Arch. Pol. Fish. (2011) 19: 95-103
DOI 10.2478/v10086-011-0011-x

RESEARCH ARTICLE

Movement and habitat use of juvenile Atlantic sturgeon in the Wisłoka River (southern Poland)

Received – 17 March 2011/Accepted – 28 April 2011. Published online: 30 March 2011; ©Inland Fisheries Institute in Olsztyn, Poland

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Abstract. The aim of conducting the study was to describe the habitats and the movements of juvenile Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchill, in the Wisłoka River. Radio telemetry methods were used to identify migration rates and the sites where sturgeon stopped during the day. In the 2009-2010 period, 25 juvenile sturgeon equiped with radio telemetry transmitters were released into the Wisłoka; most of them left the river from two to seven days later. In 2009, the sturgeon covered from 0 to 45.3 km, while one year later in 2010 they covered from 0.1 to 54.1 km; the mean migration rates in these two years did not differ significantly statistically (P>0.05). The sturgeon migrated at a mean rate of 0.84 BL (standard body length) s^{-1} in 2009 and at 0.94 BL s^{-1} in 2010. No statistically significant dependence was noted between migration rate and the size of the sturgeon. The sturgeon were most frequently located in areas with slow-flowing waters, and least frequently in riffle. In both habitats, the sturgeon stopped at deep locations most frequently in river channels, depressions formed beneath submerged tree trunks, or in whirl areas. The greatest fraction of bottom sediments in these places was sand (56-58%) followed by gravel (33-35%). The results presented in the present paper indicate that juvenile sturgeon migrate quickly from the Wisłoka to the Vistula rivers.

Keywords: *Acipenser oxyrinchus*, radio telemetry, behavior, habitat, restoration

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Introduction

Understanding habitat requirements and basic migration rules is very important when planning stocking projects and implementing protection measures for threatened fish species. This is especially significant for species of the sturgeon family, *Acipenseridae*, which includes most of the species threatened with extinction (Pikitch et al. 2005). The Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchill, is an anadromous fish that inhabits marine waters but spawns in rivers. It inhabits the Atlantic coasts of North America from Florida to Labrador (Grunwald et al. 2008). Based on the analysis of archeological and genetic materials, it has been determined that this species also inhabited the Baltic Sea basin (Ludwig et al. 2002). This species became extinct in the Baltic sea in the twentieth century (Gessner et al. 2006, Kolman et al. 2008). It was last noted in Poland in the 1960s in the lower course of the Vistula (Kolman 1996), and the last endemic individual in the Baltic Sea was caught off the coast of Estonia in 1996 (Paaver 1999). The main cause of the sturgeon's disappearance was the long-term effects of anthropogenic factors that led to the transformation of aquatic ecosystems (Gessner et al. 2006, Kolman et al. 2011).

The Atlantic sturgeon, *A. oxyrinchus*, was among the largest fish noted in this part of the Baltic Sea drainage. It spawned in the large rivers of the southern Baltic from the Oder to the Neva rivers

(Kulmatycki 1932, Kudersky 1983). Spawning migrations began in the Vistula in March, and spawning began between mid May and the end of July, depending on water temperature (Kulmatycki 1932). In the Vistula catchment area, historic sturgeon spawning grounds were located in several tributaries from the Dunajec to the Drwęca rivers (Wałecki 1864, Grabda 1968), and sturgeon also spawned in the Wisłoka River (Nowicki 1889, Mamcarz 2000). However, *A. oxyrinchus* had become a rare sight in the submontane tributaries of the Vistula River, including in the Wisłoka, by the first half of the twentieth century (Staff 1950). After spawning, the sturgeon swam downstream to the Gdańsk Bay. This was one of the least understood stages of the sturgeon life cycle. The way the sturgeon migrated, particularly in the deepest parts of streams makes observing this behavior difficult as does the catch of young specimens. Both of these factors have contributed to the weak understanding of this element of sturgeon ecology. Advances in radio telemetry methods have enabled researchers to collect a range of data regarding many aspects of fish ecology (Hodder et al. 2007), including that of the sturgeons (Rochard et al. 2001, Heublein et al. 2009). The habitat preferences of juvenile Atlantic sturgeon during the river stage of development is not well understood. In Poland, no studies of this life stage were conducted among the Baltic Sea sturgeon prior to their extinction. Studies of this kind that have been conducted among naturally-spawning North American sturgeon populations focused primarily on migration in the mouths of rivers or in estuaries (Lazzari et al. 1986, Secor et al. 2000, Halin et al. 2007, Fernandes et al. 2010). Monitoring the habitats used by juvenile sturgeon and the characteristics of their migrations are integral elements of the project to restore *A. oxyrinchus* to the Baltic Sea basin (Gessner et al. 2006, Kolman et al. 2011). The aim of the study was to identify the characteristics of the juvenile sturgeon habitats and migrations in the Wisłoka River. Radio telemetry methods were used to determine the rate of migration and to identify the places where the fish stopped during the day.

