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Large-Scale Marine and Freshwater Movements of White Sturgeon

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Abstract.—Sturgeon movements are poorly known. We report here telemetry data on the marine and freshwater movements of a 188-cm (fork length; probably 30–60 years old) white sturgeon *Acipenser transmontanus* over a 19-month period. Initially tagged in the Klamath River, California, in May 2002, it remained there until emigrating to the ocean in November 2002. It was next detected more than 1,000 km away in the Fraser River, British Columbia, where it made extended in-river movements in September and October 2003. Given the long periods of time spent in at least two very different river systems (one clear and one highly turbid), the home river is uncertain. Large-scale movements of sturgeon outside the home river have serious implications for population assessments and development of successful management plans. Our results highlight the potential value of permanent large-scale telemetry systems.

Sturgeon are an enigmatic group of ancient fish extending back 450 million years, to before the age of the dinosaurs. All species are under increasing conservation pressure as a result of their size and the high value of their meat and eggs. However, because of their long life and delayed age at maturity, they are especially vulnerable to overexploitation (Gross et al. 2002).

White sturgeon *Acipenser transmontanus* are restricted to the west coast of North America. In Canada, white sturgeon were initially classed as "special concern" in 1990, and upgraded again to "endangered" in November 2003 (COSEWIC 2003; see also Lane 1991). Elements of the basic biology have been chiefly described for sturgeon from the Columbia River (e.g., Galbreath 1985). Remarkably little is known of the biology of sturgeon within the Fraser River, British Columbia, the second largest river on the West Coast; even the location of spawning sites has only recently been reported (Perrin et al. 2003).

Virtually nothing is known of the ocean movements of white sturgeon. A variable number of tagged Columbia River white sturgeon are known to move to the ocean each year, but most recoveries are close to the Columbia River mouth along the Washington or Oregon coast, suggesting long-distance movements are uncommon. Galbreath (1985) reported that the majority of Columbia River white sturgeon appeared to remain within that river and that only four conventionally tagged fish had been recovered outside the Columbia River and only one from a reasonably distant location—Puget Sound. DeVore et al. (1999; see their Table 6) updated Columbia River tag recaptures between 1976 and 1997 and reported that of 471 out-of-system recoveries, the vast majority were recovered nearby (primarily Willapa Bay and Grays Harbor). The southernmost recovery was one in the Sacramento River, California, and northernmost was one in the Fraser River, British Columbia.

For Fraser River white sturgeon, Lane (1991; page 165) reported that "there are no tag data that would indicate either long-distance movements of white sturgeon within the Fraser River or migration to sea." Veinott et al. (1999) subsequently reported that 10% of a sample of fin rays ($N = 29$) collected from Fraser River sturgeon showed high Sr levels (interpreted as a period of marine residence) and 29% showed elevated Sr levels (interpreted as indicating possible estuarine residence). They concluded, however, that white sturgeon from the lower Fraser River rarely migrate to sea and that after about age 40 "most Fraser

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River white sturgeon are permanent residents of the river and make no migrations to the sea or estuary."

Since Lane's report, three additional recoveries of white sturgeon originally tagged with spaghetti tags in the Columbia River have been recorded for the Fraser River (Nelson et al. 2004; T. Nelson, LGL, Ltd., Sidney, British Columbia, personal communication). However, the two current records of long-distance ocean movement of a tagged white sturgeon are for a San Francisco Bay white sturgeon subsequently caught off the mouth of the Columbia River, 1,000 km to the north (Chadwick 1959), and the reciprocal recovery of a tagged Columbia River white sturgeon in the Sacramento in 1997 (DeVore et al. Table 6).

We report here the movements of a white sturgeon initially tagged in the Klamath River that subsequently migrated 1,060 km to the Fraser River. This record is particularly important because of the very extensive periods this animal spent in both river systems, the extent of the migration, and the probable age of the animal (40–60 years). The use of acoustic tracking technology also means that this one individual provides much more information on movements than is possible using conventional tagging technology.

Methods

The white sturgeon discussed in this paper was captured and tagged on May 9, 2002, near river kilometer (rkm) 45.7 in the Klamath River in northern California (124°4′2″W, 41°52′42″N) on the Yurok Indian Reservation and was implanted with both radio and acoustic tags. The sturgeon was identified as a male at the time of tagging; it was 188.0 cm total length (175.3 cm fork length) and had a measured mass of 43 kg.

Based on its length and published information on the sizes and ages of Fraser River white sturgeon, we estimated it to be between 45 and 60 years old at the time of tagging (Semakula and Larkin 1968); alternatively, using recent unpublished data, we calculated that it was roughly 30 years of age (RL&L Environmental Services, Ltd. 2000). Although green sturgeon *A. medirostris* predominate in the Klamath River, it was clearly identified by scute counts as a white sturgeon: 39 on the right side and 36 on the left, which are diagnostic of white sturgeon (range: 38–48; Scott and Crossman 1973) rather than green sturgeon (range: 23–30). A total of 186 juvenile and adult white sturgeon were caught in the Klamath River native sturgeon fisheries between 1980 and 2002, so this individual was not unique.

