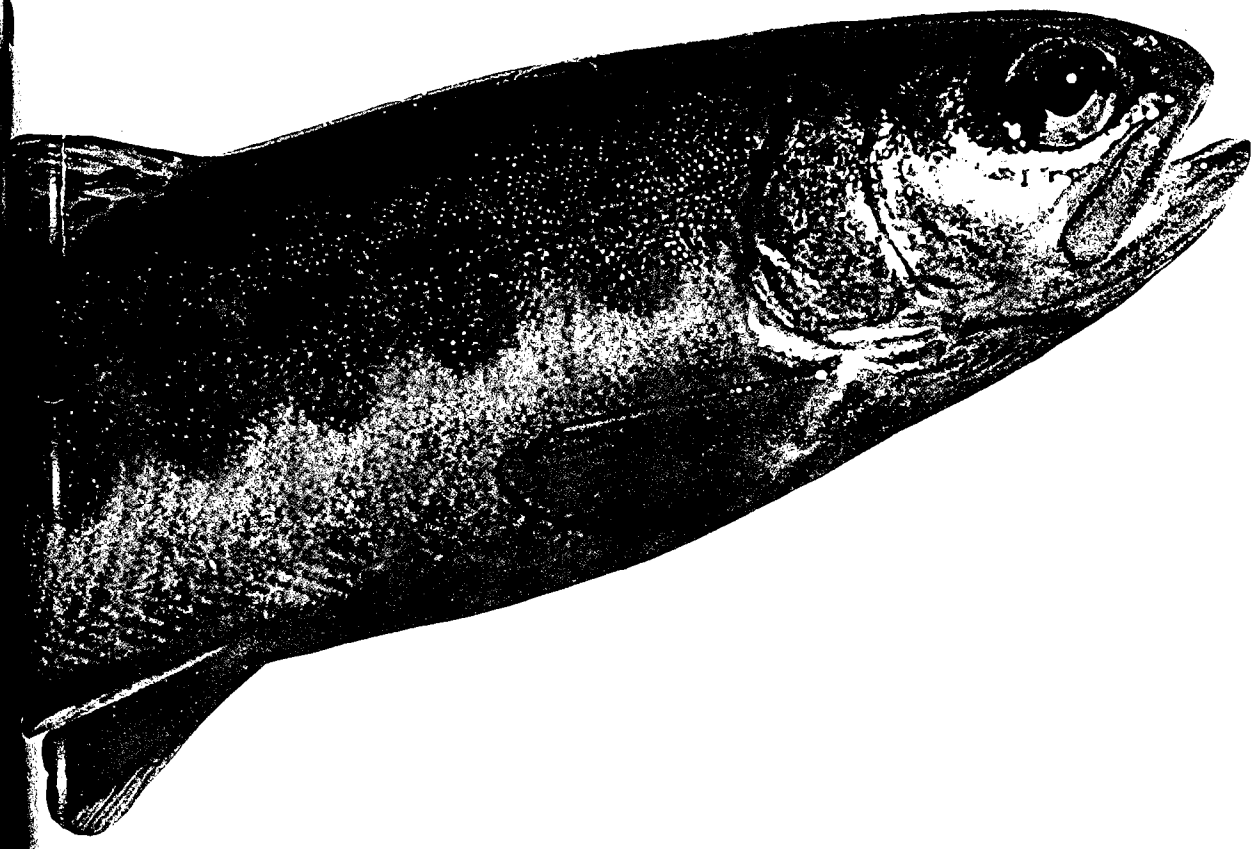
Inland Fishes OF CALIFORNIA



Peter B. Moyle

INLAND FISHES *of* CALIFORNIA

by PETER B. MOYLE

Illustrated by
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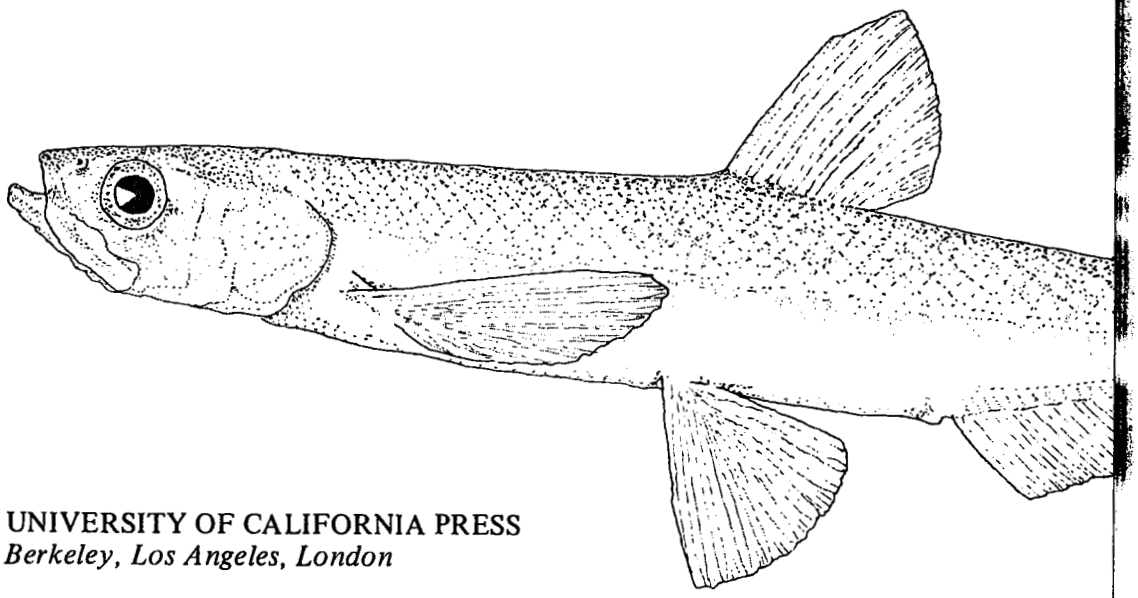
and
CHRIS van DYCK



