Vol. 37: 249–254, 2018
https://doi.org/10.3354/esr00929

ENDANGERED SPECIES RESEARCH
Endang Species Res

Published December 13

NOTE

Identification of potential wintering habitat for threatened Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* in Saco Bay, Maine, USA

Sarah N. Hylton[1,*], Amelia M. Weissman[1], Gail S. Wippelhauser[2], James A. Sulikowski[1]

[1]University of New England, Department of Marine Sciences, Biddeford, ME 04005, USA
[2]Maine Department of Marine Resources, Augusta, Maine 04333, USA

ABSTRACT: The identification of habitats critical to wintering, foraging, and spawning is imperative to the management and recovery of imperiled fishes such as the Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*. Atlantic sturgeon are threatened in the Gulf of Maine, and endangered throughout the rest of their range along the United States East coast. While the distribution of Atlantic sturgeon in freshwater and estuarine habitats has been well documented, data on use of marine habitat, particularly in winter months, remains relatively unknown. To better understand the habitat utilization of Atlantic sturgeon during winter, 6 individuals captured at the mouth of the Saco River Estuary (SRE) were fitted with both an external mark report pop-off archival satellite tag (mrPAT) and an internal acoustic transmitter (Vemco V16). Pop-off dates for mrPATs were staggered to occur in pairs on 15 and 30 January and 15 February 2017, with tags recording daily maximum and minimum temperatures while at liberty. All tags lasted the duration of scheduled deployment. Five Atlantic sturgeon appeared to aggregate in Saco Bay within 5 km of their original capture location, while 1 fish moved offshore, where the tag detached 33 km from the mouth of the SRE. The data presented herein suggest that Saco Bay and the surrounding marine environment may serve as wintering habitat for adult Atlantic sturgeon; this is the first direct documentation of such behavior in the Gulf of Maine.

KEY WORDS: Satellite telemetry · Atlantic sturgeon · Endangered species · Overwintering · Conservation · Archival tag · Anadromous

INTRODUCTION

Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* are large, anadromous fish, ranging from Florida to Canada, with 5 distinct population segments (DPS). Atlantic sturgeon are endangered in all DPSs except in the Gulf of Maine, where they are listed as threatened under the US Endangered Species Act (NOAA 2012a,b). Although distribution of Atlantic sturgeon in freshwater and estuarine habitats is well documented (ASSRT 2007), the use of marine habitats and migratory corridors is poorly understood, especially on a DPS-specific basis (Erickson et al. 2011). These gaps inhibit management of the species, particularly in winter months when Atlantic sturgeon have emigrated from rivers to the marine environment (Kieffer & Kynard 1993, Fernandes et al. 2010, Erickson et al. 2011), where interactions with commercial fishing gear occur (Stein et al. 2004).

The limited studies on wintering behavior indicate that Atlantic sturgeon aggregate near the mouths of large bays and estuaries (Laney et al. 2007), which is consistent with both acoustically tagged fish in the St. Lawrence River (Hatin et al. 2002) and satellite

*Corresponding author: shylton@une.edu

Publisher: Inter-Research · www.int-res.com

tagged fish in the St. John River, Canada (Taylor et al. 2016). Acoustic receivers in coastal marine waters have indicated similar behavior occurring in Gulf of Maine Atlantic sturgeon (Wippelhauser et al. 2017); however, no directed studies on wintering behavior have been conducted in this DPS. While the National Marine Fisheries Service (NMFS) has designated the freshwater and estuarine portions of 7 Gulf of Maine rivers as critical habitat for Atlantic sturgeon under the US Endangered Species Act (NOAA 2017), to date, no marine habitats have received protection.

The marine environment outside small coastal systems, such as Saco River Estuary (SRE), Maine, has often been overlooked as habitat essential to the recovery of Atlantic sturgeon in the Gulf of Maine DPS. However, recent studies have identified the SRE as a foraging habitat for Atlantic sturgeon (where a unique diet of American sand lance *Ammodytes americanus* is sought; Novak et al. 2017), and that it supports a population of late-stage juveniles and non-spawning adults (Wheeler et al. 2016). Long-term acoustic telemetry data also indicate that Atlantic sturgeon occupy the mouth of the SRE from late spring through autumn, and are absent from the system in winter months (Novak et al. 2017). In order to gain insight into the wintering behavior of Atlantic sturgeon in the Gulf of Maine DPS, mark report pop-off archival satellite tags (mrPATs) and acoustic tags were affixed to 6 individuals captured in the SRE in November 2016 to document their spatial use of the marine environment.

