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MIGRATORY BEHAVIOR OF YOUNG STURGEON, *ACIPENSER OXYRINCHUS* MITCHILL, IN THE ODER RIVER DRAINAGE. PRELIMINARY RESULTS OF A RADIO TELEMETRIC STUDY IN THE DRAWA RIVER, POLAND

Frank Fredrich, Andrzej Kapusta**, Markus Ebert***, Arkadiusz Duda**, Jörn Gessner****

*Society to Save the Sturgeon e.V., Rostock, Germany
**Department of Ichthyology, The Stanisław Sakowicz Inland Fisheries Institute in Olsztyn, Poland
***Department of Biology and Ecology of Fishes, Institute of Freshwater Ecology and Inland Fishery, Berlin, Germany

ABSTRACT. The movements of individual juvenile sturgeon, *Acipenser oxyrinchus* Mitchill, during their first stage of downstream migration were observed in the Drawa River, Poland. Two groups of 10 sturgeon each (9 months old, reared in closed recirculation systems) were tagged with internal radio-transmitters. The first group of sturgeon (119-184 g) were tagged with Holohill BD-2N transmitters (weight 0.43 g, operational life 14d) and released on May 7. Fish from the second group (143-206 g) were tagged with BD-2 (weight 1.2 g, operational life 56d) and were released on May 24. The releases took place in the Drawa River below Kamienna Dam, 33 km upstream from the river's confluence with the Noteć River. All of the fish moved downstream, but migration speeds differed. Seven sturgeon from the first group reached the confluence with the Noteć River, approximately 30 km downstream from the release site, during the first 18 days, which indicated there had been staging intervals in pools. Within four days, six fish from the second group had moved downstream the Drawa River and were located 20 km downstream from the confluence with the Noteć River. The downstream migration speed of the fish correlated with fish size and increased with water temperature.

Key words: MOVEMENT, INDIVIDUAL BEHAVIOR, HABITAT, STURGEONS

INTRODUCTION

The population size of the Baltic sturgeon has decreased severely since the middle of the twentieth century because of overfishing, water pollution, and habitat loss (Mamcarz 2000). The last occurrence of this species in the Oder River was recorded in 1964 near the mouth of the Dziwna River (Kraczkiewicz 1967). The restoration of Bal-

CORRESPONDING AUTHOR: Frank Fredrich, Society to Save the Sturgeon e.V., Fischerweg 408, 18069 Rostock, Germany, Tel. +49 3362 29097; e-mail: frank.fredrich@exmail.de

tic sturgeon is utilizing *Acipenser oxyrinchys* Mitchill of Canadian origin based on genetic and morphological characters (Ludwig et al. 2002).

The Oder River catchment was selected for the remediation effort, because most of the river as well as at least 50% of the historic spawning sites are freely accessible (Gessner and Bartel 2000). The spawning grounds in the Oder River drainage were located in the Oder, Prosna, Warta, Gwda, and Drawa rivers (Bartel et al. 2006). The only tributary which currently meets the postulated requirements for a sturgeon spawning habitat is the Drawa River. In all other tributaries with historic spawning sites, the substantial impact of pollution and engineered constructions reduces their suitability (Arndt et al. 2006).

Radio-tracking is used widely in studies of fish movements and behavior (Lucas and Baras 2000, Hodder et al. 2007). One of the experimental prerequisites for the effective remediation of the species in this river drainage was a telemetry study. It was initiated in 2006 in the Peene River, a tributary to the Szczecin Lagoon, and was continued in 2007 beginning in the Drawa River and following the migrating sturgeon to the lower part of the Oder River. The aim of the study was to evaluate movement patterns of juvenile *A. oxyrinchus* in the Drawa River. The study focused on the migratory behavior and habitat utilization of juvenile sturgeon in the upper segment of their migration to the sea.

