

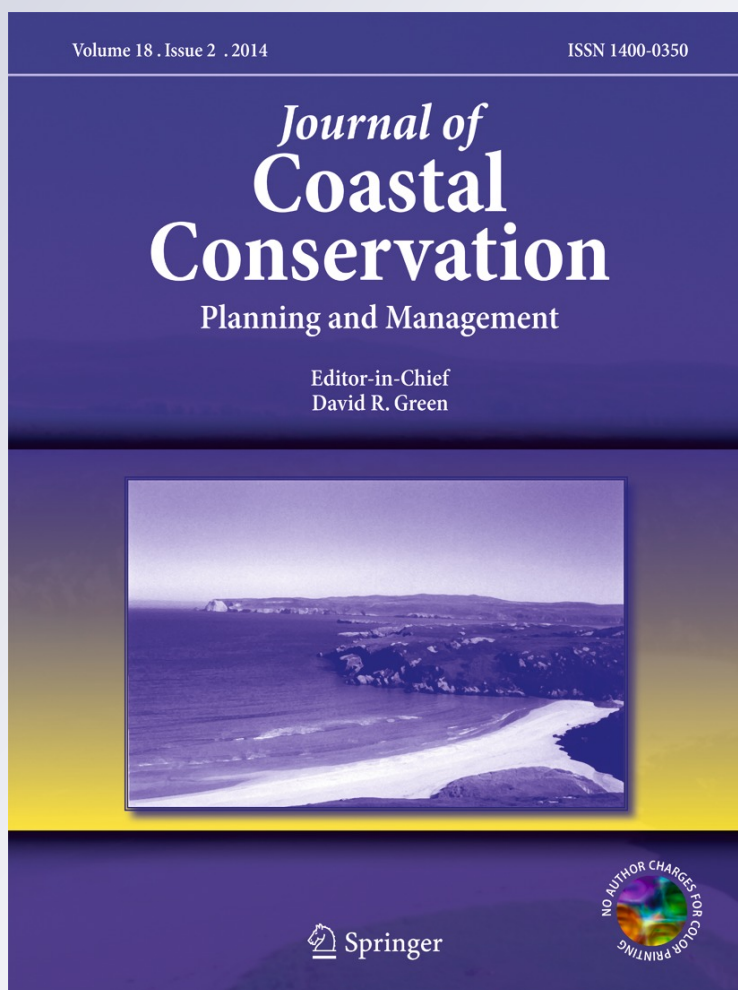
*Exploring the possibilities of seaward
migrating juvenile European sturgeon
Acipenser sturio L., in the Dutch part of
the River Rhine*

**N. W. P. Brevé, H. Vis, B. Houben,
G. A. J. de Laak, A. W. Breukelaar,
M. L. Acolas, Q. A. A. de Bruijn &
I. Spierts**

Journal of Coastal Conservation
Planning and Management

ISSN 1400-0350
Volume 18
Number 2

J Coast Conserv (2014) 18:131-143
DOI 10.1007/s11852-013-0281-0



Your article is protected by copyright and all rights are held exclusively by Springer Science +Business Media Dordrecht. This e-offprint is for personal use only and shall not be self-archived in electronic repositories. If you wish to self-archive your article, please use the accepted manuscript version for posting on your own website. You may further deposit the accepted manuscript version in any repository, provided it is only made publicly available 12 months after official publication or later and provided acknowledgement is given to the original source of publication and a link is inserted to the published article on Springer's website. The link must be accompanied by the following text: "The final publication is available at link.springer.com".

Exploring the possibilities of seaward migrating juvenile European sturgeon *Acipenser sturio* L., in the Dutch part of the River Rhine

N. W. P. Brevé · H. Vis · B. Houben · G. A. J. de Laak ·
A. W. Breukelaar · M. L. Acolas · Q. A. A. de Bruijn ·
I. Spierts

Received: 16 February 2013 / Revised: 29 July 2013 / Accepted: 25 August 2013 / Published online: 8 September 2013
© Springer Science+Business Media Dordrecht 2013

Abstract The water quality of the River Rhine has improved and might again suit the critically endangered European sturgeon *A. sturio* L., which was extirpated from the river by 1950. This study describes the tracking of 43 juvenile hatchery-reared *A. sturio*, in the Dutch part of the Lower Rhine and Delta, originating from an ex situ measure of the River Gironde population. Observing in situ juvenile downstream migration could help to identify essential habitats and potential threats, before actual stocking. Fish were implanted with transponders of the NEDAP Trail® system and released in two batches, in May ($n=13$) and June 2012 ($n=30$). Detections collected ($n=26$) exhibited no upstream movement. Test-fish moved downstream with the flow. Because the historic

estuary is disconnected from the North Sea by a sea lock “Haringvlietdam”, the migration of the fish followed the re-directed river discharge into the Port of Rotterdam (161 km). 96 % ($n=19$) of the detections was collected from the harbor in brackish water, where fish presumably acclimatized to higher salinities. 14 % ($n=6$) of the sturgeons were recaptured in coastal waters by beam trawlers, five within 1 month after release. It is concluded that sustainable coastal fisheries is a key-condition for rehabilitation of the European sturgeon. Adapted management of the sea lock will reconnect the estuary to the North Sea and create more favorable conditions for the species in the Lower Rhine and Delta.

Keywords European sturgeon *Acipenser sturio* L · NEDAP Trail® system · River Rhine · Downstream migration · Coastal fisheries · Stocking

N. W. P. Brevé (✉) · G. A. J. de Laak
Royal Dutch Angling Organization - Sportvisserij Nederland
(abbrev. SNL), Leijenseweg 115, 3721 BC Bilthoven,
The Netherlands
e-mail: breve@sportvisserijnederland.nl

H. Vis · Q. A. A. de Bruijn
VisAdvies BV, Nieuwegein, The Netherlands

B. Houben
ARK Nature, Nijmegen, The Netherlands

A. W. Breukelaar
The implementing body of the Ministry of Transport, Public Works
and Water Management - Rijkswaterstaat Waterdienst
(abbrev. RWS), Lelystad, The Netherlands

M. L. Acolas
IRSTEA, Bordeaux, France

I. Spierts
ATKB, Geldermalsen, The Netherlands

Introduction

European sturgeon (*Acipenser sturio*) is a critically endangered species, listed by the IUCN Red List 2010, CITES (2001) and Bern and Bonn conventions (Lepage and Rochard 1995). The species was extirpated from the River Rhine in 1950. Only from incidental catches in the 20th century it was deducted that the species was not extinct. Around 1990, two declining, relict populations were described in the Gironde-Garonne-Dordogne and the Rioni Rivers (Debus 1996; Bacalbasa-Dobrovici and Holčík 2000; Gessner et al. 2000; Kolman 2011; Rochard et al. 1997). According the European Action Plan for the conservation and restoration of *A. sturio* (Rosenthal et al. 2009; Gessner et al. 2010b), the rehabilitation needs to be expanded on a

European scale in different rivers of its former distribution range. At present the survival of the species depends on an ex situ measure and subsequent restocking program in the Gironde river basin (Williot et al. 2000; Williot and Chèvre 2011; Rochard and Lambert 2011; Rosenthal et al. 2009). Juvenile European sturgeons derived from this stock are used to raise a German brood stock and were experimentally released in the Elbe river basin (Gessner et al. 2010a; Kirschbaum et al. 2011). Although the decline of *A. sturio* in the River Rhine has many reasons, some of which are very difficult to address¹, several authors suggest that reintroduction can be considered (de Nie and Van Ommering 1998; van Winden et al. 2000; Houben et al. 2012). The water quality is not a limiting factor anymore (Van der Veen 1981; Jakob 1996; De Villeneuve 1996), much effort was put into habitat restoration on riverbanks and side channels, and the positive effects of nature restoration in the river on fish populations are substantial (Buijse and Cazemier 1998; Raat 2001; Reeze et al. 2005). However, due to population depletion it is impossible for *A. sturio* to complete their live cycle in the River Rhine basin on their own. Before stocking, it is necessary to close information gaps with in situ experiments (Acolas et al. 2011). With this information, potential threats and management to protect essential habitats can be specified. This should lead to a management plan for the River Rhine and the North Sea, based on the EU Action Plan.