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Contents

Sturgeon Family, Acipenseridae

Sturgeon are among the largest and most primitive of bony fishes. They are placed, along with paddlefishes, African bichirs, and numerous fossil fishes, in the infraclass Chrondrostei, from which the higher bony fishes evolved. The sturgeons themselves are not ancestral to modern bony fishes but are a highly specialized and successful offshoot of the ancestral chondrosteans. They have retained primitive features such as the heterocercal tail, fin structure, jaw structure, and spiracle. They have replaced the bony skeleton with one of cartilage and have a few large, bony plates instead of scales. They are highly adapted for preying on bottom animals which they detect with the row of extremely sensitive barbels on the underside of their snouts. They then protrude their extraordinary long lips and suck up the food. Some species will stir up the bottom with their shovellike snouts and then suck up the suspended organisms.

Sturgeons are confined to the temperate waters of the northern hemisphere. Only seven of the twenty-four species are found in North America, two in California. Although most species live primarily in salt water, moving up rivers only to spawn, a few species live exclusively in fresh water. The anadromous forms are the largest fish found in fresh water. The giant beluga sturgeon (*Huso huso*) which spawns in the Volga River of the USSR gets as long as 8.5 m (26 ft) and as heavy as 1,297 kg (2,860 lbs). White sturgeon are the largest freshwater fish in North America, supposedly growing as large as 820 kg (1,800 lbs) although the largest verified record seems to be 590 kg (1,300 lbs).

The history of the sturgeon fisheries over most of the world has been one of overexploitation followed by severe population reduction. The large size and sluggish nature of sturgeon make them vulnerable to netting and snagging and their valuable caviar, isinglass, and flesh has made such fisheries, while they last, very lucrative. However, as has been demonstrated in California and the USSR, proper management can restore overfished sturgeon populations, provided their spawning areas are not reduced by pollution and other competing uses of the water.

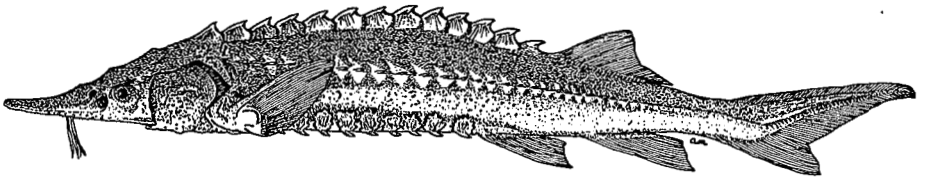

Figure 28. White sturgeon, 52 cm TL, Sacramento-San Joaquin Delta.

White Sturgeon, *Acipenser transmontanus* Richardson

Identification. White sturgeon have blunt, rounded snouts, with four barbels in a transverse row on the underside. The barbels are closer to the tip of the snout than to the mouth. Their mouths have highly protrusible lips but lack teeth. Each fish has five widely separated rows of bony plates on the body, each plate with a sharp spine. The dorsal row has 11 to 14 plates, the two lateral rows have 38 to 48 plates each, and the two bottom rows have 9 to 12 plates each. The dorsal fin has one spine and 44 to 48 rays, while the anal fin has 28 to 31 rays. The ventral surface is white, shading to grey brown on the back above the lateral row of scutes.

Names. Just where the "white" comes from in white sturgeon is a bit of a mystery since they are grey in color, but it probably refers to the pale color of their flesh compared to that of green sturgeon. *Acipenser* is Latin for sturgeon, while *transmontanus* means across the mountains, perhaps a reference to their wide distribution in the Columbia River system.

Distribution. White sturgeon are found in salt water from Ensenada, Mexico, north to the Gulf of Alaska but spawning sturgeon have been found only in large rivers from the Sacramento-San Joaquin system north. In California large runs occur only in the Sacramento and Feather rivers, but there may be small runs up the Russian, San Joaquin, Klamath, and Trinity rivers. The occasional capture of small sturgeon by anglers indicates that Lake Shasta may have a landlocked population that became established when Shasta Dam was built, trapping young sturgeon behind it. White sturgeon were planted in Lake Havasu on the Colorado River in 1967 and 1968, but the success of this introduction is not known (Minckley, 1973).