MATERIALS AND METHODS

STUDY AREA

The Drawa River is situated in the western part of Polish Pomerania. It is 199 km long and its drainage covers 3198.4 km^2. The Drawa River flows into the lower Noteć River near Krzyż. From Lake Dubie to the mouth of the left bank tributary Płociczna, the Drawa River runs for 39 km through the Drawieński National Park (DNP). A dam and hydroelectric power plant disrupt the flow in Kamienna 33 km upstream from the river mouth.

The Drawa River has retained much of its natural character especially within the DNP. It flows through dense forest and meadows, especially in its lower part. The Drawa River has a mean slope of 0.7‰ and a mean flow of 20.0 m^3 s^{-1}. The river width varies between 20 and 90 m, and the average depth is 1.5 m (Chełkowski et al. 1996). The current speed is quite diverse and reaches 1.5 m s^{-1} in in the lower part of the river. The banks are very diverse from steep precipices to gentle slopes. The river bottom structure is dominated by flat sections alternating with banks and deeper holes. The substrates are mostly sand with gravel and stone areas. In open reaches large areas of diverse macrophytes are observed. Woody debris provides structural diversity in the river. During the tracking period, the water temperature ranged from 13 to 15°C and the oxygen concentration varied between 8.7 and 13.1 mg l^{-1}. The conductivity upstream of Krzyż was less than 0.400 μS cm^{-1}, and near the mouth it was about 0.660 μS cm^{-1}.

There are 23 fish species in the part of the Drawa River within the DNP but only 13 species below the dam in Kamienna (Chełkowski et al. 1996). Dębowski et al. (2000) noted 27 species in the section of the Drawa River that flows through DNP, but 23 species below the dam in Kamienna. The fish community is dominated by roach, *Rutilus rutilus* (L.) (56% of total catch), burbot, *Lota lota* (L.) (7.8%) bream, *Abramis brama* (L.) (6.9%), silver bream, *Blicca bjoerkna* (L.) (6.2%), and perch, *Perca fluviatilis* L. (6.0%) (Chełkowski et al. 1996). Seasonally, salmon, *Salmo salar* L., and brown trout, *Salmo trutta* L., as well as eel, *Anguilla anguilla* (L.), and 12 rheophilic and four limnophilic species occur.

EXPERIMENTAL DESIGN

In May 2007 two groups of 10 young-of-the-year (YOY) sturgeon each were tagged with internal radio-transmitters. The sturgeon were nine months old and had been reared in a closed indoor recirculation system with temperature control prior to tagging. Sturgeon from the first group (30-36 cm in length and 119-184 g body weight) were tagged with BD-2N transmitters (Holohill, Canada) (weight 0.43 g, operational life 14 days) on May 3 and released on May 7 into the Drawa River below the Kamienna Dam (Fig. 1). The fish from the second group (34-37 cm in length and 143-206 g body weight) were tagged with BD-2 (weight 1.2 g, operational life 56 days) on May 21 and were released on May 24 at the same place as the first group. The fish were anesthetized with a 0.2 g l^{-1} solution of MS-222 during the tagging procedure. Radio-transmitters with external antennae were implanted into the body cavity through a 2 cm incision located approximately 3 cm behind the base of the pectoral fins. The transmitter antenna was led through the body wall laterally with a 15 cm needle. The incision was closed up with two individual stitches 10 mm apart using 4/0 Polyamide non-resorbing sutures (Supramid®, USA).