Study objective

The objective of this tracking study was to observe in situ juvenile downstream migration in the Dutch part of the Lower Rhine and Delta, to obtain information on their expected habitat use in the river and estuary, and to assess their susceptibility to fisheries in the coastal and marine environment.

¹ The decline of sturgeon species in Western Europe might have begun as early as the 17th century (Lobrecht and Van Os 1977). Over fishing started in the rivers, and with decreasing catches fisheries shifted towards catching adults in the sea (Birnstien et al. 1997; Elvira et al. 1991a; Kinzelbach 1987, 1997; Lobrecht and Van Os 1977; Mohr 1952; Seligo 1926; Verhey 1949). In the 19th century fishery industries in the Delta and Lower Rhine focused on Atlantic salmon. *A. sturio* was a rare by catch, e.g. in 1896, 602 sturgeons were delivered to the central fish market Kralingse Veer in Rotterdam, and the landings declined to zero in 1921 (Lozan and Hausch 1996; Holčík et al. 1989; Gessner et al. 2010b). Spawning and nursery grounds were destroyed by extraction of sand and gravel as well as river correction for shipping; large scale river pollution, water diversion and the building of sluices and hydropower dams damaged the European sturgeon populations beyond recovery (Castelnaud et al. 1991, Fernández-Pasquier 1999; de Groot 1992, 2002; Jakob 1996; Lepage et al. 2000; Rochard et al. 1990; Timmermans and Melchers 1994; Van Winden et al. 2000).

Material and methods

Study area

The study area includes the Lower Rhine and Delta, from the release site near the border with Germany (coordinates 51.860592, 5.981512) to the Port of Rotterdam, Europe's largest seaport and the terminus of Rhine navigation. The Lower Rhine and Delta are heavily modified, characterized by a network of channels, habitat modification by hydraulic engineering including some of the largest sea locks in the world, and intensive navigation. However, there are no dams in the Lower Rhine which might hamper fish migration.

Permission

The study received permission from the DREAL Aquitaine (Bordeaux, France) which is in charge of the French action plan (Dreal 2011). For transfer of live European sturgeons to the Netherlands the study received a CITES authorization Nr. FR1203300080-K, dated 14/03/2012. A license was received from the Dutch ministry of Economic Affairs, for the release and study of European sturgeons in the Dutch part of the River Rhine (art. 14 and art. 75 Flora- en faunawet, FF/75A/2011/066), valid from March 1 2012 till December 31 2014.

Test fish

A total of 50 juveniles from the French stock, provided by IRSTEA, experimental station Saint Seurin sur Isle, were used for this study. Genetic distance calculations show a great genetic similarity between historic *A. sturio* populations in the river Gironde and the North Sea (Ludwig et al. 2000). An overview of data of the used test-fish (43 individuals) is shown in **Annex I**. The sturgeons of cohort 2009 were on average significantly longer than those of cohort 2007 (paire-wise, Bonferroni-corrected Mann–Whitney comparisons; $U=135$, $p<0.05$). But the differences in weight were not significant (paire-wise, Bonferroni-corrected Mann–Whitney comparisons; $U=190$, $p>0.05$). 2007: 74.2 ± 5.3 cm TL+ and $1,656\pm351$ g. 2009: 77.4 ± 2.9 cm TL and $1,669\pm170$ g.

Tagging system

The study used the NEDAP Trail® system as described in Bij de Vaate and Breukelaar (2001). The detection stations (fixed receiver array) in the Rivers Rhine and Meuse are mainly installed at the main sluice-weir complexes and dams. The corresponding transponders weigh 26.5 g in air and are embedded in surgical glass. The weight of the implanted transponder was less than 2 % of the total weight of the

Fig. 1 Tagging system used (below left): NEDAP transponder Ø 15 mm and 70 mm long, PIT-tag Ø 2 mm and 12 mm long, Wot-tag 220 mm long; and surgical implantation of a NEDAP transponder and a WOT in a live European sturgeon



lightest test fish, which is an acceptable ratio for studies in underwater biotelemetry (Winter 1983). The tagging system used (Fig. 1) includes PIT tags (passive integrated transponder) and WOT tags (external loop tags, wire on tag). WOT's consist of a stainless steel wire, partially enveloped with a PVC tube, labeled with a single unique tag number and contact information. PIT's are useful for identification at the hatchery, and WOT's serves external identification at recaptures (Nelson et al. 2010).

Surgical implantation

The individually coded PIT tags were injected via a hand-held syringe beneath the skin, about 1 cm behind the head plate and on the left side of the dorsal scute line. WOT's were attached by hand with a hollow needle, and through the anterior base of the dorsal fin (Jatteau et al. 2011). On 28th and 29th March 2012, 50 sturgeons were surgical implanted with NEDAP transponders. Sturgeons were brought in a state of anesthesia, using eugenol (clove oil, 0.5 ml diluted in 5 ml of ethanol per 10 l water). Fish were positioned in a custom sling while anesthetic (0.3 ml of eugenol per 10 l water) flushed into mouth and over gills with a flow of water through a tube. The disinfected transponder (Sekusept plus and alcohol 96 %) was inserted in the abdominal cavity. Sutures (Ethicon Vicryl, cutting needle 2/0) were applied across the incision prior to recovery. After surgery, fish were kept 1 month at the hatchery in a basin with a flow through of fresh water (12 °C) for full recovery of the wounds. Between 17th and 19th April all sturgeons were thoroughly examined. It must be noted that

the wounds healed slowly. Fish were treated individually and some stitches had to be redone. Forty seven sturgeons were selected visually for good external condition and put on transport to the Netherlands.

Sturgeons released in the Lower Rhine

Sturgeons were transferred to the release site in an aerated 2.200 l tank by truck, in two batches on May 6 ($n=17$) and on June 19 ($n=30$). The temperature and oxygen concentration during both transports were 19.7 °C and 11.8 O₂ mg/l in May and 20.2 °C and 11.5 O₂ mg/l in June. The water temperature and oxygen concentration of the River Rhine were 16.3 °C and 8.2 O₂ mg/l in May, and 18.8 °C and 7.9 O₂ mg/l in June. Fish were acclimatized to the river water temperature by gradually pumping water into the tank during 3 h. All test-fish were maintained in a storage vessel in the Lake Kaliwaal, which is connected to the River Rhine, in close vicinity to the Dutch-German border. 43 sturgeons were carefully released in the river on May 8 (12:00 h, $n=2$), May 10 (14:00 h, $n=11$) and June 21 (16:30 h, $n=30$)². Fish swimming in any

² Four sturgeons were transported to the Port of Rotterdam and released on May 9 (14:00 h, $n=4$), ± 30 km upstream from detection station Nr.07. The release of these European sturgeons was carried out with the help from the Port and the City of Rotterdam and a Dutch princess. Tracking data of these 4 fish was too meager to incorporate in present study. However, the event received National media exposure, and this helped the study indirectly with goodwill from professional fisherman and anglers to report recaptures.

direction had to pass a NEDAP station. Station Nr.01 is located at 73 km in the downstream direction. While in the upstream direction the nearest station is located at 50 km in Xanten (D). Also, upstream via the river IJssel, a branch of the River Rhine is accessible with a detection station near Kampen, 70 km from the release site.

