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# Movement and habitat use of green sturgeon *Acipenser medirostris* in the Rogue River, Oregon, USA

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**Summary**

Green sturgeon (*Acipenser medirostris*) movement patterns and habitat use within the Rogue River, Oregon were evaluated using radio telemetry. Nineteen specimens ranging from 154 to 225 cm total length were caught by gill netting and tagged with radio transmitters during May–July 2000. One tagged green sturgeon was verified as a female near spawning condition. Individual green sturgeons spent more than 6 months in fresh water and traveled as far as river kilometer (rkm) 39.5. Green sturgeon preferred specific holding sites within the Rogue River during summer and autumn months. These sites were typically deep (>5 m) low-gradient reaches or off-channel coves. Home ranges within holding sites were restricted. All tagged individuals emigrated from the system to the sea during the autumn and winter, when water temperatures dropped below 10°C and flows increased. This species is extremely vulnerable to habitat alterations and overfishing because it spawns in only a few North American rivers and individuals reside within extremely small areas for extended periods of time.

## Introduction

Of the 25 living species of sturgeons found worldwide (Bemis and Kynard, 1997), the least is known about North American green sturgeon (*Acipenser medirostris*). This anadromous species reaches 2.9 m (Adair et al., 1982) during a lifespan that exceeds 60 years (T. Rien, pers. comm.). Green sturgeons are found in western North America from the Aleutian Islands, Alaska (Morrow, 1980) to Ensenada, Mexico (Moyle, 1976) and are caught by trawl fisheries in the ocean and by gill net fisheries and sport anglers in rivers and estuaries. They are known to spawn in three Pacific river drainage systems: the Rogue River in Oregon and the Sacramento and Klamath river systems in California (Moyle et al., 1994). While little is known about the spawning, rearing, migration, or feeding behavior of this species in North American rivers, most published accounts suggest that it is principally marine, venturing into fresh water for short periods to spawn (Houston, 1988; Emmett et al., 1991).

Because there appear to be only three green sturgeon spawning populations in North America, it is imperative to identify and protect habitats that are critical for their continued survival. The primary objective of this research was to identify important sites used by green sturgeon in the Rogue River for spawning, holding, and possibly feeding. This information can be used in the development of a recovery and management plan for this species.

## Materials and methods

The study was conducted in the lower 45 river kilometers (rkm) of the Rogue River in southwest Oregon, USA (Fig. 1). This river originates in the Cascade Mountains and flows 347 rkm before entering the Pacific Ocean near Gold Beach, Oregon. The first man-made obstruction on the Rogue River is Savage Rapids Dam, located at rkm 172. Green sturgeons are known to travel at least as far as Raine Falls, a major rapid located at rkm 118 (T. Rien, pers. comm.).

Nineteen green sturgeon captured by gill net during May–July, 2000 received radio transmitters (Table 1). External and internal transmitters were mounted using methods described by Fox et al. (2000). Fish receiving internal tags were visually identified as male or female. Stages of gonad development were not presented herein because gonads were visually staged in the field by various individuals and gonad samples (required to verify visually assessed stages) were inconsistently collected.

A gonad sample was collected from one ripe female (fish number 8; Table 1) during the 2000 field season. Oocytes were measured and a polarization index (PI) was calculated using methods described in Van Eenennaam et al. (2001).

Telemetry was conducted by boat, 2–8 times per month between rkm 45 (Agness, Oregon) and rkm 8 (Fig. 1). Depth (m) and position (latitude and longitude) were recorded each time a tagged fish was located. Water-volume and water-temperature data were obtained from a U.S. Geological Survey gauging station (14372300) located at rkm 47.6. River currents were not measured, but general observations were made on current presence or absence and their relative strength.

A scanning logging receiver (=recording station) was placed at rkm 8 to continuously monitor movements of radio-tagged sturgeon into and out of the river (Fig. 1). This recording station accurately confirmed the passage of sturgeon carrying 830- and 270-day transmitters (Table 1); however, dates and times recorded were inaccurate due to a hardware malfunction. In addition, the recording station did not log passage of the 700-day transmitters that were made by a different manufacturer. Hence, the date of emigration from the river to sea for each individual was estimated as the midpoint between the date of the final recorded location and the subsequent tracking date (i.e., when the individual was not found).

