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biology letters

Biol. Lett. (2010) **6**, 708–710
doi:10.1098/rsbl.2010.0144
Published online 17 March 2010

Population ecology

Changes in age composition and growth characteristics of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) over 400 years

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Populations of sturgeon (Acipenseridae) have experienced global declines, and in some cases extirpation, during the past century. In the current era of climate change and over-harvesting of fishery resources, climate models, based on uncertain boundary conditions, are being used to predict future effects on the Earth's biota. A collection of approximately 400-year-old Atlantic sturgeon spines from a midden in colonial Jamestown, VA, USA, allowed us to compare the age structure and growth rate for a pre-industrial population during a 'mini-ice age' with samples collected from the modern population in the same reach of the James River. Compared with modern fish, the colonial population was characterized by larger and older individuals and exhibited significantly slower growth rates, which were comparable with modern populations at higher latitudes of North America. These results may relate to higher population densities and/or colder water temperatures during colonial times.

Keywords: Atlantic sturgeon; age and growth; climate change; fin spine; population change

1. INTRODUCTION

Human activities have severely depleted stocks of many marine and freshwater fish species (Myers & Worm 2003; Pauly *et al.* 2003; Safina *et al.* 2005). Populations of sturgeon (Acipenseridae) have experienced global declines, and in some cases extirpation, as a consequence of unsustainable commercial harvest, habitat loss and water pollution (Birstein *et al.* 1997; Atlantic Sturgeon Status Review Team 2007). Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is a large (up to 4.5 m and 368 kg) and long-lived (up to 60 years) anadromous fish that supported a large US commercial fishery in the late 1800s (Ryder 1890; Magnin 1964; Scott & Scott 1988). Owing to low catch numbers, the fishery collapsed in the early twentieth century (Smith 1985). The Atlantic sturgeon's life history (high age of maturation and 2–5 years between female broods) probably inhibits population recovery (Boreman 1997; Smith & Clugston 1997). All major rivers along the North American Atlantic slope supported Atlantic sturgeon (Atlantic Sturgeon Status Review Team 2007) but owing to overharvest, dredging, habitat destruction, pollution and dam construction, many populations are currently extirpated or exist at severely depleted numbers (Smith & Clugston 1997; Hatin *et al.* 2007).

Atlantic sturgeon harvested from the James River, Virginia, were essential to the survival of Jamestown Colony, the first successful English settlement in the Americas (Bowen & Andrews 2000). As documented by the Virginia Company, Atlantic sturgeon provided food and was the first commercial crop of the colony. Atlantic sturgeon pectoral spine samples were recovered from a well ($n = 32$) and a basement ($n = 3$) during archaeological excavation at Colonial Jamestown conducted by the Association for the Preservation of Virginia Antiquities (APVA). The well was dug soon after colonization in 1607 and was converted to a rubbish pit, probably owing to saltwater intrusion associated with the drought during the starving time of 1609 (B. Straube, APVA 2006, personal communication). Layering of items in the well and basement indicate the spines date from *ca* 1610–1617, providing the opportunity to compare somatic growth and age structure of the extant James River Atlantic sturgeon population with the colonial population prior to industrialization. Over time, genetically distinct Atlantic sturgeon population segments have evolved (King *et al.* 2001) owing to high site fidelity and the extant James River population is, therefore, considered a remnant of the colonial population.

2. MATERIAL AND METHODS

The colonial-era spines were brittle and could not be processed using standard methods. Jamestown samples were coated in paraffin, sectioned by isomet saw equipped with a diamond-tipped blade and examined at 40× magnification using reflected light. Modern samples came from ship strike mortalities and collections by commercial fishermen (8–35 cm stretch gill nets) ensuring that no fish were killed for this project. A piece of the pectoral spine near the base was removed and used to determine age by counting annual rings using transmitted light at 40× magnification (Brennan & Cailliet 1989; Van Eenennaam *et al.* 1996; Stevenson & Secor 1999; Sulak & Randall 2002). All samples were read blind by two experienced readers. Average diameter (average of height and width) of the spine base from extant James River Atlantic sturgeon ($n = 211$) was measured and plotted against fish fork length. Age and size distributions were compared between the two extant and colonial populations using a t-test. Growth curves were compared using coefficient regression analysis.