Tracking and data analysis

The length and weight data of the test-fish were not normally distributed; a non-parametric Mann–Whitney U test was used to test for differences between both age groups. The significance levels of these tests were adjusted using a Bonferroni correction. This correction ensures that the cumulative Type 1 error is below 0.05, it divides α by the number of comparisons (Field 2008). The migration route (river route) was mapped with the NEDAP Trail® system from data points. On the first river stretch to station Nr.01, differences in net ground speed (km per hour) between the two released groups were tested with a Mann–Whitney U test. In order to find out if the test-fish moved to the sea immediately after their release, the number of detections per station (except station Nr.07) was correlated with the number of days after their release, from day 0 (release dates 10 May and 21 June) till day 119 and 77 (5 September). Because this data was not normally distributed, a Spearman correlation was used. It was analyzed whether sturgeons preferred migrating during the day or night, from the release site to the Port of Rotterdam, using a non-parametric binomial test. Data were also analyzed in relation to discharge and water temperature, but this was found to be excursive because the fish left the river in a short period. At station Nr.07 (Rotterdam harbor), nine sturgeons were detected for up to several weeks, supposedly acclimatizing to higher salinities. The NEDAP cables are installed on the channel bottom in front of the open storm surge barrier, approximately 6 km from the North Sea. In this brackish tidal area, the salinities depend on the tide and vary between 0 and 12‰. The difference between high and low tide was on average 174 cm. For each individual fish a plot was made of the detections in relation to the tidal curve.

Results

Downstream migration

Tracking with the NEDAP system started on May 8 and the last detection was received on October 30. Table 1 shows the confirmed detections, derived from seven NEDAP stations. In total 60 % ($n=26$) of the test-fish

were detected. No sturgeon was detected moving upstream. Figure 2 gives a visual representation of this information, combined with the numbers of deducted passages (May/June) per station. No sturgeon was detected in the vicinity of sea lock Haringvlietdam. The pathway utilized by the sturgeons led towards the Port of Rotterdam. The time observed for seaward migration ranged between 2.5 and 48 days.

Both groups of sturgeons moved downstream, directly after their release in the river (release on 10 May 2012: Spearman's rho, $R_p=-0.402$, $p<0.05$; release on 21 June 2012: Spearman's rho, $R_p=-0.457$, $p<0.05$). 85 % (first group) and 73 % (second group) of the test-fish were detected in the first week after their release. Consecutively fewer sturgeons were being detected at upstream stations as more test-fish left the study area. No sturgeons were registered within 10 min of each other at any NEDAP station, thus fish were moving individually. In the first river stretch no difference was found in net ground speed (river flow speed $\pm$ swim speed) between groups released (paire-wise, Bonferroni-corrected Mann–Whitney comparisons; $U=50.5$, $p>0.05$), averaging 106 ± 18.8 km/day (1.2 m/s, $n=19$). Nineteen sturgeons reached station Nr.01 (73 km) within 8:13 h. The fastest fish No. 10151 moved with 142 km/day (1.6 m/sec). One sturgeon No. 10201 showed a deviant speed of 18 km/day (0.2 m/sec) and reached station Nr.01 after 4 days. Figure 3 displays the migration duration (in days) of sturgeons that were detected for the first time at station Nr.07 ($n=16$). Of those, 69 % ($n=11$) reached station Nr.07 within 7 days.

Photoperiod (daylight)

Of all registrations in the River Rhine, 44 % were received between sunrise and sunset. On the registration days, the average length of the day was 16:36 hours and of the night 7:24 hours. After the observed registrations were adjusted for the duration of daylight (photoperiod), no preference was found for migrating during the night or day (Binomial test; $N=48$; $p>0.05$).

Detections collected in the Port of Rotterdam

The majority of NEDAP detections (96 % of the total observations, $n=19$) was collected from station Nr.07, in the Port of Rotterdam in brackish water. Seven fish left the area within a day. Nine fish were detected during several weeks. In May ($n=4$) sturgeons were observed within the harbor on average 21.8 ± 13.6 days and in June ($n=5$) 27.7 ± 17.3 days. Individual plots of detections versus the tidal

Table 1 Overview of registrations per station

Release (<i>n</i> =43)			Registrations of individual test-fish			Total number of registrations		
→ May (<i>n</i> = 13), June (<i>n</i> = 30)								
NEDAP station name	Km ^a	Nr. ^b	May	June	Sum	May	June	Sum
Waal_Brakel	73	Nr.01	5	15	20	5	15	20
Beneden Merwede_Sliedrecht		Nr.02	2	–	2	2	–	2
Dordtsche Kil_'sGravendeel	118	Nr.03	2	6	8	2	6	8
Noord_Kinderdijk		Nr.04	1	–	1	1	–	1
Oude Maas_Spijkenisse	136	Nr.05	3	6	9	5	8	13
Hartelkanaal_Europoort		Nr.06	1	1	2	1	3	4
Nieuwe waterweg_Europoort	161	Nr.07	7	9	16	935	236	1171
Detected			7	19	26	951 ^c	268	1219
Not detected			6	11	17			

^a Distance (in km) for the observed route

^b Numbers of stations are given for tracking purposes, these are not the official NEDAP numbers

^c 840 detections came from one test-fish, No. 10180, between June 26 and July 6

curve showed that most sturgeons were detected during the turning of the tide, but one sturgeon moved across this station with regular daily intervals.

Reported catches

Figure 4 represents the data received from all reported catches. On June 28 a sturgeon with transponder No. 10196 was found dead on the river bank upriver of station Nr.01. Considering its state, this fish may have been hit by a ship propeller. Between July 19 and August 20, three sturgeons were recaptured from the North Sea and two from the Wadden Sea, all within ca 5 km from the shore where water depths are less than 25 m. These data were obtained from commercial fishermen, fishing for shrimps with beam trawlers. On October 30, a sixth sturgeon was reported from the North Sea. Five sturgeons were released alive, and one sturgeon died during trawling from a big stone picked up by the trawl net. Three of these recaptures were previously not detected with the NEDAP Trail® system. In total, 19 test-fish were confirmed to have moved into the North Sea.

Discussion

Downstream migration route

19 sturgeons were registered passing detection station Nr.01 within 8:13 h after their release, averaging a speed of $106 \pm 18,8$ km/day (1.2 m/sec). According to the SOBEK pre-calculation table, the velocity of the River Rhine at a discharge of 2,000 m³/s is ~1.2 m/sec (SOBEK 2000). This simple comparison shows that most fish had drifted down the first river stretch. While fish were released in the River Rhine, the main flow was redirected from the estuary into the Port of Rotterdam³.

³ The interconnected channels of the Lower Rhine and Meuse contain complicated directional flows, they fluctuate according to river discharge, the tide, and the management of the 17 discharge sluices of sea lock “Haringvlietdam” (Paalvast et al. 1998; van Hees and Peters 1998; Steenkamp 2002; van Kreveld et al. 2009). In the first week after both releases (8–15 May and 21–28 June), the river discharge was normal, approx. 2200 m³/s and 2443 m³/s (RWS Helpdesk 2012), and subsequently the average opening of sea lock “Haringvlietdam” was 164 m² and 314 m² (RWS Operationele bedieningsstaat Haringvlietdam May–August 2012). As a result the water flow was redirected into the Port of Rotterdam via the channel “Dordtsche Kil”, and only the redundant river discharge flowed through the sea lock (approx. 50 times less).

