Rare Treasure from River Bottom: Juvenile Goldeye (*Hiodon alosoides*) for Medium-Sized Aquaria

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Our trawl was a 16-foot triangular net bag with wooden wings on each side of the opening and a long sock tied-off at the end. We dropped it into the warm (28°C), murky (24-43 NTUs[1]) water, backed our boat downstream, tied the lead lines to the bow, and dragged it along the bottom of the Mississippi River near Vicksburg, MS. After a few minutes, the engine was stopped, the lines reined in, and the trawl hauled to the surface. The heavy net was yanked up over the gunnel of the boat, the cod end of the net untied, and the contents emptied onto the deck and into large metal tubs. Out spilled sand, gravel, and flipping, glittering fishes. We were searching for sturgeon and species that live with them. On this particular day, 5 Sept. 2001, calm water and clear weather made collecting conditions near perfect. We were rewarded not only with sturgeon, but also with goldeye (*Hiodon alosoides*). Typically considered a pelagic (open water) fish, we were surprised to collect this species on the bottom of the mighty Mississippi River.

Seldom-Seen Fishes

Goldeye (see back cover) and their look-alike relative, the mooneye (*H. tergisus*, Fig. 1), are slab-sided silvery fishes that superficially resemble shad. Their mouths are much larger and toothier, though, with teeth occurring on the palate and tongue (not just the jaws), leading some to dub them "toothed herrings." The two species are often confused with each other but can be readily distinguished in the field (Ross et al., 2001). Goldeye have a shorter dorsal fin (9-10 rays) set forward of the anal fin and a long ventral keel that extends forward beyond the pelvic fins; mooneye have a slightly longer dorsal fin (11-12 rays) set behind the anal fin and a short ventral keel that does not extend to the pelvic fins. Eye color, as the names imply, is also different between the species. Goldeye have a golden iris, mooneye a silver-white iris, but the structure of their eyes is identical (Moore and McDougal, 1949). Both species have a retina comprised entirely of similarly shaped rod cells (for vision in low light) and a reflective layer called the tapetum lucidum (which produces the characteristic "eye-shine" of nocturnal animals).

Goldeye and mooneye are usually not encountered on hook-and-line by anglers, nor in shallow-water seines by collectors, which makes them something of a rarity to both fish fanciers and some fish biologists. Mooneye are native to deep rivers, lakes and impoundments in the St. Lawrence-Great Lakes (except Superior), Mississippi River and Hudson Bay basins from Québec and Alberta south to the Gulf of Mexico, and Gulf Slope drainages from Mobile Bay, Alabama, to Lake Pontchartrain in Louisiana. Goldeye have a more

[1] NTUs, or nephelometric turbidity units, provide a value for the opaqueness of water. Values are determined by using a small electronic device (turbidimeter) to direct a beam of light through a water sample and measuring how much of that light is scattered by the particles suspended in the water (e.g., silt, clay, bacteria, phytoplankton). Zero indicates water of perfect transparency (e.g., distilled water), low values (0-5 NTUs) indicate clear water, higher values (10-100 NTUs) cloudy, murky, or muddy water.

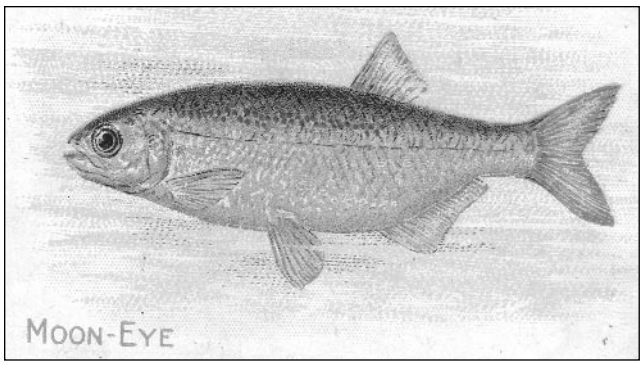

Fig. 1.
Trading card produced by Sweet Caporal Cigarettes, 1910-1915. The back of the card describes the mooneye as a game fish taking small minnows, artificial flies, or worms, and lists alternate names "toothed herring" and "silver bass." The card reads (in part): "A beautiful fish, sometimes esteemed as food, although bony . . . Some people consider it equal to the Yellow Perch in flavor but excelling it in richness."

northwestward distribution, living in deeper waters of the Arctic, Missouri, Mississippi, and Ohio basins from the Northwest Territories to western Pennsylvania, south to Louisiana. A disjunct population of goldeye is found in tributaries of James Bay in Québec and Ontario. Both goldeye and mooneye are characteristic of "big water" systems (Ross et al., 2001), but we have not found them to be very common in the lower Mississippi River. In three-and-a-half years of work, from Venice, LA to Lake Providence, LA, a distance of 475 river miles, we have taken 688 samples using trawls, trotlines, and gillnets. Of more than 9500 specimens collected, none have been mooneye and only 143 have been goldeye. Nearly 80% of all goldeye collected have been taken in a 30-mile stretch of river between Vicksburg, MS and Transylvania, LA.

