Capture Locations and Growth Rates of Atlantic Sturgeon in the Chesapeake Bay

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Abstract.—Little information exists on temporal and spatial distributions of wild and hatchery-reared Atlantic sturgeon Acipenser oxyrinchus oxyrinchus in the Chesapeake Bay. Approximately 3,500 hatchery-reared Atlantic sturgeon comprised of two size groups were released into the Nanticoke River, a tributary of the Chesapeake Bay, on 8 July 1996. During January 1996–May 2000, 1099 Atlantic sturgeon were captured incidentally (i.e., bycatch) by commercial watermen in the Chesapeake Bay, including 420 hatchery-reared individuals. Wild and hatchery-reared Atlantic sturgeon were captured primarily in pound nets and gill nets. Biologists tagged each fish and recorded weight, length, and location of capture. Although two adults greater than 2000 mm fork length (FL) were captured in Maryland waters, wild sturgeon were primarily juveniles from Maryland and Virginia waters (415 and 259 individuals below 1000 mm FL, respectively). A growth rate of 0.565 mm/d (N = 15, SE = 0.081) was estimated for wild individuals (487–944 mm TL at release) at liberty from 30 to 622 d. The average growth of the group of hatchery-reared Atlantic sturgeon raised at 10°C exceeded that of the group raised at 17°C. Our distributional data based on capture locations are biased by fishery dependence and gear selectivity. These data are informative to managers, however, because commercial effort is widely distributed in the Chesapeake Bay, and little distributional data were available before this study.

Atlantic sturgeon Acipenser oxyrinchus oxyrinchus, an anadromous acipenserid of the Atlantic coast (Gruchy and Parker 1980), once supported commercial and recreational fisheries. Researchers have attributed the decline in population size of Atlantic sturgeon to habitat degradation, poor water quality, river blockages, and commercial overexploitation (T. Smith 1985; Smith and Clugston 1997). Waldman and Virgin (1998) described the Hudson River stock as “apparently declining,” the Delaware River stock as “relict-sized,” and the Chesapeake Bay stock as “apparently extirpated.” A goal of the Atlantic States Marine Fisheries Commission (ASMFC) fishery management plan is to enhance and restore stocks of Atlantic sturgeon (Taub 1990). A 1997 petition to list Atlantic sturgeon as threatened or endangered prompted a status review of the species (NMFS 1998). A fishing moratorium currently protects Atlantic sturgeon in the United States (ASMFC 1998), but incidental capture (bycatch) occurs from commercial fisheries (Collins et al. 1996).

Efforts to manage species with declining populations, such as Atlantic sturgeon, are often hindered by a lack of distributional data. An un-
derstanding of geographic distributions of wild and hatchery-reared Atlantic sturgeon in the Chesapeake Bay is important because it provides (1) basic information on the status of the population and (2) data for management decisions concerning habitat alterations, such as bottom dredging and fill material placement. Atlantic sturgeon distribution data have been published for Canadian waters (Leim and Scott 1966; Vladykov and Greeley 1963) and waters of New Hampshire (Kieffer and Kynard 1993), New York (C. Smith 1985), Delaware (Lazzari et al. 1986), South Carolina (Collins and Smith 1997), and Chesapeake Bay (Gruchy and Parker 1980; Gilbert 1989).

Currently there are no large-scale stocking programs for Atlantic sturgeon in the United States (NMFS 1998). Hatchery stocking programs have been used to supplement and re-introduce sturgeons along their historical ranges (Smith and Dingley 1984; St. Pierre 1996; Beamesderfer and Farr 1997; Waldman and Virgin 1998), including 4,929 hatchery-reared sturgeon released in October 1994 into the Hudson River, New York (Peterson et al. 2000). As part of a mortality and growth study, approximately 3,300 yearling Atlantic sturgeon (produced by the U.S. Fish and Wildlife Service (USFWS)–Northeast Fishery Center in Lamar, Pennsylvania) were stocked into the Nanticoke River, Chesapeake Bay, on 8 July 1996. Juveniles were reared in captivity for 13 months before release and were progeny of one female and three male sturgeon from the Hudson River (spawned in 1995). Hatchery-reared Atlantic sturgeon released into the Hudson and Nanticoke rivers were marked with binary coded wire tags (CWT, Northwest Marine Technology, Shaw Island, Washington).