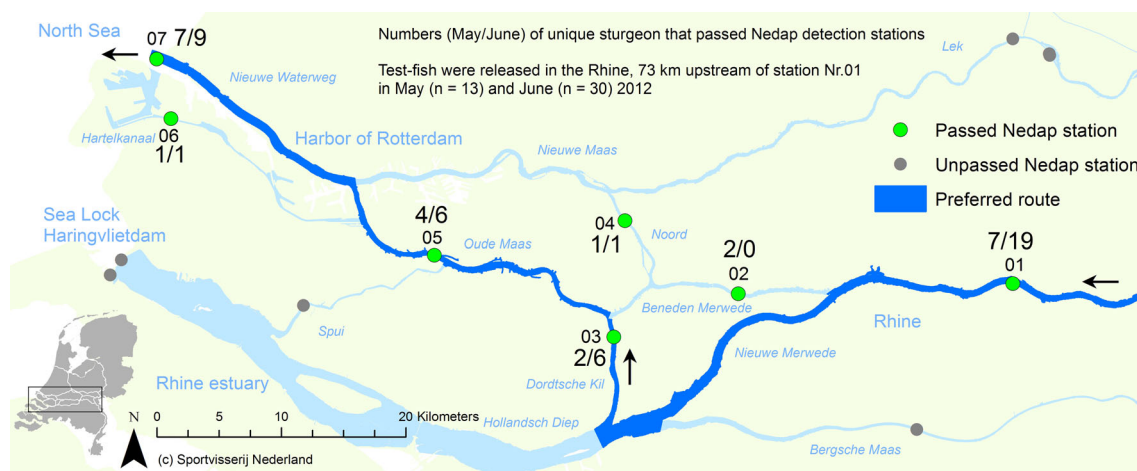


Fig. 2 Study area and overview of confirmed detections (May/June) of passing individual sturgeons per NEDAP station

This was expressed through the route followed by the test-fish in their downstream migration. This route displays a sharp turn towards the north, leading fish out of the old river mouth (Fig. 2). Data detected at station Nr.03 confirmed that six sturgeons escaped from the estuary into the Port of Rotterdam, via the channel “Dortsche Kil” passing the station at outgoing tide. Although sturgeons were detected at the turning of the tide (an example of two individuals is shown in Fig. 5), fish had moved during outgoing tide, because station Nr.03 is located at the northern end of the channel “Dortsche Kil”. Two other sturgeons were detected at station Nr.03, approximately 2 weeks after they had passed station Nr.01, indicating that both fish had spent this time upstream of this station. Similar late arrivals at station Nr.03 were observed from silver eels in the estuary by Winter and Bierman (2010), when the sea lock was closed.

NEDAP non-detections

During the study time 17 tagged fish were not detected. Station Nr.01 confirmed the passage of 47 % of the test-fish ($n=20$), but from detections further downstream it was concluded that at least 60 % ($n=26$) must have passed this station. Following this result, the functionality of station Nr.01 and the registered data were thoroughly checked by technical staff of RWS and NEDAP. No technical defects in the function of the system were detected. It was suggested that test-fish might have positioned themselves somewhat oblique while drifting down the river. Any transponder positioned oblique to a NEDAP antennae causes non-detections. A similar result was

obtained from a NEDAP tracking study with silver eels (Vriese et al. 2006).

Possible vessel-strike

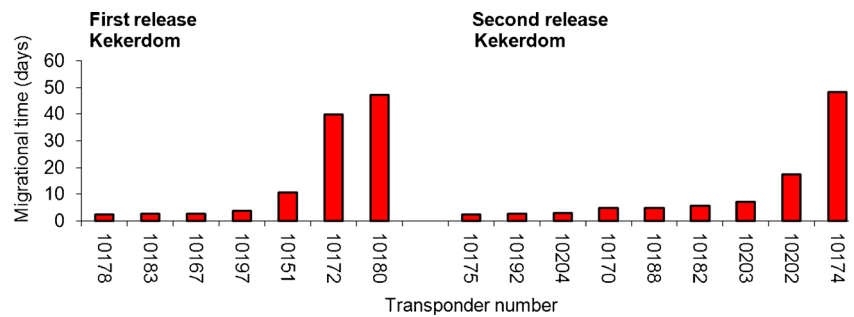
Sturgeon No. 10196 was released 21th June and found a week later, dead on a river bank. The sturgeon was not preserved by the finder. From the given description and as can be seen on the provided photograph the fish was decapitated and already dead for a few days. Brown and Murphy (2010) reported finds of severely damaged sturgeon in the Delaware River (U.S., New Jersey). At least 50 % of these sturgeons were hit by propellers, of which 71 % were cut in half near the torso or the head. The River Rhine is an important European transportation route; the intense navigation might imply a risk to the rehabilitation of sturgeon, especially during dry summer months.

Detections collected at the Port of Rotterdam

At the start of this tracking study it was hypothesized that the 3 and 5 year old juveniles would spend more time in the estuary to confirm findings from the Gironde estuary⁴. Although the majority of detections was collected from the

⁴ Young sturgeons grow up in the Gironde River and estuary, and after a residence time of 2–4 years, they migrate into the sea. From this age, the sturgeons are able to adapt to fluctuating and higher salinities (Rochard et al. 2001; Williot et al. 2009, 2011). *A. sturio* of 4–5 years live within this estuary where salinity can range 15–31‰, these fish can endure a surge of 10.5 ‰ per day (Rochard et al. 2001; Taverny et al. 2002). Older individuals (from age seven) can adapt more easily when they are transferred from freshwater to salt water or vice versa (Magnin 1962).

Fig. 3 Migration duration per fish, from their release till the first registration at station Nr.07



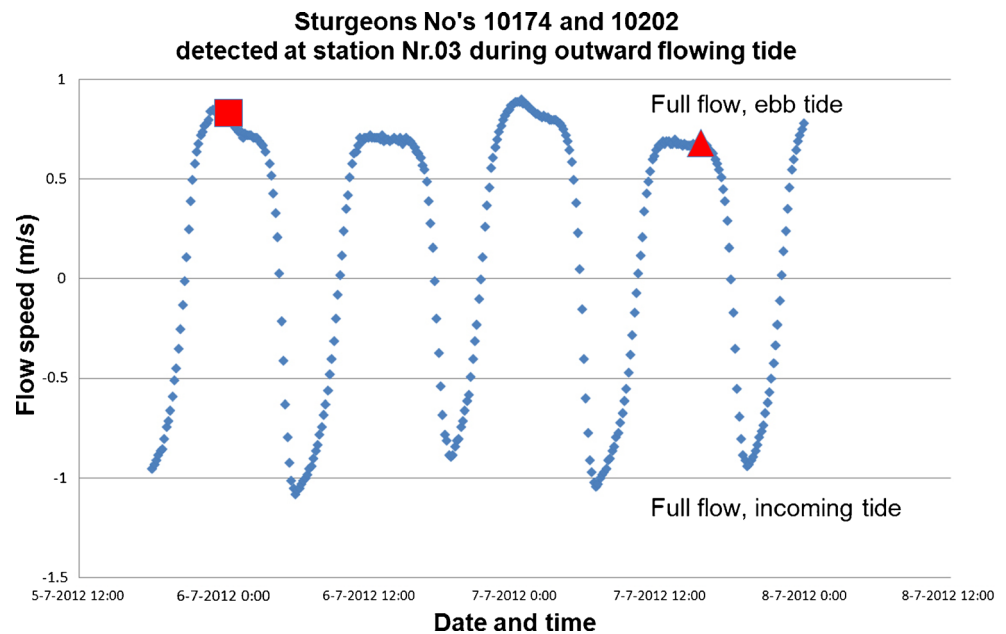
Port of Rotterdam (96 %, $n=16$), most fish left the study area within several weeks. It was concluded that the fish

left the Rotterdam harbor and were able to acclimatize fast to higher salinities.

