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Juvenile White Sturgeon, *Acipenser transmontanus*, in Laboratory Aquaria

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White Sturgeon (*Acipenser transmontanus*), native to Pacific coastal drainages, are infrequently maintained in public aquaria or laboratories of the southeastern United States. We were given the special opportunity to obtain juvenile White Sturgeon for a swimming performance study and to keep them indefinitely for future research. Our observations have provided a great deal of information about care, growth, behavior, and physical variation of captive White Sturgeon. We believe that this information will be of interest to professional aquarists and biologists who are considering work with this remarkable species, and possibly to native fish aquarists since young White Sturgeon are sometimes sold in the pet trade (Goldstein et al., 2000).

Biggest Fish in the River

White Sturgeon are the largest freshwater fish in North America and can reach lengths of 6 m (20 ft) and nearly 900 kg (2,000 lb) (front cover photo). They are long-lived, possibly exceeding 100 years, and slow to mature, taking as long as 25 years (Sullivan et al., 2003). As young-of-year, White Sturgeon are, paradoxically, gray to jet black (Fig. 1). They have light, often snow-white bellies and their rostra are long and sharply pointed. With age, the dorsal pigmentation becomes lighter and the rostrum recedes, leaving a bullet-shaped or snub-nosed head.

The geographic range of the White Surgeon includes the Aleutian Islands of Alaska, British Columbia, and big rivers of the West Coast of the United States south to Monterrey, California (Lee, 1980). White Sturgeon are anadromous or semi-anadramous, with adults moving upriver from the ocean to spawn, and juveniles moving from large river systems to coastal waters. Land-locked populations occur in the Kootenai and upper Columbia Rivers. A 3 m (9 ft) female White Sturgeon can contain close to 5 million eggs, making this species an important resource in the caviar market (Perrin et al., 2003).

The European caviar embargo, which began on 3 Jan. 2006 (Vidal, 2006), has re-focused concern for our own native sturgeon (Raloff, 2006). Overharvest, which devastated North American populations at the turn of the century (Tower, 1908) and now threatens Eurasian populations (Saffron, 2003), is not a widespread threat to White Sturgeon, which are cultivated in large numbers at aquaculture facilities. These hatchery-reared fish are used to produce caviar and meat for gourmet markets. They also provide a valuable opportunity for biologists to study these fish with no impact to natural (and in some cases fragile) populations.

We received our fish from Sterling Caviar, LLC. Sterling produces White Sturgeon on farms in California. Sturgeon are artificially spawned and then raised in warm-water tanks for eventual processing into caviar and meat products. Our sturgeon were spawned from Sacramento-San Joaquin River broodstock in August 2005. Over 100 fish were sent to us, double-bagged in two Styrofoam shipping containers, by overnight delivery, and arrived 11 October 2005. Within 24 hours, all fish were actively swimming and feeding in fiberglass, re-circulating tanks made by Living Streams, which we have used successfully in the past to maintain small Pallid

Fig. 1.
Lateral view of juvenile White Sturgeon, showing that it is actually black (or gray) instead of white.

Sturgeon (Hoover et al., 1999). Because of their small size (60 mm), we initially confined them in plastic tubs with mesh side panels (Fig. 2). This prevented the fish from getting caught in crevices around the filter inserts and around the screen near the agitator, but allowed effective circulation of water.

We tested White Sturgeon to quantify swimming performance: orientation into flowing water, endurance, and station-holding behaviors. Testing took place in a Blazka swim tunnel and followed previous protocols used for Paddlefish and other species of sturgeon (Hoover et al., 2005). Tests consisted of timed trials at specific water velocities. After the trial, the fish was placed back in a Living Stream or in a flowing fiberglass racetrack with water velocity of 11 cm/s (Fig. 3). Retesting fish from the racetrack allowed us to evaluate the effects of "training" on swimming performance. We studied White Sturgeon swimming performance to estimate risk of entrainment from dredges and to evaluate certain rearing practices prior to stocking.

Living Conditions and Daily Care

Nearly all fish were kept in one of three 530-liter Living Streams or in the 1500-liter racetrack. Water temperature was 19°C. A few fish were kept in a rectangular 80-liter all glass aquarium at room temperature (~22°C). Fish experienced almost no "natural" mortality. Some accidental deaths occurred when the slender caudal fins of individuals slipped between the narrow space of the false bottom and the wall of the Living Streams. Weekly water changes of 15% were sufficient to maintain water quality. Mean specific conductance was 0.275 mmhos; pH ranged from 7.6 to 8.3, dissolved oxygen 7.4 to 8.1 mg/L, and turbidity 0.2 to 0.6 NTUs. Fish were fed four times daily during the first few months of captivity (when swimming performance tests were underway) and then twice daily afterwards. Principal foods were frozen brine shrimp and bloodworms. Other foods included krill, mosquito larvae and chopped shrimp. Swimming tests were completed after four months. At that time, most fish were transferred to Living Streams or Ferguson flumes for long-term accommodation. We observed no mortality as a result of experimental tests.