3. RESULTS

Mean spine diameter was related linearly with fish fork length ($r^2 = 0.92$, $p < 0.001$) (figure 1*b*) and the regression equation was used to estimate fork lengths for Jamestown samples. Extant James River Atlantic sturgeon ages ranged between 1 and 19 years (mean 4 ± 3 s.d. years) compared with 5–42 years for the colonial samples. The coefficient of variation (CV) based on multiple reads of extant samples was 1.8 per cent (70% exact agreement) while the Jamestown CV was 4.0 per cent (46% agreement). Average disagreement was 1.3 years for modern and 2.2 years for Jamestown samples. The absence of fish less than

Received 12 February 2010
Accepted 24 February 2010

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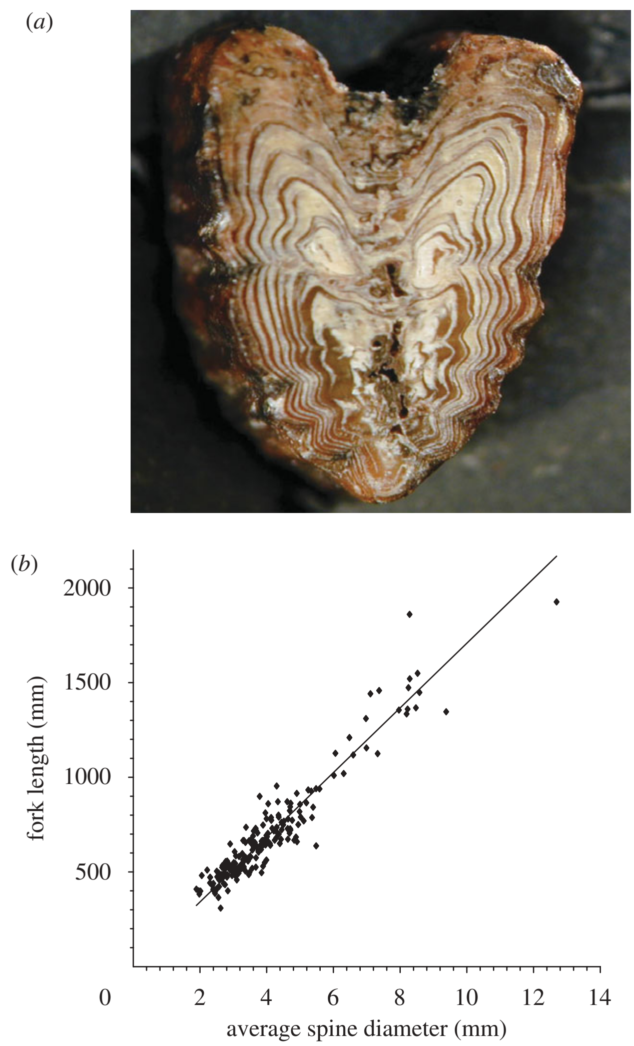

Figure 1. (*a*) Photograph of a spine of an 11 year old Atlantic sturgeon from the well in colonial Jamestown, *ca* 1610. (*b*) Relationship of fork length to average spine diameter from extant James River sturgeon ($y = 11.198x$, $r^2 = 0.92$, $p < 0.001$).

