Arch. Pol. Fish. (2011) 19: 69-76
DOI 10.2478/v10086-011-0008-5

RESEARCH ARTICLE

Distribution and growth of juvenile Atlantic sturgeon released into the Drwęca and Wisłoka rivers (Poland)

Received – 23 April 2011/Accepted – 28 May 2011. Published online: 30 June 2011; ©Inland Fisheries Institute in Olsztyn, Poland

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Abstract. The Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchill, has been considered to be an extinct species in the Baltic Sea for many years. A program to restore it to the Vistula basin was initiated in 2006 using cultured fish. This paper presents data regarding the distribution of juvenile Atlantic sturgeon released into the Drwęca and Wisłoka rivers (Vistula drainage). Tag returns from juvenile Atlantic sturgeon were few at just 3.15% for fish released into the Drwęca and 0.85% for those released into the Wisłoka. Information obtained from stocking the Drwęca River was used to analyze the distribution and growth of juvenile Atlantic sturgeon. These fish were caught most frequently in the Gdańsk Bay and the mouth of the Vistula River. Catches were made from March to December with two periods of much more abundant catches in July and October. The size of the fish released had an impact on the daily total length growth rate and the period of time between fish release and recapture, the mean of which ranged from 177 to 362 days, at a minimum of 10 and a maximum of 664 days. Absolute juvenile fish growth increased along with the period of time the fish spent in open waters; however, this period had no impact on daily body length growth rates.

Keywords: sturgeon, Baltic Sea, species protection, growth, restoration

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Introduction

One hundred years ago sturgeon were still fished in some regions of the southern Baltic Sea. Until recently, it was believed that the Baltic Sea basin had been inhabited by *Acipenser sturio* L. (Kolman 1996, Gessner 2000, Gessner et al. 2006). However, phylogenetic and historical genetic population studies of sturgeon remains indicated that the Baltic Sea was inhabited by the Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchill (Ludwig et al. 2002). Formerly, the Atlantic sturgeon was of commercial significance, and the fish caught and the roe harvested were exported to many European countries (Kolman 1996, Cios 2007). Decreases in the abundance of this species were noted as early as in the seventeenth and eighteenth centuries (Kulmatycki 1932, Cios 2007). By the beginning of the twentieth century, Atlantic sturgeon was already being caught in small numbers in the lower reaches of the Vistula River. Distinct decreases in the abundance of this fish were noted in the 1920s, and the last specimens of it was caught in the Vistula in the 1960s. (Grabda 1968, Kolman et al. 2008). Environmental pollution, overfishing, increased river transport, and damming were the most important long-term anthropogenic factors that contributed to the extinction of the species in this region (Kulmatycki 1932, Gessner 2000, Gessner et al. 2006). While the last individual of the Baltic sturgeon population was caught off of the Estonian coast in 1996, the North American population

of this species is still fairly abundant (Pikitch et al. 2005, Grunwald et al. 2008).

Work to restore the Atlantic sturgeon to the Baltic Sea drainage basin gained momentum when fertilized eggs, larvae, and juveniles began to be imported to Europe (Kolman and Szczepkowski 2005, Gessner et al. 2006). In Poland, several rearing facilities incubate eggs obtained from reproduction of wild spawners caught in the St. John River (Kolman et al. 2011). Some of these juvenile specimens are being reared to create brood stocks. However, the remaining individuals are released into rivers which sturgeon ascended previously to spawning. The first stocking in the Vistula basin was performed in 2006 (Kolman 2007), and the first juvenile species were caught in the following year.

Sub-adult and adult Atlantic sturgeon spent significant periods of their lives in coastal waters (Erickson et al. 2011), and ascended rivers to spawning (Van Eenennaam et al. 1996). Historically, these sturgeon ascended ten rivers to spawning (Rembiszewski and Rolik 1975, Mamcarz 2000). Spawning migrations began in March and April, and spawning, depending on water temperature, occurred from mid May to mid July (Kulmatycki 1932). The sturgeon ascending the Vistula River migrated as far as the Dunajec and San rivers, while in its lower reaches this fish was caught most frequently in the Drwęca, in which descending juveniles were also caught in mass numbers (Grabda 1968). Vistula fishers caught Atlantic sturgeon of lengths of up to 20 cm in the autumn period sporadically (Kulmatycki 1932). Juvenile Atlantic sturgeon were also caught in Baltic coastal waters, and one of the last individuals of natural origin (TL 385 mm, W 255 g) was caught near Jurata in 1965 (Grabda 1968).