Materials and methods

The Wisłoka River is a mid-sized river in Poland and one of the largest tributaries in the upper Vistula. The Wisłoka drains a 4110 km^2 catchment and its total length is 164 km. The source of the river is in the Low Beskid Mountains at an altitude of 575 m above sea level, while its mouth is at an altitude of 154 m above sea level. The flow of water in the Wisłoka fluctuates significantly throughout the year. The mean flow at the mouth is 34 m^2 s^{-1}, and fluctuations in water level reach as much as 8 m. The upper course of the river flows through forests, while the mid and lower courses flow through agricultural and populated urban areas. The upper course of the Wisłoka is subjected only to slight anthropogenic pressure which means that water quality and the ecological state of the river are good (WIOS 2010). However, in the mid and lower courses of the river the water is in a poor sanitary state because of bacterial contamination. Barriers on the Wisłoka include six weirs and one dam that forms a reservoir. Despite these threats, the hydrographic diversity of the Wisłoka catchment remains high. Various riparian habitats are found here, and the ichthyofauna is distinguished by high species richness (Włodek and Skóra 1999, Jelonek et al. 2002). In total, 29 fish species were registered in 1994-2001. European chub, *Leuciscus cephalus* (L.), nase, *Chondrostoma nasus* (L.), and barbel, *Barbus barbus* (L.) were the most abundant and frequent species (Jelonek et al. 2002).

Sturgeon habitat preferences and migration were studied in a segment of the lower course of the Wisłoka measuring 58 km from the weir in Dębica to the river mouth near the Ostrówek. The width of the river fluctuated from 30 to 55 m, and depth from 0.5 to 5.0 m. Segments of the river were regulated and the banks were reinforced. The bottom substrate was initially rock-gravel or sand with slight silty sedimentation, while the mouth segment substrate was either silt or sand-silt sediment. The weir at the discharge of the water pipeline in Mielec had a significant impact on the environmental conditions. The river current was slowed, debris transport was halted, and the bottom substrates were significantly silty. The water

Table 1
Total length (TL) and body weight (BW) of juvenile Atlantic sturgeon used in radio telemetry studies in the Wisłoka River in 2009-2010

Age (month)	N	TL ± SD (cm)	TL range (cm)	BW ± SD (g)	BW range (g)
14	15	53.6±2.74	50-58	539.1±86.46	370-656
26	10	79.3±3.68	74-84	2152.4±690.13	1482-3790

level during the study was average, which meant it measured from 188 to 318 cm at the Institute of Meteorology and Water Management (IMGW) station in Mielec.

Artificial reproduction of wild fish from the St. John River was performed in Canada, and fertilized eggs were imported to Poland. Egg incubation, larval hatching, and rearing to the juvenile stage were all performed in recirculating system tanks at the Department of Sturgeon Breeding in Pieczarki (Inland Fisheries Institute). Initially, the larvae were fed Artemia napulii, which was then supplementing with artificial feed. The subjects of the radio telemetry studies comprised 25 juvenile sturgeon ranging in age from 14 to 26-months with a mean body length range of 53.6-79.3 cm and a mean body weight range of 539.1-2152.4 g (Table 1). The fish were anesthetized with Propiscin (IFI, Olsztyn) before the transmitters were implanted. Three sizes of cylindrical transmitters (Advanced Telemetry Systems) weighing 7, 14, or 17 g were implanted. In 2009, the weight of the implanted transmitters was from 1.3 to 3.0% of the fish body weight, while in the following year it was from 0.4 to 1.1%. The guaranteed working time of the transmitters is from 114 to 410 days. The abdominal incisions were stitched with either indissoluble surgical thread (Supramid) or polyamide thread and disinfected with Betadine (EGIS, Hungary). After implantation, the fish were held for about two weeks in tanks at the culture facility. No mortality was noted among the sturgeon at this time. The fish were transported by car to the stocking release site (550 km) in tanks that were aerated with oxygen. In 2009, the fish were released into the Wisłoka on October 6, while in the 2010 the fish were released into the river on October 7. In both years the fish were released into the river at the same site.