Our objectives were to examine distributions (based on capture locations) and growth rates of wild and hatchery-reared Atlantic sturgeon in the Chesapeake Bay.

Methods

Distributional data

Beginning in 1994, we cooperated with commercial watermen in a tagging program to determine distributions of Atlantic sturgeon within Maryland waters of the Chesapeake Bay. Initially, we asked watermen to keep a sturgeon alive until a biologist could tag the fish, but this resulted in a low reporting rate (only two fish in two years). As an incentive, a US$100 reward was offered for live sturgeon from Maryland waters of the Chesapeake Bay in January 1996. After release of hatchery-reared individuals in June 1996, the reward program was modified to US$25 for hatchery-reared sturgeon, and US$100 for wild sturgeon, and announced by postcard to all licensed watermen. The reward program in Maryland waters was closed on 1 July 1998 and reopened on 1 December 1998. An Atlantic sturgeon tagging and reward program for Virginia waters of the Chesapeake Bay began in February 1997 (US$100 for live sturgeon) and included the lower sections of the James, York, and Rappahannock rivers. The Virginia reward program was suspended on 6 November 1997, and reopened for four days in February 1998 with a lower reward (US$50 for live sturgeon).

When a waterman reported a captured sturgeon by phone, a USFWS biologist recorded the location of capture, date of capture, and type of gear. Watermen typically held fish at dockside in pens, cages, crab pots, or tethered fish by rope around the caudal peduncle. Sturgeon captured and reported by watermen were scanned for CWTs using a Northwest Marine Technology detector wand to determine hatchery or wild origin. Additionally, the total length (mm TL) and fork length (mm FL) of sturgeon were recorded, and length-frequencies were plotted. The same money reward was given for recaptured fish as first-time captures. Therefore, fishermen did not benefit from removing external tags from previously tagged fish. Wild Atlantic sturgeon in Maryland and Virginia waters were tagged (yellow Hallprint TBA-2, T-bar, Holden Hill, Australia) at the base of the dorsal fin (left side), and through the left pectoral fin. Also, individuals larger than 700 mm TL from Maryland waters were tagged in the anterodorsolateral region with a yellow double barb tag (FIM 96, Floy Tag & Mfg., Inc.).

Growth data

Growth rates of wild and hatchery-reared Atlantic sturgeon were examined separately. Growth rates (mm/d) were calculated for wild Atlantic sturgeon at liberty more than 29 d, and were estimated as the change in TL during time at liberty.

2 Reference to trade names or manufacturers does not imply government endorsement of commercial products.
Time at liberty was calculated as the difference in days between the date of release and the date of recapture.

Two groups of hatchery sturgeon were reared at different water temperatures (10°C and 17°C) for six months before release. At the time of release, sturgeon reared at 10°C had a mean TL of 156 mm (SE = 0.57, N = 2,409), while those reared at 17°C had a mean TL of 232 mm (SE = 0.7, N = 929). Before release, a CWT was injected under the anterior portion of the right side of the 3rd dorsal scute of individuals of both size groups. Due to their larger size, individuals reared at 17°C were also tagged with a T-bar at the base of the dorsal fin (left side). Sturgeon reared at 10°C water temperature are hereafter referred to as the smaller size-group and those reared at 17°C water temperature are referred to as the larger size-group.

Because hatchery-reared sturgeon were primarily caught in three distinct fishery-related time periods after release, growth analysis was separated into three recapture periods: November 1996 to March 1997 (gill net), April 1997 to August 1997 (pound net), and October 1997 to April 1998 (gill net). We assumed high retention of CWTs and T-bar tags based on previous studies of sturgeon (Collins et al. 1994; Rien et al. 1994; U. S. Fish and Wildlife Service, unpublished data). The average size at release was subtracted from the recapture total length to estimate growth (mm/d) for the smaller size-group within each recapture period. The size at release was known for each individual of the larger size-group, so actual growth (mm/d) was calculated for each recapture period. Growth rate and TL were normally distributed within each time period of recapture for both groups. A standard t-test (a = 0.05) was used to test for differences in growth rate and TL between the smaller and larger size groups within each time period.