Life History. White sturgeon are one of California's important fish resources. Hence their life history has been investigated in some detail by the California Department of Fish and Game (Pycha, 1956; Skinner, 1962; Ganssle, 1966; Radtke, 1966; Stevens and Miller, 1970; McKechnie and Fenner, 1971; L. Miller, 1972a,b,c; Fry, 1973). The results of these studies form the basis for this summary.

White sturgeon spend most of their lives in the estuaries of large rivers, such as the Sacramento-San Joaquin, moving up into fresh water to spawn. In the estuaries they prefer mud bottoms and water with salinities less than that of seawater. A few do make extensive saltwater migrations, however, since they are occasionally captured far from any major stream system. They are also capable of completing their entire life cycle in fresh water. Populations are known to exist as far up the Columbia River as Montana, above barriers (dams) impassable to fish (Brown, 1971). Such a population may now be established in Lake Shasta on the upper Sacramento River.

The food of white sturgeon is taken on or close to the bottom. In the Delta, young sturgeon (around 20 cm FL) feed mostly on crustaceans, especially amphipods (*Corophium*) and oppossum shrimp, (*Neomysis*). As they get larger, their diet becomes

more varied, although it still consists mostly of bottom-dwelling estuarine invertebrates: various species of clams, crabs, and shrimp. Fish also assume some importance in the diet of larger sturgeon, especially herring, anchovy, striped bass, starry flounder, and smelt. When herring move into the estuaries to spawn, white sturgeon feed heavily on the eggs. Other items recorded from stomachs of large sturgeon include onions, wheat, Pacific lampreys, crayfish, frogs, salmon, trout, striped bass, carp, squawfish, suckers and, in one case, a domestic cat (Carlander, 1969).

Young white sturgeon grow rapidly in the Delta, reaching 18 to 30 cm FL by the end of their first year. Growth gradually slows as they get older but they can reach 102 cm FL (40 inches), the smallest size anglers can legally keep, by their sixth or seventh year. In subsequent years they add 2 to 6 cm per year to their length. Just how large they can grow is a matter of some dispute since the largest fish were taken prior to 1900 and were subject to inaccurate measurements and exaggerated reporting. Nevertheless, they probably achieved at least 4 m FL and 590 kg (1,300 lbs.). Such large fish were probably over 100 years old and were the largest fish to occur in the fresh waters of North America. The largest white sturgeon taken in recent years, a 3.2 m FL fish from Oregon, was 82 years old (Carlander, 1969). The largest recent record from California is a 2.8 m FL, 21 kg female, aged 47, that was accidentally caught in a fish trap. Age of sturgeon is determined by taking cross-sections of fin rays or spines and counting the number of rings visible, on the assumption that a new ring is laid down every year.

Female white sturgeon are at least eleven or twelve years old and 1.1 to 1.5 m FL before they are sexually mature. The males generally mature at smaller sizes than the females. When they are ready to spawn they migrate upstream, although some upstream movement to the lower reaches of the rivers may take place in the winter months prior to spawning. Spawning seems to take place between mid-March and early June, when water temperatures range from 10 to 24°C. Exactly where and how white sturgeon spawn is not known but they can migrate several hundred miles upstream to find suitable spawning sites. They probably spawn either over deep gravel riffles or in deep holes with swift currents and rock bottoms. In the Sacramento-San Joaquin system, most spawning takes place in the upper Sacramento and Feather rivers. The San Joaquin River may have been an important spawning stream before its flows were reduced, since large sturgeon are still caught moving up it on occasion. When spawning is completed the sturgeons move back down to the estuaries. White sturgeon do not spawn every year and the interval between spawnings is not precisely known. It seems to be about five years in the Sacramento-San Joaquin system (L. Miller, pers. comm.).

Female sturgeon are very fecund: 1.1 to 1.5 m FL fish contain around 100,000 eggs. The number of eggs increases with size, so the 2.8 m FL female from the Sacramento River contained 4.7 million eggs. The eggs are adhesive after fertilization and stick to the substrate. The larvae hatch from the eggs in one to two weeks. The larvae stay close to the bottom and are washed downstream into the estuary. Juvenile sturgeon apparently have a greater tendency to live in the upper reaches of the estuaries than do the adults.

Status. White sturgeon in the Sacramento-San Joaquin Estuary are an almost classic case of a valuable fish resource being nearly wiped out by overfishing but

restored through proper management. The large size and late age of maturity of sturgeons makes them extremely vulnerable to overfishing, so it is not surprising that they were decimated by the commercial fishery that started in the 1860s and lasted until 1901. The peak catch was 1.66 million pounds taken in 1887. By 1895 the catch was down to 300,000 pounds and declining annually. The fishery was closed in 1901 after less than 200,000 pounds were caught. Low catches in 1909, 1916, and 1917, when the fishery was reopened, indicated that the population had not recovered so the commercial fishery was closed for good in 1917.