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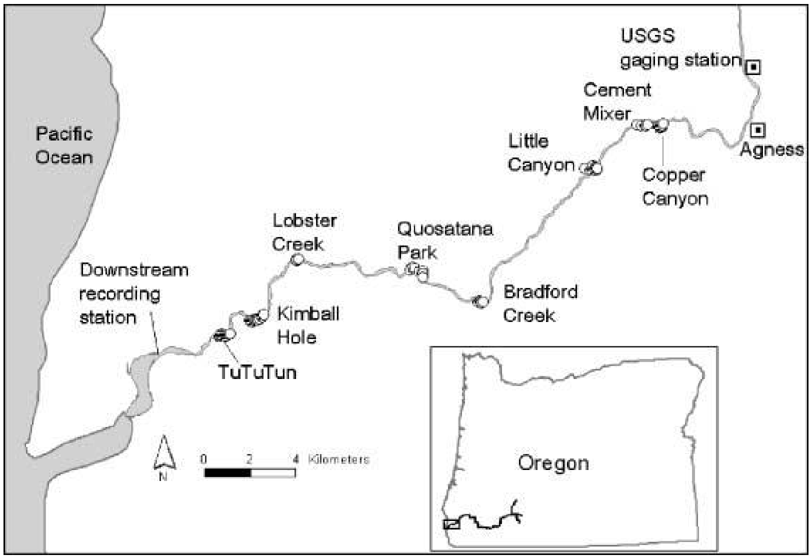


Fig. 1. Map of the study area within the Rogue River, Oregon showing positions recorded for radio-tagged green sturgeon. Circles represent recordings at holding sites where radio-tagged fish were found on 5 or more days. Locations for individuals in transit (13 of 325 recorded locations) are not shown. A recording station was positioned at rkm 8.0 to monitor passage of tagged individuals

Table 1
Capture and tagging information for green sturgeon tagged with radio transmitters in the Rogue River, Oregon. Sex: male (M), female (F) or unknown (U). Tag type: internal (I) or external (E). Emigration date is the estimated date of departure from the Rogue River to the sea (see Methods)

| Fish no. | Capture date | Capture rkm | Water temp. (°C) | Sex | TL (cm) | Tag type | Tag life (days) | Emigration date |
|---|---|---|---|---|---|---|---|---|
| 1 | 5/31 | 13.7 | 16.0 | M | 184 | I | 700 | 12/6 |
| 2 | 5/31 | 13.7 | 16.0 | U | 157 | I | 700 | 10/29 |
| 3 | 6/01 | 17.4 | 15.5 | F | 198 | I | 830 | 10/21 |
| 4 | 6/02 | 35.3 | 15.0 | M | 154 | I | 830 | 12/6 |
| 5[a] | 6/02 | 11.5 | – | F | 190 | I | 830 | – |
| 6 | 6/02 | 11.5 | – | F | 208 | I | 830 | 12/6 |
| 7 | 6/08 | 11.5 | 17.2 | F | 180 | I | 830 | 10/29 |
| 8[b] | 6/08 | 17.4 | 17.2 | F | 169 | I | 270 | – |
| 9 | 6/12 | 13.7 | – | F | 197 | I | 700 | 12/31 |
| 10 | 6/13 | 13.7 | – | U | 205 | I | 700 | 12/6 |
| 11 | 6/27 | 35.3 | 21.0 | F | 225 | I | 270 | 12/6 |
| 12 | 6/27 | 35.3 | 21.0 | U | 158 | I | 270 | 12/6 |
| 13[a] | 6/27 | 35.3 | 21.0 | U | 174 | I | 270 | – |
| 14[c] | 6/28 | 35.3 | 21.9 | M | 177 | I | 270 | – |
| 15 | 7/11 | 39.2 | 23.0 | U | 176 | E | 700 | 12/6 |
| 16 | 7/12 | 13.7 | 22.0 | U | 207 | E | 700 | 12/31 |
| 17 | 7/25 | 39.4 | 22.0 | U | 198 | E | 270 | 12/6 |
| 18 | 7/25 | 39.4 | 22.0 | U | 215 | E | 700 | 12/6 |
| 19 | 7/26 | 23.9 | 23.0 | U | 202 | E | 270 | 12/6 |

[a]Radio transmitter remained at the same location throughout the tracking period.
[b]Radio transmitter was extruded from the fish.
[c]Confirmed mortality.

