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Shortnose sturgeon use small coastal rivers: the importance of habitat connectivity

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Summary

Contrary to conventional wisdom for shortnose sturgeon (*Acipenser brevirostrum*), we document shortnose sturgeon use of habitats beyond large rivers. Telemetry data from 2008 to 2010 in the Gulf of Maine demonstrates that adult shortnose sturgeon (up to 70%) frequently move between Maine's two largest rivers, the Kennebec and Penobscot Rivers. Even more interesting, small rivers located between these watersheds were used by 52% of the coastal migrants. Small river use was not trivial, 80% of observed movements extended more than 10 km upstream. However, visits were short in duration. This pattern indicates one of several possibilities: directed use of resources, searching behaviors related to reproduction (i.e. straying) or undirected wandering. Data suggest a relationship between residence time in small rivers and distance to the lowermost barrier. Restoring connectivity to upstream habitats in these rivers could allow opportunities for metapopulation expansion. Regional management of shortnose sturgeon in the Gulf of Maine should incorporate a habitat framework that considers small coastal rivers.

Introduction

Access to suitable habitats at different life stages is critical for population viability (Ray, 2005; Nabe-Nielsen et al., 2010; Stoddard, 2010). Generally, populations persist longer and have higher abundance in connected landscapes (Stoddard, 2010). Therefore, estimates of population viability must be determined at appropriate scales. For diadromous fishes, mainstem dams can fragment spawning and rearing habitats in a river or its estuary (e.g. Ray, 2005). Conversely, restoring connectivity through habitat restoration can result in improved population viability (NRC, 2004; Nicol and Possingham, 2010).

Shortnose sturgeon (SNS) (*Acispenser brevirostrum*) is a diadromous species that ranges from the St John River, in New Brunswick to the St Johns River, Florida (NMFS, 1998). Accepted theory is that SNS are amphidromous, spending time in both freshwater and marine environments of their river of origin throughout their life history (Bain et al., 2007). Historic spawning habitats are believed to be at river 200 km or greater (Kynard, 1997). After the industrial revolution, access to spawning habitat in many US east coast rivers was blocked by dams and shortnose sturgeon are in most cases now forced to spawn below these barriers throughout their range (Kynard, 1997). Dams could restrict SNS to suboptimal spawning habitat and greatly limit juvenile rearing habitat since young-of-the-year do not acquire salinity tolerance until they reach about 1 year of age (e.g. Ziegeweid et al., 2008). Consistent with this assertion, population viability of SNS within a river is related to accessible spawning and juvenile rearing habitat (as measured by distance to the first dam Kynard, 1997).

Shortnose sturgeon, listed as endangered under the US *Endangered Species Act* (1967), have been managed as river-specific populations based on the understanding that the life history is limited to *large* natal rivers and associated estuaries (Kynard, 1997; Bain et al., 2007). In Maine, documented presence of SNS is limited to the Penobscot and the Sheepscot-Kennebec-Androscoggin complex (NMFS, 1998). Recent evidence from acoustic telemetry in the Gulf of Maine demonstrates that movements of SNS are not restricted to a single large river (Fernandes et al., 2010). There is a high degree of movement between Maine's two largest rivers, the Kennebec and Penobscot (Fernandes et al., 2010). Seventy-two percent of individuals tagged in the Penobscot exit the river and 85% of these are detected in the Kennebec River within 3 years (P. E. Dionne, unpublished data). Genetic evidence further supports a high degree of reproductive exchange (Wirgin et al., 2009). Given the prevalence of movement between these two rivers, we sought to document whether sturgeon make use of the small coastal rivers between them and the importance of such small rivers in population viability and management.

Methods

Adult SNS were captured with gillnets in the Penobscot River (between the Veazie Dam and Verona Island, Fig. 1) from May to November in 2006–2009 and were measured and tagged as outlined in Fernandes et al. (2010). Forty-one SNS with acoustic tags met the criteria for use in this study, that is: (i) tag functionality throughout the monitoring period (2008, 2009 or 2010), and (ii) movement patterns indicating the tag was in a live SNS. Transmitters were individually coded 69 kHz Vemco model V9 or V13 (Amirix Systems Inc., Halifax, Nova Scotia, Canada), with a battery life of 250–750 days. In 2008, 2009, and 2010 arrays of acoustic receivers (Vemco VR2 or VR2W) were deployed in the Penobscot and Kennebec Rivers and three smaller rivers (St George, Medomak, and Damariscotta) that are located between the two larger rivers (Fig. 1; Table 1) from April to November (the 'monitoring period'; 195 ± 2 days in 2008, 208 ± 2 days in 2009; 262 ± 2 days in 2010).