A pontoon boat was sailed downstream the river once per day at a speed of 6-8 km h^{-1}, and the fish were located using a three-element Yagi antenna and a R410 manual receiver (Advanced Telemetry Systems). The location of the sturgeon was determined to the nearest 10 m using a GPSmap 76 CSx (Garmin), and the researchers made a visual inspection of the habitat. The type of habitat was determined (riffle, run, pool, whirl) as were its basic parameters (depth and substrate). Additionally, R4500S dataloggers with and four- or five-element Yagi antennas tracked fish migrations 24 hours per day. The tracking stations were located in Dębica (1.1 km from the stocking site), Pustków (10.5 km, only in 2009), Mielec (35.8 km), and Gawłuszowice (55.8 km).

The daily sturgeon migration rates were determined as the distance covered by individual fish on subsequent days. Previous studies indicated that juvenile sturgeon migrate in rivers nocturnally (Fredrich et al. 2008). Based on the length of the night during the period analyzed, the sturgeon active period was 13 hours per day. Differences between the migration rates of the sturgeon in both study years were analyzed with the U Mann-Whitney test. The dependence between fish size and migration rate was analyzed using Spearman's correlation. All of the statistical analysis was conducted using Statistica (Statsoft Poland, Kraków).

Results

Most of the stocked sturgeon left the Wisłoka River within a period of two to seven days following release. The fates of four fish were not determined definitively (Table 2). The sturgeon were tracked for an

Table 2
Fish characteristics and migration data for migrating juvenile Atlantic sturgeon in the Wisłoka River in 2009 and 2010

Year	Release date	TL (cm)	BL (cm)	BW (g)	Tag weight (g)	Number of observation (days)	Mean migration speed (km d^{-1})	Date of last signal detection	Fate of fish
2009	6 October	56	42	646	14	4	14.0 (10.5-25.3)	9 October 2009	swam out of river
	6 October	55	41	610	14	3	18.6 (10.5-45.3)	8 October 2009	swam out of river
	6 October	52	39	502	14	3	18.6 (1.1-34.7)	8 October 2009	swam out of river
	6 October	55	41	625	14	7	8.0 (3.0-20.0)	12 October 2009	swam out of river
	6 October	51	37	460	14	5	9.3 (4.4-20.0)	11 October 2009	swam out of river
	6 October	57	41	622	14	3	18.6 (10.5-25.3)	8 October 2009	swam out of river
	6 October	58	44	608	14	4	0.3 (0.0-0.9)	9 October 2009	unknown
	6 October	53	40	486	7	3	18.6 (10.5-25.3)	8 October 2009	swam out of river
	6 October	56	39	428	7	4	14.0 (10.5-20.0)	9 October 2009	swam out of river
	6 October	50	36	370	7	5	7.0 (5.0-15.2)	10 October 2009	unknown
	6 October	51	37	528	7	3	18.6 (1.1-34.7)	8 October 2009	swam out of river
	6 October	52	39	538	14	4	14.0 (1.1-22.2)	9 October 2009	swam out of river
	6 October	51	36	476	7	3	18.6 (9.1-36.2)	8 October 2009	swam out of river
	6 October	53	39	532	14	7	8.0 (2.6-20.0)	12 October 2009	swam out of river
	6 October	58	43	656	14	3	18.6 (1.1-45.3)	8 October 2009	swam out of river
2010	7 October	84	66	2520	17	4	3.2 (1.1-6.8)	10 October 2010	unknown
	7 October	79	58	1712	17	4	14.0 (1.1-32.2)	10 October 2010	swam out of river
	7 October	84	66	3790	17	3	18.6 (17.0-20.0)	9 October 2010	swam out of river
	7 October	76	59	1546	17	4	14.0 (1.4-24.5)	10 October 2010	swam out of river
	7 October	75	55	1482	17	4	14.0 (3.5-32.3)	10 October 2010	swam out of river
	7 October	82	63	2640	17	2	27.9 (1.1-54.7)	8 October 2010	swam out of river
	7 October	77	60	1818	17	3	18.6 (1.1-34.7)	9 October 2010	swam out of river
	7 October	82	62	1992	17	4	0.4 (0.1-0.8)	10 October 2010	unknown
	7 October	80	60	2160	17	4	14.0 (1.1-43.1)	10 October 2010	swam out of river
	7 October	74	57	1864	17	3	18.6 (13.2-22.6)	9 October 2010	swam out of river