## Results

Green sturgeons fitted with radio transmitters were captured at six locations between rkm 11.5 and 39.4 (Table 1). Water temperature at capture sites was 15–23°C. One fish died within 2 days of tagging, one internal tag was extruded from a fish that was later recaptured, and two internal tags were recorded as inactive (i.e., motionless) through the end of 2000 and beyond. The fate of fish associated with the latter two tags is uncertain. The remaining 15 green sturgeons retained their transmitters until departing from the system to the sea.

Fish receiving transmitters ranged from 154 to 225 cm total length (TL; Table 1). Only fish larger than the maximum retention size for sport anglers (152 cm TL) were tagged to: (i) ensure that fish anesthetized with MS-222 and injected with oxytetracycline were not ingested by sport anglers, (ii) minimize the probability of losing transmitters to sport anglers, and (iii) maximize the probability of tagging mature fish. Most green sturgeon larger than 152 cm TL are sexually mature (T. Rien, pers. comm.).

Green sturgeon behavior was similar among most externally- and internally-tagged individuals immediately after capture (Fig. 2). In most cases, fish remained at or near the capture site for months after tagging. Two green sturgeons, both tagged internally, moved downstream soon after tagging. One downstream migrant (fish number 4) traveled 21.6 km within 5 days after capture, whereas the other fish (number 12) moved progressively downstream throughout the field season. Only one green sturgeon (fish number 8) exhibited extensive upstream movement immediately after tagging; this individual traveled 18.4 km in approximately 13 days, and

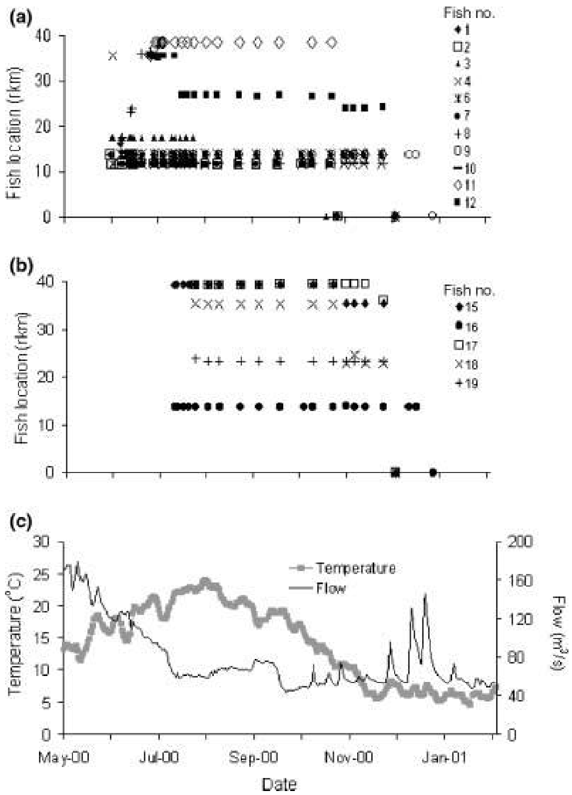


Fig. 2. Positions (rkm) of individual green sturgeon carrying (A) internal and (B) external radio transmitters in the Rogue River, Oregon. Symbols represent individual fish. (C) Water temperature (°C, squares) and flow ($m^3$ $s^{-1}$, line) recorded by a U.S. Geological Survey gaging station at rkm 47.6

subsequently extruded its tag. This specimen was visually staged as a ripe female, and contained green oocytes that averaged 4.45 mm in diameter. Oocytes from this green sturgeon exhibited a low PI (0.037), indicating that the female was in spawning condition at the time of capture (J. Van Eenennaam, pers. comm.).

