Establishment of Parameters Critical to Sturgeon Management in the Pacific Northwest

University of California, Davis
R/F-90
Project Initiated: October 1, 1983
Project Completed: September 30, 1986

Serge Doroshov, Graham Gall, and Richard Swallow

Reproductive biology of sturgeon is a key to wild stock management and domestication in aquaculture. In this study we examined reproductive conditions of wild and domestically raised white sturgeon (*Acipenser transmontanus*) from San Francisco Bay.

Wild Fish

Three discrete stages of gonadal development were found in adult fish (>90 cm fork length) during the sampling (winter) season: (1) refractory—previtellogenic follicles in females, undifferentiated cysts with only gonial cells in males; (2) active—vitellogenesis in females, spermatogenesis in males (spermatocytes in various stages of meiosis); (3) ripe—polarization of pigmented eggs in females, spermiogenesis or ripe spermatozoa in males. Based on observations of domestic broodstock and hatchery spawned wild fish, we concluded that stage 1 will be recruited to the breeding population after at least two years, stage 2 will breed the following year, and stage 3 is a current year broodstock. We examined gonadal tissues of 773 fish sampled during six consecutive winters (Table 1). More than half the sampled fish were females stage 1 (32%) and males stage 2 (28%). The breeding group, stage 3, was composed of a small number of females (9%) and approximately twice as many males (20%). The ratio of females to males was 1:1 in all adult stock and 1:2 in the breeding group, reflecting faster recruitment of males. Maturity was dependent on body size (Figure 1a). Reproductively active (stages 2 and 3) males dominated in adult male stock, particularly in 120-160 cm classes. Reproductively inactive (stage 1) females compose the majority of stock in all size classes (Figure 1b); maturing and ripe fish were mainly in the 160-180 cm classes. We assume that the reproductive potential of relatively small sturgeon is low, since only a small fraction of these adult fish are recruited for annual spawning.

Maturation of wild females was also evaluated by measuring concentrations of estrogen and vitellogenin (alkali-labile phosphorprotein, ALPP) in plasma. In stage 1, concentrations of estrogen and ALPP were low (< 0.25 ng/ml and 4.2 + 0.3 mg/ml, respectively). In stages 2 and 3, they rose to 3.68 + 0.62 ng/ml and 24.2 + 4.2 mg/ml. In gravid females prior to spawning, plasma concentrations of both sex steroid and yolk precursor significantly decreased. Thus, synthesis of vitellogenin in sturgeon (as in other fish and many vertebrate animals) appears to be controlled or at least stimulated by estrogen.

Domestic Broodstocks

Small white sturgeon colonies (35 to 150 each), born at the UCD hatchery in 1980-1984, were raised in freshwater tanks at ambient temperature and photoperiod. Fish were fed a commercial trout diet and sampled for reproductive conditions and body size. Results obtained at the last sampling (fall of 1986) are shown in Table 2. Data on wild fish aged by examination of fin sections are used for comparison. Captive males matured at age 3 years and were smaller in body size, compared with the wild stock. More than 80% of the captive males matured every year, whereas wild males appear to have a biennial cycle. Captive females had previtellogenic ovaries and low plasma concentrations of estrogen and ALPP. No vitellogenesis was observed at 3 to 6 years of age and 8 to 20 kg in mean body weight. Some wild females were ripe at age 12 to 16 years with a mean body weight of 16

Table 1. Distribution of Different Maturity Stages in the Adult Stock of San Francisco Bay*

	Females			Males			
Stages	1	2	3	1	2	3	(n)
Years							
1979-80	32	10	7	7	34	10	102
1980-81	28	6	10	0	33	23	91
1981-82	42	4	10	2	25	17	261
1982-83	13	5	7	5	45	25	99
1983-84	27	8	13	2	13	37	60
1984-85	51	6	4	11	20	8	160
Mean	32	6	9	5	28	20	N=773
CL (95%)	18-46	4-9	5-12	0-8	16-41	9-31	

*(percent of annual sample, n). Gonadal stages: 1—refractory; 2—vitellogenesis/spermatogenesis; 3—ripe.