MATERIALS AND METHODS

Capture, handling, and tagging of Atlantic sturgeon followed recommended protocols described in Kahn & Mohead (2010). All individuals were caught between the jetties at the mouth of the SRE, Maine, on 7 November 2016, and were transported to a 10 000 gallon (37 854 l) tank in the University of New England's Marine Science Center, where sampling protocols (data collection, tagging) as described by Novak et al. (2017) were performed. To track the winter migratory behavior of Atlantic sturgeon in the marine environment over time, individuals received mrPATs with staggered release dates, and acoustic transmitters to determine date of departure and return to the SRE.

In total, 6 individuals were fitted with mrPATs (Wildlife Computers; length: 127 mm, diameter: 28 mm, weight: 40 g). Holes (1/4 inch, 6 mm diameter) were drilled through the ridge of 2 to 3 consecutive dorsal scutes posterior to the pectoral fins, and a small loop of 0.5 cm diameter rubber tubing was inserted through each hole. A 400 lb (ca. 180 kg)-test monofilament leader was looped through the release mechanism of the mrPAT and crimped. The leader was then fed through 7 cm of rubber tubing, 2 metal crimps, the most anterior loop of rubber tubing, and back through the metal crimps to anchor the tag. Additional loops of tubing were closed using monofilament and 2 crimps, and the anchored tag was inserted through these loops to prevent abrasion and entanglement (Fig. 1). All individuals were held for a 24 h recovery period prior to release; no mortalities occurred.

Scheduled pop-off dates were staggered over a period of 8–12 wk to reflect either the progression of linear movement or the occupation of a specific location over time. Tags were active from 9 November until pop-off dates of 15 January (n = 2), 30 January (n = 2), and 15 February (n = 2). While at liberty, mrPATs recorded daily minimum and maximum temperatures (±0.1°C); these data, along with pop-off location, were transmitted to ARGOS upon release.

In addition, 5 Atlantic sturgeon also received individually coded acoustic tags (model V16; VEMCO; 69 kHz, 16 mm diameter, approximate battery life 10 yr). Tags were surgically implanted into the abdominal cavity of 4 fish following methods of Novak et al. (2017), and externally affixed to the rubber tubing on 1 individual (162182). An array of stationary acoustic receivers (model VR2W; VEMCO) is deployed in the SRE year-round with a maximum detection range of 900–1000 m (see Novak et al. 2017 for details). Maps of pop-off locations were created using ArcMap 10.4.1 (ArcGIS; ESRI), and figures were created using R package 'ggplot2'.

Fig. 1. Attachment of a mark report pop-off archival satellite tag (mrPAT) on the dorsal surface of an Atlantic sturgeon; 3 anchor points were used on all individuals < 170 cm fork length (FL)

Table 1. Six Atlantic sturgeon mark report pop-off archival satellite tag (mrPAT) deployments summarized in order of tag pop-off date. Emigration dates determined by last consecutive detections in acoustic array, and return dates by first consecutive detections in array after a period of more than 2 mo without transmission. Individual 162181 was not double tagged with an acoustic transmitter; therefore, emigration and return dates are unknown. TL: total length; FL: fork length; dates are mm/dd/year

Fish ID	Tag ID	TL (cm)	FL (cm)	Scheduled pop-off date	Active tag-days	Pop-off location	Emigration date	Return date
1	162181	151.4	134.6	01/15/2017	67	43.493° N, 70.360° W	–	–
2[a]	162182	175	155.5	01/15/2017	67	43.486° N, 70.352° W	12/14/2016	07/20/2017
3	162183	194	172.5	01/30/2017	82	43.478° N, 70.372° W	11/09/2016	06/09/2017
4	162184	175.6	154.2	01/30/2017	82	43.448° N, 69.969° W	11/11/2016	04/27/2017
5	162185	152.7	141	02/15/2017	98	43.462° N, 70.324° W	11/09/2016	05/10/2017
6	162186	158	138.6	02/15/2017	99	43.480° N, 70.341° W	11/14/2016	04/22/2017

[a]Individual with external acoustic tag

RESULTS

The Atlantic sturgeon captured in this study were considered adults (Wheeler et al. 2016), ranging from 134.6–172.5 cm fork length (FL) (Table 1). Individuals with acoustic transmitters were detected near the mouth of the river until emigration, which ranged from date of release on 9 November to 14 December (Table 1). All mrPATs reported pop-off locations to ARGOS on their programmed release dates except 162185, which released 1 d late.