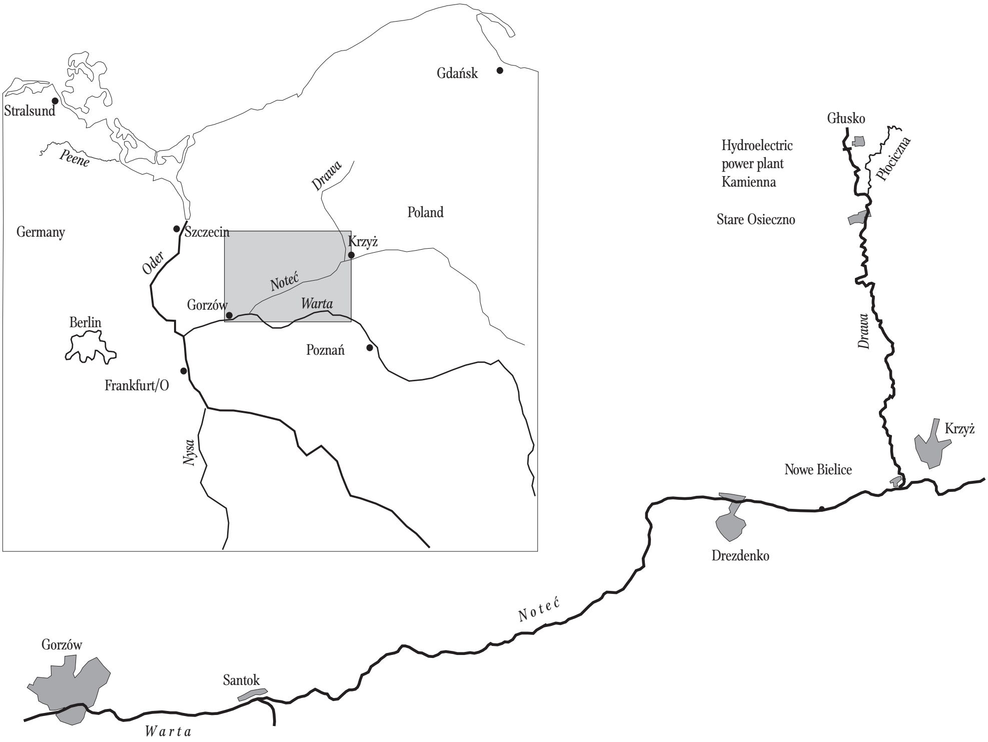

Fig. 1. Map of study area.

Additionally, all fish were tagged with yellow Floy T-bar anchor tags with four-digit number below the dorsal fin to enable any fishermen capturing a sturgeon to identify the individual. The radio-telemetric equipment was supplied by LOTEK (Canada). An SRX-400 receiver was used with the pulsed radio transmitters (Table 1), while hand held Yagi-antennas (three to five elements) were used for manual tracking from the boat. The last three digits of the frequencies of the pulsed tags were used to designate the individual sturgeon.

Fish were hand-tracked once per day throughout their migration in the Drawa River. After entering the Noteć River tracking was performed once per week. Stationary tracking was impossible because of the incompatibility of Lotek's receiver software with the transmitters from Holohill.

TABLE 1

Data on sturgeon stocking material with length and weight as well as tag type and frequency

Date of tagging	Length (cm)	Body weight (g)	Type of radio- transmitter	Frequency MHz	Floy-tag No.	Date of release
Group 1	33	113	BD-2N	154.057	2011	07/05/07
03/05/07	34	166		154.078	2021	
	36	184		154.097	2013	
	32	154		154.137	2014	
	32	153		154.158	2015	
	34	165		154.178	2016	
	34	168		154.199	2017	
	30	119		154.217	2018	
	34	163		154.238	2019	
	33	143		154.257	2020	
Group 2	37	205	BD-2	154.279	2208	24/05/07
21/05/07	37	201		154.301	2207	
	37	206		154.322	2206	
	36.5	180		154.340	2205	
	37	202		154.360	2204	
	34	143		154.398	2203	
	36	182		154.440	2202	
	36	170		154.471	2201	
	37	196		154.489	2200	
	35	173		154.511	2199	

Positions were recorded with a H20-GPS receiver (Lowrance, USA), to within a 10 m range. Later continuous tracking experiments in the Noteć, Warta, and Oder rivers revealed that sturgeon moved in spring and summer only during darkness and interrupted migration during daylight (unpubl. data). Based on average day length, an activity period of 9 hours was calculated for the first group and of 8 hours for the second group. The estimation of the activity periods took into consideration the low light intensity in the dark forest along the banks of the Drawa River. Direct tracking of moving sturgeon was not possible because of the limitations river morphology imposed on boating. Therefore, the calculated speed is based on the net distances covered per day.