**Results**

**Distributions based on capture location**

From January 1996 through May 2000, watermen captured and reported 679 wild and 420 hatchery-reared Atlantic sturgeon in the Chesapeake Bay, and recaptured and reported 35 wild and 68 hatchery-reared individuals (Table 1, Figures 1 and 2). Sturgeon captured in Maryland and Virginia waters were reported by 141 and 45 watermen, respectively. All but three hatchery-reared Atlantic sturgeon were from the 1996 release into the Nanticoke River of the Chesapeake Bay. Three hatchery-reared Atlantic sturgeon (76–127 mm TL, marked with a clipped left pelvic fin and a CWT under the first dorsal scute) released in the Hudson River in October 1994 (Peterson et al. 2000) were recovered in Chesapeake Bay (30 October 1997, 965 TL; 9 November 1997, 965 TL; 30 January 1998, 790 TL).

**Table 1. Numbers of captures (event 0) and recaptures (events 1 - 3) of wild and hatchery-reared Atlantic sturgeon in the Chesapeake Bay, Maryland (includes Potomac and Pocomoke rivers) during January 1996 - May 2000. Captures and recaptures were reported by 141 watermen.**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Gear type</th>
<th>Event 0</th>
<th>Event 1</th>
<th>Event 2</th>
<th>Event 3</th>
<th>Total by Gear type</th>
</tr>
</thead>
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<tr>
<td>Wild</td>
<td>Anchored gill net</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Drifted gill net</td>
<td>58</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>65</td>
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<tr>
<td></td>
<td>Crab pot</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td></td>
<td>Pound net</td>
<td>356</td>
<td>18</td>
<td>2</td>
<td>1</td>
<td>377</td>
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<tr>
<td></td>
<td>Trawl</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td></td>
<td>422</td>
<td>24</td>
<td>3</td>
<td>1</td>
<td>450</td>
</tr>
<tr>
<td>Hatchery</td>
<td>Anchored gill net</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Drifted gill net</td>
<td>265</td>
<td>48</td>
<td>10</td>
<td>0</td>
<td>323</td>
</tr>
<tr>
<td></td>
<td>Pound net</td>
<td>138</td>
<td>20</td>
<td>8</td>
<td>1</td>
<td>167</td>
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<tr>
<td></td>
<td>Trawl</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<tr>
<td></td>
<td>Fish trap</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>407</td>
<td>68</td>
<td>18</td>
<td>1</td>
<td>494</td>
</tr>
</tbody>
</table>
Figure 1. Capture locations of wild Atlantic sturgeon in the Chesapeake Bay (recaptures included) during January 1996–May 2000 by commercial watermen.
Figure 2. Capture locations of hatchery-reared Atlantic sturgeon in the Chesapeake Bay (recaptures included) during January 1996–May 2000 by commercial watermen.
and 5 January 1998, 912 TL) and the individual captured on 9 November 1997 was caught two months earlier (9 September 1997) in the upper Delaware Bay (C. Shirey, Delaware Department of Natural Resources and Environmental Control, personal communication).

Wild and hatchery-reared sturgeon were distributed widely in Maryland waters of the Chesapeake Bay, with the majority of individuals captured near Cove point, east and north of the mouth of Patuxent River (Figures 1 and 2). The number of hatchery-reared individuals exceeded that of wild individuals captured in the upper Chesapeake Bay (primarily near Kent Island). In Virginia waters, the reward program targeted the James, Rappahannock, and York rivers; wild individuals were captured primarily in the James River, but few hatchery-reared individuals were captured. Sturgeon were captured in all months of the year, but most were netted in summer and winter months in Maryland waters and in fall and winter months in the James River, Virginia. Bycatch of sturgeon during summer was primarily from a pound net fishery near the shoreline, whereas most sturgeon captured in winter were bycatch from a gill-net fishery in deeper waters. Wild Atlantic sturgeon were captured in Maryland waters in pound nets (83.8%), gill nets (15.8%), and other gears (<1%; Table 1). Hatchery-reared Atlantic sturgeon were captured in Maryland waters in pound nets (34%), gill nets (65%), and other gears (<1%; Table 1). Wild and hatchery-reared Atlantic sturgeon were primarily captured in gill nets in Virginia waters.