Typically, when present in our trawl samples, less than five goldeye are obtained in any single tow. On this day, however, they were more abundant. More than a third of our samples contained 6-20 specimens. Biologists from another agency, out to see how we collect sturgeon, became interested in this infrequently encountered species and asked us to save some for them. Over the course of our work, we collected 94 of the fish and put two dozen into our live well. By the end of the day, however, the collecting groups had separated, and we were left holding all the fish.

Our team drove the short distance back to Waterways Experiment Station where we considered what to do. Three fish had already died during the few hours we had them. The water in the live well was warm (29°C), so we transferred several gallons of water and all of the fish to a large ice chest. We carried the ice chest inside our wet lab and gradually added cooler (23°C) water from a standing unoccupied tank over the next hour. When the temperatures were equalized, we transferred the fish. During the next 24 hours another six fish died, but the remaining specimens were looking active and vigorous.

We keep a small collection of live fishes for research and education. The seldom-seen goldeye seemed an attractive candidate for both, but we wondered whether it could be successfully and conveniently maintained as part of our holdings. A quick search of bookshelves and reprints was not encouraging. There was little information on southern populations of the fish and no information on care and feeding. This was surprising considering the attention that the North American "bonytongues" had received from ichthyologists in the past.

Hiodon from the Ohio

The osteoglossomorphs (or "bonytongues") are the most primitive of the living teleosts (Maisey, 1996). They include the arawanas (Osteoglossidae), featherbacks (Notopteridae), and elephantnose fishes (Mormyridae) familiar to tropical fish fanciers, as well as the mooneyes (Hiodontidae) of North America. The mooneyes are the least aberrant of the group, though, with normally shaped toothed jaws and an unspecialized body form (Gregory, 1933).

Mooneyes closely resemble the world's oldest osetoglossomorph, *Lycoptera*, a fish found in upper Jurassic and lower Cretaceous deposits of China (Maisey, 1996). These deposits were formed approximately 135 million years ago. Like the mooneyes, *Lycoptera* had an elongate body, posteriorly placed dorsal fin, large saucer-shaped eyes, and prominent jaws. This fish was ancestral to the group, though, and not a member of the mooneye family. The earliest-known mooneye appeared later, during the Eocene 49 million years ago (see sidebar). Today there is only a single living genus in the family, occurring only in eastern North America. It contains just two species . . . but this was not always the case.

The genus *Hiodon* was described nearly two centuries ago by French naturalist Charles Alexandre LeSueur. With specimens collected from the Ohio River in 1816, LeSueur described the fish we now call the "true" mooneye (LeSueur, 1818). He noted multiple rows of distinctive conical teeth, the deciduous scales, and the peculiar extensions of the swim bladder on each side of the cranium. (These "auditory fenestra" connect the swim bladder to the ear and probably enhance hearing.) LeSueur examined stomach contents and described

the diet of the fish: scarab beetles and mayflies. He also described a second species of mooneye (*H. clodalis*). He seemed less sure of its taxonomic distinction, however, and suggested that it could be a different gender of the same species. Subsequent taxonomists also doubted the validity of LeSueur's second form, but the other species in the genus would be described shortly thereafter by another well-known naturalist who was also plying the waters of the Ohio River.

Constantine Samuel Rafinesque, the infamous taxonomic "splitter" who recognized four "species" of North American paddlefishes, also applied his discriminating eye to the North American bonytongues, which he referred to as "the false herrings" (Rafinesque, 1820). Professor Rafinesque believed that there were five species, distinguished by body shape, fin placement, fin ray counts, subtleties in coloration, tooth size, and jaw size. He consolidated LeSueur's two mooneyes into a single species, which he called the lake false herring, and described the goldeye, which he called the toothed false herring. Rafinesque also recognized three additional species: spring false herring, May false herring, and summer false herring. He believed in the distinctiveness of these species and that each appeared at a different time of year, but admitted that "all the species are blended by the fishermen and considered as alike."