A total of 5 mrPATs popped off in Saco Bay, Maine, within 5 km of shore between 10 and 30 m isobaths (Fig. 2a) on sandy substrate (Fig. 2b) on 15 and 30 January and 15 February. In contrast, 1 tag, individual 162184, popped off 33 km offshore from the mouth of Saco River on 30

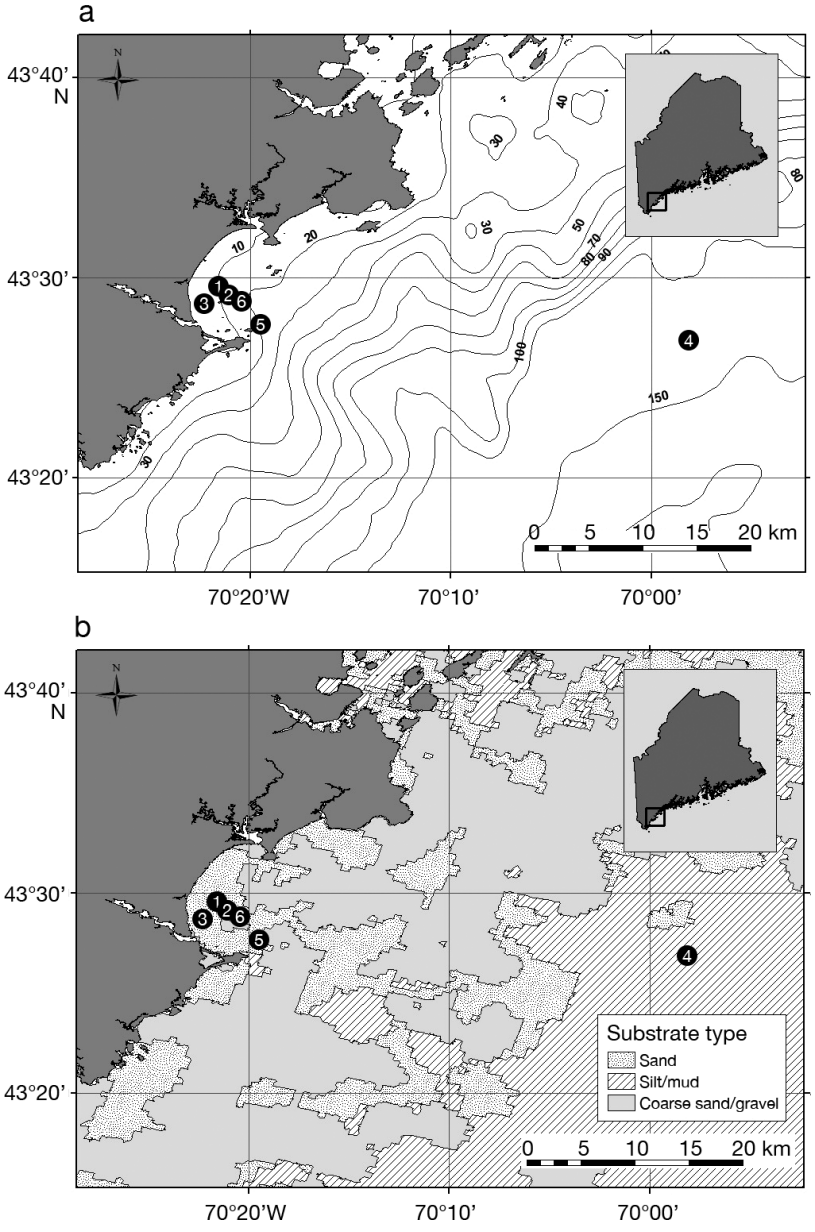

Fig. 2. (a) Bathymetric map of sample area Saco Bay, Maine, USA, and offshore where Atlantic sturgeon mark report pop-off archival satellite tags (mrPATs) popped off on 15 January (points 1 and 2), 30 January (points 3 and 4), and 15 February (points 5 and 6). Bathymetric contours denoted in increments of 10 m; (b) substrate map of Atlantic sturgeon pop-off locations. Individuals located inshore (points 1, 2, 3, 5, and 6) are present over sand substrate, and the individual located offshore (point 4) is present over silt/mud. Figure generated by ArcMap Software 10.4.1 (ArcGIS; ESRI)