RESULTS

MIGRATORY BEHAVIOR

During the first 6 hours upon release in the early afternoon, the sturgeon moved either 40 m upstream or 340 m downstream of the release point. With the onset of darkness, they started to move farther downstream. On the first morning after release, all the fish of both groups had left the release site. They were tracked between 1,050 and 18,815 m downstream from the release point (Figs. 2 and 3). Seven fish from the first group and six fish from the second group moved less than 5 km downstream, whereas the quickest sturgeon moved 16,350 m (first group) and 18,815 m (second group) (Figs. 2 and 3). During the second day, seven sturgeon from group 1 moved downstream from 1.5 to 6.5 km with a mean migration distance of 3.34 km. Sturgeon no. 238 was already outside the tracking area, more than 27.6 km downstream from the release point, on day two following release. In comparison, eight sturgeon from the second group moved much quicker (between 3.4 and 19.54 km) than did the fish from the first group. A second batch fish of both of the groups revealed a different migration pattern. One fish from group 2 moved 250 m upstream and four fish (three from group 1 and one from group 2) stopped or moved very slowly (10-400 m). On the third day the differences in downstream migration between groups 1 and 2 persisted with only three individuals from group 1 (9.88 to 17.2 km) but seven from group 2 (5.25 to 34.915 km) moving quickly downstream and four of them entering the Noteć River (Fig. 2). One sturgeon per group moved slowly (1.2 km) and three (group 1) and two (group 2) individuals interrupted their migrations. Sturgeon no. 257 from group 1 went missing on the third day, probably because of very weak transmitter signals.

Group 1 sturgeon were not tracked on the fourth day due to technical problems. Only sturgeon no. 217 was tracked from the bank at the same site as on the previous days. Sturgeon 137 and 158 probably entered the Noteć River. Three sturgeon from group 2 (no. 360, 398, 440) followed on the fourth day after release. Altogether, four days after release, three sturgeon from group 1 and seven sturgeon from group 2 moved into the Noteć River.

Finally, sturgeon no. 97 and no. 178 from group 1 and sturgeon no. 158 from group 2 also entered the Noteć River. In total, 11 days after release five sturgeon from the first group and eight from the second group had left the Drawa for the Noteć River and continued to move downstream there. The daily distances moved in both rivers did