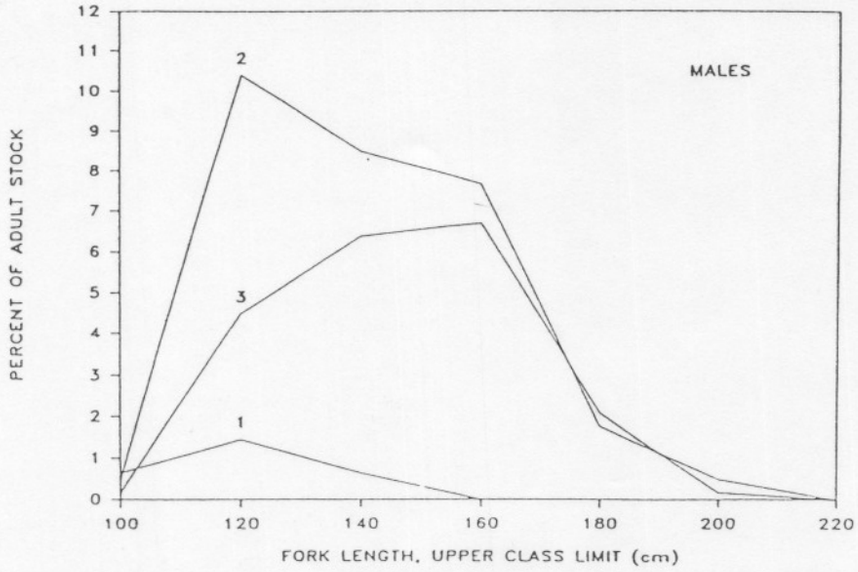

Figure 1a. Size distributions of males in adult stocks of white sturgeon at different stages of maturity (1—refractory gonads; 2—active gametogenesis; 3—ripe fish).

kg. However, the majority of ripe wild females were in age groups 18 to 26 years with body weights ranging from 25 to 45 kg. It is not clear yet, whether the observed lack of vitellogenesis in captive females is an abnormal phenomenon caused by the artificial environment. It is possible that the onset of vitellogenesis requires a certain genetically determined threshold body size (our captive colonies originated from only a few parents).

Ripe captive males are now used in commercial aquaculture for sturgeon fingerling production. We evaluated their reproductive performance by comparing five consecutive hormonally induced spermiations of five captive and five wild males. We then compared fertility and performance of their progenies, resulting from the crosses of each male to each of the 5 wild females. Data were analyzed to fit the model $Yijk = u + Type + Male\ j(i) + Block + Type \times Block + Error$, where Type was domestic or wild male, Male j(i) was the random effect of either male type and Block was the random effect of females. The only significant effect was Block. No significant differences in performance were found between domestic and wild males. For domestic and wild males, mean fertility was 77% and 73%, respectively; hatchability was 54% and 51%; larval survival to metamorphosis 32% and 29%; and individual weight of fry at metamorphosis was 1.45 g and 1.33 g. In addition, there were no significant differences between the two types of males in terms of semen density or spermatozoa motility.

Hatchery Studies

We established standard tests to predict ovulatory response of wild fish to exogenous hormonal stimulation. Samples of the ovarian follicles are removed by catheter and incubated in culture medium with 10 µg/ml progesterone. Eggs are boiled and sectioned to examine the position of germinal vesicles in freshly collected follicles and are compared with the incidence of germinal vesicle breakdown in those eggs exposed to progesterone. Estimates of germinal vesicle position anticipated egg quality (fertility and viability), while hormonally induced egg maturation is a predictor of ovulatory response.

The "imprinting" effect of live diets on hatchery-raised juveniles was experimentally confirmed. Survival and growth were significantly reduced following a switch from a more natural diet (Tubifex worms) to a prepared semi-moist diet (Biodiet), whereas growth was improved and survival was improved or unaffected following the reciprocal diet switch. This suggests that progenies of wild fish are more "prepared" physiologically and anatomically to accept and assimilate the more natural diet during the early life stages and that they establish strong