Behavior

As soon as the White Sturgeon entered the tanks, they swam throughout the tank at a rapid pace that continues even now. Most sturgeon species swim actively but periodically rest at the bottom. We rarely saw our White Sturgeon stop for breaks. They were constantly swimming and exploring their tank. They are extremely active but not "frantic" in their behavior.

Fig. 2.
Juvenile White Sturgeon in plastic mesh-sided tubs submerged in a Living Streams recirculating tank.

They rarely dash about the tank and we have observed no injuries, including fish maintained in the traditional all-glass aquarium with sharp corners. Our fish also seem to lack the "jumping" behavior seen by other captive sturgeon species. Therefore, the water levels in the tanks can be relatively high and a cover is not necessary. A previous account of a captive White Sturgeon (76 mm TL), indicated more extreme behavior (caught in plants and cutting rostrum on tank) in captivity and required special modification of its tank to prevent the fish from injuring itself (Fulton, 1985).

Fish were strongly rheotactic with very few fish failing to orient into flowing water. During swimming tests sturgeon exhibited four swimming behaviors: energetic free-swimming up in the water column, slower skimming along or just above the tank bottom, stationary hunkering when appressed to the tank bottom, and tail-bracing against the back cap of the swim tunnel. These behaviors have all been reported for Pallid Sturgeon and Lake Sturgeon (Hoover et al., 2005). When not being tested, and when allowed to move at will in a gradient of water velocities, sturgeon exhibit all of these behaviors with skimming predominating and tail-bracing rarely observed. Swimming endurance of trained fish was significantly higher than untrained or naïve fish.

Growth and Facial Variation

Fish grew rapidly at first (Table 1). On arrival, one group of fish appeared to be >60 mm TL, the other group somewhat smaller and slimmer. During the first month of testing, fish averaged 85 mm TL and 2.9 g. During the second month of testing, fish averaged 108 mm TL and 5.3 g, an increase of 26% in length and 83% in weight. After three months, fish averaged only 112 mm TL and 6.0 g, an increase of <5% in length and only 13% in weight. Condition factor, an index expressing robustness of a fish, did not vary greatly over time, but was slightly higher during the first month. (Note: Ranges of length and weight overlap among periods and maximum values do not consistently increase because not all fish were tested and measured during every period.)

Now, 15 months later, a typical fish is only 150 mm TL. This is small, no matter what the basis for comparison. Fish at the aquaculture facility where we obtained the fish report that 25% of Age I fish weigh 1 kg (P. Struffenegger, pers. comm.), which corresponds to a length of >600 mm FL (Carlander, 1969). Wild fish from California are 406-508 mm FL at Age I, and 457-584 mm FL at Age II (Carlander, 1969). Our fish are also quite small when compared with the published account of a captive 76 mm TL fish that grew to 510 mm in 18 months (Fulton, 1985). Clearly, our sturgeon are stunted.

We also observed different facial colors (and anterior portions of the body and pectoral fins) which may be due to

Table 1. Growth of juvenile White Sturgeon in laboratory aquaria. N is the number of fish measured. Values for length, weight, and condition (an index of robustness) represent arithmetic mean (and ranges).

Period in Captivity	Total Length, mm	Weight, g	Condition, K
First Month, N=67	85 (65-108)	2.9 (1.3-5.1)	0.46 (0.34-0.60)
Second Month, N=53	107 (90-131)	5.3 (3.0-8.7)	0.42 (0.34-0.53)
Fourth Month, N=28	112 (104-123)	6.0 (4.5-8.2)	0.42 (0.35-0.50)