Table 3
Number of detections, mean daily migration rate (km h^{-1}) and mean migration rate (BL s^{-1}) of juvenile Atlantic sturgeon in the Wisłoka River. Data represents means ± standard deviation

Age (in months)	No. of detections	Range of localization (days)	Mean daily migration rate (km h^{-1})	Mean migration rate (BL s^{-1})
14	71	4.1±1.39	1.42±0.82	0.84±0.45
26	42	3.44±0.71	2.02±1.87	0.94±0.88

Table 4
Characteristics of habitats chosen by juvenile Atlantic sturgeon in the Wisłoka River in 2009-2010

Parameter	2009	2010	Chi^2	P
Habitat			23.59	>0.001
riffle	4.8	18.75		
run	85.7	62.5		
whirl	9.5	18.75		
Micro-habitats			6.83	0.08
river channel	66.7	56.3		
pool	9.5	18.8		
submerged tree	4.8	6.3		
flats	19.0	18.8		
Depth (m)			22.67	>0.001
<1	19.0	0		
1-2	28.6	0		
>2	52.4	100		
Bottom substrate			0.02	0.99
sand	0.58	0.56		
gravel	0.35	0.33		
rocks	0.07	0.11		

average of four days in 2009 and for three in 2010. The sturgeon left the stocking site during the first night following release. In 2009, the sturgeon migrated from 0 to 45.3 km per day, while in 2010 they migrated from 0.1 to 54.1 km. Only once was a sturgeon noted to migrate upstream. On the first night it swam 4.1 km (0.31 km h^{-1}) downstream, and then the next night it migrated 1.4 km (0.11 km h^{-1}) upstream. In the subsequent days, it migrated downstream and seven days after release it left the Wisłoka. The sturgeon migrated individually, and each individual kept its own pace. The mean migration rate in each of the years did not differ significantly statistically ($P>0.05$). The sturgeon migrated with a mean speed of 0.84 BL s^{-1} in 2009 and of 0.94 BL s^{-1} in 2010 (Table 3). The maximum migration rate was 3.1 km h^{-1} in 2009 and 7.3 km h^{-1} in 2010. No statistically significant dependence between migration rate and sturgeon size was noted ($P>0.05$).

Statistically significant differences were determined among the habitats in which the the sturgeon stayed during the day (Table 4). In both years these were located most frequently in or near run, and least frequently in riffle. The sturgeon chose deep areas of both of these habitats, and these were most frequently to river channels, deep pools beneath submerged trees, or near whirls. The highest fraction of bottom substrate in these places was sand (56-58%) followed by gravel (33-35%). A separate evaluation of siltation at sites inhabited by sturgeon indicated it was an average of 20%.

Discussion

Radio telemetry has been used in studies of sturgeon migration and habitat preferences. The possibility of locating and identifying individual sturgeon has been exploited to determine sturgeon habitat preferences and the general rules of their migrations (Taverny et al. 2002, Heublein et al. 2009). Knowledge of these aspects of *A. oxyrinchus* behavior remains inadequate, and no detailed studies of sturgeon behavior in rivers was conducted prior to the extinction of the Baltic population. Information regarding juvenile Atlantic sturgeon was not plentiful, and that which was available generally pertained to the size of young fish and the location of their capture (Kulmatycki 1932, Grabda 1968). With the beginning of the program to restore sturgeon to the Baltic Sea basin, studies were begun on their migration, followed by studies of the habitat preferences of sturgeon reared at hatcheries as stocking material and then released into rivers (Fredrich and Gessner 2007, Kapusta et al. 2007). The first field work was conducted in the Drawa and Drwęca rivers, which are lowland streams flowing in the north of Poland and which offer the most advantageous conditions for sturgeon reproduction (Gessner and Bartel 2000, Kolman et al. 2008). The results presented are the first data on sturgeon migration and habitat preference in submontane rivers.