To determine the extent of small river use, residence time was calculated as percent of the monitoring period. Distance to the first barrier to upstream migration was measured using Google Map imagery. For the Penobscot, Medomak, Damariscotta, and Kennebec the first barrier was a dam. In the St

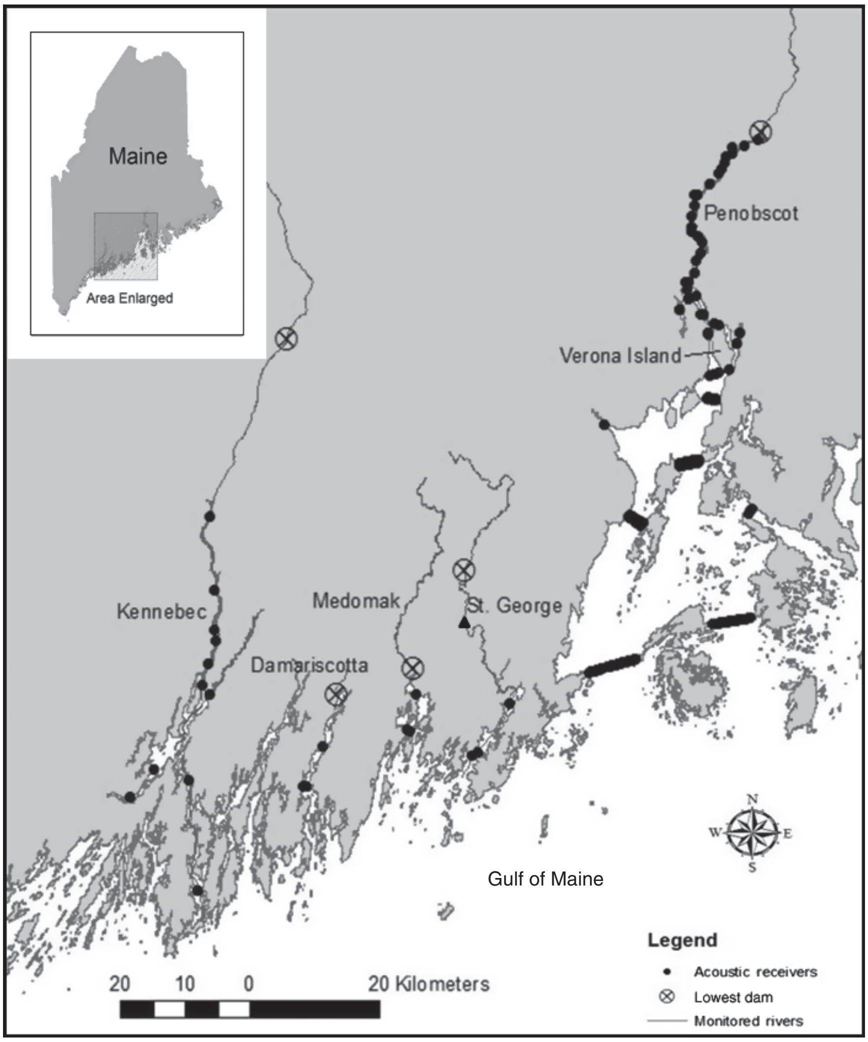

Fig. 1. Map of coastal Gulf of Maine rivers and acoustic receiver locations. Dark grey lines indicate rivers monitored by acoustic telemetry with the locations of acoustic receivers marked by black circles. The location of the first downstream dam on each river is indicated by the circled 'X'. The small triangle on the St George indicates the likely lowermost barrier to migration. On the Penobscot River, the southern end of Verona Island is considered river-km 0, and the first dam is at river-km 47

George the first barrier was a natural barrier (Table 1). To determine if there was a causal relationship between residence time and distance to the first barrier or watershed size, a best subset regression analysis was used.

