Davis Professor Serge Doroshov and technician Robert Pipkin remove a 37-pound female white sturgeon from a holding tank.

The big fish:

Restoring California's sturgeon population

Ann McGuire

Benefits of the Davis Aquaculture Program will be protection of sturgeon from extinction, enhancement of sport fishery, and provision of seedstock for commercial development.

The sturgeon, known and hunted for its delicate eggs and tasty flesh, is a primitive, hearty, and rather docile beast that can grow to impressive size. Historical records show that some species can weigh as much as two tons; sturgeon weighing about 500 pounds are relatively common in some waters. Traditional habitats for these anadromous fish (which include 21 species in two families) consist of many of the freshwater and saltwater bodies in the Northern Hemisphere. Demand for sturgeon, coupled with pollution and the construction of dams that has blocked its access to spawning grounds, have decimated populations of this fish around the world.

History in the U.S.

Today, commercial and sport fishermen are extremely interested in restoring sturgeon populations, in contrast to attitudes toward the fish in the 1800s, when large numbers were destroyed by salmon fishermen because they damaged nets. The fish were sometimes used as fuel and fertilizer, but more often, they simply were burned in piles on the beaches of the Great Lakes and other habitats.

Excluding the fish thus destroyed, the annual sturgeon catch in the United States before the end of the 19th century was estimated to be around 15 million pounds on the East Coast and 10 million on the West Coast. In the late 1800s, fishing was mainly concentrated around the Great Lakes

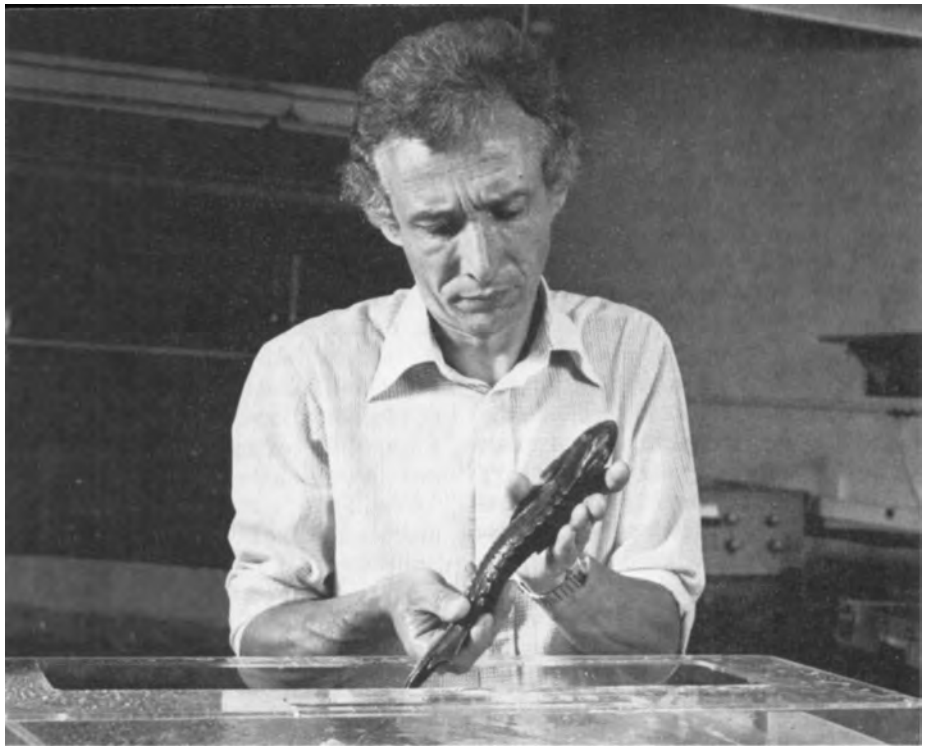
Technicians and graduate students comprise the audience for a discussion on surgical techniques employed in ovarian sampling. At left is Professor Wallace Clark and in the center is Professor Serge Doroshov. Dr. Clark is director of the Aquaculture Program at Davis and with Dr. Doroshov is co-principal investigator in the sturgeon study.

and the Hudson River, though there were other small operations along both coasts. Most of the flesh and caviar was shipped to Western Europe because Americans had yet to develop their current taste. Sturgeon products also included oil and isinglass, a semitransparent gelatin prepared from the swimbladder and used in jellies and glues. Commercial sturgeon fishery was successful for awhile, with the United States producing a substantial part of the world's caviar.