The large size of the sturgeon released into the Wisłoka was unusual for the stocking material normally released in Poland (Bartel and Kardela 2007). The survival of the sturgeon in the Wisłoka was high. Among the individuals that did not leave the river, it is most likely that just one fish had died; while the other three had probably not left the river before the end of the study. The sturgeon remained at the release site in the Wisłoka only briefly and began swimming downstream the first night following release. During similar studies conducted in June in the Drwęca, a few hours after release the sturgeon moved to the nearest depression in the river bottom. More than 90% of the fish moved downstream with very few swimming upstream. The fish remained within 200 m of the release site for a period ranging from one to 21 days (Kapusta 2010). However, the sturgeon released into the Drwęca in October responded just like those released into the Wisłoka and left the release site within a day or two. Determining the period during which the sturgeon remain at the release site can be significantly important to the success of the stocking operation. Considerable concentrations of rather bold fish might be attractive prey for piscivorous animals. Attacks by American mink, *Neovison vison* Schreber, on juvenile sturgeon were confirmed in the Drwęca river (A. Kapusta, unpublished data). Illegal catches, including those of juvenile fish just after stocking, are still prevalent in the inland waters of Poland (PROP 2007). Because of this, determining the time the sturgeon spend at the stocking site following release can be of practical use in implementing protection measures.

Natural river systems are open hydraulic systems that are in dynamic equilibrium. The water flow in submontane rivers results in alternating segments of riffle and run. Constructions on the Wisłoka have disrupted natural processes occurring in the riverbed. The movements of the sturgeon were studied in the lower reaches of the river where riffle occurred rarely and were usually much shorter than neighboring segments of run. Because of this, the sturgeon had substantially more segments of run to their disposal than they did of riffle with fast water flow. The sturgeon usually stopped at deep sites with either sand or gravel substrates. Similar habitats were also chosen by sturgeon in the Drwęca (Kolman et al. 2008). The sturgeon were most frequently found in smaller or larger lengthwise channels that had formed in the riverbed. However, in the Drawa, the sturgeon first choice habitat was deep holes in the riverbed followed by visible woody debris (Fredrich et al. 2008). In contrast to the Wisłoka, there are a large number of submerged trees in the Drawa riverbed, which is why the availability of this micro-habitat was higher in the Drawa as compared to the Wisłoka. Generally, in all the rivers studied, juvenile Atlantic sturgeon chose deep, sandy sites without submerged vegetation. During the stage when juvenile Atlantic sturgeon inhabited the Hudson River they also preferred deep sites (Bain 1997).

Similar preferences were also confirmed in other sturgeon species. Under laboratory conditions, juvenile *A. oxyrinchus desotoi* exhibited preferences for sandy substrates (Chan et al. 1997). However, in the lower course of the Peshtigo River lake sturgeon, *Acipenser fulvescens* Rafinesque, aged 0+ stopped most frequently at sites with depths of 1.3 m and sandy substrates (Benson et al. 2005). Under laboratory conditions, it was confirmed that juvenile sturgeon prefer sandy to rock, gravel, or smooth plastic substrates (Peale 1999).

The speed at which the juvenile Atlantic sturgeon migrated downstream in the Wisłoka was faster in comparison to that noted in the Drwęca. The mean daily migration rate in the Wisłoka ranged from 1.42 to 2.02 km h^{-1}. In the Drwęca four-month-old sturgeon (mean total length – 21 cm, mean body weight – 33 g) migrated at a speed of 0.85 km h^{-1}, while 16-month-old sturgeon (at 39 cm and 490 g, respectively) migrated at a mean speed of 0.51 km h^{-1} (Kapusta et al. 2008). These differences noted could be linked to the mean water flow speed in the two rivers. The mean water flow rate in the Wisłoka was faster than that in the Drwęca. The sturgeon migrated at various speeds, and periods of slower migration were punctuated with periods of very fast migration. Similar behavior was also noted in both the Drawa and the Drwęca (Fredrich et al. 2008, Kapusta et al. 2008). However, no incidents of halted migration with the fish remaining in one area for a few days were noted. In the Drawa and the Drwęca, a small number of the sturgeon remained in one area for a period of two to three weeks. The juvenile sturgeon rarely switched direction and began migrating upstream, and just one instance of this was noted in the Wisłoka in 2009 when a sturgeon swam 1.4 km upstream in one night. Fredrich and Gessner (2007) noted that one sturgeon migrated 7 km upstream in the Peene River from the stocking site before swimming into the Szczecin Lagoon. In turn, about 5% of the migrations tracked in the Drwęca River were upstream (Kapusta et al. 2008); however, the length of these ranged from several to several tens of meters, and they were undertaken within the vicinity of one distinct type of bottom structure (deep holes, channels).