January between isobaths of 100 and 150 m (Fig. 2a), over mud/silt substrate (Fig. 2b). During the first month of deployment, mean daily temperatures varied widely (as much as 3.75°C) between the 5 inshore individuals (Fig. 3). After 18 December, however, mean daily temperature variation among these individuals remained within 1.5°C for the remainder of tag life (Fig. 3b). Mean daily temperatures at liberty for the individual located offshore (162184) were higher than those experienced by the 5 individuals located inshore on their respective pop-off dates (Fig. 3b). All sturgeon with acoustic tags returned to the SRE the following spring (April–June) or summer (July–August) and the average individual was detected for 52 d (±20 d SE) in the SRE through the fall. One individual (162185) was recaptured at the mouth of the SRE on 15 September 2017 in good condition.

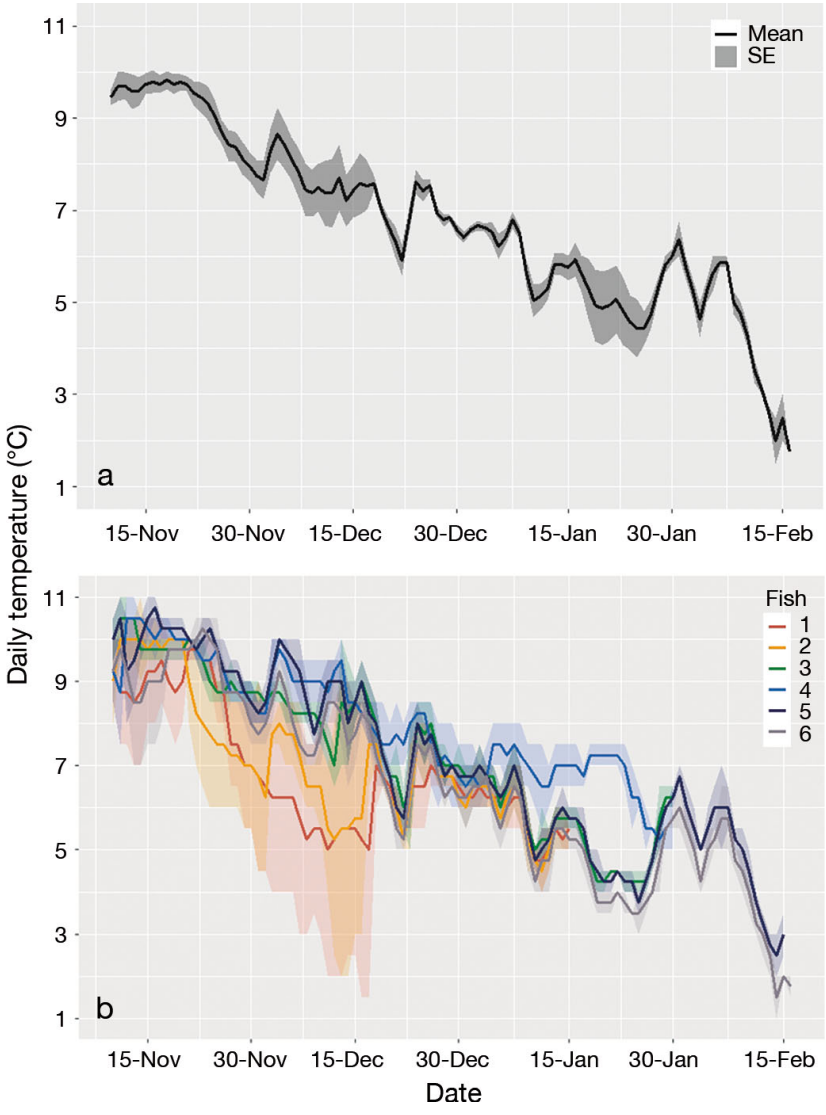

Fig. 3. Daily temperature profiles of tagged Atlantic sturgeon from 10 November to 15 February. (a) Mean (±SE) temperature of all individuals; (b) daily mean temperature (solid line) and temperature range (shadow) for each individual for duration of tag deployment