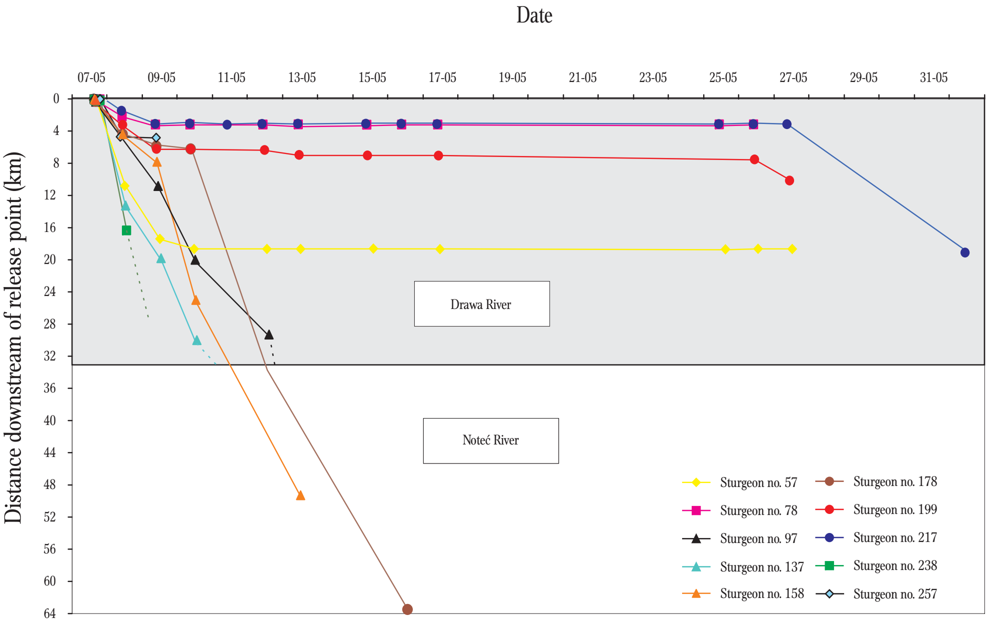

Fig. 2. Downstream migration of sturgeon of the first tracking group from May 7 to June 1 in Drawa and Noteć rivers .

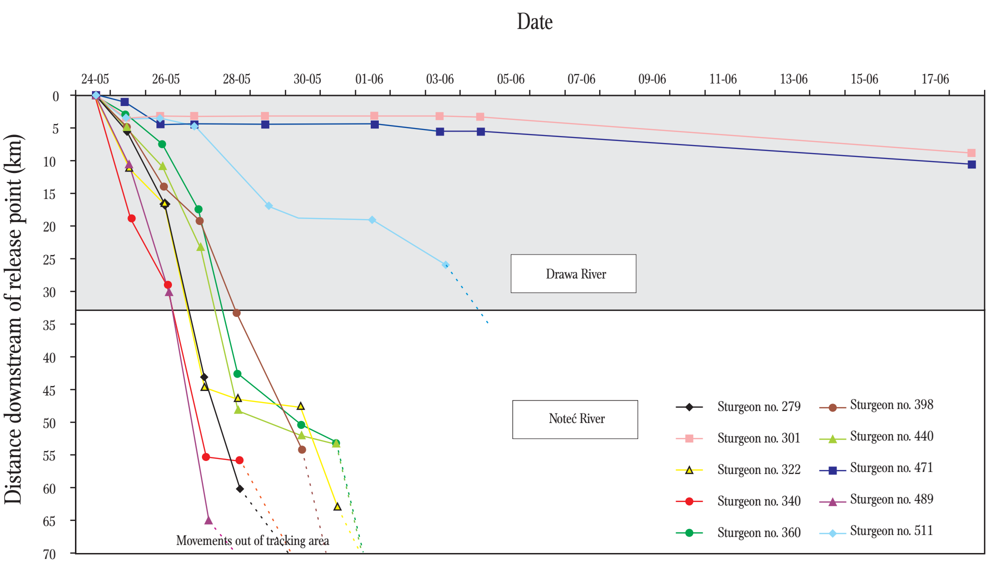

Fig. 3. Downstream migration of sturgeon of the second tracking group from May 24 to June 18 in Drawa and Noteć rivers.