In 1954, a year-round sport fishery was legalized, with a 102 cm size limit and one fish per day per fisherman bag limit. The fishery was an immediate success and large numbers of sturgeon were caught, mostly by snagging from party boats. Apparently because snagging was considered unsportsmanlike, this method was outlawed in 1956. Since no other effective method had been found to catch sturgeon on hook and line, the catch by anglers declined. Most of the sturgeon caught were taken by fishermen angling for other species, especially striped bass. In 1964, it was discovered that shrimp worked well as sturgeon bait and the sport fishery intensified. The catch now appears to have stabilized at 8,500 sturgeon per year or about 270,000 pounds. This represents an acceptable exploitation rate of catchable size sturgeon of 2 to 10 percent of the population per year. An independent estimate of the catchable-size sturgeon populations in the Sacramento-San Joaquin Estuary is 115,000 fish, with 95 percent confidence limits of 72,000 and 212,000 fish (Miller, 1972a).

The value of proper management of this fishery is clearly indicated by the fact that the present-day sturgeon catchs are, on a sustained yield basis, nearly 70 percent of the *average* commercial catch from 1875 to 1899 of 374,000 pounds. The unregulated commercial fishery nearly wiped out the populations in a short period of time, while the present managed sport fishery promises to yield continuous returns for years to come. Even large sturgeon occasionally appear in the catch again. In April, 1973, a 190 kg, 2.8 m FL sturgeon was caught in the Sacramento River, a hook and line record.

References. Brown, 1971; Carlander, 1969; Ganssle, 1966; L. Miller, 1972a,b,c; McKechnie and Fenner, 1971; Pycha, 1956; Skinner, 1962; Stevens and Miller, 1970.

Figure 29. Green sturgeon, 22 cm TL, Klamath River Estuary. CAS 36968.

Green Sturgeon, *Acipenser medirostris* Ayres

Identification. Green sturgeon are similar in appearance to white sturgeon except that the barbels are closer to the mouth than to the tip of the long, narrow snout; the dorsal row of bony plates numbers 8 to 11, the lateral rows, 23 to 30, and the bottom rows, 7 to 10; the dorsal fin has 33 to 36 rays, the anal, 22 to 28; and the body color is olive green, with an olivaceous stripe on each side.

Names. *Medirostris* means moderate snout. The snout is more elongate than that of the white sturgeon but less so than that of many other species. Other names are as for the white sturgeon.

Distribution. Green sturgeon have been taken in salt water from Ensenada, Mexico, to the Bering Sea and Japan (Miller and Lea, 1972). They are found in the lower reaches of large rivers from the Sacramento-San Joaquin on north, including the Eel, Mad, Klamath and Smith rivers. They seem to be the most common sturgeon in the Klamath and Trinity rivers at the present time, and will migrate considerable distances upstream (Fry, 1973).

Life History. Much less is known about green sturgeon than white sturgeon because they are less abundant, they spend less time in estuaries and fresh water and seldom penetrate far up the rivers (except the Klamath and Trinity rivers), and they are held in low esteem by fishermen. The relative abundance of green sturgeon, at least in the Sacramento-San Joaquin system, is reflected in the numbers of the two species of sturgeon tagged in San Pablo Bay by the California Department of Fish and Game during their 1967 and 1968 sturgeon studies: 2,692 white sturgeon and 54 green sturgeon (Miller, 1972b). While tagged white sturgeon were mostly recaptured in fresh water or in the estuary, the five tagged green sturgeon were taken in salt water off Washington (2), Oregon (1), Santa Cruz, California (1), and San Pablo Bay (1). Although spawning of green sturgeon has not been confirmed for the Delta, juveniles are common in freshwater areas, especially in the summer. A particularly heavy concentration was found in shallow water of the lower San Joaquin River in the summer of 1964 (Radtke, 1966). In the Klamath River, the famous "sturgeon hole" about 1.5 km upstream from Orleans, Humboldt County, may be a major spawning grounds. Leaping and other frantic behavior indicative of spawning or courtship is frequently observed there in the spring and early summer.

The diet of adult green sturgeon appears to be similar to that of white sturgeon: bottom invertebrates and small fish (Ganssle, 1966). Juveniles in the Delta feed on opposum shrimp, *Neomysis*, and amphipods, *Corophium* (Radtke, 1966).

Nothing is known about age and growth in green sturgeon except that they can reach 2.3 m FL and 159 kg. However, they seldom exceed 1.3 m FL and 45 kg, at least in the Delta (Skinner, 1962).

Status. Because of its low numbers and bad reputation as food fish, the green sturgeon has not been subjected to as heavy fishing pressure as has the white sturgeon. Jordan and Evermann (1923, p. 7) express what is perhaps the most common attitude towards it: "As a food-fish, it is of very inferior rank; indeed, it is commonly believed to be poisonous, but this belief is without any warrant. Its flesh, however, is dark, has a strong, disagreeable taste, and an unpleasant odor, and is regarded as inferior to that of the white sturgeon." Even the roe has been rejected as unfit for caviar! In fact, the bad culinary reputation of green sturgeon probably stems mostly from the dark color of the flesh since, properly prepared, they can be quite tasty (L. Miller, pers. comm.). Recently a commercial fishery has developed for green sturgeon in Washington and Oregon.