DISCUSSION

The unique double tagging method, using acoustic transmitters and mrPATs, allowed wintering locations to be observed during specific temporal periods in the marine environment where no acoustic array was deployed. Data from mrPATs suggest 5 of the 6 fish settled in marine habitat just outside of the SRE in Saco Bay, Maine, from mid-December through duration of tag life in mid-January to mid-February. Unfortunately, low resolution data precluded the determination of accurate daily locations of individuals. However, the considerable inter-individual variation in mean daily temperature from November–December may indicate that individuals were exploring different habitats, perhaps related to foraging behavior. The sudden decrease in variation of mean daily temperature among individuals in mid-December may thus indicate a convergence in habitat occupancy, as would be expected for individuals seeking an over-wintering site. All individuals whose mrPAT deployed in Saco Bay were located in <30 m depths over sand, the preferred substrate of Atlantic sturgeon and their prey, American sand lance *Ammodytes americanus*, in the SRE (Stein et al. 2004, Dzaugis 2013, McLean et al. 2013, Novak et al. 2017, Wippelhauser et al. 2017). Thus, while a larger sample size is necessary before any conclusions can be drawn, data presented herein suggest that Saco Bay may provide a suitable over-wintering habitat for this sturgeon species.

The lone individual (162184) located 33 km offshore on 30 January generally occupied higher water temperatures, and may have occupied greater maximum depths (100–150 m) and different substrate than those that remained in Saco Bay. After returning to the SRE in late April, 162184 spent

June and July in the Kennebec River spawning sites during the spawning period (G. Wippelhauser pers. comm.). Immediately following this event, 162184 returned to the SRE and remained in and around the mouth of the system through autumn. The movement of this individual fits the recurrent pattern of presumed spawning behavior, where Atlantic sturgeon use the SRE to forage on American sand lance (Novak et al. 2017) before venturing to the Kennebec River system to spawn (Wippelhauser et al. 2017), returning shortly afterwards to the SRE to resume foraging behavior. While 162184 was not directly assessed for reproductive status, the alternate wintering behavior exhibited by this fish suggests individuals preparing to spawn may have different overwintering requirements than those that are not. However, further research on reproductive status and higher sample sizes are needed before conclusions can be drawn.

Evidence of tagged Atlantic sturgeon remaining in Saco Bay during winter months highlights the need for year-round monitoring of the coastal marine environment outside of rivers which exhibit sturgeon activity. Continued research via long-term satellite tags or a marine acoustic array is needed to determine if Atlantic sturgeon are wintering in Saco Bay annually, and for what portion of the winter. Increased monitoring over winter months may show that the high annual return rate of Atlantic sturgeon to the SRE (Wippelhauser et al. 2017) may also correlate to wintering site fidelity, as exhibited in other species of sturgeon such as Gulf sturgeon *Acipenser oxyrinchus desotoi* (Parauka et al. 2011). At present, only rivers with potential spawning habitat are designated as critical habitat for Atlantic sturgeon in the Gulf of Maine (NOAA 2017). Since the SRE does not have the physical characteristics that allow spawning, it is not deemed critical habitat. Given the availability of a unique prey source (Novak et al. 2017), the high annual return rate of individuals (Wippelhauser et al. 2017), and the identification of a potential wintering site, the SRE may indeed be critical to supporting the life cycle of Atlantic sturgeon in the Gulf of Maine. The documentation of wintering behavior in Saco Bay emphasizes the pressing need for similar studies in river systems with large resident populations, such as the Kennebec, Penobscot, and Merrimack rivers, to determine if similar winter aggregations are occurring and to identify locations where Atlantic sturgeon may be at risk of bycatch mortality. The identification of such aggregations is crucial to the conservation and recovery of Atlantic sturgeon stocks.

Acknowledgements. We thank the graduate and undergraduate students of the Sulikowski Shark and Fish Research Lab at the University of New England. We also thank the Marine Science Center staff for logistical support. This research was made possible through the funding of the Morton-Kelly Charitable Trust and the Davis Conservation Foundation. This research was approved by the University of New England's Animal Care and Use Committee (Institutional Animal Care and Use protocol no. UNE-20140401SULIJ). The manuscript represents Marine Science Center contribution number 122.