Evaluating the environmental state of rivers which sturgeon would likely ascend for spawning is part of the Atlantic sturgeon restoration program. The status and availability of the habitats necessary for sturgeon spawning have been assessed most completely in the rivers of the Oder River basin (Gessner and Bartel 2000, Arndt et al. 2006). The passability of rivers and the accessibility of potential spawning grounds has also been assessed in the Vistula drainage basin (Wiśniewolski and Engel 2006), and a series of telemetry studies were performed to provide an understanding the patterns of descending rivers and habitat used of hatchery-reared juvenile Atlantic sturgeon (Kapusta et al. 2008, 2011). Telemetry studies provide information about the life histories of single individuals, while studies using external tags help to determine the distribution and growth of juvenile Atlantic sturgeon. Identifying patterns of distribution and the growth of juvenile sturgeon in the Baltic Sea are crucial steps in restoring the population of this species in Europe. The current paper presents the distribution and characterizes the growth and catches of sturgeon released into the Drwęca and Wisłoka rivers.

Materials and methods

The study materials comprised fish cultured at the Department of Sturgeon Fish Breeding, Inland Fisheries Institute in Olsztyn and the Hatchery for Stocking Material of the Polish Angling Association in Toruń. Eyed-egg stage larvae obtained from the artificial reproduction of wild spawners from the St. John River were imported to Poland. They were reared in tanks that were part of recycling systems and initially fed with Artemia sp. nauplii, followed by commercial feeds. The smallest sturgeon (body weight <10 g) were not tagged, but the larger fish were tagged with external Carlin tags prior to release. The age of the juvenile Atlantic sturgeon released into the rivers ranged from 4 to 19 months, at a total length range of 138 to 840 mm, and a body weight range of 11.7 to 3790 g. The fishes were anesthetized before tagging with Propiscin (IFI Olsztyn). The tags were attached to the base of the dorsal fin with a stainless steel wire. All of the fish were measured (± 1 mm) and weighed (± 0.1 g). After tagging, the fish were held for at least a few days in their tanks during which time their condition and tag attachments were observed. Stocking was performed either in spring or autumn in the 2007-2010 period in two different rivers (Table 1). A total of 2,214 juvenile Atlantic sturgeon were tagged.

Table 1
Details of stocking juvenile Atlantic sturgeon

River	Drwęca	Wisłoka
Years	2006-2010	2009-2010
Number of release sites	3	2
Type of stocking material released	larvae, juvenile	juvenile
Number of tagged fish released	2097	117
% of returns	3.15	0.85

Monetary rewards (50 PLN=15 USD) were offered for reports of information regarding catches of tagged sturgeon. Those who returned tags accompanied by full information including fish total length, weight, and the date, location (geographic position and fishing grounds), and type of gear used to make the catch received the full reward amount. Incomplete information was rewarded with half of the full amount. The information could be collected from live fish; it was required to measure the fish, record the tag number, and preferably document the catch with a photograph. Only two Atlantic sturgeon were caught twice, while the rest were caught only once (most were dead).

The information collected regarding fish length and weight and place and date of catch was analyzed. The Surfer 8 program (Golden Software Inc.) was used to analyze the location of sturgeon catch sites. Smoothing was applied to obtain an isoline map on which dark gray signified areas where juvenile Atlantic sturgeon were caught most frequently in the Gdańsk Bay. Among the sturgeon released into the Drwęca, two experimental groups were identified with respect to the season (spring and autumn) when stocking was performed and the age of the fish released (11 or 4 months). These fish were analyzed in detail. The non-parametric Mann-Whitney U test was applied to compare the total length of Atlantic sturgeon during tagging and after catch, the daily growth rates (DGR), and the period between fish release and recapture (RP). In most instances, the data characterizing the location, time, and size of the fish caught was incomplete. The body weights reported were approximate, which the analysis of sturgeon growth only included the calculation of DGR. Pearson's correlation of absolute growth of total length and the number of days between fish release and recapture (RP) was also performed.