Fig. 4 Locations of reported recaptures of European sturgeon, originating from 2 subsequent releases in 2012 of 43 fish in total in the River Rhine (yellow square), the different groups of recaptured fish are given in the Legend



Fig. 5 The tidal curve of flow speed (blue dots) and detections at station Nr.03 of two individual test fish (red square and triangle); in this figure the flow speed is positive during ebb tide and negative during incoming tide



Coastal recaptures

The Dutch coastal zone is intensively fished by trawlers (Tulp et al. 2011). Beam trawl fisheries have a high chance of catching ground foraging round fish such as sturgeons (Bergman and Hup 1992; Van Winden et al. 2000). According to Polet et al. (2008) over 600 shrimp trawlers fish the Dutch coastal waters. Although in present study quantifying catch ability is impossible with the available data, it must be high since 14 % ($n=6$) of all released sturgeons were reported from beam trawl fisheries. Catches were rather evenly distributed along the Dutch coast. Five sturgeons were captured between half July and the end of August, a period during which the shrimpers were licensed to fish without sieve net: a provision to reduce by catch (Tulp et al. 2011; Managementplan garnalenvisserij maart 2009). The last recaptured sturgeon was reported 30th October 2012. Potential missed recaptures can be explained by the adjusted trawl nets, or by a shifting fleet, which moves seasonally from the Dutch coast towards Germany and Denmark (Oostenbrugge et al. 2010). Sturgeons could also have out-migrated into deeper water with less intensive beam trawl fisheries. According to several authors (Rochard et al. 2001; Brosse et al. 2011) *A. sturio*'s migration patterns can be traced back to the most abundant and preferred prey. But it is unknown on which preys the test-fish should be feeding, European sturgeons own a flexible diet (Trouvery et al. 1984; Hochleithner 1996; Brosse et al. 2000). In fact, the mechanics of foraging behavior and the

survival of *A. sturio* in the North Sea is uncovered territory. It is concluded that protection of the European sturgeon can only be achieved in cooperation with professional fisherman. It would be useful to incorporate findings from the French communication program (Rochard and Lepage 1996; Michelet 2011) in a River Rhine and North Sea Action Plan.

Sea lock Haringvlietdam

An intact, natural estuary is important for the survival of young European sturgeon (Rochard et al. 2001). The River Rhine estuary was well known for its presence of important migratory fish populations (Van Winden et al. 2000). At present the estuary is disconnected from the sea, it contains fresh water, lacks clear directional tidal currents and a noticeable salt water gradient exists only temporarily at the sea side of the sea lock Haringvlietdam, at river dischargers higher than 2,000 m³/s (Van Vessem 1998). Several studies (e.g. Raat 2001; Vriese et al. 2006; Vriese and Breukelaar 2007; Spierts et al. 2010; Winter and Bierman 2010; Brevé et al. 2013) state that the sea lock constitutes a migration barrier to diadromous species. This study showed that fish deliberately took another route, thus missing out on suitable habitat, potentially available in the estuary. According to a calculated scheme (de Leeuw and Backx 2001) the discharge sluices could be opened longer during high water levels in the North Sea, in ± 70 % of these situations. With this adjusted management of the discharge sluices, partial rehabilitation of estuarine habitat and ecological

flow can be expected in the Delta and Lower Rhine, creating more favorable conditions for *A. sturio*.

Conclusions

Redirection of the main flow of the River Rhine, imposed by the sea lock “Haringvlietdam”, led the sturgeons into the Rotterdam harbor. Consequently, out migrating sturgeons encountered less suitable habitat than they would have had with an intact, natural estuary. During the study 17 fish were not detected with the NEDAP Trail® system. Three of those were recaptured in the North Sea, thus it is plausible that more sturgeons must have reached the North Sea. Catch ability from beam trawler fisheries was found to be high. At least 14 % of all released sturgeons were recaptured in shallow, coastal waters. An ongoing extractive or damaging activity, such as fishing, can impact a reintroduced population of *A. sturio*. It is concluded that sustainable fisheries in the North Sea and cooperation with the fisheries sector is a critical prerequisite for a reintroduction program. Potential habitat improvements for rehabilitation of the European sturgeon in the River Rhine can be achieved by adapted management of the sea lock. Reconnecting the estuary to the North Sea will increase habitat availability in the transitional zone between fresh and salt water (i.e. acclimatization area) and create more favorable estuarine conditions in the Delta. Additionally, it is suggested to consider the protection of the Rhine estuary and adjacent coastal areas because of their importance to diadromous species.

Recommendations

Further tracking

The license from the Ministry of Economic Affairs was received under the condition that fish must be monitored for at least 24 months. This proved to be an impossible task, simply because the fish swam out to sea. Although European sturgeons migrate in spring to the spawning grounds in the rivers (Williot et al. 1997), it is unlikely that the test-fish will be detected again. The implanted NEDAP transponders have a battery life-span of maximal 4 years, but *A. sturio* males and females won't reproduce before 12 and 16 years respectively. The external WOT-tags on the other hand, are clearly visible upon recapture and due to their size and appearance sturgeons will stand out in the catch. Retention rates for external tags can vary, but it is not unusual to maintain retentions above 70 % for up to 3 years (Rien et al. 1994). New recaptures can reveal whether the animals survived to adulthood and provide

additional understanding of the temporal and spatial distribution of the test-fish and survival after recapture. Thus test-fish can be positively identified many years following release and long-term data collection from the sea therefore is possible.

In addition it is suggested to repeat this present movement study from a release location further upstream, with 1+ sturgeons and higher numbers. Younger sturgeons have a longer residence time in the river and the estuary (Taverny et al. 2002). This could help to gain more insight into influences of physical and chemical river factors on migration and bonding behavior. Consequently younger sturgeons restrict the usable tagging system to floy tags and the smallest transponders available (with a battery life span of approximately 1 year). To carry out such a study it is preferred to install several NEDAP stations (temporarily) in the Lower Rhine in Germany.

Limit and monitor the increasing number of exotic sturgeons

During present study, the Royal Dutch Angling Association received information on captured exotic sturgeons from commercial fisherman and anglers, captures from the Lower Rhine, the Delta and the North Sea. In middle Europe an increase is observed in numbers of exotic sturgeon species, e.g. *A. baerrii* and *A. gueldenstaedtii* and *A. ruthenus* (Gessner et al. 1999; Arndt et al. 2000, 2002). Their presence could form an extra constraint, considering hybridization and habitat competition. According to Kirschbaum et al. (2003), no spawning of exotic sturgeons was seen in the regions of the North Sea or the Baltic's. It is suggested to monitor the developments and discourage illegal release of exotic sturgeons.

In addition, the Delta and Lower Rhine exhibit high numbers of non-indigenous fish species. This is a result of the sea port which functions as an invasion gateway, and the extensive network of inland waterways which facilitate species from different bio-geographical regions to mingle (Leuven et al. 2009). Colonization by aquatic invasive species can raise limitations on the rehabilitation of the native biodiversity.

Acknowledgments The authors would like to thank these organizations for their support: The Irstea research institute and the DREAL Aquitaine, the Interreg IVB North Sea Region Programme Living North Sea, the World Wide Fund (WWF), the Dutch Ministry of Transport, and the Public Works and Water Management (RWS). Gijs van Zonneveld, ARK Nature helped with the coordination of meetings, acquiring the licenses and so much more. Robin Blokhuijzen, VisAdvies BV, helped with field work. We would like to thank Gerard Manshanden, commercial fisherman and inventor, for using his storage vessel, the staff from the brick factory de Beijer BV for their facilities in the Kaliwaal, the international transport company 'la Fregate Sarl' for transportation of fish to the Netherlands and Jan van Mechelen, fish farm Valkenswaard, for the transport of four sturgeons to Rotterdam.