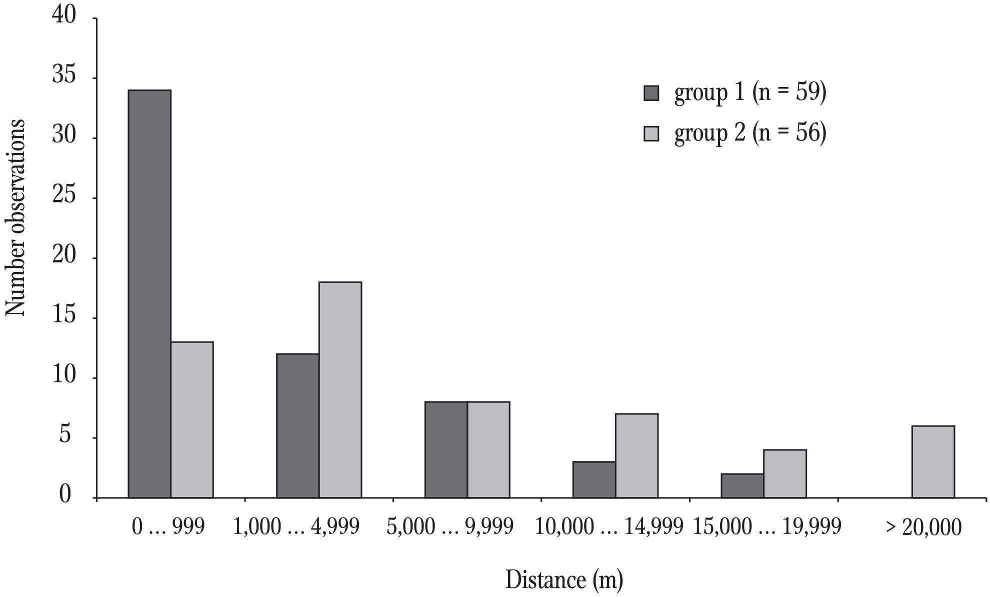

Fig. 4. Absolute number of grouped net distances moved by radio-tagged sturgeon of group 1 and 2 per day classified over all fish.

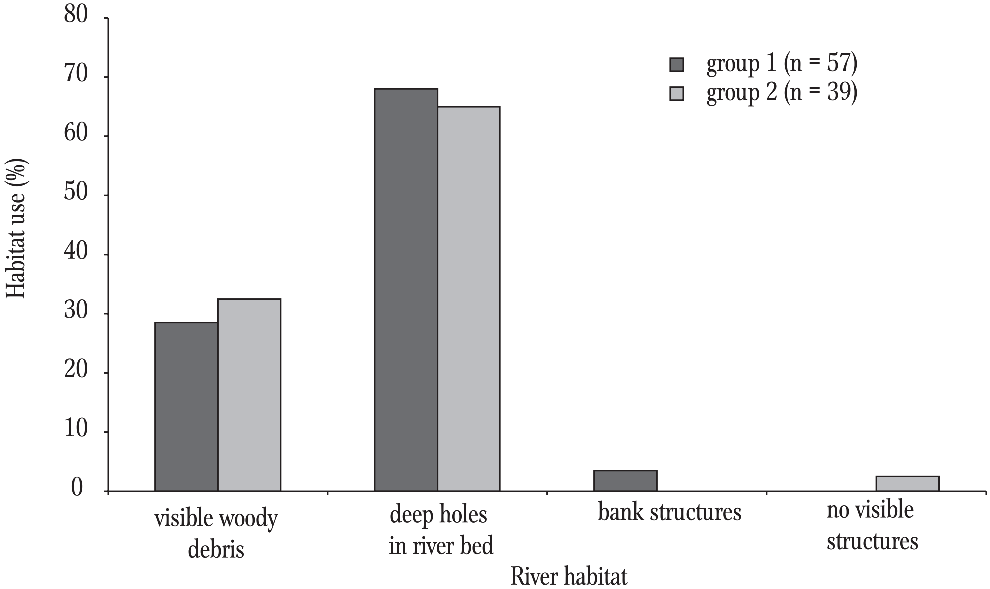

Fig. 5. Relative habitat use of juvenile sturgeon in the Drawa River during May and June 2007.

not differ. The longest distance moved per day (sturgeon no. 489) was 34.9 km, 2.9 km in the Drawa River and 32 km in the Noteć River. Four sturgeon from group 1 did not leave the Drawa River throughout the tracking period, and utilized different river stretches of about 200 m in length. During the last period of transmitter activity, two of the fish moved 2.6 (no. 199) and 17.3 km (no. 217) downstream. Two sturgeon from group 2 stayed in confined areas 100 m in length in the Drawa River until the end of tracking. Only during the last days of tracking in the Drawa River did they move 5.64 (no. 301) and 5.01 km (no. 471) downstream. The larger sturgeon from group 2 were less stationary and moved longer net distances per day downstream (Fig. 4) than did the smaller fish from group 1.