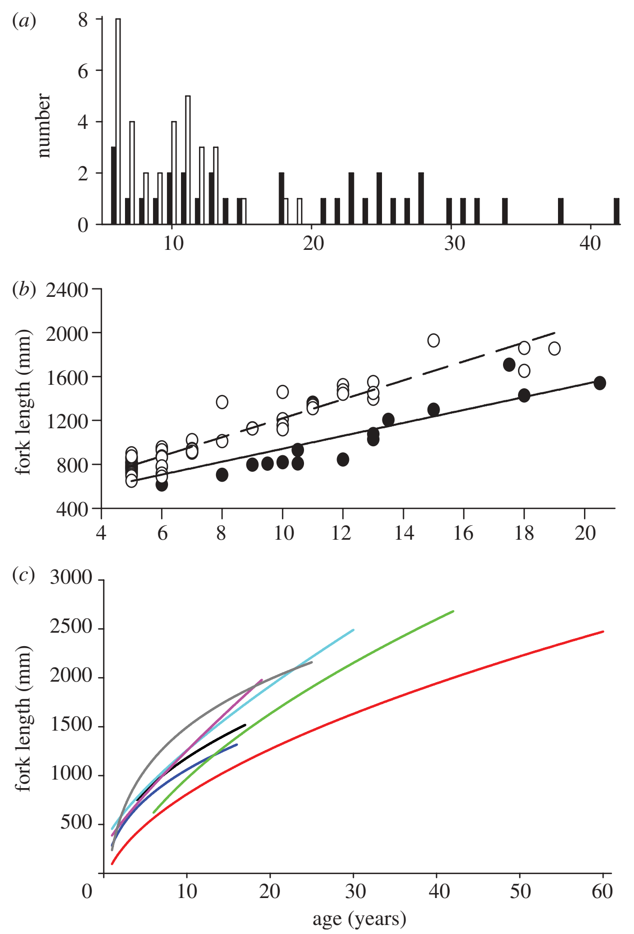

Figure 2. (*a*) Age-frequency distribution of James River Atlantic sturgeon from *ca* 1610 (black bars) compared to extant population (white bars). (*b*) Comparison of fork length-at-age for *ca* 1610 and extant James River Atlantic sturgeon population (*ca* 1610, $y = 58.903x + 352.621$, $r^2 = 0.77$, $p < 0.001$; extant, $y = 76.271x + 487.67$, $r^2 = 0.82$, $p < 0.001$). Black circles, *ca* 1610; white circles, extant. (*c*) Relationship of fork length to age for various population of Atlantic sturgeon (Magnin 1964; Squires & Smith 1979; Smith *et al.* 1982; Dovel & Berggren 1983; Smith 1985). Red line, St Lawrence, QC; dark blue line, St John River, NB; black line, Kennebec River, ME; light blue line, Hudson River, NY; purple line, extant James River, VA; green line, *ca* 1610 James River, VA; grey line, Winyah Bay, SC.

five years of age in the colonial samples probably reflects selective fishing for large individuals. Therefore, all comparisons exclude modern fish less than five years of age. Mean age-at-capture was significantly younger for extant fish (8 ± 3 years) than for historic samples (19 ± 10 years; $t_{91} = 7.49$, $p < 0.001$, figure 2*a*). Mean length-at-capture (1048 ± 338 mm) for extant fish was significantly less than in historic samples (1511 ± 625 mm; $t_{91} = 4.64$, $p < 0.001$). Finally, the slope of growth curves from areas of sample overlap (present day $n = 58$, Jamestown $n = 19$), for extant fish was significantly higher (*ca* 25%) than comparably aged, *ca* 1610 samples (slopes: $t_{73} = 3.80$, $p < 0.001$, figure 2*b*).

Growth curves comparing populations at various latitudes from South Carolina to Quebec indicate clinal growth (figure 2*c*), suggesting that colder water temperatures and/or a shorter growing season decreased annual growth. Analysis of covariance showed that the *ca* 1610 James River population was significantly different from all populations except for the St John River, New Brunswick, Canada ($p = 0.232$).

4. DISCUSSION

There are probably multiple causes for the differences in life-history characteristics of James River Atlantic sturgeon between modern and colonial periods. One factor could be the severe depletion of Atlantic sturgeon stocks from a century or more of unsustainable harvest. The population from 1610 is unknown; however, John Smith wrote 'there was more sturgeon here than could be devoured by dog or man' (Barbour 1986). Atlantic Sturgeon Status Review Team (2007) stated that the Chesapeake Bay Atlantic sturgeon population qualified for federal threatened status. Over-exploited fisheries are characterized by a decrease in mean individual size (i.e. loss of larger individuals), higher (i.e. compensatory) rates of somatic growth and truncated age distribution (Berkley *et al.* 2004).

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Climate changes since the late sixteenth century may also explain growth differences in the James River population between the colonial period and the present. Slower growth rates at higher latitudes suggesting a temperature effect on growth have been demonstrated in lake sturgeon (*Acipenser fulvescens*) and American shad (*Alosa sapidissima*) (Legget & Carscadden 1978; Power & McKinley 1997). Somatic growth characteristics inferred from colonial Virginia samples were consistent with data from modern populations at substantially higher latitudes (e.g. New Brunswick, Canada). The Jamestown Colony was established during a period of globally lower temperatures ('the little ice age') when mean sea-surface temperatures in Chesapeake Bay were at least 2.5°C cooler than current conditions (Cronin *et al*. 2003). These findings may represent evidence of the effects of global climate change on the growth dynamics of a long-lived anadromous fish.

We thank the APVA, especially Bly Straube, for the Jamestown material and Albert Spells (United States Fish Wildlife Service), Chuck Frederickson (James River Association), Kelly Place and George Trice for supplementary material and advice. This is VCU Rice Center contribution 008.

Atlantic Sturgeon Status Review Team 2007 Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Report to National Marine Fisheries Service, Northeast Regional Office, 23 February 2007.

Barbour, P. 1986 *The complete works of Captain John Smith (1580–1631)*, vol. I, p. 264. Chapel Hill, NC: The University of North Carolina Press.

Berkley, S., Hixon, M., Larson, R. & Love, M. 2004 Fisheries sustainability via protection of age structure and spatial distribution of fish populations. *Fisheries* **29**, 23–32. (doi:10.1577/1548-8446(2004)29[23:FSVPOA]2.0.CO;2)

Birstein, V., Bemis, W. & Waldman, J. 1997 The threatened status of acipenseriform species: a summary. *Env. Biol. Fishes* **48**, 427–435. (doi:10.1023/A:1007382724251)

Boreman, J. 1997 Sensitivity of North American sturgeons and paddlefish to fishing mortality. *Env. Biol. Fishes* **48**, 399–405. (doi:10.1023/A:1007345806559)

Bowen, S. & Andrews, S. 2000 *The starving time at Jamestown: faunal analysis of Pit 1, Pit 3, the Bulwark Ditch, Ditch 6, Ditch 7, and Midden 1*. Williamsburg, VA: APVA.