Green sturgeons remained at specific sites within the Rogue River for extended periods of time (up to 6 months) during the summer and autumn (Fig. 2). Eight sites were identified as holding areas (Fig. 1), where individuals were recorded five times or more. One individual was recorded 27 times at the same holding area over a 6-month period. As many as nine radio-tagged green sturgeon inhabited a single holding area. Although movement was limited during the summer and autumn period, individuals did move between holding areas (Fig. 2).

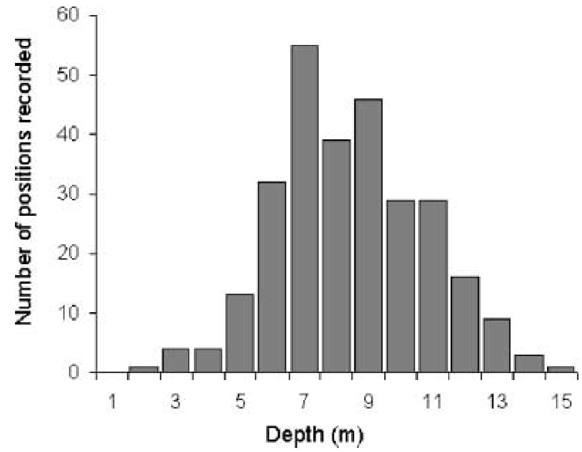


Fig. 3. Depths (m) recorded at sites where green sturgeon carrying radio transmitters were located in the Rogue River, Oregon

Green sturgeons were most often found at depths greater than 5 m (Fig. 3) in areas of low to no current. Holding sites were typically off-channel coves or low-gradient reaches of the main channel. Many such sites were close to sharp bends in the river (Fig. 1).

Home ranges of individual adult green sturgeon within holding areas were restricted (Fig. 4). Repeated recordings of individuals within small home ranges (some as small as 50 × 50 m) were common, especially during July–September when fish were exceptionally inactive.

The first green sturgeon carrying a transmitter left the Rogue River on approximately October 21 (Table 1), when water temperatures ranged from 12 to 13°C (Fig. 2). Downstream passage of this individual was confirmed by the recording station located at rkm 8. The estimated emigration date for 10 of 15 tagged green sturgeons was December 6 (i.e., between November 28 and December 15), after the water temperature dropped below 10°C. The final two tagged green sturgeons left the system on approximately December 31 (i.e., between December 20, 2000 and January 11, 2001). In addition

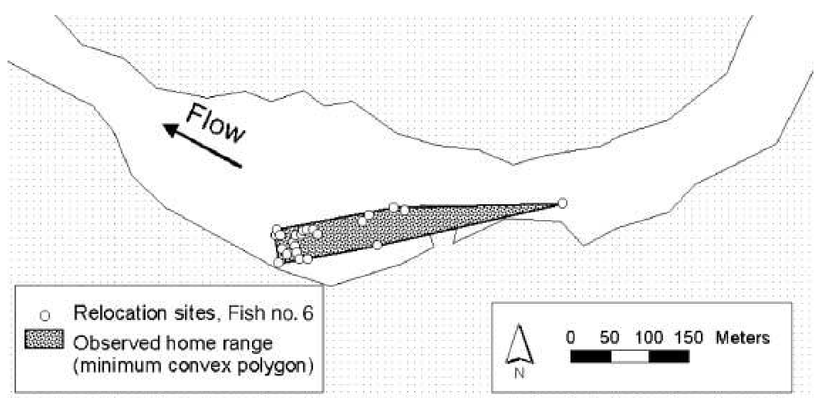


Fig. 4. Recorded locations and home range for an individual green sturgeon (number 6) in the Rogue River, Oregon. This fish was caught on 2 June, 2001 and was last recorded on 28 November, 2001

to water temperature, timing of emigration from the Rogue River appeared to be related to flow (Fig. 2). Most individuals left the system when flow exceeded 100 $m^3 s^{-1}$ (i.e., winter freshet).