Physician, ornithologist, and ichthyologist Jared P. Kirtland may have been inclined to side with the fishermen rather than the professor. In his piecemeal opus, "Descriptions of the Fishes of Lake Erie, the Ohio River, and their Tributaries," Dr. Kirtland acknowledges only the mooneye as a valid species, noting that "Rafinesque describes several other species, which I have not had an opportunity to obtain" (Kirtland, 1842-1845).

Unlike Dr. Kirtland, we had that opportunity. With goldeye in our tanks, we were able to address fundamental questions of their captive husbandry.

Accommodating the Goldeye

Our goldeye were maintained in closed-system tanks having unidirectional flow and bare bottoms. Fish were initially housed in a 300-liter Model LS-510 Living Stream (a fiberglass rectangular tank with a false bottom and external agitator creating vertically elliptical flow). When a larger tank became available a few weeks later, fish were transferred to a 347-liter Ferguson mini-flume (a Plexiglas rectangular tank with internally rounded corners and a central partition allowing horizontally elliptical flow). Water temperature was not regulated and ranged from 15°C (winter) to 19°C (summer). Water velocity 1-3 cm/s) and filtration (external and internal foam filters) were minimal, but water quality showed little fluctuation (7.4-7.8 pH, 0.5-0.9 NTU). Low variation in these water quality parameters was probably due to frequent water changes (15% weekly or 30% semi-monthly) and a regimented feeding schedule (once every 1-3 days).

Because they are voracious and generalized predators, goldeye were very easy to feed. Specimens in the laboratory readily accepted "rosy red" feeder minnows. Each fish would typically eat three or four 30-40 mm feeders within a few minutes of their introduction. Minnows were often taken head first, but also laterally (the strike occurring just behind the minnow's head) and occasionally by the tail. Goldeye sometimes missed their targets, though, and it was not unusual to see a minnow wriggle free from their toothy maw. Once feeding commenced, it did not cease until all fish were eaten. A batch of 18-36 minnows would usually be obliterated in less than 30 minutes.

Goldeye also fed on a wide array of other foods: large flakes, chopped earthworms, frozen bloodworms, shrimp chunks, clam chunks, live mealworms, live crickets, and cooked squashed peas. They sometimes hit the surface for floating food (especially when they had not been fed for two or three days) but appeared to preferentially feed from the water column, nabbing prey as they sank, or from the bottom, as the current slowly pushed food about the tank. This may be related to their behavior in nature—occurring near the surface at night and deeper in the water by day (Robison and Buchanan, 1988).

Two types of prey, however, were conspicuously avoided: live western mosquitofish (*Gambusia affinis*) and live young-of-year bluegill (*Lepomis macrochirus*). When these fishes were introduced into the tank, a few would occasionally be eaten, but most would persist for days, weeks, and sometimes months. They were appropriate in size (<35 mm), but apparently somehow less "attractive" as food. Surface-hugging habits of the mosquitofish and fin spines of the bluegill may make them less available and less palatable, respectively, than minnows. Hungry goldeye were willing to pass them up, sometimes indefinitely, until choicer fare was offered.

900 Days in Captivity

Goldeye, like other pelagic fishes, swim continuously. This restless activity has not changed since their introduction into our tanks. Two behaviors of the goldeye, however, have changed substantially over time: their responses to light and

The Oldest Mooneye in North America: A Case of Mistaken Identity

In 1912, Bruce Rose, a geologist exploring western Canada, discovered four small fossilized fish from the Tranquille bed deposits at Kamloops Lake, British Columbia. Rose sent the fossils, presumably Miocene in origin (13-25 million years ago), to Louis Hussakof, curator at the American Museum of Natural History, for identification. Hussakof, an expert on primitive species, had authored an illustrated catalog of fossil fishes and several papers on living sharks, paddlefish, and gar.

Hussakof examined the fossils and described them as a new species of minnow belonging to the same genus as the European chub (*Leuciscus*) and naming the fish after its discoverer (Hussakof, 1916). Hussakof's description was based on fin placement, body proportions, fin ray and vertebral counts. He provided few osteological details but noted that the pharyngeal teeth, so characteristic of minnows, had not been preserved. *Leuciscus rosei* languished in obscurity for the next half century.