LITERATURE CITED

ASSRT (Atlantic Sturgeon Status Review Team) (2007) Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). National Marine Fisheries Service, Northeast Regional Office, Gloucester, MA

Dzaugis M (2013) Diet and prey availability of sturgeons in the Penobscot River, Maine. BSc thesis, University of Maine, Orono, ME

Erickson DL, Kahnle A, Millard MJ, Mora EA and others (2011) Use of pop-up satellite archival tags to identify oceanic-migratory patterns for adult Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchell, 1815. J Appl Ichthyol 27:356–365

Fernandes SJ, Zydlewski GB, Zydlewski JD, Wippelhauser GS, Kinnison MT (2010) Seasonal distribution and movements of shortnose sturgeon and Atlantic sturgeon in the Penobscot River Estuary, Maine. Trans Am Fish Soc 139: 1436–1449

Hatin D, Fortin R, Caron F (2002) Movements and aggregation areas of adult Atlantic sturgeon (*Acipenser oxyrinchus*) in the St. Lawrence River estuary, Québec, Canada. J Appl Ichthyol 18:586–594

Kahn J, Mohead M (2010) A protocol for use of shortnose, Atlantic, Gulf, and green sturgeons. NOAA Tech Memo NMFS-OPR-45. US Department of Commerce, Washington, DC

Kieffer MC, Kynard B (1993) Annual movements of shortnose and Atlantic sturgeons in the Merrimack River, Massachusetts. Trans Am Fish Soc 122:1088–1103

Laney RW, Hightower JE, Versak BR, Mangold MF, Cole WW, Winslow SE (2007) Distribution, habitat use and size of Atlantic sturgeon captured during cooperative winter tagging cruises, 1988–2006. Am Fish Soc Symp 56:167–182

McLean MF, Dadswell MJ, Stokesbury MJW (2013) Feeding ecology of Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchill, 1815 on the infauna of intertidal mudflats of Minas Basin, Bay of Fundy. J Appl Ichthyol 29: 503–509

NOAA (National Oceanic and Atmospheric Administration) (2012a) Final listing determinations for two distinct population segments of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) in the southeast. Fed Regist 77: 5914–5982

NOAA (2012b) Threatened and endangered status for distinct population segments of Atlantic sturgeon in the northeast region. Fed Regist 77:5880–5912

NOAA (2017) Endangered and threatened species; designation of critical habitat for the endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic distinct population segments of Atlantic sturgeon and the threatened Gulf of Maine distinct popu-

lation segment of Atlantic sturgeon. Fed Regist 82: 39160–39274

Novak AJ, Carlson AE, Wheeler CR, Wippelhauser GS, Sulikowski JA (2017) Critical foraging habitat of Atlantic sturgeon based on feeding habits, prey distribution, and movement patterns in the Saco River Estuary, Maine. Trans Am Fish Soc 146:308–317

Parauka FM, Duncan MS, Lang PA (2011) Winter coastal movement of Gulf of Mexico sturgeon throughout northwest Florida and southeast Alabama. J Appl Ichthyol 27: 343–350

Stein AB, Friedland KD, Sutherland M (2004) Atlantic sturgeon marine distribution and habitat use along the northeastern coast of the United States. Trans Am Fish Soc 133:527–537

Taylor AD, Ohashi K, Sheng J, Litvak MK (2016) Oceanic distribution, behaviour, and a winter aggregation area of adult Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, in the Bay of Fundy, Canada. PLOS ONE 11: e0152470

Wheeler CR, Novak AJ, Wippelhauser GS, Sulikowski JA (2016) Using circulating reproductive hormones for sex determination of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) in the Saco River estuary, Maine. Conserv Physiol 4:cow059

Wippelhauser GS, Sulikowski J, Zydlewski GB, Altenritter MA, Kieffer M, Kinnison MT (2017) Movements of Atlantic sturgeon of the Gulf of Maine inside and outside of the geographically defined Distinct Population Segment. Mar Coast Fish 9:93–107

Editorial responsibility: Austin Gallagher, Herndon, Virginia, USA

Submitted: July 11, 2018; Accepted: September 26, 2018
Proofs received from author(s): November 15, 2018