Results

Information was obtained from 67 sturgeon caught, among which 66 originated from stocking in the Drwęca River. Atlantic sturgeon were caught most frequently with flounder nets in the Gdańsk Bay and the mouth of the Vistula River (Fig. 1). Single individuals were caught in the Włocławskie Reservoir, the lower Vistula River, the Baltic Sea, and the Gdańsk Bay, where the most abundant catches were noted in the vicinity of the Vistula mouth and to the east near

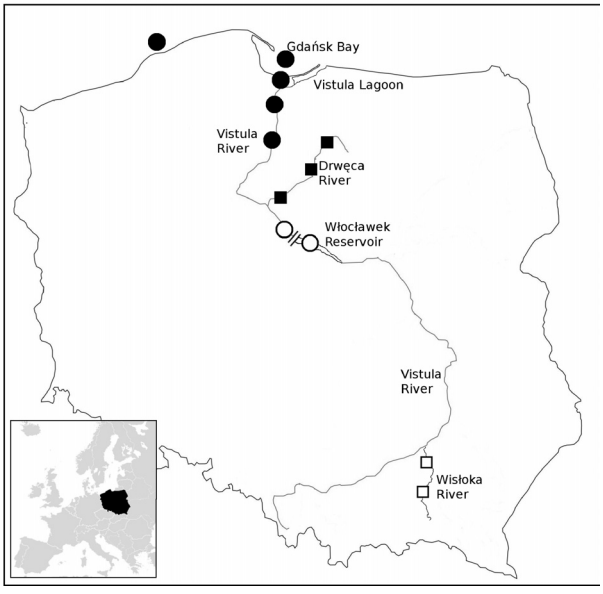

Figure 1. Location of release site (squares) and catch (dots) of juvenile Atlantic sturgeon released into the Drwęca (black) or Wisłoka (white) rivers.

Table 2
Description of juvenile sturgeon fitted with Carlin tags released into the Drwęca River (mean ± SD). Experimental groups – spring (11-month-old fish) and autumn (4-month-old fish) – determined based on fish age and release period. DGR – daily growth rate (mm d^{-1}); RP – period between fish release and recapture dates (d). Variables in the same column with the same letter index do no differ significantly statistically (P>0.05)

Experimental group	Spring	Autumn
Number of fish released	684	340
Age (months)	11	4
% of returns	4.5	4.7
Total length (mm)	474 ± 90.5^{a}	181 ± 18.6^{b}
Total length of fish caught (mm)	561 ± 61.5^{a}	548 ± 78.3^{a}
DGR (% d^{-1})	0.08 ± 0.06^{a}	0.11 ± 0.01^{b}
RP (d)	177 ± 140^{a}	362 ± 139^{b}