The speed and direction of juvenile Atlantic sturgeon migration can change depending on the distance to the estuary or the season of the year, among other factors. In the Nanticoke River, the juvenile Atlantic sturgeon from rearing facilities migrated downstream at a daily rate of 0.04 to 0.08 km (Secor et al. 2000). The migration speed depended on the distance between the stocking site and the river mouth; the migration rate quickened as the distance from the river mouth increased (0-60 km). However, the migration rate of juvenile Atlantic sturgeon from a wild population in the Cape Fear River depended on water temperature (Moser and Ross 1995). In summer, the sturgeon migrated very slowly (mean rate of 0.7 km d^{-1}), while in winter and spring they were significantly faster (1.3 km d^{-1}). During the migration in the Wisłoka, the sturgeon migrated a daily average of 18.5 km d^{-1} in 2009 and 26.2 km d^{-1} in 2010. The fastest fish recorded migrated a distance of 20 km in four hours. Similar results were obtained by Moser and Ross (1955) who studied the migrations of juvenile *Acipenser brevirostrum* Lesueur. The sturgeon, which were fitted with transmitters, migrated within a speed range of 8.5 to 36 km d^{-1}.

The behavioral ecology of the sturgeon that inhabited the Baltic Sea catchment area is not well understood. Using telemetry in migration studies permitted collecting data that would be difficult to obtain using conventional methods. The survival of the Atlantic sturgeon released into the Wisłoka was high. The sturgeon swam downstream quickly, at a mean speed of 1.42 km h^{-1} in 2009 and at 2.02 km h^{-1} in 2010. The migration rate was not connected to fish size, and migrating upstream was noted very infrequently. During the day, the sturgeon stayed at deep holes with sandy bottoms. The studies indicated that the conditions in the Wisłoka are advantageous for sturgeon as they migrate to the sea. The key question remains unanswered: will the juvenile Atlantic salmon released return as mature adults, and will they find appropriate breeding conditions? Since restoration of the Atlantic sturgeon is being performed in the Wisłoka River, the state and size of sites suitable for spawning should be determined.

Acknowledgments. This study was financed by the Inland Fisheries Institute within the scope of statutory project S-027/2010-2012. A. Duda and G. Wiszniewski assisted with implanting transmitters in the fish, while the staff at the Rzeszów chapter of the Polish Angling Association assisted in field work, for which the authors are especially thankful.

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Streszczenie

Przemieszczanie się i wybór siedlisk przez juwenalne jesiotry ostronose w Wisłoce (południowa Polska)

Przeprowadzono badania, których celem była charakterystyka siedlisk oraz przemieszczania się juwenalnych jesiotrów ostronosych *Acipenser oxyrinchus oxyrinchus* Mitchill w Wisłoce. Za pomocą metody telemetrycznej określono tempo migracji oraz zidentyfikowano miejsca, w których jesiotry zatrzymują się w ciągu dnia. W latach 2009-2010 wpuszczono do Wisłoki 25 juwenalnych jesiotrów zaopatrzonych w nadajniki radiotelemetryczne. Większość wpuszczonych jesiotrów opuściła Wisłokę w okresie od dwóch do siedmiu dni po zarybieniu. W 2009 roku jesiotry pokonywały w ciągu doby od 0 do 45,3 km, z kolei w 2010 roku od 0,1 do 54,1 km. Średnie tempo migracji w obu latach nie różniło się istotnie statystycznie ($P>0,05$). Jesiotry przemieszczały się ze średnią prędkością 0,84 BL (długość ciała) s^{-1} w 2009 roku i 0,94 BL s^{-1} w roku 2010. Nie stwierdzono istotnej statystyczne zależności pomiędzy tempem migracji a wielkością jesiotrów. Najczęściej ryby były lokalizowane w obrębie plos, a najrzadziej zatrzymywały się w bystrzach. W obu tych siedliskach jesiotry zatrzymywały się w miejscach głębokich, najczęściej były to rzeczne rynny, głębokie doły pod drzewami zatopionymi w nurcie rzeki lub w obrębie zastoisk. Największą cześć substratu dennego w takich miejscach stanowił piasek (56-58%), a w dalszej kolejności żwir (33-35%).