References. Fry, 1973; Ganssle, 1966; Jordan and Evermann, 1923; L. Miller, 1972a,b; Miller and Lea, 1972; Radtke, 1966; Skinner, 1962.

Status. Since arctic grayling have so far failed to establish any self-reproducing populations in California, they can be maintained only by a continued program of stocking. They seem to have only minor value in the management of mountain-lake fisheries. They have not proven to be much better at surviving in shallow, winterkill lakes than brook trout but in a few California lakes they have shown slightly better growth rates than trout. They can also provide surface angling in midsummer when trout may be difficult to catch. Most good grayling lakes, however, are also likely to be good trout lakes. Thus the main justification for continuing to maintain grayling populations in California is to provide a novelty fishery for a rather attractive fish (Gerstung, 1972). Even so, anglers fishing for trout will occasionally discard grayling thinking they are "chubs" (D. Ahrenholz, pers. comm.).

References. Brown, 1971; Carlander, 1969; Emig, 1969; Gerstung, 1972; McPhail and Lindsey, 1970; Minckley, 1973.

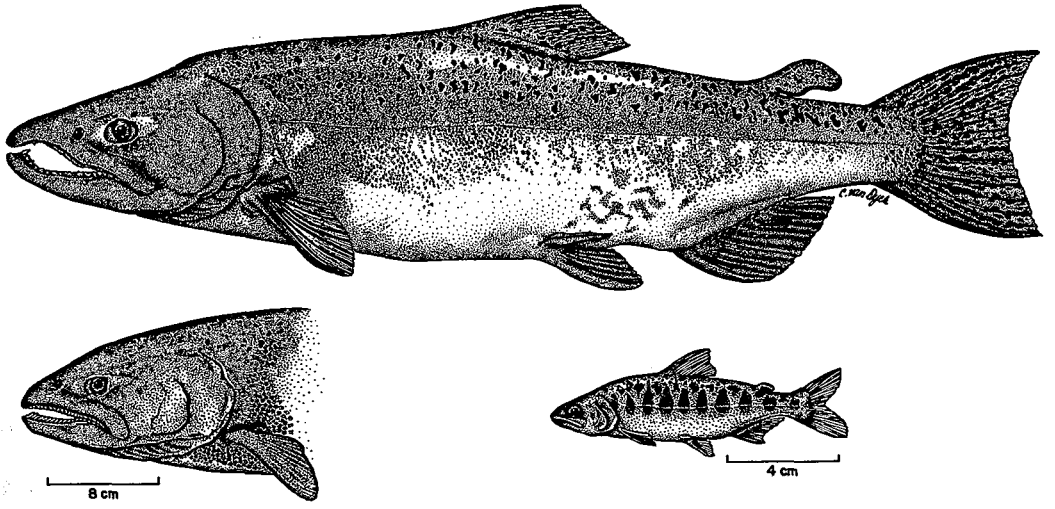

Figure 34. Chinook salmon, spawning male (64 cm SL) and female (60 cm SL); American River, Sacramento County; parr (9 cm SL), Mill Creek, Fresno County.

Chinook Salmon, *Oncorhynchus tshawytscha* (Walbaum)

Identification. Spawning adults are olive brown to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. There are numerous small black spots in both sexes on the back, dorsal fin, and both lobes of the tail. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw. They have 10 to 14 major dorsal fin rays, 14 to 19 anal fin rays, 14 to 19 pectoral fin rays, 10 to 11 pelvic fin rays, 130 to 165 pored lateral line scales, and 13 to 19 branchiostegal rays on each side of the jaw. The gill rakers are rough and widely

spaced, with 6 to 10 on the lower half of the first gill arch. Spawning adults are the largest Pacific salmon, typically 75 to 80 cm SL (9 to 10 kg). The largest on record for California weighed 38.6 kg (Fry, 1973). Parr have 6 to 12 parr marks, each equal to or wider than the spaces in between them and most centered on the lateral line (or at least passing through it). The adipose fin of parr is pigmented on the upper edge, but clear at its base. The dorsal fin occasionally has one or more spots on it but the other fins are clear.

Names. King salmon is the most widely used name in California but chinook salmon, the most widely used name in Canada, has been adopted as the official common name by the American Fisheries Society. Other names often applied are spring salmon, quinnat salmon (especially in New Zealand), and tyee (for large adults). Chinook is the name of a large tribe of Indians that lived along the Columbia River. *Oncorhynchus* means hooked snout, while *tshawytscha* is an approximation of the word for these fish used by the natives of the Kamchatka Peninsula (USSR) as interpreted by Johann Julius Walbaum, a German naturalist employed by Catherine the Great of Russia.