SWIMMING SPEED

The fish released at the Kamienna Dam exhibited a significant pattern of downstream movement. Some sturgeon that moved slowly migrated at maximum speeds of 0.15 and 0.17 m s^{-1} for the first and second group of fish respectively (up to 5 km day^{-1}). The sturgeon that migrated at a medium speed (0.31 and 0.35 m s^{-1}) moved up to 10 km per day. The maximum swimming speed in the first group was 0.53 m s^{-1} or 1.5 body lengths (BL) s^{-1}, while the quickest sturgeon from the second group moved at 1.21 m s^{-1} or 3.3 BL s^{-1}.

HABITAT USE

During daylight, the sturgeon used different structures in the rivers, and they never left the main channel to move into tributaries or backwaters. There are no differences in bank structure use between the two tracking groups. Sturgeon from both groups preferred deep holes in the river bed for prolonged stationary phases during daylight (Fig. 5). In approximately 60% of all the tracking events, the sturgeon stayed in deep holes in the river bed. Visible barriers contributed almost 30% of all the fixes. In only two cases were the sturgeon located close to bank structures, and only once was a place without visible structures utilized during daytime.

DISCUSSION

Little is known about the ecology of juvenile Atlantic sturgeon, but even less is known about the behavior of juvenile sturgeon in small-scale tributaries like the Drawa

River. While in North America and Russia different sturgeon species spawn in the upper and middle parts of large rivers (Votinov and Kas'yanov 1978, Sulak and Clugston 1999, Johnson et al. 2006, Hatin et al. 2007), the historical spawning grounds in the Oder River drainage were also situated in smaller tributaries like the Drawa River. Early juveniles stay in the downstream reaches of the rivers for two to six years (Dovel and Berggren 1983, Bain et al. 2000). Hatin et al. (2007) observed the first excursions into slightly saline waters at age 2 in the St. Lawrence River. Rochard et al. (2001) reported that juvenile *Acipenser sturio* L. spent about two years in brackish estuarine water before moving to the open sea. The majority of juvenile sturgeon released in the Peene River 50 km upstream from its mouth into the Szczecin Lagoon moved immediately downstream into the lagoon (salinity 0.5-2‰). Only one sturgeon was captured close to the Baltic Sea (local salinity 8‰) in the mouth of the Świna River (Fredrich and Gessner 2007).

The juveniles used in the telemetry experiment were quite large their size resembled that of 2-year-old fish from natural recruitment. Therefore it is reasonable to assume that there were no secondary effects. In tracking experiments with juvenile Atlantic sturgeon in the St. Lawrence estuarine transition zone, Hatin et al. (2007) were successful in using sonic transmitters with a relative weight of 0.9 to 2.5% of fish weight. Other authors observed no effects on growth or fish behavior with transmitters smaller than 1.6% (Ross and McCormick 1981, Lucas 1989, Baade and Fredrich 1998), 2.5% (Thoreaux and Baras 1996), or even 5% (Schulz and Berg 1992). In telemetric studies it is important to know if tagging disturbs the behavior of the fish. Based upon the results of the studies listed above, it is assumed there were no significant tagging influences on fish behavior. The transmitters were smaller than 0.38% (group 1) and 0.84% (group 2) of individual fish body weight. All tagged sturgeon recovered from tagging in about 10 minutes. Two sturgeon recaptured during the current experiment looked well and were in good condition with well healed incision scars after two months. Immediately after release, the radio-tagged sturgeon behaved like untagged sturgeon of the same size released at the same time and place.

During daylight, juvenile sturgeon of all sizes used deep holes in the middle of the Drawa and Noteć rivers or close to erosion banks in about 95% out of all locations. The depth of these holes was between 3 and 5 m, which was the maximum depth in the stretches of river. Hatin et al. (2007) used a habitat selection model to show that age-2 sturgeon in the St. Lawrence Estuary preferred intermediate water depths of 6-10 m with a range from 0.5 to 15.8 m, and avoided depth strata deeper than 20 m. In the Hudson and Delaware estuaries, early juvenile sturgeon used deep channel habitats of 10-25 and 6-16 m, respectively (Lazzari et al. 1986, Bain et al. 2000).