Soon after the turn of the century the fishery declined rapidly because of improper or nonexistent fishing regulations coupled with a high demand for the fish. At least three important sturgeon species indigenous to the United States—the Atlantic (*Acipenser oxyrhynchus*), the lake (*A. fulvescens*), and the white (*A. transmontanus*)—were nearly wiped out by overfishing. Reacting to this situation, the United States began to regulate sturgeon fisheries more strictly around 1918, but the program has not been considered effective. From 1920 to 1950, sturgeon populations were reduced further by the damming of many rivers used as spawning grounds. Although fish locks and fish ladders were constructed as part of these dams, they were designed for salmon and, therefore, did not allow passage of sturgeon. Sturgeon habitats also were damaged by pollution, to which the fish are highly sensitive.

Sturgeon populations are still extremely low in this country, with the possible exception of the shovelnose sturgeon (*Scaphyrinchus platorhynchus*) indigenous to the Mississippi Basin. Currently, the total harvest in the United States probably does not exceed 5 million pounds per year. Populations of the Atlantic sturgeon in the Hudson River—one of the main sites of the historical East Coast sturgeon fishery—now have declined to an estimated 100,000 juveniles, and commercial fishermen report seeing only about two dozen adults in the river in a single year. The white sturgeon, though nearly decimated by river damming in some regions, is able to support small-scale commercial fisheries in the Columbia River and is an incidental catch along the Oregon and Washington coastlines. A small number of green sturgeon (*Acipenser medirostris*) is found in waters along the West Coast. In addition, a growing California sport fishery for white and green sturgeon is developing in the Sacramento-San Joaquin Delta and the San Francisco Bay.

ovary. Such ovarian tissue represents prized caviar.



The feeding rates and preferences of 1-year-old white sturgeon fingerlings are being studied on the U.C., Davis campus.

The Sacramento and Columbia river populations of white sturgeon may now be the most abundant of all United States sturgeon species. Whereas the Columbia River (Oregon) populations are under intensive commercial exploitation, those in California are not, because commercial sturgeon fisheries have been prohibited in California since 1918, and sturgeon spawning grounds have not been disrupted by dams. Based on tagging experiments, the population of adult white sturgeon in the Sacramento-San Joaquin Delta and the San Francisco Bay system is estimated to be from 150,000 to 300,000.

This current status of the sturgeon fishery in the United States is similar to that found in the USSR before 1960. Populations in Russia had declined substantially, but the USSR developed a highly successful program—almost 20 years ago—to replenish and culture the endangered species. Through this program, the USSR now produces 70 million sturgeon fingerlings annually in 20 large hatcheries. In addition, Russian scientists have developed captive sturgeon broodstock; they have repeatedly spawned sturgeon held in freshwater ponds throughout the life cycle, and they have raised sturgeon in ponds and freshwater enclosures for commercial flesh production. In the USSR, three generations of sturgeon are produced in captivity in the same time one generation is produced in nature.

Sturgeon culture in California

Recently, aquaculturists at U.C., Davis, began a program designed to replenish California sturgeon populations and to develop the technology of their culture for use in the United States. They are establishing a prototype sturgeon hatchery on the Davis campus, using specimens from the nearby populations of white and green sturgeon. Research includes development and adaptation of culture techniques and the gathering of information necessary to initiate the program. Funding is provided by grants from the United States Fish and Wildlife Service and the National Marine Fisheries Service.

The main goal of the UCD sturgeon program is to develop the technology for efficient, controlled reproduction of sturgeon in an economically feasible manner. This

technology will have wide-ranging uses: for stock replenishment operations designed to protect sturgeon from extinction is areas where the natural spawning grounds are destroyed, for enhancement of sport fishery, and for production of seedstock to aid the development of commercial aquaculture of sturgeon.

Much of the foundation necessary to establish the UCD sturgeon culture program has been laid. This work includes completion of a literature search, various trials with raising sturgeon fingerlings artificially, genetic investigations, initial work leading toward development of a captive broodstock, and gonadal sampling from various natural sturgeon populations.

The literature search revealed a strong potential for sturgeon aquaculture and replenishment in northern California, particularly for white sturgeon. Biological data on the white sturgeon's life cycle are relatively scarce, yet early reports indicate that it is among the fastest-growing sturgeon species. The largest specimen caught to date in the Northwest was an 1800-pound fish from the Fraser River in British Columbia, although the average catch is now 50 to 100 pounds. It is estimated that a 500-pound white sturgeon is 40 years old and that these fish reach sexual maturity between the ages of 15 and 25.