Results

Twenty-five of 41 individual adult SNS (73–105 cm FL) tagged in the Penobscot River were observed outside the Penobscot River ('emigrants'). All but one were subsequently located in the Kennebec River and of those, 18 (72%) subsequently returned to the Penobscot River. In general, emigrants spent most of their time in the two larger rivers, 67 ± 5% in the Penobscot and 22 ± 5% in the Kennebec (Table 1). However, 52% (13) of emigrants were observed in the small rivers. Time spent there was limited compared to the larger rivers (1–48 h; Table 1), though one SNS spent 3 months in the Damariscotta River. The location of some emigrants could not always be determined (16 ± 2% of the time).

Shortnose sturgeon were usually observed (21 of 26 observations, Table 2) more than 10 km from the coast (at the upstream receiver) in each of the small rivers. Five SNS visited multiple small rivers (Table 2). There was no clear pattern of river preference (within or among individuals) but there was a seasonal pattern. Visits tended to be more frequent in the fall (15 visits by eight SNS) while spring and summer visits were fewer (nine visits by six SNS; Table 2).

There was some indication that visit length increased with distance to the first barrier (Fig. 2). There was an exponential relationship between distance to first barrier and residence time at the $P < 0.10$ level (adjusted $R^2 = 0.140$, $P = 0.09$) The second best model combined distance to the first barrier and watershed area (adjusted $R^2 = 0.117$, $P = 0.111$ and 0.432, respectively). In addition, more SNS individuals visited rivers with more available habitat (Table 1).

Discussion

There is an emerging pattern of SNS movements between large rivers (Fernandes et al., 2010; P. E. Dionne, unpublished data) and among small coastal rivers. This is contrary to previous perceptions that SNS remain in large natal rivers (Bain et al., 2007). Most movements into small rivers were substantial (> 10 km), while the duration of the visits was short. The extent of movement indicates directed searching behavior which may be associated with foraging (e.g. one fish spent

Table 1
Physiographic information for each river, annual periods (month and day listed) when acoustic receivers were deployed, number of shortnose sturgeon detected and percent of observed time spent by migratory shortnose sturgeon in rivers of the Gulf of Maine in 2008 and 2009

	First barrier (km from coast)	Water-shed area (km^2)	2008 deploy period	2009 deploy period	2010 deploy period	No. of unique SNS detected	% residence time
Penobscot estuary (26 receivers)	45.8	22 300	3 April–26 November	8 April–11 December	13 March–29 November	41 (25 emigrants)	67.4 ± 4.9 (n = 16, emigrants only)
Penobscot bay (124 receivers)			1 May–10 November	8 April–9 November	19 April–4 November		
St George River (2 receivers)	38.9[a]	718	9 May–24 November	18 May–12 December	17 March–11 December	11	0.25 ± 0.09 (n = 8)
Medomak River (2 receivers)	17.5	271	9 May–24 November	18 May–12 December	17 March–11 December	5	0.03 ± 0.02 (n = 3)
Damariscotta River (3 receivers)	30.3	277	13 May–1 December	18 May–12 December	24 March–10 December	7	0.14 ± 0.03 (n = 5[b])
Kennebec River (17 receivers)	100.3	15 203	10 April–13 November	16 April–2 December	11 March–30 November	24	22.3 ± 4.54 (n = 20)

Values for % residence time are mean (±SE) for all fish observed both years. Numbers under % time are those with similar total active tag time used for calculating residence time.
[a]Distance to first barrier to migration; distance to first dam is 49.1 km.
[b]One additional fish in the Damariscotta resided there for >3 months and was considered an outlier.