Distribution. Spawning runs of chinook salmon once occurred as far south as the Ventura River but the southernmost runs at the present time occur in the Sacramento-San Joaquin system. In North America they occur in streams north to Point Hope, Alaska, and in Asia they are found from northern Japan to the Anadyr River, USSR. Since 1872 many attempts have been made to establish chinook salmon elsewhere in the world, but the only successful transplants seem to have been made to New Zealand and, possibly in recent years, the Great Lakes (Scott and Crossman, 1973). In northern California, runs occur in the Klamath, Trinity, Smith, and Eel rivers, as well as in a few smaller streams such as Redwood Creek, Mad River, and Mattole River (Fry, 1973). At the present time attempts are being made to establish a run up the Russian River. Prior to the construction of Shasta Dam, chinook salmon ran up into the upper reaches of the Sacramento River, the McCloud River, and the lower Pit River. Today they spawn only in the Sacramento River below the dam and in its tributary streams, especially the American and Feather rivers. Prior to the construction of Friant Dam, they also spawned in the upper San Joaquin River, and occasionally, the Kings River. Today only occasional salmon manage to spawn in either river, in years of high runoff (Moyle, 1970). In the San Joaquin system, large runs still exist only in the lowermost portions of the Stanislaus, Tuolumne, Mokelumne, and Consumnes rivers, largely as a result of artificial propagation.

Life History. The life history of chinook salmon is characterized by variability. In one spawning run, mature fish can be found at ages ranging from two to seven years. In one stream there are likely to be several distinct spawning populations, each spawning at a different time of the year. For example, fall, winter, and spring chinook runs exist in the Sacramento River. Even juvenile fish can adopt a variety of life-history strategies. Reimers (1973) recognized five major life-history types among the juveniles of fall-spawning chinook salmon of the Sixes River, Oregon. The types are defined according to the amount of time spent in the river, the estuary, and the ocean.

Most chinook salmon in California are fall spawners; they start to move upstream in the early fall, as the water begins to cool. Such fish spawn between October and February. In the past, a high percentage of the chinook salmon in the Sacramento-San Joaquin system ran up the rivers in May and June, and spent the summer in deep holes of upstream areas where water temperatures seldom exceeded 21 to 25°C. They would then spawn in late fall. Such runs are now gone because dams block access to the

upstream areas. In the Sacramento River, however, Shasta Dam has actually caused an increase in winter-run salmon. These fish move up in December through February but do not spawn until May or June. Cool water flowing from the base of the dam lowers water temperatures of the main river enough so that the eggs and young can survive the summer (Frey, 1971).

Spawning chinook salmon can migrate considerable distances upstream: over 2,000 km in the Yukon River, Alaska, and over 350 km in the Sacramento River. They home to the stream they were spawned in, using olfactory and visual cues to find their way back (Groves et al., 1968). Enough fish miss these cues so that in years of high water they can be found spawning in unexpected places. Most spawning runs are up fairly large streams; chinook salmon leave most of the smaller coastal streams entirely to coho salmon. However, spawning may occur in surprisingly small tributaries to the larger streams, although most spawning takes place in coarse gravel riffles in the main streams. For maximum egg survival, water temperatures have to be less than 14°C. Spawning behavior is similar to that of other Pacific salmon. Because the spawning fish are so large, redds over 3.6 m long and 30 cm deep may be constructed (Scott and Crossman, 1973).

Each female, depending on her size, lays 2,000 to 14,000 eggs. Eggs laid in the fall hatch in the spring (March to April) while those laid in the spring, by winter-run fish, may hatch in late August. The alevins remain in the gravel for two to three weeks, until the yolk sac is absorbed. Once they emerge, most California fry start moving downstream at once, seldom spending more than three to four weeks in fresh water. A majority of these fish also move through the estuaries fairly rapidly and enter the ocean when they are only two to four months old (4 to 8 cm SL). The peak of movement through the Sacramento-San Joaquin Estuary occurs in May and June (Sasaki, 1966). Small numbers of juvenile chinook salmon spend up to a year in the rivers or in the estuaries, a pattern that is much more common in northern populations than it is among California populations. However, the extent to which juvenile chinook salmon use estuaries along the north coast of California is poorly known.

While in fresh water, juvenile chinook salmon are opportunistic drift feeders and take a wide variety of terrestrial and aquatic insects. In the Sacramento-San Joaquin Delta, terrestrial insects are by far the most important food, but crustaceans are also taken in some numbers. Adult salmon feed mostly on fish.

Parr that are resident in streams defend feeding territories. The preferred locations for these territories are, at first, shallow, silty-bottomed areas along the stream edge, but as the fish grow larger they gradually move out into deeper and swifter water. Their precise habitat in any given stream depends on their interactions with resident juveniles of coho salmon and steelhead rainbow trout, as well as on food and cover availability (Chapman and Bjornn, 1969; Everest and Chapman, 1972; Stein et al., 1972).

Status. Although chinook salmon are the least abundant of the species of Pacific salmon, they are the most important species in California. Because fish spawned in California streams spend most of the marine portion of their life cycle off the California coast, the valuable sport and commercial fishery of the state depends on the maintenance of its own spawning streams. Since the commercial salmon fishery started in the 1860s, the total California salmon catch (up to 90 percent chinook) has varied

from 2 to 14 million pounds (0.7 to 6.4 million kg) per year and the price per pound has increased steadily. Each year 40,000 to 130,000 salmon are also caught by anglers, so the worth of the salmon in recreational dollars is considerable as well.