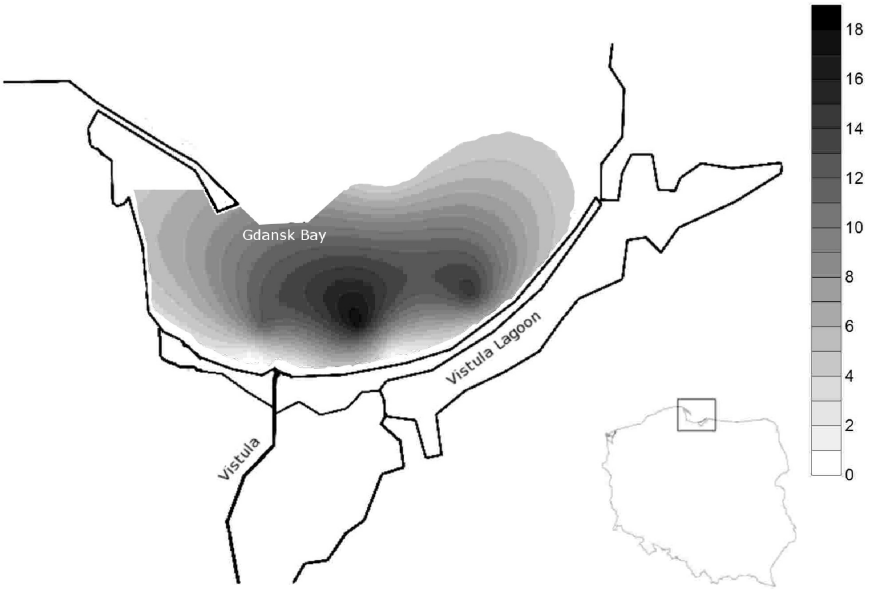

Figure 2. Location of most frequent catches of juvenile Atlantic sturgeon in the Gdańsk Bay. Black outline presents the highest concentration.

Jantar and Krynica Morska (Fig. 2). To the west, juvenile Atlantic sturgeon were caught most frequently near Sobieszewo Island and less frequently near Northern Port in Gdańsk. The fish were caught from March to December, with two periods of substantially higher catches noted in July and October (Fig. 3).

The period of time between fish release and recapture ranged from 10 to 664 days. The sturgeon released in June (spring) were caught on average after 177 days (Table 2). However, the RP of smaller, younger Atlantic sturgeon released into the Drwęca in autumn was statistically significantly longer (P<0.05) at a mean of 362 days. The total length of fish caught in the two experiments was not statistically significant (P>0.05). As the length of the period between the release of sturgeon into the Drwęca and recapture increased, so did total fish length growth (Fig. 4). Simultaneously, juvenile Atlantic sturgeon released in autumn exhibited higher DGR values in comparison to older fish released into the Drwęca in June (Table 2). No statistically significant correlations were confirmed between DGR and RP (P>0.05).

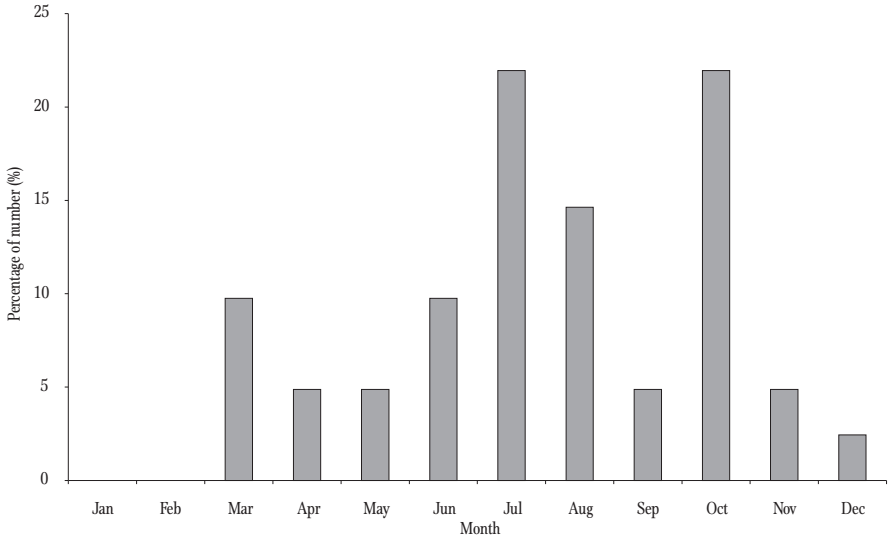

Figure 3. Monthly catch statistics for juvenile Atlantic sturgeon.