## Discussion

Earlier studies indicate that green sturgeons are principally marine and venture into freshwater for short periods of time to spawn (Houston, 1988; Emmett et al., 1991). Emmett et al. (1991) suggest that this species rarely migrates far upstream in Oregon and Washington rivers. Our radio-telemetry data show that individual green sturgeons spend up to six consecutive months in fresh water. Although our radio-tagged individuals did not migrate above rkm 39.5, green sturgeons in the Rogue River are commonly caught as far upstream as rkm 118 (T. Rien, pers. comm.).

During summer and autumn months, green sturgeons preferred specific sites that were deep ($>5$ m), low-gradient reaches or off-channel coves. Use of discrete holding areas for extended periods of time have been described for other sturgeon species (Buckley and Kynard, 1985; Hurley et al., 1987; Hall et al., 1991; Kieffer and Kynard, 1993; Bain, 1997; Curtis et al., 1997; Foster and Clugston, 1997; Sulak and Clugston, 1999; Collins et al., 2000; Hightower et al., 2002). Potential reasons for this site-specific behavior include thermal refugia (Hightower et al., 2002), food availability (Kieffer and Kynard, 1993), or energy balance (Sulak and Clugston, 1999). The Rogue River is considerably warmer than the Pacific Ocean during summer and autumn months and therefore is not a cool water thermal refuge for this species. It is possible that green sturgeons, like other anadromous sturgeon species discussed by Sulak and Clugston (1999), do not feed while in fresh water. Sulak and Clugston (1999) suggest that 'position holding and fasting' may be a life history trait designed to 'minimize the imbalance between the high energetic cost of foraging and the low benefit derived from sparse prey in oligotrophic rivers'. However, the Rogue River is extremely productive and offers large concentrations of molluscs (e.g., Asiatic clam, *Corbicula* spp. and freshwater mussel, Unionidae), resident fish (e.g., northern pikeminnow *Ptychocheilus umpquae*, and sculpin *Cottus* spp.) and anadromous species such as salmon (*Oncorhynchus* spp.) and Pacific lamprey (*Lampetra tridentata*) throughout the spring, summer, and autumn (D. Erickson, unpubl. data). Hence, we speculate that green sturgeon hold in these deep holes (i.e., areas of low current) to conserve energy and feed on readily available food resources.

Most green sturgeons carrying radio transmitters emigrated to the sea from the Rogue River during the late autumn and early winter when water temperatures dropped below 10°C and flows increased above 100 $m^3 s^{-1}$. It should be noted that flows were below average in 2000. Flows normally exceed 100 $m^3 s^{-1}$ beginning early in November, rather than December as observed during 2000. Hence, peak timing of departure for green sturgeon may be earlier during average-flow years.

A sample of oocytes was collected from one female (number 8) that was visually staged as ripe. These oocytes were green, large in size (4.45 mm diameter) and exhibited a low PI (0.037), suggesting that the female was in spawning condition at the time of capture (J. Van Eenennaam, pers. comm.). These diameter and PI measurements are similar to those found for ripe green sturgeon in the Klamath River, California (Van Eenennaam et al., 2001).

## Conclusions

Results presented herein strongly suggest that adult green sturgeons, due to their small freshwater home ranges, are vulnerable to habitat degradation and overfishing. Precautionary management measures may be justified in order to protect their populations and habitats. Currently, sport fishing regulations on the Rogue River are precautionary. The maximum retention size, established to protect mature individuals, is 152 cm TL, and most green sturgeons caught in the Rogue River exceed 152 cm (T. Rien, pers. comm.). However, this species may be extremely vulnerable to poaching as it tends to aggregate at specific sites for extended periods of time. Green sturgeons may also be vulnerable to water quality anomalies (e.g., elevated water temperatures) due to their extended residence time at specific sites. Sewage discharge, farm-runoff, and artificial flow manipulation may threaten the health of green sturgeon populations in the Rogue River both directly (e.g., egg and larvae development) and indirectly (e.g., forage base). For example, flow is artificially manipulated to enhance salmon spawning migrations. The effect of these artificial flow regimes to sturgeon in the Rogue River is uncertain, although this study suggests that green sturgeon are sensitive to flow conditions as cues for migration.

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