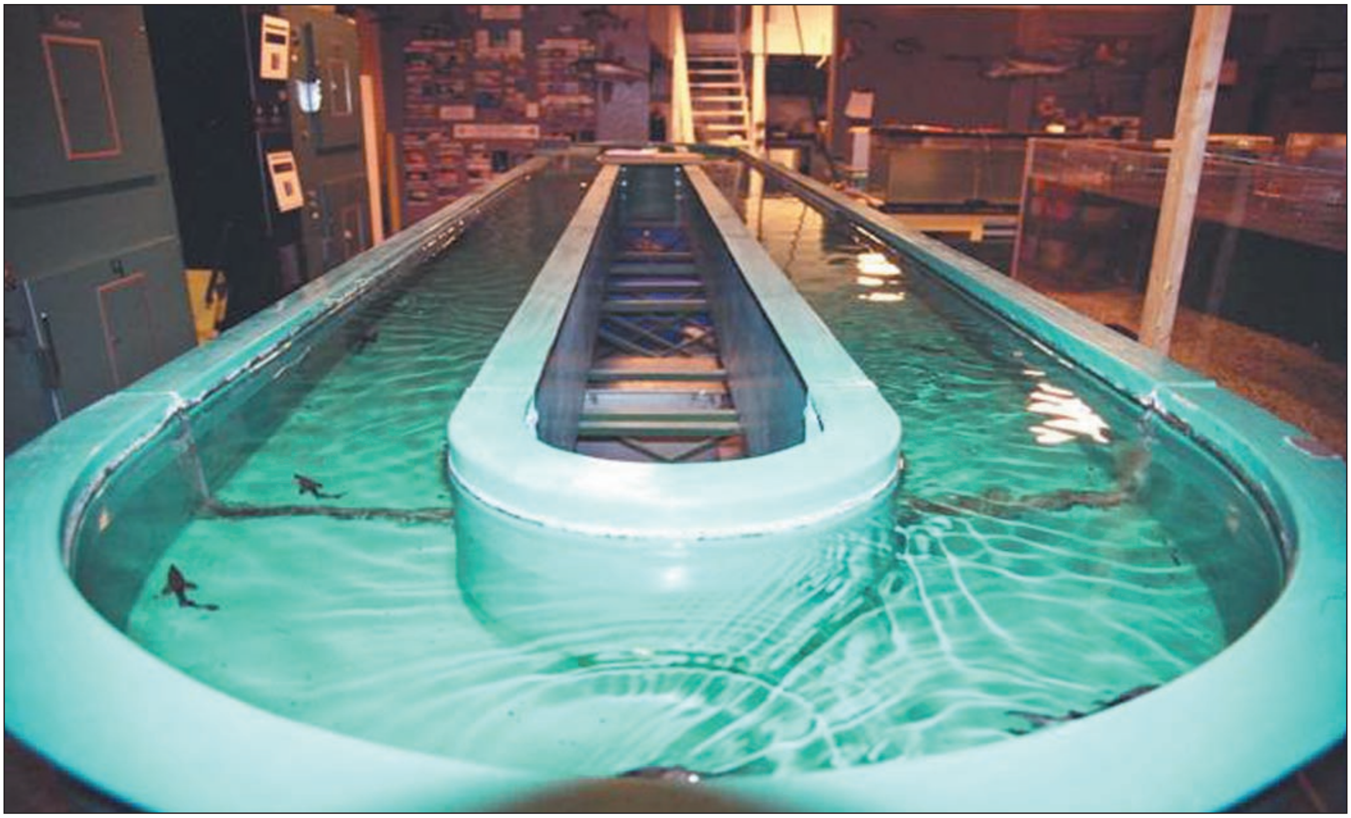

Fig. 3.
Racetrack used to train juvenile White Sturgeon.

our variable accommodations. Colors ranged from black, gray, white with gold highlights, and pure white (Table 2). White Sturgeon from tanks with lighter bottoms were more likely to exhibit darker pigmentation than those from tanks with darker bottoms. When ventral surfaces were dark, however, lips and the oral cavity were still lightly pigmented (Fig. 4). Frequency of the different pigmentation patterns were not correlated with size of fish but may have been influenced by size of the tank, with darker fish being more common in smaller tanks. Relative roles of bottom color and tank size on fish pigmentation cannot be determined, however, without additional experiments. In addition to variation in ventral face color, we also observed rostra receding prematurely, or precociously (Fig. 5). This was seen in only in a few fish.

Lesser Leviathan in the Lab

We found that White Sturgeon are ideal laboratory animals —easy to maintain in captivity and resilient to recovery from experimental studies. Our fish exhibited very low mortality, high levels of activity, and excellent condition, but relatively "restrained" growth. Small size may be a physiological

Table 2. Characteristics of juvenile White Sturgeon maintained in aquaria of different sizes and bottom types after 11 months in captivity.