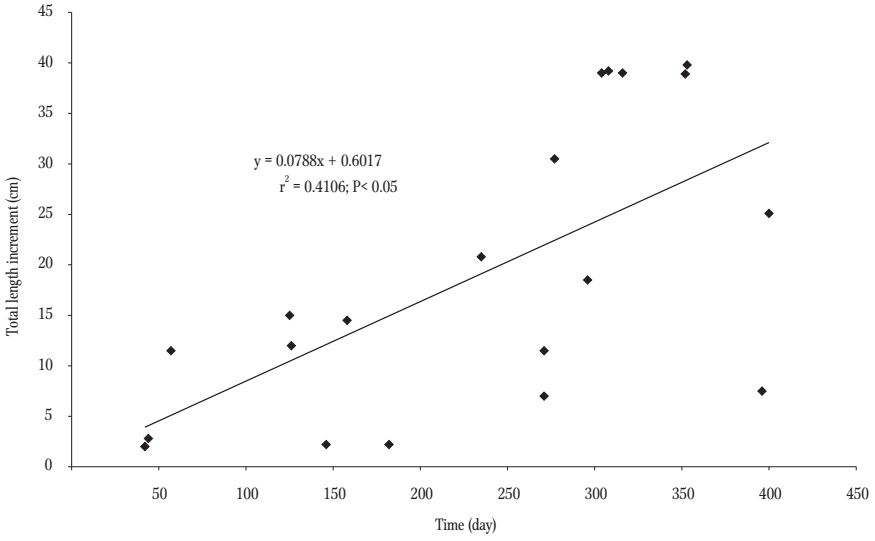

Figure 4. Dependency between the period spent in open waters and the absolute total length growth of juvenile Atlantic sturgeon released into the Drwęca.

Discussion

The information obtained after the Atlantic sturgeon were recaptured referred to a scant 3% of the tagged fish released. However, information collected from fishers working the Vistula River mouth and Gdańsk Bay suggest that Atlantic sturgeon were caught more frequently in this region than was indicated by tag returns. The Atlantic sturgeon is under a year-round protection period, which might be why fishers were reluctant to report accidental catches of these fish. As in the case with salmonids, tag returns represent an insignificant portion of the fish caught (Bartel et al. 2010), and without programs to educate citizens about returning tags then the share of returns will be even smaller. Gessner et al. (2008) obtained a much higher percentage of information from tagged fish released into the Oder River basin. They also reported that as distance from the institution collecting information increased, the number of reports of caught

sturgeon decreased. Additionally, the number of sturgeon captured again was significantly higher than in the case of fish released into Vistula drainage.

Telemetry studies have indicated that Atlantic sturgeon usually remain in the Drwęca from 2 to 5 weeks (Kapusta et al. 2009, Kolman et al. 2011). The fish spent the rest of the time in either the Vistula or the coastal waters of the Baltic. Juvenile Atlantic sturgeon were caught most frequently in the Gdańsk Bay and the mouth of the Vistula, while there were sporadic reports of fish being caught in the lower Vistula, the Vistula Lagoon, and in the southern part of the Baltic Sea. Atlantic sturgeon catches in the Gdańsk Bay are certainly more frequent than was indicated by tag returns. Fishers and employees of local ports reported frequent catches of sturgeon measuring from 70-80 cm and weighing 14 kg, which were marketed for sale mainly as smoked fish.

The North American population of Atlantic sturgeon migrate and select different habitats in river estuaries and coastal waters of the Atlantic throughout the year (Lazzari et al. 1986, Fernandes et al. 2010). The population that naturally inhabited the Baltic Sea was not known to exhibit similar behavior patterns; however, the rivers which sturgeon ascended for spawning do not form similar estuaries, and the salinity of the Baltic is significantly lower (Meier and Kauker 2003). The results presented here indicate that seasonal habitat change and associated migration can also occur among juvenile Atlantic sturgeon released into rivers flowing into the Baltic Sea. Most of the juvenile Atlantic sturgeon in the Oder River basin were caught in October, and stocking was performed from May to November (Gessner et al. 2008). Catches of Atlantic sturgeon released into the rivers of the Vistula basin were distinguished by distinct seasonality. During the year, significantly larger numbers of Atlantic sturgeon were caught in July and October for a combined total of 44% of the fish caught. No sturgeon catches were noted in January or February. There is a lack of data regarding the intensity of catches in this region; however, it can be assumed that the lack of reported catches in January and February could have been caused by lower fishing intensity because of weather conditions. During these months, the waters of the lower Vistula and Gdańsk Bay are covered with ice.