In 1961, the Tranquille bed deposits were aged using the newly developed potassium-argon technique and found to be much older than previously believed (Cavender, 1966). The deposits were in fact from the middle Eocene (49 million years ago). Cyprinid fishes were unknown from any time prior to the Miocene, prompting re-examination of Hussakof's mysterious "minnow." Ted Cavender of Ohio State University studied the fossils and compared skeletons to those of living mooneyes. He identified several distinctive skeletal features, including the toothed parasphenoid bone, which distinguishes the mooneyes from all other freshwater teleosts in North America. The parasphenoid is a long, conspicuous bone in the skulls of fishes that projects from the base of the braincase anteriorly to the bones of the nose and palate. In most fishes, the parasphenoid is smooth, but in mooneyes it bears prominent peg-like teeth (Gregory, 1933). Cavender re-assigned Hussakof's misidentified fish to a new genus, *Eohiodon*, which appeared to be ancestral to our modern mooneyes.

Hussakof's lifetime body of work was "marked by close observation and analysis and a keen sense of the value of details in the systematic identification of fossil fish remains" (Smith, 1965). How then did he make such a taxonomic blunder? The answer may be methodological. The type specimen of *E. rosei* is an imprint made in hard shale. It is, essentially, a two-dimensional "negative" of the animal. It provides a great deal of information but not all possible detail. For maximum detail, a three-dimensional "positive" is required. Hussakof did not take this step in his analysis, but Professor Cavender did. He poured ink-impregnated latex over the specimen, which penetrated all crevices and pores in the fossil and solidified into a peel; when removed, the latex showed all of the fine features of the skeleton in three dimensions (T. Cavender, pers. comm.). This critical step, where the "rubber met the *rosei*," revealed the oldest mooneye in North America.

their responses to each other. Initially, they were photonegative. Immediately after capture, while still in the live well, goldeye cruised near the water's surface until the cover was removed. When exposed to the bright sunlight, the fish dove to the bottom of the turbid water and remained there. After transfer to the Ferguson mini-flume, goldeye swam about but would not feed during the day or when lights were on. They ate minnows during the night, but they were not seen to eat during the light of day until six weeks after their capture. Afterwards, they switched to diurnal feeding.

After seven months in captivity, a dichotomy in social structure was apparent. One fish, slightly larger than the rest, patrolled a single corner of the tank. The other fish remained at some distance—most of them with scales missing from their back and upper sides. After nine months, two specimens were apparently dominant, each larger than the rest of their cohort, each patrolling one side of the tank, separated from each other on opposite sides of the clear partition. The sub-dominant fish flitted about in the ends of the tank. This social structure was maintained permanently.

During their captivity, goldeye have grown appreciably, but at somewhat slower rates than they would have in the river. When the fish were collected in Sept. 2001, they ranged in size from 76-140 mm total length (TL), but the majority

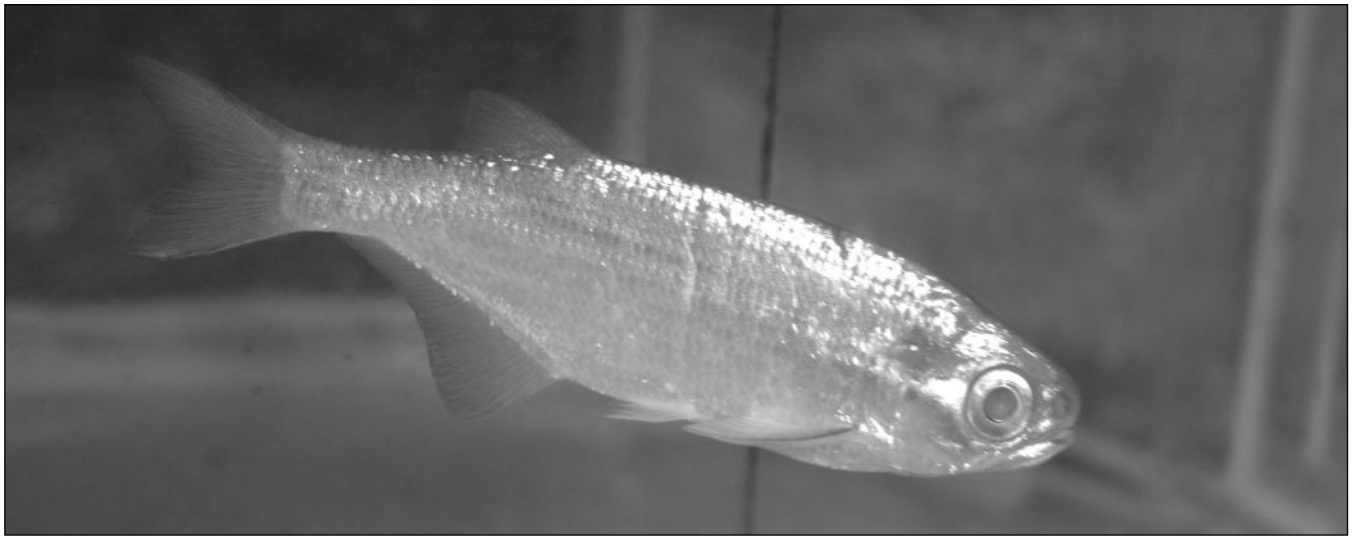

Fig. 2.
Goldeye (*Hiodon alaosoides*) collected Sept. 2001, maintained in an aquarium, and photographed March 2004. The line appearing behind the fish is the edge of a Plexiglas partition in the tank. Photo by the author.