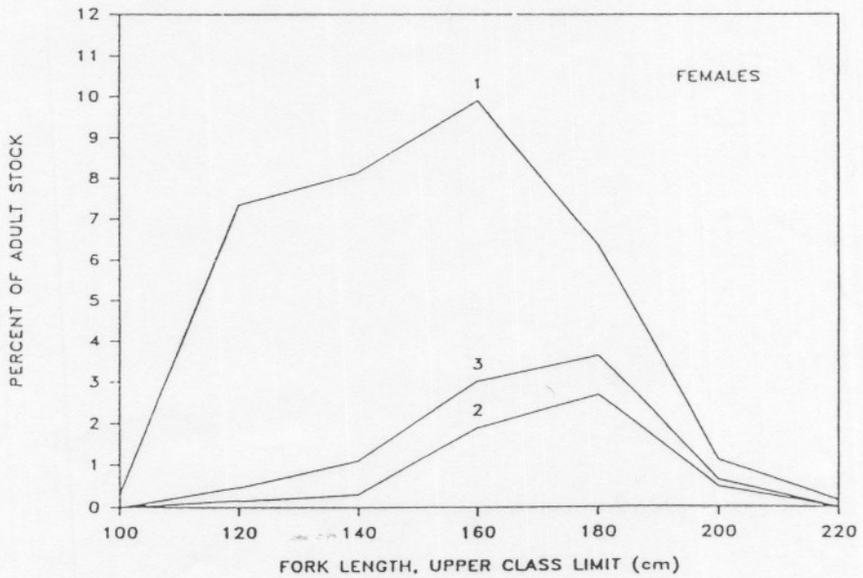

Figure 1b. Size distributions of females in adult stocks of white sturgeon at different stages of maturity (1—refractory gonads; 2—active gametogenesis; 3—ripe fish).

preference to these diets associated with specific attractants (most probably, scent). Knowledge of these factors will be needed for the improvement of existing larval diets.

Cooperating Organizations

California Aquaculture Association
California Department of Fish and Game
Center for Great Lakes Studies, University of Wisconsin, Milwaukee

Publications

Bartley, D. M., G. A. E. Gall, and B. Bentley. 1985. Preliminary description of the genetic structure of white sturgeon. In *North American Sturgeons*, F. P. Binkowski and S. I. Doroshov, eds. pp. 105–110.

Binkowski, F. P. and S. I. Doroshov, eds. 1985. *North American Sturgeons: Biology and Aquaculture Potential.* Dr. W. Junk, Publishers. 163 pp.

Buddington, R. K. and J. P. Christofferson. 1985. Digestive and feeding characteristics of the chondrosteans. In *North American Sturgeons*, F. P. Binkowski and S. I. Doroshov, eds. pp. 31–43.

Buddington, R. K. and S. I. Doroshov. 1986. Structural and functional relations of the white sturgeon alimentary canal. *J. Morphology* 190:201–213.

Lindberg, J. C. and S. I. Doroshov. 1986. Effect of diet switch between natural and prepared foods on growth and survival of white sturgeon juveniles. *Trans. Amer. Fish. Soc.* 115:166–171.

Lutes, P. B. 1985. Oocyte maturation in white sturgeon *Acipenser transmontanus*. In *North American Sturgeons*, F. P. Binkowski and S. I. Doroshov, eds. pp. 87–93.

Swallow, R. L. 1985. The effect of food deprivation on the plasma free amino acid levels of sturgeon, *Acipenser transmontanus*. In *North American Sturgeons*, F. P. Binkowski and S. I. Doroshov, eds. pp. 93–96.

Wang, Y. L., F. P. Binkowski, and S. I. Doroshov. 1985. Effect of termperature on early development of white and lake sturgeon. In *North American Sturgeons*, F. P. Binkowski and S. I. Doroshov, eds. pp. 43–51.

Wang, Y. L., R. K. Buddington, and S. I. Doroshov. 1987. In press. Influence of temperature on yolk utilization by the white sturgeon. *J. Fish Biol.*

Table 2. Sexual Maturation in Domestic and Wild Broodstocks

	Domestic				Wild				
Age (years)	3	4	5	6	8–12	12–16	16–20	20–24	24–28
Females									
Ripe (%)	0	0	0	0	0	12	31	57	50
W, ripe (kg)	–	–	–	–	–	16	25	36	44
W, immat (kg)	8	9	12	20	8	13	21	31	44
Sample (n)	11	38	20	20	4	8	16	30	14
Males									
Ripe (%)	95	79	87	93	0	11	33	22	–
W, ripe (kg)	7	9	10	14	–	15	33	37	–
W, immat (kg)	7	8	10	12	8	14	27	28	–
Sample (n)	20	48	15	15	5	18	6	18	–