There is little information regarding the size of juvenile Atlantic sturgeon caught by fishers. Secor et al. (2000) concluded that most juvenile Atlantic sturgeon caught by fishers working the Chesapeake Bay depended on the gear deployed and was either 61 or 66 cm. Growth rates for juvenile Atlantic sturgeon in released into rivers in the Vistula drainage (0.19-2.02 mm day^{-1}) are generally consistent with growth rates from other systems. Armstrong and Hightower (2002) reported a growth rate equivalent to 0.59-0.81 mm day^{-1} for Albemarle Sound, compared with 0.57 for juveniles in the Delaware River (Lazzari et al. 1986), and 0.34 for ages 1 and 2 fish from the Hudson Estuary (Dovel and Berggren 1983). The results presented in this paper indicate that the mean sizes of the fish caught were similar in both experiments. This suggests that the gear used by the fishers in the coastal waters of the Gdańsk Bay were selective with regard to sturgeon measuring more than about 55 cm. Smaller, younger fish released in the autumn achieved such sizes in the year following release and were caught mainly in October. However, the larger specimens released during the spring were caught more regularly throughout the year, but usually in July of the same year or in March of the year following stocking. In the Gdańsk Bay, fishers caught Atlantic sturgeon mainly in flounder nets, while in the lower Oder and the Szczecin Lagoon these fish were caught in fyke-nets and gillnets (Gessner et al. 2008). In the Chesapeake Bay juvenile Atlantic sturgeon were fished mainly with driftnets or fyke-nets (Secor et al. 2000). The current study indicated that sturgeon are susceptible to being caught with various types of gear although most of them are caught by gears deployed in the benthic zone. A modification to gillnets was made that placed a window between the weighted line and the net which guaranteed limited by-catches of sturgeon (Gessner and Arndt 2006).

Atlantic sturgeon were caught mainly in the mouth of the Vistula River and in the Gdańsk Bay. The current study indicates that the size of the fish released had an impact on the on the daily growth rate

of total length and the time period between release and recapture. The mean period from release to recapture ranged from 177 to 362 days. The absolute growth of juvenile Atlantic sturgeon increased the longer the fish spent in open waters; however, this had no impact on the daily growth rate of body length. Tagging juvenile sturgeon is a useful study tool, but the low returns require organizing community information programs to raise awareness about fish tagging.

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Streszczenie

Rozprzestrzenianie się i wzrost juwenalnych jesiotrów ostronosach wpuszczanych do Drwęcy i Wisłoki (Polska)

Jesiotr ostronosy *Acipenser oxyrinchus oxyrinchus* Mitchill od wielu lat uważany jest za gatunek wymarły w Morzu Bałtyckim. Wykorzystując ryby wyhodowane w warunkach akwakultury w zlewni Wisły od 2006 roku realizowany jest projekt restytucji tego gatunku. W pracy przedstawiono dane dotyczące rozprzestrzeniania juwenalnych jesiotrów ostronosych wpuszczanych do Drwęcy i Wisłoki (zlewnia Wisły). Zwrot znaczków pochodzących ze znakowanych juwenalnych jesiotrów ostronosych był mały i wynosił 3,15% w przypadku ryb wpuszczanych do Drwęcy oraz 0,85% ryb wpuszczonych do Wisłoki. Na podstawie informacji uzyskanych z zarybień Drwęcy przeprowadzono analizę rozmieszczenia i wzrostu juwenalnych jesiotrów ostronosych. Jesiotry najczęściej łowione były w Zatoce Gdańskie i ujściowym odcinku Wisły. Poławiano je od marca do grudnia, z dwoma okresami znacznie liczniejszych odłowów odnotowanych w lipcu i październiku. Wielkość wpuszczanych ryb miała wpływ na dobowe tempo wzrostu długości całkowitej oraz czas, jaki upłynął od zarybienia do złowienia ryb. Średnio od zarybienia do złowienia upłynęło od 177 do 362 dni, minimalnie wynosząc 10 dni a maksymalnie 664 dni. Wraz z długością przebywania w wodach otwartych wzrastały bezwzględne przyrosty juwenalnych ryb, natomiast nie miało to wpływu na dobowe tempo wzrostu długości ciała.