Annex I

Table 2 Forty three sturgeons released at Kekerdom

NEDAP number	PIT number	WOT number	Cohort	Weight (g)	TL (cm)	Date of release	NEDAP data?	Recaptured dead or alive
10114	3336354	8005	2009	1730	79	10 May 2012		
10150	3225404	8024	2009	1700	76.5	21 June 2012		
10151	3336484	8018	2009	1490	75	10 May 2012	Yes	
10153	3231222	8029	2009	1580	75.5	21 June 2012	Yes	
10157	3336675	8046	2009	1700	77.7	21 June 2012		
10158	3336445	8026	2009	1760	78	21 June 2012		
10160	3220195	8047	2007	2160	84	21 June 2012		
10161	3225642	8003	2009	1600	76	10 May 2012		
10163	3336507	8013	2009	1780	78.5	21 June 2012		
10166	3219613	8045	2007	1240	69	21 June 2012		alive
10167	3261357	8008	2009	1700	78	8 May 2012	Yes	
10168	3336350	8011	2009	1750	79	21 June 2012		
10169	63224	8006	2007	2330	83.5	21 June 2012	Yes	
10170	3220068	8021	2007	1390	74.4	21 June 2012	Yes	alive
10171	3336338	8028	2009	1320	71.5	21 June 2012		alive
10172	3196417	8019	2009	1920	75	10 May 2012	Yes	alive
10174	3219897	8037	2007	1640	69	21 June 2012	Yes	
10175	3254941	8027	2009	1520	74	21 June 2012	Yes	dead
10177	3207523	8032	2007	1400	71.5	21 June 2012	Yes	
10178	3336436	8022	2009	1760	75.5	10 May 2012	Yes	
10180	3336334	8025	2009	1480	74	10 May 2012	Yes	
10182	3219871	8030	2007	1330	71	21 June 2012	Yes	
10183	3220181	8023	2007	1680	72	10 May 2012	Yes	
10184	3220031	8007	2007	1720	74.5	10 May 2012		
10186	3336435	8017	2009	1720	80	10 May 2012		
10188	3336478	8016	2009	1390	75	21 June 2012	Yes	
10189	3221892	8040	2009	1940	83.5	21 June 2012		
10191	3220169	8043	2007	1320	66	21 June 2012	Yes	
10192	3219713	8038	2007	1360	70	21 June 2012	Yes	
10193	3336342	8015	2009	1600	77.8	21 June 2012	Yes	
10194	3207577	8033	2007	2090	79.8	21 June 2012	Yes	
10195	3336429	8010	2009	1470	77.5	10 May 2012		alive
10196	3207560	8041	2007	2050	79	21 June 2012		dead
10197	3224349	8002	2009	1940	82.5	8 May 2012	Yes	
10198	3336383	8009	2009	1850	81	10 May 2012		
10199	3219633	8042	2007	1500	72	21 June 2012	Yes	
10200	3336327	8020	2009	1810	81.5	21 June 2012	Yes	
10201	3219730	8039	2007	1380	69	21 June 2012	Yes	
10202	3219740	8001	2007	1400	72.5	21 June 2012	Yes	
10203	3336434	8036	2009	1550	75	21 June 2012	Yes	
10204	3219959	8035	2007	2170	80.5	21 June 2012	Yes	
10205	3207538	8034	2007	1400	72.6	21 June 2012	Yes	
10206	3219902	8044	2007	1900	80	21 June 2012		
Total detected							7+19=26	7
Not detected							6+11=17	

