11.5	20.9	75.0	2433.0	16.2
No. of all stomachs/with food items		13/4					
% of empty stomachs		69.2%					

N, composition by number; W, composition by weight; F, frequency of abundance; IRI, index of relative importance.

Savvaitova, Sokolov, & Alekseev, 1994) as well as the risk of hybridization (Ludwig, Lippold, Debus, & Reinartz, 2009). Furthermore, in the context of restoration programmes of Atlantic sturgeon, escapements of sturgeons from fish farms weaken the awareness of the handling and protection of native sturgeon species among fishers and fishery inspectors (Skóra, 2012; Skóra & Arciszewski, 2013).

Based on official fishery statistics for marine areas of Poland, the by-catch of sturgeons seems extremely infrequent (Skóra & Arciszewski, 2013), given that only one fish was registered over a six-year period (January 2006 – May 2013). This single fish was found on a boat during a fisheries inspection (I. Wawrzyniak, pers. comm.). Various sources (Arndt et al., 2000; Gessner et al., 1999; Keszka & Hesse, 2003; Skóra & Arciszewski, 2013), including the present study, suggest that the number of NN sturgeons in the Baltic is largely underestimated. Numerous captures of NN sturgeons in the Vistula Lagoon during the present study could indicate a very singular appearance of the fish or a potential impact of commercial fisheries upon these NN species as well as its outmigration from the fishery area. According to a fishery inspector, NN sturgeons in the by-catch became extremely rare a year after the present study, and in a following season they disappeared completely from landings.

According to Kapusta, Skóra, Duda, Morzuch, and Kolman (2011), fishers often caught NN sturgeons (most likely stocked Atlantic sturgeon) with 70–80 cm total length in the Gulf of Gdańsk, which were sold as a smoked fish. To some extent, a lack of records is due to the absence of logbooks in fishery vessels <15 m long and the (landed or released) sturgeons were not recorded in monthly catch reports, although some might have been classified as 'other freshwater fishes'. On the other hand, when regulations were not in place (2006–2008, inclusive) and it was legal to take the Atlantic sturgeon, some records should have been available from logbooks of larger boats. After 2008, the absence of sturgeon in logbooks could be considered as a consequence of legislation for stock protection banning catches and illegal marketing (Regulation 2009a, b). To enhance recovery of native sturgeon in the Vistula Lagoon, as well as along entire Polish coast, an education campaign for local fishers is needed to inform them of the need to protect the species by reducing fish moralities in this brackish environment.

Information on NN sturgeons in the Russian part of the Vistula Lagoon is fragmentary, with no official by-catch statistics. A fisher from the fishery association "Za Rodinu" reported that ≈ 250 sturgeons were caught by poachers in August 2011 (A. Guschin, pers. comm.). The fishes (≈ 19–23 cm SL) were caught in two instances of approx. 200 and 50 specimens, while fishing for common bream and pikeperch. A single sturgeon was identified in the Atlantic branch of the P. P. Shirshov Institute of Oceanology, Russian Academy of Science, in Kaliningrad as Siberian sturgeon.

What are the origins of all of these NN sturgeons? Fish escapees can happen in all farms at different times. However, timing of the catch (one season) and the co-existing two species and hybrids might provide information on the origins of sturgeons. Among fish farms rearing two or more sturgeon species, a potential suspect is located in the Polish part of the Vistula Lagoon at its confluence with a tributary of the River Pasłęka drainage area. Detailed information on the sturgeon farms in the Russian area is unavailable, but the Russian origin of fish should not be excluded.

In the present study, most NN sturgeons forwarded to fishery inspectors had empty stomachs, which might be a consequence of the extensive time lag between capture and frozen storage. The benthos and necto-benthos found in full stomachs do not reflect the biodiversity of the benthic fauna in the Vistula Lagoon (Ezhova, Żmudziński, & Maciejewska, 2005), e.g. absence of higher taxa levels such as Oligochaeta, Polychaeta and Mollusca (Bivalvia, Gastropoda). However, non-native organisms such as a crustacean *Cercopagis pengoi* (Ostroumov, 1891) and fish *N. melanostomus* (Hornatkiewicz-Żbik, 1999; Ojaveer, 2006; Ojaveer & Lumberg, 1995), were present. The lack of oligochaetes in sturgeon stomachs is also a common phenomenon in the Gulf of Finland, Gulf of Riga, and Ladoga Lake (Egelskiy & Stepanova, 1972; Gerbilskiy, 1970; Kairov & Kostrickina, 1970). Absence of oligochaetes in the sturgeon diets most likely resulted from the relatively small size of these animals in the Baltic Sea.

In terms of parasite load, the nematode *Raphidascaris acus* was not reported previously in sturgeons in Poland, although it was noted in 25 other fish species in the Gulf of Gdańsk and the Vistula Lagoon (Bystydzieńska, Rolbiecki, & Rokicki, 2005; Pojmańska, Niewiadomska, & Okulewicz, 2007; Rolbiecki, 2003). This nematode is a Holarctic species widely spread throughout Europe, Asia and North America, that thrives on sturgeon species such as the Fringebarbel sturgeon *Acipenser nudiventris* Lovetsky, 1828, sterlet, starry sturgeon (Bykhovskaya-Pavlovskaya et al., 1964; Kulakovskaya & Koval, 1973; Skrjabina, 1974) as well as on Siberian sturgeon (Bykhovskaya-Pavlovskaya et al., 1964). This nematode has a complicated life cycle that involves paratenic, intermediate and definitive (predatory fish) hosts. According to Moravec (1994), *R. acus* females mature sexually in Acipenseridae but do not produce eggs (fish are a para-definitive host). However, nematode females with eggs visible in the uterus in the present study prove that Siberian sturgeon can play a role of definitive host for this parasite. The third stage larvae of *R. acus* lives in Gobiidae (Naydenova, 1974), including round goby that were found in the diet of collected fish. Therefore, it can be concluded that round goby might be the source of infection with this nematode for Siberian sturgeon in the Vistula Lagoon basin.

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