Wild Atlantic sturgeon captured by Maryland watermen in pound nets had a wider range of lengths than those captured by gill nets (Figure 3). Although it is difficult to determine maturity based on length, 415 wild individuals below 1000 mm FL (\( \bar{x} = 675 \) mm FL, range 400–994 mm FL) from Maryland waters were likely juveniles. The two largest individuals were captured in Maryland waters (2170 and 2184 mm FL); however, adults were rarely captured and reported. Fourteen individuals from Maryland waters greater than 1000 mm FL were either juveniles, subadults, or adults (individuals were not sexed). Eight of these were captured in pound nets (\( \bar{x} = 1609 \) mm FL, range 1172–2184 mm FL), whereas six were captured in gill nets (\( \bar{x} = 1133 \) mm FL, range 1015–1290 mm FL). Of 264 wild individuals captured and reported from Virginia waters, 259 were less than 1000 mm FL (\( \bar{x} = 482 \) mm FL, range 235–890 mm FL), and five were larger (\( \bar{x} = 1269 \) mm FL, range 1030–1525 mm FL).

**Sturgeon growth**

Of 35 wild Atlantic sturgeon recaptured, reported, and measured, 15 were at liberty more than 29 d (range 30–622 d). These 15 individuals ranged from 487 to 944 mm TL at time of release. An average growth rate of 0.565 mm/d (SE = 0.081) was estimated for these 15 wild individuals.

Between November 1996 and April 1998, 255 (10.6%) hatchery-reared individuals of the smaller size-group and 115 (12.6%) of the larger size-group were recaptured at least once in the Chesapeake Bay, but only data from first recaptures were analyzed. For two years following release, growth rate of the smaller size-group significantly (\( p < 0.01 \)) exceeded that of the larger size-group (Table 2). The mean length of sturgeon in the smaller size-group (Figure 4), compared with the larger size-group (Figure 5), was shorter (\( p < 0.01 \)) in the first time period, not significantly different in second time period (\( p = 0.57 \)), and longer in the third time period (\( p < 0.01 \)).

**Discussion**

Our data indicate that wild juvenile Atlantic sturgeon occur in the Chesapeake Bay. Our mark–recapture data were insufficient to estimate population size of Atlantic sturgeon in the Chesapeake Bay, but the capture of more than 600 wild juveniles depicts a larger population than previously thought. Historically, Atlantic sturgeon spawned in the Chesapeake Bay (Hildebrand and Schroder 1927), but recent spawning is undocumentd and researchers have suggested that Atlantic sturgeon of Chesapeake Bay origin may be extirpated (Secor 1996; Waldman and Wirgin 1998). Small wild juvenile Atlantic sturgeon (200–400 mm) have been captured recently near the James River, Virginia (NMFS 1998), and may be natal to Chesapeake Bay.

Juvenile Atlantic sturgeon often move large distances from their natal rivers (Kahnle et al. 1998), and those reported herein from the Chesapeake Bay are possibly migrants from other coastal rivers or estuaries. Migration of juvenile Atlantic sturgeon into the Chesapeake Bay is supported by our recovery of three hatchery-reared individuals from the Hudson River. Additionally, Dovol and Berggren (1983) reported that 43 wild Atlantic sturgeon juveniles tagged in the Hudson
Figure 3. Length-frequencies of wild Atlantic sturgeon from the Chesapeake Bay, Maryland, (January 1996–May 2000) separated by capture gear (gill nets and pound nets).

Table 2. Mean growth rates (mm/day) of the smaller and larger size groups of hatchery-reared Atlantic sturgeon during three time periods following release into the Chesapeake Bay, Maryland.

<table>
<thead>
<tr>
<th>Recapture period</th>
<th>Smaller size group</th>
<th>Larger size group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>x</td>
</tr>
<tr>
<td>November 1996–March 1997</td>
<td>63</td>
<td>2.13</td>
</tr>
<tr>
<td>April 1997–August 1997</td>
<td>58</td>
<td>1.57</td>
</tr>
<tr>
<td>October 1997–April 1998</td>
<td>134</td>
<td>1.32</td>
</tr>
</tbody>
</table>
Figure 4. Length-frequencies of the smaller size-group of hatchery-reared Atlantic sturgeon separated by recapture periods (Period 1, November 1996–March 1997; Period 2, April 1997–August 1997; and Period 3, October 1997–April 1998) following release into the Chesapeake Bay, Maryland.
Figure 5. Length-frequencies of the larger size-group of hatchery-reared Atlantic sturgeon separated by recapture periods (Period 1, November 1996–March 1997; Period 2, April 1997–August 1997; and Period 3, October 1997–April 1998) following release into the Chesapeake Bay, Maryland.
River were captured in the Delaware Bay (20 individuals) and Chesapeake Bay (23 individuals). The occurrence of juveniles (regardless of geographic origin) suggests that the Chesapeake Bay may be a nursery area for Atlantic sturgeon. In addition to migration of juvenile Atlantic sturgeon into the Chesapeake Bay, emigration has also been observed (USFWS, unpublished data). Recaptures of 10 hatchery-reared individuals (Nanticoke River) outside of Chesapeake Bay range from Fire Island, New York, to Currituck Beach, North Carolina, including locations from the Atlantic coast and Delaware River. Additionally, recaptures of 20 wild Atlantic sturgeon tagged during the reward program in Chesapeake Bay range from Long Island and Smith Point, New York, to Roanoke and Pamlico Sounds, North Carolina, including locations from the Atlantic coast and Delaware River.