References

- Acolas ML, Gessner J, Rochard E (2011) Population conservation requires improved understanding of in situ life histories. *Biology and Conservation of the European Sturgeon Acipenser sturio* L. 1758. pp 585–592
- Arndt GM, Gessner J, Anders E, Spratte S, Filipiak J, Debus L, Skora K (2000) Predominance of exotic and introduced species among sturgeons captured from the Baltic and North Seas and their watersheds, 1981–1999. In: Symposium on Conservation of the Atlantic Sturgeon *Acipenser sturio* L., 1758 in Europe. *Bol Inst Esp Oceanogr* 16(1–4): 29–6
- Arndt GM, Gessner J, Raymakers C (2002) Trends in farming, trade and occurrence of native and exotic sturgeons in natural habitats in Central and Western Europe. *J Appl Ichthyol* 18:444–448
- Bacalbasa-Dobrovici N, Holčík J (2000) Distribution of *Acipenser sturio* L., 1758 in the Black Sea and its watershed. *Bol Inst Esp Oceanogr* 16(1–4):37–41
- Bergman MJN, Hup M (1992) Direct effects of beamtrawling on macrofauna in a sandy sediment in the southern North Sea. *ICES J Mar Sci J Cons* 49(1):5–11
- bij de Vaate A, Breukelaar AW (2001) De migratie van zeeforel in Nederland. Rijksinstituut voor Integraal Zoetwaterbeheer & Afvalwaterbehandeling, rapport nr. 2001.046. ISBN 9036954037
- Birstein VJ, Bernis WE, Waldman JR (1997) The threatened status of acipenseriform fishes: a summary. *Environ Biol Fishes* 48(1–4): 427–435
- Brevé N, Vis H, Spierts I, de Laak G, Moquette F, Breukelaar A (2013) Exorbitant mortality of hatchery-reared Atlantic salmon smolts *Salmo salar* L., in the Meuse river system in the Netherlands. *J Coast Conserv* 1–13
- Brosse L, Lepage M, Dumont P (2000) First results on the diet of the young Atlantic sturgeon *Acipenser sturio* L., 1758 in the Gironde estuary. *Bol Inst Esp Oceanogr* 16(1–4):75–80
- Brosse L, Taverny C, Lepage M (2011) Habitat, movements and feeding of juvenile European sturgeon (*Acipenser sturio*) in Gironde Estuary. *Biology and Conservation of the European Sturgeon Acipenser sturio* L. 1758, 153–163
- Brown J, Murphy GW (2010) European sturgeon Vessel-Strike mortalities in the Delaware Estuary. *Fisheries*, p. 72–83
- Buijse T, Cazemier W (1998) Fischbestandshebungen im Rhein im Rahmen des landesweiten Ökosystem-Monitorprogramms. *LÖBF-Mitt* 23:47–56
- Castelnaud G, Rochard E, Jatteau P, Lepage M (1991) Données actuelles sur la biologie d'*Acipenser sturio* dans l'estuaire de la Gironde. In: Williot P (ed) *Acipenser*. IRSTEA Publication, Antony, p 251–275
- CITES (2001) CITES Identification guide - Sturgeons and Paddlefish: Guide to the identification of sturgeon and paddlefish species controlled under the Convention of International Trade in Endangered Species of Wild Fauna and Flora/CITES (Convention of International Trade in Endangered Species of Wild Fauna and Flora). Gèneve(International): Secretariat CITES, 2001. ISBN 0-660-61641-6
- de Groot SJ (1992) Herstel van riviervalkvissen een realiteit? 6. De steur. *De Levende Natuur* 93(1):14–18
- de Groot SJ (2002) A review of the past and present status of anadromous fish species in the Netherlands: is restocking the Rhine feasible? *Hydrobiologia* 478(1–3): 205–218 In: *Hydrobiologia*. Springer, Berlin. ISSN 0018–8158
- de Leeuw CC, Backx JJGM (2001) Naar een herstel van estuariene gradiënten in Nederland. RIKZ/RIZA. RIKZ rapport nr 2000.044. RIZA rapportnr. 2000.034
- de Nie HW, van Ommering G (1998) Bedreigde en kwetsbare zoetwatervissen in Nederland. Toelichting op de Rode Lijst. IKC Natuurbeheer, Wageningen
- De Villeneuve CH (1996) Western Europe's artery: the Rhine. *Nat Resour J* 36:441
- Debus L (1996) The decline of the European sturgeon *Acipenser sturio* in the Baltic and North Sea. In: Kirchhofer A, Hefti D (eds) *Advances in life sciences: conservation of endangered freshwater fish in Europe* (July, 1994, Bern, Switzerland). Birkhaeuser Verlag, Basel-New York, pp 147–156, XII + 341 pp
- Dreal A (2011) Plan national d'actions en faveur de l'esturgeon européen *Acipenser sturio* 2011–2015. 69. Dreal Aquitaine
- Elvira B, Almodóvar A, Lobón-Cerviá J (1991a) Sturgeon (*Acipenser sturio* L. 1758) in Spain, the population of the river Guadalquivir: a case history and a claim for a restoration programme. In: Williot P (ed) *Acipenser: Actes du premier colloque international sur l'esturgeon*, 3–6 octobre 1989, CEMAGREF, Bordeaux. ISBN 2-85362-208-8. pp. 337–347
- Fernández-Pasquier V (1999) *Acipenser sturio* L., in de Guadalquivir river, Spain. Water regulation and fishery as factors in stock decline from 1932 to 1967. *J Appl Ichthyol* 15:133–135
- Field A (2008) Discovering statistics using SPSS, and sex, drugs and rock 'n' roll. 821 p. SAGE Publications Ltd, ISBN 1847879063
- Gessner J (2000) Reasons for the decline of *Acipenser sturio* L., 1758 in central Europe, and attempts at its restoration. *Bol-Ins Esp Oceanogr* 16(1/4):117–126
- Gessner J, Debus L, Filipiak J, Spratte S, Skora KE, Arndt GM (1999) Recent development in sturgeon catches from German and adjacent waters. *J Appl Ichthyol* 15:131–142
- Gessner J, Fredrich F, Williot P, Kirschbaum F (2010a) Preparatory measures and initial release as a prerequisite for the remediation of the European Sturgeon, *Acipenser sturio*, in Germany. *Bull Fish Biol* 11:21–36
- Gessner J, Tautenhahn M, von Nordheim H, Borchers T (2010b) Nationaler Aktionsplan zum Schutz und zur Erhaltung des europäischen Störs (*Acipenser sturio*). Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit und Bundesamt für Naturschutz (Hrsg.), Bonn. 84 pp. Castlenaud 1991
- Hochleithner M (1996) Störe (*Acipenseriformes*): Verbreitung, Lebensweise, Aquakultur. Ratgeber Österreichischer Agrarverlag Wolfsberg (International): Theiss, Wolfsberg. ISBN 3-7040-1261-0
- Holčík J, Kinzelbach R, Sokolov LI, Vasil'ev VP (1989) *Acipenser sturio* Linnaeus, 1758. In: Holčík J (ed) *The freshwater fishes of Europe. Acipenseriformes*, vol 2. AULA Verlag, Wiesbaden, pp 367–394, 469 pp
- Houben B, Linnartz L, Quak J (2012) De terugkeer van de steur in Nederland. ARK Natuurontwikkeling, Nijmegen, 35p
- Jakob E (1996) Das Potential des Unteren Niederrheins als Laich- und Bruthabitat des europäischen Stör *Acipenser sturio*. *LÖBF* (Landesanstalt für Ökologie, Bodenverordnung und Forsten Nordrhein Westfalen). Kirchhundem, Duitsland
- Jatteau P, Castelnaud G, Rochard E, Gessner J, Lepage M (2011) Chapter 24 Tagging European and atlantic sturgeons in Europe. In: Williot P, Rochard E, Desse-Berset N, Kirschbaum F, Gessner J (eds) *Biology and conservation of the Atlantic European sturgeon Acipenser sturio* L., 1758. Springer
- Kinzelbach RK (1987) Das ehemalige Vorkommen des Störs, *Acipenser sturio* (Linnaeus 1758), im Einzugsgebiet des Rheins (Chondrostei: *Acipenseridae*). *Z Angew Zool* 74(2):167–200
- Kinzelbach RK (1997) The Sturgeon (*Acipenser sturio* L. 1758) in Europe. *Z Ökol Naturschutz* 6:129–135
- Kirschbaum F, Ludwig A, Gessner J, Hensel E, Würtz S, Kloas W, Williot P (2003) Restoration of the European sturgeon, *Acipenser sturio* L., in Germany: background, actual situation and perspectives. IGB (Institut für Gewässerökologie und Binnenfischerei). Jahresforschung 2001. Ch. Steinberg
- Kirschbaum F, Williot P, Fredrich F, Tiedemann R, Gessner J (2011) Restoration of the European Sturgeon *Acipenser sturio* in Germany. *Biology and Conservation of the European Sturgeon Acipenser*