Tags were surgically implanted into the abdominal cavity. No anesthetic was used because implanted animals were released immediately and, thus, could potentially be recaptured in local net fisheries before the 21-d holding period mandated for animals treated with tricane methanesulfonate (MS-222). Animals retrieved from gill nets were also observed to lie in the stretcher with little struggling and showed minimal response to the surgical procedure.

The techniques used for making and suturing the abdominal incision were modified from those used for collecting ovulated eggs from white sturgeon (Webb et al. 1999; Doroshov et al. 1994). Sex was recorded from a visual inspection of the gonads. A radio tag was inserted anteriorly through the incision, and an acoustic tag was inserted posteriorly. Surgical incisions were closed with four to six interrupted cross stitches.

Each sturgeon caught in 2002 was implanted with both a Vemco V16-5H coded acoustic tag (16 mm in diameter, 92 mm long, 16 g; projected lifespan, >600 d) and an Advanced Telemetry Systems model F-1250 radio tag (29 mm diameter, 112 mm long, 100 g; projected lifespan, >555 d). The combined mass of these tags was 0.1% of the mass of the white sturgeon. Each fish was held after surgery for up to 30 min before release.

Vemco VR-2 acoustic receivers were placed at various points in the Klamath River and moved over the summer, depending on movement information from the concurrent radiotelemetry surveys. The movements of the white sturgeon were then followed in the lower Klamath River from mid-April through November 2002. Radio tag observations were also supplemented with underwater video and snorkel observations. Sturgeon were located bi-weekly with radiotelemetry surveys during the migration and spawning period (April through mid-July), and weekly during summer and fall (mid-July through November).

An unrelated acoustic study, initiated to study the movements of sockeye salmon *Oncorhynchus nerka* in the Fraser River in southern British Columbia, provided an auxiliary means of detecting the acoustically tagged white sturgeon. A marine acoustic array was placed on the seabed of the Strait of Georgia on 11–13 August 2003, consisting of a total of 21 Vemco VR-2 receivers. The array extended 36 km north from the USA–Canada border and offshore from the four possible entrances into the Fraser River 7–9 km into the Strait of Georgia. Three additional acoustic receivers were placed (August 26, 2003) at 43, 65, and 83 rkm upstream from the mouth of the Fraser River, near the Pitt River (49.22°N, 122.75°W), Whonnock (49.17°N, 122.48°W), and Mission (49.14°N, 122.27°W).

Results

After release in the Klamath River, the tagged white sturgeon (number 261) moved slowly upstream to rkm 49 and held in this location through May 17. By May 21 the sturgeon had moved downstream and was detected near rkm 46, and by May 24 the sturgeon was located at rkm 43 (Moore's Rock Hole).

Radiotelemetry observations confirm that it remained at Moore's Rock Hole for 98 d and then moved downstream to hold with other tagged sturgeon at rkm 39 for 49 d. After the first major storm of the season on November 8–9, 2002, river flows increased from 56 to 182 m^3/s. The sturgeon was detected at rkm 26 on November 8 from 0038 to 1242 hours. It was then briefly detected in the estuary (Requa; rkm 1) 8 h later from 2356 to 0000 hours on November 9. No further detections in the Klamath River were made.

The tagged white sturgeon was next detected by the Fraser River acoustic array at rkm 43 on September 16, 2003, almost 1 year later, but it was never detected by the Strait of Georgia marine array. A sequence of upriver and downriver movements occurred (Table 1), the sturgeon reaching the uppermost receiver on September 27 then reappearing on September 30, when it then moved downstream, reaching the downstream-most site on October 4. It was then subsequently detected back at the mid-river detection site on October 11 and again on October 19. No further records of its movement were made before the three acoustic receivers were retrieved on November 23, 2003, suggesting that it remained somewhere between rkm 43 and 83. A boat survey of the river from rkm 20 to rkm 88 on February 7, 2004, using both acoustic and radio receivers, failed to find the sturgeon.

TABLE 1.—Daily detections of acoustically tagged white sturgeon within the Fraser River, British Columbia, in river kilometers from the mouth. The array was deployed from 26 August to 23 November 2003.

	Distance upstream			
Date	43 rkm	65 rkm	83 rkm	Total
Sep 16	2			2
Sep 20		39		39
Sep 27			1[a]	1
Sep 28			36	36
Sep 30			24	24
Oct 2		11		11
Oct 4	42			42
Oct 11		28		28
Oct 19		1		1
Total	44	79	61	184

[a]Single detection at 2058 hours.

Discussion

Knowledge of the marine movements of sturgeon and their exchange between river systems is very limited. If movements between river systems are extensive, important questions concerning white sturgeon management and conservation arise. For example, white sturgeon needing protection in one system, such as the Fraser River, which has regulations precluding harvest, could be subjected to harvest in other systems that have active commercial sturgeon fisheries (e.g., Columbia River, Puget Sound, and parts of the Washington coast; Wydoski and Whitney 2003). Significant movement out of rivers into the sea also has implications for the validity of population assessments because a key assumption in estimating abundance from mark–recapture studies is that the population is closed to emigration or immigration.