In May 1989, Winter-run salmon declared "threatened" under ESA, "endangered" under CESA

There is little doubt that California chinook salmon populations have declined in the last one hundred years. Fortunately, the remarkable ability of the salmon to adapt to changing conditions has minimized the decline. Thus the loss of the large spring runs of salmon in the Sacramento River, caused by the construction of dams that blocked access to upstream spawning grounds, was at least partially compensated for by the development of winter runs, which take advantage of cool summer outflows from the dams. Chinook salmon still manage to spawn in many streams that have been radically altered by man's activities ranging from gold mining to water diversion for irrigation. For example, a few fish still spawn in Putah Creek, which flows through the University of California, Davis campus despite the fact that it has been dammed, the stream bed has been bulldozed, and the water has been polluted with agricultural and domestic runoff. They accomplish this feat by spawning when there is winter runoff and by having young that leave before the stream dries up in the summer. During years of high runoff, small numbers of chinook salmon wander into streams normally too small for spawning, including streams they had been forced to abandon as a result of man's activities. During such years, a few appear at the base of Friant Dam, Fresno-Madera counties, the construction of which eliminated the large runs that once spawned in the upper San Joaquin River. In 1969, a few salmon even managed to spawn in the Kings River, Fresno County, from which they had not been recorded for over twenty-five years (Moyle, 1970). Such incidents indicate that with the will and a commitment to release of minimal flows during critical times of the year, some salmon runs now gone could be reestablished, and most present runs can be maintained.

Despite the adaptability of the salmon and the value of the fishery, there are constant threats to the continued existence of many chinook salmon runs. Foremost among these are the proposed construction of more dams for hydroelectric power production, for flood control, and for water supply. One critical factor that needs investigation is the amount of flow needed in the spring to permit maximum survival of fry migrating out to sea (Jensen, 1972). The reduction in natural spawning created by dams and other projects can be at least partially compensated for by hatcheries, such as the Nimbus Hatchery on the American River, and by the construction and maintenance of artificial spawning channels. Such methods, however, can seldom completely make up the losses and, indeed, can never compensate for the aesthetic loss of being able to watch salmon spawn in a free-flowing stream.

For further information on California's salmon populations consult Skinner (1962), Hallock and Fry (1967), Hallock et al. (1970), Frey (1971), Jensen (1972), and Fry (1973).

References. Chapman and Bjornn, 1969; Everest and Chapman, 1972; Frey, 1971; Fry, 1973; Groves et al., 1968; Hallock and Fry, 1967; Hallock et al., 1970; Jensen, 1972; McAfee, 1966; McPhail and Lindsey, 1970; Moffett and Smith, 1950; Moyle, 1970; Reimers, 1973; Sasaki, 1966; Scott and Crossman, 1973; Skinner, 1962; Stein et al., 1972.

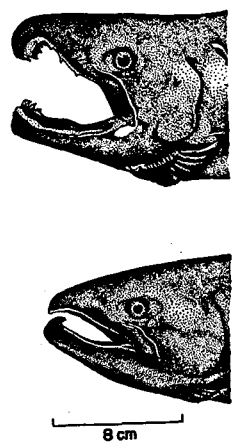

Figure 35. Coho sa
Columbia; parr (7 c

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Identification.
back, dull maroon
black on the belly.
sides. Males have a
spots on the back,
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Crossman (1973).

Distribution
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the California D

In the Truckee Meadows area of Nevada, introduced blackfish have hybridized with tui chubs, *Gila bicolor* (La Rivers, 1962).

Status. The herbivorous filter-feeding habits of blackfish, coupled with their ability to survive in warm, turbid waters, allows them to continue to be successful despite changes in their environment. Nevertheless, they are probably less abundant than formerly. They have done well when introduced as forage fish in reservoirs. Such introductions have largely ceased, however, since there is some evidence (Burns, 1966) that blackfish are not particularly useful as a forage fish. They grow too fast and, when young, may consume small invertebrates also eaten by young gamefish. Despite this, in Clear Lake they are at times important in the diet of the largemouth bass.

At the present time, their chief value seems to be as commercial fish, sold live in the oriental fish markets of San Francisco. Fifty to one hundred thousand pounds per year are now being taken from Clear Lake. Regardless of their commercial value, Sacramento blackfish merit further study for their role in aquatic food chains because they are one of the few North American fishes that seem to be largely herbivorous.

References. Burns, 1966; Casteel and Hutchinson, 1973; Cook et al., 1964, 1966; Kimsey and Fish, 1964; La Rivers, 1962; Murphy, 1950; Turner, 1966.