Information on the white sturgeon's reproductive biology and physiology (especially on gametogenesis and spawning) is limited. It is believed that the white sturgeon lives mainly in the sea or in large estuarine areas, migrating up rivers to spawn. In the Sacramento River, the upstream spawning migration of whites reportedly occurs during the late winter and early spring, and spawned fish return to the San Pablo and San Francisco bays during the late summer. To spawn, white sturgeon broadcast their eggs on hard bottoms in the mainstream of rivers at a depth of 10 to 30 feet and a temperature of 50° to 60°F. Estimates suggest that females spawn from 600,000 to 4 million eggs at one time and that embryonic development before hatching takes seven days. In nature, the eggs spread out over considerable distances to attach individually to the river bottom until hatching.

After hatching, sturgeon juveniles travel downstream and begin feeding. Studies have shown that sturgeon are carnivorous benthophags that consume insect larvae, decapods, clams, shrimp, worms, and small fish. According to Bay Area fishermen, white sturgeon in the San Francisco Bay feed heavily on herring spawn whenever available.

The literature review showed that even less is known about the green sturgeon populations than is known about the white. The green sturgeon is considerably smaller than the white, weighing up to 350 pounds but averaging 25 to 40 pounds. No large population of green sturgeon is known to exist, although a few sturgeon are found in the Columbia and Sacramento rivers, and the Klamath River has a small, unique population fished traditionally by members of Indian tribes. According to these Klamath River fishermen, the green sturgeon migrate up the river in May and June, spawn 25 to 50 miles from the river mouth, and return to the ocean during August and September.

Laboratory work

Initial laboratory work with sturgeon at UCD involved white sturgeon fingerlings caught in the Sacramento River by the California Department of Fish and Game (CDFG). Upon arrival at the Davis aquaculture facilities, the fish were weighed, tagged, treated with antibiotics (if injured), and held in large, round tanks with continous supplies of fresh water. These fingerlings were raised in controlled conditions for several months on diets consisting of artificial salmonid feeds and frozen brine shrimp. Within six months, they grew from an average initial weight of 15 grams to about 200 grams.

In addition, large-volume blood samples were taken from these fingerlings via heart puncture and used to initiate red cell cultures for karyotyping. Results show that the white sturgeon has an n number of 60 chromosomes, similar to other *Acipenser* species. This work indicates the possibility of hybrid formation between the white and other species. Such techniques have provided the Russians with a fertile hybrid sturgeon extremely successful under culture conditions.

The UCD aquaculture program—with the help of the CDFG, the Yurok Indians near the Klamath River, and sport fishermen in the San Francisco Bay area—also has obtained adult sturgeon specimens for broodstock work. Methods of transporting and holding the spawners have been developed as well as initial techniques for hormone-induced spawning. Though it is known that injections of sturgeon pituitaries provide the best spawning results, their limited availability necessitated trials with injections of human chorionic gonadotropin (HCG). At doses of 5 I.U. per kilogram of body weight, HCG has been shown capable of stimulating spermiation in males and hydration of mature oocytes in females.

Using histological and electron microscope techniques, preliminary analysis of gonadal samples have been made on sturgeon caught in the Columbia and Sacramento rivers. The Columbia River animals exhibited a wide range of gonadal maturation, and ovarian samples from two females showed progressive reabsorption similar to that reported in animals whose spawning grounds were blocked by river damming. Gonadal samples collected from the Sacramento River sturgeon during the fall and winter exhibited advanced stages of vitellogenesis. These results corroborate accounts from sport fishermen who have reported catches of gravid females during the fall and winter. Thus, it appears that the spawning season of Sacramento River sturgeon is far more extensive than described in the literature.

These results represent part of an extensive program of gonadal sampling from different sturgeon populations at various times of the year. The program was initiated by UCD aquaculturists because of the dearth of knowledge concerning gonadal maturation in white and green sturgeon and the importance of this information to the artificial reproduction and environmental protection of sturgeon. Included in the program are studies on the connection of gonadal maturation with age, morphometric characters, and—possibly—genetic diversity of sturgeon stocks (using electrophoretic analysis of polymorphic enzyme systems).

Davis facility

At this writing, a rearing facility is under construction on the Davis campus for the culture of sturgeon. The above-described work will be continued and new projects—designed to develop the technology necessary for artificial fertilization and controlled larval rearing—are being initiated with cooperation of scientists from varied disciplines (e.g., physiologists, developmental biologists, nutritionists, and engineers).

Scientists at U.C., Davis, believe their prototype sturgeon hatchery will be capable of producing 500,000 to 1 million sturgeon fingerlings annually, once the methodology is developed fully. The sturgeon project is becoming a major focus of the aquaculture research program, eventually providing California with the technology required to protect and prevent extinction of this highly valued, endemic fish as well as the means for further development of the state's sport fishery and the aquaculture industry.

Ann McGuire is Science Writer for the Aquaculture Program at U.C., Davis. *Her position has been supported by the Sea Grant Writing Program.*