- sturio L. 1758 Biology and Conservation of the European Sturgeon *Acipenser sturio* L. 1758, 309–333.
- Kolman R (2011) European Sturgeon, *Acipenser sturio* in Georgia. Biology and Conservation of the European Sturgeon *Acipenser sturio* L. 1758, 243–250
- Lepage M, Rochard E (1995) Threatened fishes of the world: *Acipenser sturio* Linnaeus, 1758 (*Acipenseridae*). *Environ Biol Fishes* 43(1): 28
- Lepage M, Rochard E, Castelnaud G (2000) Atlantic sturgeon *Acipenser sturio* L. 1758 restoration and gravel extraction in the Gironde estuary. *Bol Inst Esp Oceanogr* 16(1–4):175–179
- Leuven RS, van der Velde G, Baijens I, Snijders J, van der Zwart C, Lenders HR, bij de Vaate A (2009) The River Rhine: a global highway for dispersal of aquatic invasive species. *Biol Invasions* 11(9):1989–2008
- Lobrecht P, Van Os J (1977) De laatste riviervissers. Walburg Pers. ISBN 9060114736, 9789060114735
- Lozan JL, Hausch H (1996) Warnsignale aus Fluessen und Aestuaren. Verlag Paul Parey, Berlin, 390 pp
- Ludwig AN, Jenneckens I, Debus L, Ludwig A, Becker J, Kirschbaum F (2000) Genetic analyses of archival specimens of the Atlantic sturgeon *Acipenser sturio* L., 1758. In: Symposium on Conservation of the Atlantic Sturgeon *Acipenser sturio* L., 1758 in Europe. *Bol Inst Esp Oceanogr* 16(1–4):181–190
- Magnin E (1962) Recherches sur la systématique et la biologie des acipenséridés: *Acipenser sturio* L., *Acipenser oxyrinchus* Mitchell et *Acipenser fulvescens* Raf. Parijs: Station Centrale d'Hydrobiologie Appliquée
- Managementplan garnalenvisserij, maart 2009, Vissersbond (2012) Nbwetvergunning garnalen - gebruik zeeflap <http://www.vissersbond.nl/index.php?mod=news&id=217>
- Michelet N (2011) Why, How and Results from an Awareness Campaign Within Marine Professional Fishermen for the Protection of Large Migratory Fish, the European Sturgeon *Acipenser sturio*. In: Biology and Conservation of the European Sturgeon *Acipenser sturio* L. 1758 (pp. 489–498). Springer, Berlin Heidelberg
- Mohr E (1952). *Der Stör*. Brehm. Leipzig: 86 pp
- Nelson TC, Doukakis P, Lindley ST, Drauch Schreier A, Hightower JE, Hildebrand LR, Whitlock RE, Webb MAH (2010) Modern technologies for an ancient fish: tools to inform management of migratory sturgeon stocks. A report for the Pacific Ocean Shelf Tracking (POST) Project. Available: <http://www.postprogram.org>
- Oostenbrugge JV, Bartelings H, Buisman FC (2010) Distribution maps for the North Sea fisheries: Methods and application in Natura 2000 areas
- Paalvast P, Iedema W, Ohm M, Posthoorn R (1998) MER beheer Haringvliet-sluizen. Over de grens van zoet en zout. RIZA rapport 98.051
- Polet H, Slabbinck B, Verschoore K, van Gompel J (2008) Visserij in de Noordzee samen sterk voor een zee vol vis(sers)
- Raat AJ (2001) Ecological rehabilitation of the Dutch part of the River Rhine with special attention to the fish. *Regul Rivers Res Manag* 17(2):131–144
- Reeze AJG, Buijse AD, Liefveld WM, Postma R (2005) Weet wat er leeft langs Rijn en Maas: ecologische toestand van de grote rivieren in Europees perspectief. Ministerie van Verkeer en Waterstaat, Rijkswaterstaat
- Rien TA, Beamesderfer RC, Foster CA (1994) Retention, recognition, and effects on survival of several tags and marks for white sturgeon. *Calif Fish Game* 80(4):161–170
- Rochard E, Lambert P (2011) Chapter 30 Modelling the future of stocked fish. In: Williot P, Rochard E, Desse-Berset N, Kirschbaum F, Gessner J (eds) Biology and conservation of the Atlantic European sturgeon *Acipenser sturio* L., 1758. Springer
- Rochard E and Lepage M (1996) Avis scientifique concernant la repartition en mer de l'esturgeon europeen *Acipenser sturio* et la necessite de l'extension de sa protection a l'ensemble des pays de l'Union Europeenne. IRSTEa (Centre National du Machinisme Agricole du Genie Rural, des Eaux et des Forets). Bordeaux, France
- Rochard E, Castelnaud G, Lepage M (1990) Sturgeons (Pisces: Acipenseridae), threats and prospects. *J Fish Biol* 37(suppl A): 123–132
- Rochard E, Lepage M, Meauzé L (1997) Identification et caractérisation de l'aire de répartition marine de l'esturgeon européen *Acipenser sturio* à partir de déclarations de captures. *Aquat Living Resour* 10:101–109
- Rochard E, Lepage M, Dumont P, Tremblay S, Gazeau C (2001) Downstream migration of juvenile european sturgeon *Acipenser sturio* L. in the Gironde Estuary. *Estuaries* 24(1):108–115
- Rosenthal H, Bronzi P, Gessner J, Moreau D, Rochard E (2009) Action plan for the conservation and restoration of the European sturgeon. Council of Europe. *Nat Environ* (152):125
- RWS (2012) Operationele bedieningsstaat Haringvlietssluizen, mei-augustus 2012
- Seligo A (1926) Änderungen in der Zusammensetzung der Tierwelt des Frischen Haffes. *Verhandlungen der. Int Ver Theor Angew Limnol* 3:434–443
- SOBEK-Rhine version 2000.31, Frontoffice ANI (DLB)
- Spierts ILY, Vis H, Breukelaar AW (RWS Waterdienst) (2010) Downstream migration of salmon smolts in the River Rhine: 2010. VisAdvies BV, Nieuwegein. VA2009_57. 25pp
- Steenkamp BPC (2002) Systeembeschrijving Noordelijk Deltabekken. RIZA werkdokument 2002.207x, Project nr 6100.017.03
- Taverny C, Lepage M, Piefort S, Dumont P, Rochard E (2002) Habitat selection by juvenile European sturgeon *Acipenser sturio* in de Gironde estuary (France). *J Appl Ichthyol* 18:536–541
- Timmermans G, Melchers M (1994) De steur in Nederland. *Natura* 91(7): 155–158
- Trouvery M, Williot P, Castelnaud G (1984) Biologie et ecologie d'*Acipenser sturio*. Etude de la pecherie. Serie Esturgeon No 1. IRSTEa, Bordeaux (France)
- Tulp I, Jansen J, Craeymeersch J, Steenbergen J, Jak R (2011) Effecten van de garnalenvisserij in de Natura 2000 gebieden
- Van der Veen C (1981) Facts and figures on Rhine pollution. *Int'l Bus Law* 9:41
- van Hees J, Peters H (redactie) (1998) MER Beheer Haringvlietssluizen: Over de grens van zout en zoet. Deelrapport Water- en Zoutbeweging. ISBN: 903694871. RWS, notanummer: apv 98/093
- van Kreveld A, van Winden A, te Linde A, Zwolsman G, Jacobs P, Souwerbren P, Gilbert A (2009) Het Benedenrivierengebied in tijden van klimaatverandering Rapport nummer: KvR 014/2009 ISBN 978-90-8815-009-8
- van Vessem P (1998) Morfologie monding Haringvliet. MER beheer Haringvlietssluizen. Rapport RIKZ-98.016
- van Winden A, Overmars W, Bosman W, Klink A (2000) De Atlantische steur: Terugkeer in de Rijn. Wereld Natuur Fonds/Stichting ARK, Hoog Keppel (Neder-land). ISBN 90-74647-49-9
- Verhey CJ (1949) Het voorkomen van de steur (*Acipenser sturio* L.) in de Nieuwe Merwede tussen 1900–1931. *De Levende Natuur* 52:152–159
- Vriese FT, Breukelaar AW (2007) Downstream migration of salmon smolts in the River Rhine in 2007. VisAdvies BV, Utrecht. VA2006_68. 35 pag
- Vriese FT, Merkx JCA, Breukelaar AW (2006) Population study of female downstream migrating silver eel *Anguilla anguilla* in the Rhine system in 2005. VisAdvies BV, Utrecht. Project VA2005_06, 72 pages
- Williot P, Chèvre P (2011) Chapter 32 Reproduction of the cultured brood fish. In: Williot P, Rochard E, Desse-Berset N, Kirschbaum F, Gessner J (eds) Biology and conservation of the Atlantic European sturgeon *Acipenser sturio* L., 1758. Springer
- Williot P, Rochard E, Castelnaud G, Rouault T, Brun R, Elie P (1997) Biological and ecological characteristics of European Atlantic sturgeon, *Acipenser sturio*, as foundations for a restoration program in France. *Environ Biol Fishes* 48:359–370

- Williot P, Brun R, Pelard M, Mercier D (2000) Induced maturation and spawning in an incidentally caught adult pair of critically endangered European sturgeon, *Acipenser sturio* L. J Appl Ichthyol 16(6): 279–281
- Williot P, Rochard E, Castelnaud G, Rounault T, Brun R, Legape M, Elie P (2009) Biological characteristics of European European sturgeon, *Acipenser sturio*, as the basis for a restoration program in France. Environ Biol Fishes 48:359–370
- Williot P, Rouault T, Brun R, Gessner J (2011) Characteristics of the reproductive cycle of wild *Acipenser sturio*
- Winter JD (1983) Underwater biotelemetry. In: Nielsen LA, Johnsen JD (eds) Fisheries Techniques. Am. Fish. Soc., Bethesda, Maryland, 371–395
- Winter HV, Bierman SM (2010) De uittrekmogelijkheden voor schieraal via de haringvlietsluizen. Rapport C155/10. BAS code BO12-04