In the current experiment, the majority of fish from both groups left the Drawa and Noteć rivers within days. Immediately upon release, five fish from group 1 and eight from group 2 started a quick downstream migration in the Drawa and Noteć rivers. Food availability or habitat quality in general might have been driving forces indicating the limited suitability of streams like the Drawa River for the size or number of fish released. The fact that six sturgeon did not move or only moved very slowly for a substantial portion of the tracking period indicates the wide variation in behavior of the juvenile sturgeon. These fish found acceptable habitats for at least a month even in these small rivers.

Sturgeon movement rates have been reported to increase with age, and the daily distances covered by age-2 sturgeon were influenced by fish size (Smith and King 2005). Accordingly, the sturgeon from group 2, which were about 16% heavier than those from group 1, had fewer stationary fish and moved longer net distances per day (Fig. 4). The maximum migration distances were 17.2 km (group 1) and 34.9 km (group 2) per day. The resulting maximum swimming speeds were 1.9 km h^{-1} (group 1) and 4.4 km h^{-1} (group 2). Differences in temperature or current velocity between the groups were not observed. The length of the fish revealed that the maximum swimming speed in each group only differs by 5 cm (18%). The results do not concur with those of Peake et al. (1997), who reported that sturgeon swimming performance increases with total length. Hatin et al. (2007) reported a daily movement rate of 4 km d^{-1} on average for age-2 Atlantic sturgeon in the St. Lawrence Estuary.

The current results constitute the first data of a telemetry experiment with YOY Atlantic sturgeon in such a small river. Considering the rapid out migration and the low number of stationary fish, it is concluded that even the smallest fish tagged were too large to inhabit the upstream reaches of the rivers close to the spawning sites. This observation concurs with data from other studies (Bain et al. 2000, Hatin et al. 2007). It is highly probable that the Drawa River does not meet the requirements of juvenile sturgeon larger than 30 cm. The higher residency in fish below 30 cm indicates that this might be a threshold for the riverine phase. In general, telemetric studies with very small fish, particularly in deep natural rivers, are still difficult.

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STRESZCZENIE

BEHAWIOR JUWENALNYCH JESIOTRÓW, *ACIPENSER OXYRINCHUS* MITCHILL W CZASIE WĘDRÓWKI W ZLEWNI ODRY. WSTĘPNE WYNIKI BADAŃ RADIOTELEMETRYCZNYCH W DRAWIE, POLSKA

Obserwowano przemieszczanie się juwenalnych jesiotrów *Acipenser oxyrinchus* Mitchill w ciągu ich pierwszego etapu migracji w dół rzeki Drawy. Dwie grupy po 10 jesiotrów (9-miesięczne ryby podchowywane w zamkniętym obiegu wody) zaopatrzono w wewnętrzne nadajniki radiotelemetryczne. Jesiotry pierwszej grupy (masa ciała od 119 do 184 g) z nadajnikami BD-2N (Holohill, Kanada) (waga 0,43 g, przeciętny czas działania 14 dni) wypuszczono do rzeki 7 maja. Ryby z drugiej grupy (143-206 g) z nadajnikami BD-2 (waga 1,2 g, przeciętny czas działania 56 dni) wpuszczono do Drawy 24 maja poniżej Elektrowni Kamienna. W trakcie migracji w Drawie ryby lokalizowano ręcznie raz dziennie, natomiast w Noteci raz w tygodniu. Wszystkie ryby przemieszczały się z nurtem w dół rzeki, a tempo migracji poszczególnych osobników było zróżnicowane. Ogólnie dystans 30 km, od miejsca wpuszczenia ryb do ujścia Drawy do Noteci, siedem jesiotrów z pierwszej grupy pokonało w ciągu 18 dni. Sześć ryb z drugiej grupy w ciągu 4 dni od zarybienia spłynęło z Drawy i przemieściło się 20 km od jej ujścia do Noteci. Tempo migracji było dodatnio skorelowane z wielkością ryb i temperaturą wody.