of specimens were 95-105 mm TL. Size indicated that they were probably all young-of-year (Carlander, 1969). After 30 months, remaining fish are approximately 160 mm TL (sub-dominants) and 230 mm TL (dominants). In Oklahoma, three-year-old fish ranged from 254-356 mm TL (Martin, 1952). This suggests that our behaviorally dominant fish grew at rates nearly that of lower rates observed in the field, but that sub-dominants were "runts." Either captivity stunted their growth, or small specimens are eliminated from natural populations (possibly by predation). Both explanations could be supported by aquarium observations.

Long-term survival of goldeye was high. Of the 21 specimens brought back to our tank, 13 died during the following week, but the eight remaining specimens thrived for the next 18 months. Since March 2003 four specimens have died, all several months apart. Those fish were all behavioral "runts." Sizes ranged from 122-167 mm TL and weights less than 17 grams. Goldeye in that size range should weigh >30 grams (Martin, 1952; Carlander, 1969). Harassment by dominant individuals or by larger sub-dominants may have prevented those fish from feeding effectively and may have imposed greater energy expenditures (or injuries).

Gleanings for Goldeye Aquarists

One problem confronting the aquarist in search of goldeye is the habitat of the fish. Because they inhabit large rivers, the solitary collector does not easily procure goldeye, but they *are* obtainable. In addition to trawling, goldeye may be collected using long seines. We have seined them from sandbars in the White River, Arkansas, using 20-foot nets hauled parallel to shore in moderately deep water (1.5-2.0 m). At those locations, the river was wide (>100 m) and deep (>3 m), and on those occasions water was warm (19-28°C) and turbid (34-61 NTUs). We have also seined goldeye from the Red River in Louisiana, where the river was very wide (>200 m), very deep (>15 m), warm (25°C), and moderately turbid (18 NTUs).

Another problem facing goldeye collectors is the apparent scarcity of small specimens. During the late 1940s, goldeye were abundant in Lake Texoma, but a biologist who collected more than 1000 obtained only a single young-of-year (Martin, 1952). Subsequent fish surveys in the lake, an impoundment of the Red River, confirmed the abundance of the species in clear open water but reiterated the rarity of young-of-year (Riggs and Bonn, 1959). Likewise, in the 1970s, new records for goldeye farther upstream in the Red River system prompted interviews with local people who stated that they had been catching goldeye for 30 years but that they had never seen small individuals (Tyler and Mills, 1978). These observations could be artifacts of where and how fish were being collected. Biologists and fishermen may have been working areas where juveniles do not occur and/or using gear to which they were not susceptible. Our experiences suggest that the young-of-year may be more benthic (bottom-living) than pelagic.

A different explanation for the lack of small specimens in some collections is that the sampling efforts did not coincide with the time of year when juveniles recruit into the population.

Goldeye apparently breed during the period May-July, at northern and southern latitudes (Ross et al., 2001). Assuming, a two-month period of growth to "fingerling" stage, they should be optimally sized (for home aquaria) during July-Sept. In the Mississippi River, we have collected goldeye 53-205 mm TL during the period April-December, but small goldeye (<100 mm TL) predominated only during the period July-Sept.

Once obtained, however, small goldeye are hardy. Our losses with the Mississippi River specimens were primarily due to not having made any provisions for transporting live fish. Even apparently moribund specimens, though, sometimes recovered after being transferred to fresh, aerated water. Size and restless swimming make goldeye unsuitable for small tanks (i.e., <20 gallon), but a few can probably be accommodated short term in 40- or 55-gallon tanks. Their large mouth and piscivorous habits would dictate caution when combining them with some tank mates, but the coexistence of our fish for indefinite periods with mosquitofish and young-of-year sunfishes indicates that mixed assemblages are possible.

Goldeye require special techniques and accommodations, and are not colorful or even particularly distinctive in appearance (Fig. 2). However, for the adventurous native fish enthusiast with a passion for primitive species, they offer an opportunity to keep an animal infrequently encountered by the average collector and rarely displayed by the average aquarist.

Acknowledgments

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