The degree to which white sturgeon populations move between different rivers and intermingle is unknown, as is the importance of such movements for conservation. Chadwick (1959) reports a single record of a white sturgeon tagged in San Pablo Bay, San Francisco, that was recovered from the mouth of the Columbia River, about 1,000 km to the north. To our knowledge, our observations form the first report of extensive freshwater residency for a white sturgeon in multiple watersheds and the second observation of very long-distance movements at sea.

The assumptions that the sturgeon present within a given river system necessarily constitute a single resident stock and the degree to which white sturgeon from protected stocks migrate and are exposed to fisheries in other regions need to be carefully assessed. The importance of both emigration and immigration could be readily addressed using properly designed acoustic tagging studies. An integrated acoustic tracking network for the west coast of North America, including both continental shelf and river tracking components, is currently under development (Welch et al. 2003). Such a system would allow precise measurement of rates of movement of anadromous fish, such as sturgeon or Pacific salmon, into or out of their natal rivers and allow measurement of their residence time in nonnatal rivers and estuaries. It would also provide information on their movement and survival along the continental shelf. Our results are based on chance detection of a single tagged animal. A coordinated acoustic tagging (with long-lived tags) of perhaps 100 sturgeon in each of the major West Coast watersheds and then assessing their rates of movement into the ocean and degree of residency in other watersheds should prove instructive. Such measurements are sorely needed to better assess the importance of large-scale movements of white sturgeon, particu-

larly in light of recent decisions to list British Columbia white sturgeon as endangered (COSEWIC 2003).

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References

Chadwick, H. K. 1959. California sturgeon tagging studies. California Department of Fish and Game 45(4):297–301.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2003. COSEWIC assessment and update status report on the white sturgeon *Acipenser transmontanus* in Canada. COSEWIC, Ottawa. Available: http://www.sara-registry.gc.ca/status/status_e.cfm. (January 2006)

DeVore, J., B. James, and R. Beamesderfer. 1999 Lower Columbia River white sturgeon current stock status and management implications. Washington Department of Fish and Wildlife, Report SS 99-08, Olympia.

Doroshov, S. I., J. P. Van Eenennaam, and G. P. Moberg. 1994. Reproductive management of cultured white sturgeon (*Acipenser transmontanus*). Pages 156–161 *in* D. D. Mackinlay editor. High performance fish: proceedings of an international fish physiology symposium, July 1994. Fish Physiology Association, Vancouver.

Galbreath, J. L. 1985. Status, life history, and management of Columbia River white sturgeon, *Acipenser transmontanus*. Pages 119–125 *in* F. P. Binkoski and S. I. Doroshov editors. North American sturgeons: biology and aquaculture potential. Dr W. Junk, Dordrecht, The Netherlands.

Gross, M. R., J. Repka, C. T. Robertson, D. H. Secor, and W. Van Winkle. 2002. Sturgeon conservation: insights from elasticity analyses. Pages 13–29 *in* W. Van Winkle, P. Anders, D. H. Secor, and D. Dixon editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

Lane, E. D. 1991. Status of the white sturgeon, *Acipenser transmontanus*, in Canada. Canadian Field Naturalist 105:161–168.

Nelson, T. C., W. J. Gazey, M. L. Rosenau, and K. K. English. 2004. Status of white sturgeon in the lower Fraser River: report on the findings of the Lower Fraser River White Sturgeon Monitoring and Assessment Program 1999–2004. Prepared for the Fraser River Sturgeon Conservation Society, Vancouver, British Columbia, by LGL Limited, Sidney, British Columbia.

Perrin, C. J., L. L. Rempel, and M. L. Rosenau. 2003. White sturgeon spawning habitat in an unregulated river: Fraser River, Canada. Transactions of the American Fisheries Society 132:154–165.

RL&L Environmental Services, Ltd. 2000. Fraser River White Sturgeon Monitoring Program: comprehensive report (1995 to 1999). Report 815F prepared for British Columbia Fisheries, Vancouver.

Semakula, S. N., and P. A. Larkin. 1968. Age, growth, food, and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. Journal of the Fisheries Research Board of Canada 25:2589–2602.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Veinott, G., T. Northcote, M. Rosenau, and R. D. Evans. 1999. Concentrations of strontium in the pectoral fin rays of the white sturgeon (*Acipenser transmontanus*) by laser ablation sampling–inductively coupled plasma mass spectrometry as an indicator of marine migrations. Canadian Journal of Fisheries and Aquatic Sciences 56:1981–1990.

Webb, M. A. H., J. P. Van Eenennaam, S. I. Doroshov, and G. P. Moberg. 1999. Preliminary observations on the effects of holding temperature on reproductive performance of female white sturgeon, *Acipenser transmontanus* Richardson. Aquaculture 176:315–329.

Welch, D. W., G. W. Boehlert, and B. R. Ward. 2003. POST: the Pacific Ocean Salmon Tracking Project. Oceanologica Acta 25:243–253.

Wydoski, R. S., and R. L. Whitney. 2003. Inland fishes of Washington. University of Washington Press, Seattle.