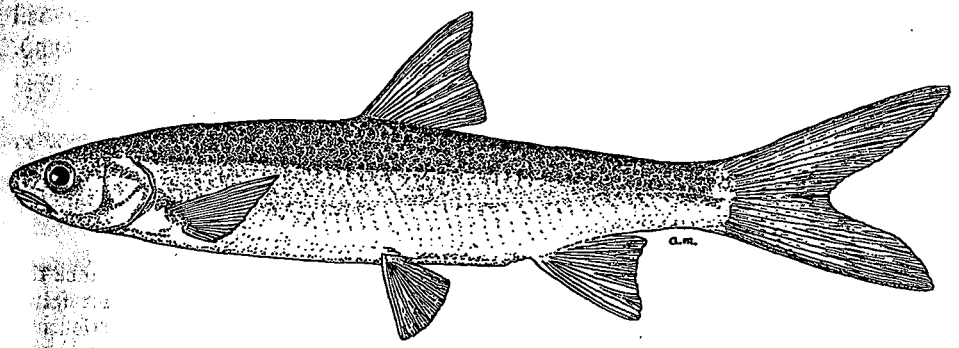

Figure 60. Sacramento splittail, 19 cm SL, Sacramento-San Joaquin Delta.

Sacramento Splittail, *Pogonichthys macrolepidotus* (Ayres)

Identification. These large (up to 40 cm FL) cyprinids are readily recognized by the enlarged upper lobe of the tail, barbels (sometimes weak or absent) at the corners of the slightly subterminal mouth, and small head (head length goes into body length less than 4.5 times). The dorsal rays are 9 to 10; pectoral rays, 16 to 19; pelvic rays, 8 to 9; anal rays, 7 to 9; the lateral line scales, 57 to 64 (usually 60 to 62); and the gill rakers, 14 to 18 (usually 15 to 17). The pharyngeal teeth, usually 2,5-5,2 but variable, are hooked and have narrow grinding surfaces. The inner tooth rows are very small. Live fish are a dull silvery gold on the sides; the older the fish, the duller the color. The back is usually a dusky olive grey. Adults develop a distinct nuchal hump on the back. During the breeding season, the paired and caudal fins are tinged with red orange (retained by some fish all year) and the males become darker colored, developing tiny white tubercles on the head.

Names. Pogon-ichthys means bearded fish, referring to the typically well-developed barbels, while *macro-lepidotus* means large-scaled.

Distribution. Formerly widely distributed in the lakes and rivers on the floor of the Central Valley, Sacramento splittail now seem to be confined to the Delta region and the lower reaches of the Sacramento River, up to the Red Bluff Diversion Dam (M. Caywood, pers. comm.). There is also a single highly questionable record from the Russian River (Pintler and Johnson, 1958).

Life History. Surprisingly little is known about the life history of this fish. They live mostly in the slow-moving stretches of the main rivers and the Delta. For a cyprinid, they are extremely tolerant of brackish water. Following the high flows of winter, it is common to find splittail in the diluted waters of Suisun Bay, San Pablo Bay, and the Carquinez Straits. Messersmith (1966) found that they were most common in the Carquinez Straits from February through April, when salinities were less than 5 ppt. A few, however, were captured in May and June when salinities had risen to 10 to 12 ppt. There also seems to be a resident population of splittail in Napa Marsh, where the water is brackish much of the year (M. Caywood, pers. comm.).

Their small subterminal mouth, maxillary barbels, large upper tail lobe, and generalized pharyngeal teeth suggest that splittail are adapted for feeding in areas of moderate current on bottom invertebrates, such as amphipods, aquatic insect larvae, and oppossum shrimp. Two splittail collected from the Delta in September, 1972, were feeding on small clams. When water levels rise in February and March, splittail may move into flooded areas to feed on earthworms (M. Caywood, pers. comm.). Rutter (1908) reported large numbers of splittail feeding on loose eggs in upstream areas where salmon were spawning. Splittail no longer occur in these areas.

Spawning takes place from early March to mid-May, when splittail congregate in deadend sloughs. They apparently spawn over flooded streambank vegetation or over beds of aquatic plants, mostly in the evening (M. Caywood, pers. comm.). No studies have yet been published on age, growth, or other aspects of their life history.

Status. The range of Sacramento splittail has been drastically reduced since the arrival of civilization in the Central Valley. They are today the most abundant native minnow in the Delta (M. Caywood, pers. comm.) but they are not particularly abundant compared to introduced fishes such as striped bass. They do not appear to be in any immediate danger of extinction but their ecological requirements are just beginning to be understood (a detailed life-history study is being conducted by M. Caywood, California State University, Sacramento). Their reproductive cycle may be especially vulnerable to interference by man. They seem to require deadend sloughs with beds of submerged vegetation for spawning, and a number of the sloughs that are important for spawning are proposed as outlets for the Peripheral Canal. Whether or not the movement of water through these sloughs from the canal will disrupt splittail spawning needs to be taken into consideration for the following reasons: splittail are thought to be one of the most primitive North American cyprinids (Hopkirk, 1973) and an irreplaceable member of the Sacramento-San Joaquin fish fauna; they are the object of a small sport fishery that is particularly important to the Chinese-Americans who catch them in flooded areas in the spring; and they are of some importance as forage for striped bass (Thomas, 1967). They may also have some potential for aquaculture.

References. Ganssle, 1966; Hopkirk, 1973; Kimsey and Fisk, 1964; Messersmith, 1966; Rutter, 1908; Thomas, 1967; Turner and Kelley, 1966.