Brennan, J. & Cailliet, G. 1989 Comparative age-determination techniques for white sturgeon in California. *Trans. Am. Fish. Soc.* **118**, 296–310. (doi:10.1577/1548-8659(1989)118<0296:CATFWS>2.3.CO;2)

Cronin, T., Dwyer, G., Kamita, T., Schwede, S. & Willard, D. 2003 Medieval warm period, little ice age and 20th century temperature variability from Chesapeake Bay. *Glob. Planet. Change* **36**, 17–29. (doi:10.1016/S0921-8181(02)00161-3)

Dovel, L. & Berggren, T. 1983 Atlantic sturgeon of the Hudson estuary. New York. *NY Fish Game J.* **30**, 140–172.

Hatin, D., Lachance, S. & Fournier, D. 2007 Effect of dredged sediment deposition on use by Atlantic sturgeon and lake sturgeon at an open-water disposal site in the St. Lawrence estuarine transition zone. *Am. Fish. Symp.* **56**, 235–255.

King, T., Lubinski, B. & Spidle, A. 2001 Microsatellite DNA variation in Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and cross-species amplification in the Aciperseridae. *Conserv. Gen.* **2**, 103–119. (doi:10.1023/A:1011895429669)

Legget, W. & Carscadden, J. 1978 Latitudinal variation in the reproductive characteristics of American shad (*Alosa sapidissima*): evidence for population specific life history strategies in fish. *J. Fish. Res. Board Can.* **35**, 1469–1478.

Magnin, E. 1964 Croissance en longeur de trios sturgeons d'Amerique du Nord: *Acipenser oxyrhynchus* Mitchell, Acipenser fulvenscens Raffinesque, et Acipenser brevirostris LeSueur. *Verh. Int. Verein. Theor. Angew. Limnol.* **15**, 968–974.

Myers, R. & Worm, B. 2003 Rapid worldwide depletion of predatory fish communities. *Nature* **423**, 280–283. (doi:10.1038/nature01610)

Pauly, D., Alder, A., Bennett, E., Christensen, V., Tyedmers, P. & Watson, R. 2003 The future of fisheries. *Science* **302**, 1359–1361. (doi:10.1126/science.1088667)

Power, M. & McKinley, R. 1997 Latitudinal variation in lake sturgeon size as related to the thermal opportunity for growth. *Trans. Am. Fish. Soc.* **126**, 549–558. (doi:10.1577/1548-8659(1997)126<0549:LVILSS>2.3.CO;2)

Ryder, J. A. 1890 The sturgeon industries of the eastern coast of the United States, with an account of experiments bearing upon culture. *US Fish Comm. Bull.* **8**, 231–238.

Safina, C., Rosenberg, A., Myers, R., Quinn II, T. & Collie, J. U. S. 2005 Ocean fish recovery: staying the course. *Science* **309**, 707–708. (doi:10.1126/science.1113725)

Scott, W. B. & Scott, M. G. 1988 *Atlantic fishes of Canada*. Toronto, Canada: Toronto University Press.

Smith, T. 1985 The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. *Env. Biol. Fishes* **14**, 61–72. (doi:10.1007/BF00001577)

Smith, T. & Clugston, J. 1997 Status and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. *Env. Biol. Fishes* **48**, 335–346. (doi:10.1023/A:1007307507468)

Smith, T., Marchette, D. & Smiley, R. 1982 Life history, ecology, culture and management of the Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchell, in South Carolina. Final Technical Report, AFS-9, p. 75. SC Wildlife Marine Resource Commission.

Squires, T. & Smith, M. 1979 Distribution and adundance of shortnose and Atlantic sturgeon in the Kennebec River estuary, p. 51. Maine Department of Marine Resources (Comple. Rep. to the US Fish and Wildlife Service. Proj:AFC-19).

Stevenson, J. & Secor, D. 1999 Age determination and growth of Hudson River Atlantic sturgeon, *Acipenser oxyrinchus*. *Fish. Bull.* **97**, 153–166.

Sulak, K. & Randall, M. 2002 Understanding sturgeon life history: enigmas, myths, and insights for scientific studies. *J. Appl. Ichthyol.* **18**, 519–529. (doi:10.1046/j.1439-0426.2002.00413.x)

Van Eenennaam, J., Doroshov, S., Moberg, G., Watson, J., Moore, D. & Linares, J. 1996 Reproductive conditions of the Atlantic sturgeon (*Acipenser oxyrinchus*) in the Hudson River. *Estuaries* **19**, 769–777. (doi:10.2307/1352296)