	80-liter tank; white gravel	**347-liter flume; Plexiglas over wood**	**530-liter Living Stream; blue fiberglass**
Number	8	41	28
Mean Total Length (mm)	153	137	137
Black Ventral Surface	37.5%	4.9%	0%
Gray Ventral Surface	37.5%	17.1%	3.6%
White/Gold Ventral Surface	0%	29.3%	25.0%
White Ventral Surface	25.0%	48.8%	71.4%

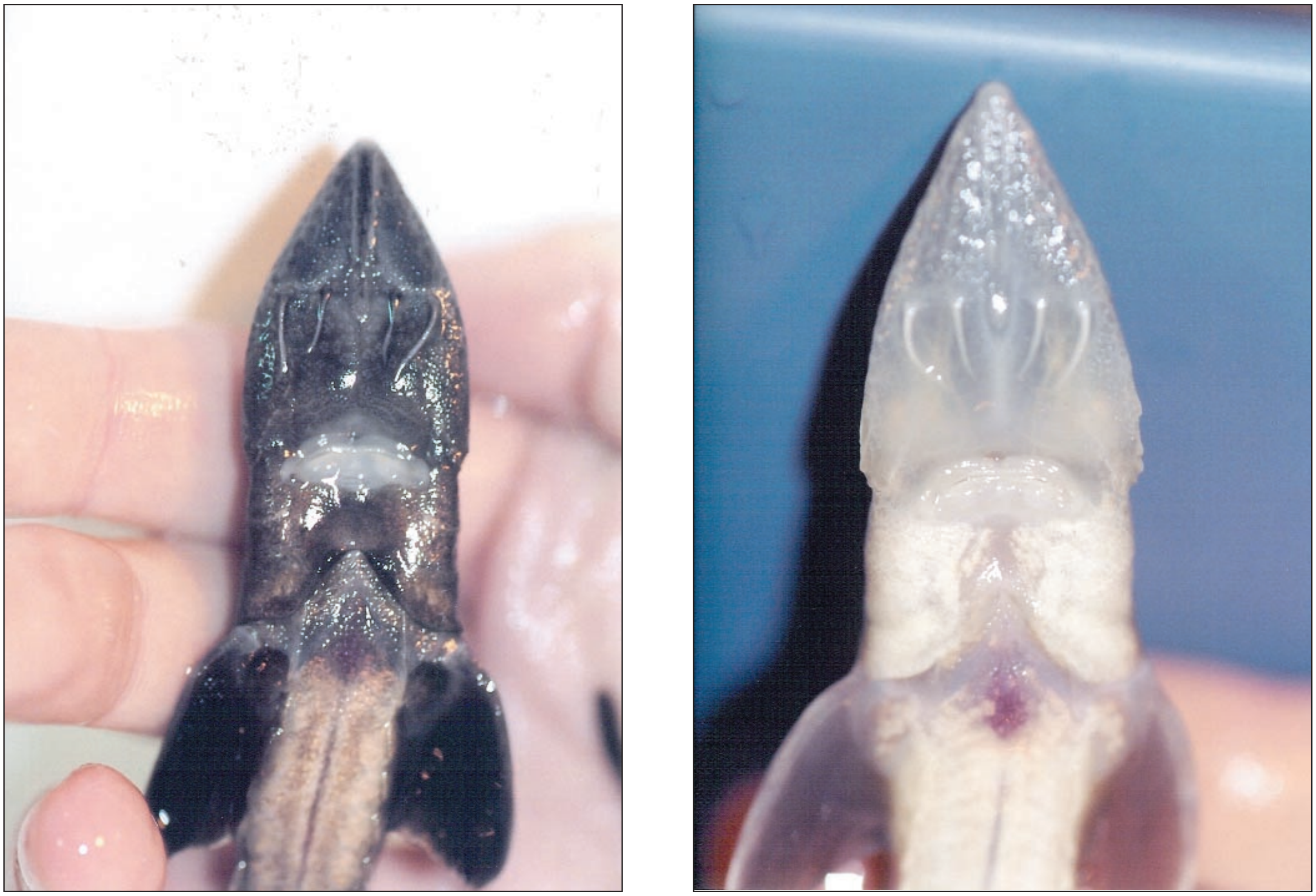

Fig. 4.
Black and white ventral surfaces of White Sturgeon.

response to our low, near-constant rearing temperatures, to effects of fish density or container size, or possibly to some nutritional deficiency. Pallid, Lake and Atlantic Sturgeon raised in our laboratory under similar conditions, however, have attained larger sizes than the White Sturgeon, so we cannot say for certain why our fish are growing so slowly. Our observations do suggest, though, that the largest freshwater fish in North America does not have to be a "tankbuster," and can, in fact, be successfully maintained for more than a year at relatively small (and convenient) sizes.

Acknowledgments

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Fig. 5.
White Sturgeon with atypically rounded rostrum (left) and typically pointed rostrum (right).

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