Table 2
Detailed observations of shortnose sturgeon movements in small river systems between the Penobscot and Kennebec Rivers

		St George		Medomak		Damariscotta	
Fish #	Year	Date	No. h in river	Date	No. h in river	Date	No. h in river
1	2008	7 July	24 (D, U, D)	8 July	7 (D)		
	2009					10 June–13 September	2283 (D, U, D)
	2010					1–21 July	480 (D, U, D)
2	2008	13 September	12 (D, U, D)				
3	2008	8 October	18 (D, U)			11 October	7 (D)
4	2008	21 October	20 (D, U, D)	24 October	1 (U)	26 October	18 (D, U, D)
	2009	22 May	4 (D, U, D)				
5	2008					30 October	19 (D)
	2009	9 October	6 (D, U, D)	11 October	2 (U ,D)		
	2010					25–26 April	33 (D, U, D)
6	2008	5 November	12 (D, U, D)	7 November	1 (U)	9 November	10 (D, U, D)
7	2009			17 June	4 (D)		
8	2009	8 October	48 (D, U, D)				
9	2009					21 October	6 (D)
10	2009	28 October	9 (D, U, D)				
11	2010	21 May	6 (U, D)			19 May	4 (D, U)
12	2010	14 June	2 (D, U)				
13	2010	13 June	7 (U, D, U)				

Gray shading indicates fall periods. 'D' and 'U' indicate detection at the downstream and upstream receivers, respectively. For example, if an SNS was detected at a downstream, then the upstream, and not again on a downstream receiver, D, U would be indicated.

3 months in the Damariscotta River during the summer). Alternatively, short forays may be 'stop-overs' en route to larger rivers or a temporary refuge. Finally, entry could be incidental wandering during near-shore coastal migrations (some SNS moved between the Penobscot and Kennebec Rivers without being detected in small rivers). This last alternative seems unlikely as most SNS entering small rivers moved further upstream than might be expected if simply following coastal bottom contours or being temporarily disoriented.

In this study, no individuals remained in the small rivers in the fall, possibly because they did not find suitable spawning or wintering habitat. Frequently observed fall forays were consistent with pre-spawning searching behavior, or 'straying'. In northern rivers SNS use areas downstream of spawning habitat the fall and winter before spawning (Kynard, 1997). Based on the known relationship between spawning location and number of adults, SNS are unlikely to be present in rivers with access to <34 km of a river (Kynard, 1997). For the small rivers in this study, the lowermost barriers were at 18–39 km. Where this distance was greater (i.e. more habitat available) there were more individuals spending more time. However, time in the rivers was limited (usually hours), suggesting that the lowermost barrier may limit access to required habitat.

Regardless of the specific basis for SNS use of small coastal rivers in the Gulf of Maine, recognition of this behavior is critical to species management and recovery. In many fishes, straying results in the recolonization of suitable habitat, such that all or nearly all suitable habitats become occupied over relatively short periods of time (Schtickzelle and Quinn, 2007); hence buffering the species against the vagaries of local

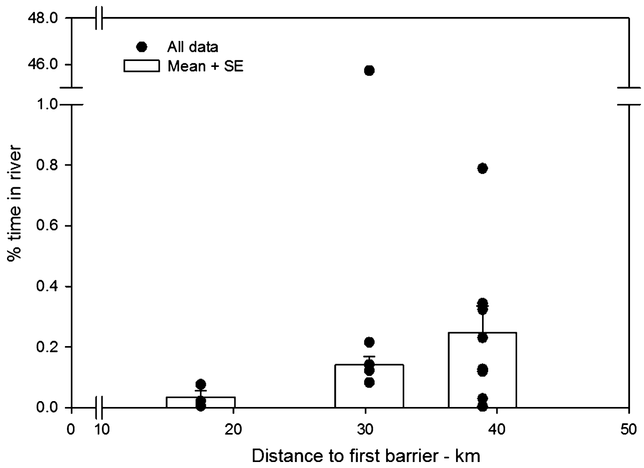

Fig. 2. Percent time shortnose sturgeon spent in each small river system between the Kennebec and Penobscot Rivers. Circles are all data. Bars are mean ± SE. Outlier from the Damariscotta River is shown but not included in calculation of the mean or SE

disturbances (Young, 1999; Schtickzelle and Quinn, 2007). Conversely, loss of population connectivity due to degradation of critical corridors, stop-over sites, or refuges greatly raises risks to population and species persistence (Schtickzelle and Quinn, 2007). At present, small coastal rivers are not managed as critical habitat for shortnose sturgeon in the Gulf of Maine. Protection of these systems may be necessary to prevent further declines of SNS, and restoration activities aimed at increasing available habitat in these systems could serve to enhance population viability via improved connectivity or even recolonization of small historic demes.

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