Although biased by fishery dependence, we believe our data of capture locations represent distributions of wild and hatchery-reared Atlantic sturgeon in Maryland because commercial effort and the coverage of the reward program was throughout Maryland waters of the Chesapeake Bay. Capture locations in Virginia waters represent Atlantic sturgeon distributions in part of the lower Chesapeake Bay, because the reward program in Virginia waters was restricted by location (James, Rappahannock, and York rivers) and time (nine months in 1997 and four days in February 1998). We believe distribution data for Maryland and Virginia waters provide useful information for management of Atlantic sturgeon because little distributional data were previously available for the Chesapeake Bay. The objective of the reward program was to obtain information on distributions of Atlantic sturgeon in the Chesapeake Bay, and was not designed to estimate bycatch mortality. Mortality from bycatch, however, could be important given the large numbers of Atlantic sturgeon captured by watermen in the Chesapeake Bay.

The higher occurrence of juveniles in Maryland waters in nearshore areas during summer, and deeper areas during winter is possibly an artifact of a summer pound net fishery and a winter gill-net fishery that primarily target striped bass Morone saxatilis. Mesh sizes of gill nets fished by commercial watermen are more likely to capture juvenile than adult Atlantic sturgeon, and gear selectivity (instead of rareness) may explain the low number of adults collected in the Chesapeake Bay during this study. Additionally, watermen may not have reported adult sturgeon during the reward program because large individuals are difficult to transport and keep alive. Gill nets with a stretched mesh of 12.7–17.8 cm (5–7 in) are fished during winter months for striped bass, and those with smaller meshes are also fished during specified seasons for smaller game fish and baitfish. Pound nets have low selectivity for size, but are selective for fishes that occur in nearshore areas. The majority of pound nets are set and fished between April and November in relatively shallow water (<6 m) and target many gamefishes.

Length data can be useful for understanding growth and size distributions of sturgeon populations (Collins and Smith 1997), and we used lengths at time of release and time of recapture to estimate growth rates, and length distributions to document sizes of Atlantic sturgeon within Chesapeake Bay. Growth rate estimates and length-frequency distributions based on bycatch data are biased by gear selectivity (Collins and Smith 1997), and data reported herein are not exceptions. We did not record gill-net mesh sizes for most Atlantic sturgeon captured in Chesapeake Bay, so an analysis of fish length based on stretched-mesh size was not possible.

Our estimate of growth rate (0.565 mm/d) based on 15 wild individuals is similar to growth estimates from other studies. Growth rates of 1, 2, 3, and 4 year old wild Atlantic sturgeon from the Hudson River were 0.974, 0.662, 0.513, and 0.233 mm/d, respectively (Dovel and Berggren 1983). Wild juvenile Atlantic sturgeon in the Delaware River (range 424–721 mm FL) grew 0.453 mm/d (Lazzari et al. 1986).

Our estimates of growth rates of hatchery-reared individuals after two years postrelease are an extension of Secor et al. (2000). We are uncertain as to why hatchery-reared Atlantic sturgeon (age-1) released at a smaller size grew faster and were larger by age 3 than those released at a larger size. Secor et al. (2000) did not find these differences after one-year post release, although sample sizes were small during their initial study. Individuals of the larger size-group were marked with external T-bar tags and internal CWTs, whereas those of the smaller size-group only received CWTs. External tags may reduce growth rates of fishes (Scheirer and Coble 1991; Xiao 1994; Hughes 1998), and may have reduced growth of hatchery individuals from the larger size-group.
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