The Ecology of Warmouth (*Lepomis gulosus*) as an Invasive Species

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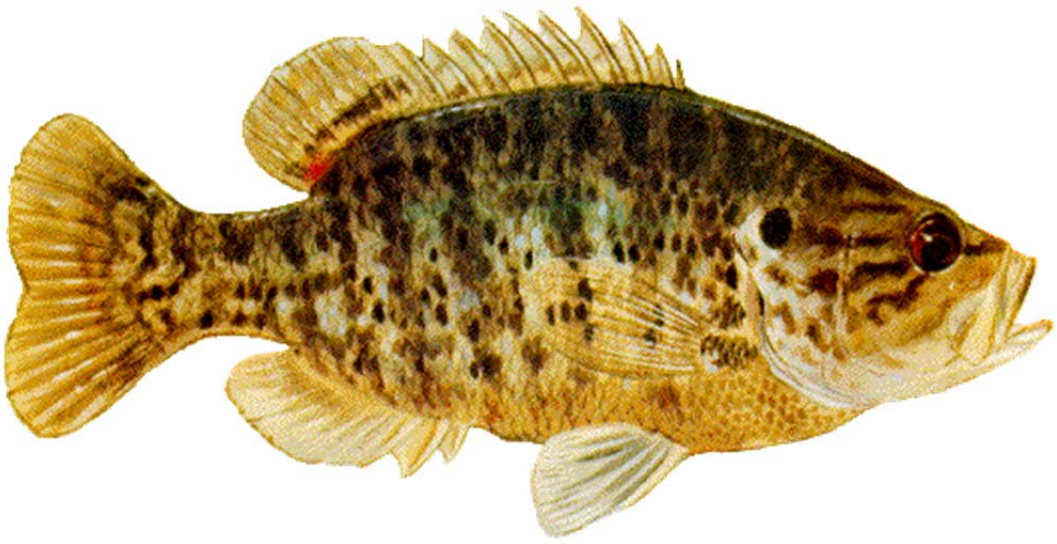

Illustration by Texas Parks and Wildlife Department

Image from Tennessee Wildlife Resources Agency

Diagnostic information

Scientific name

Order Perciformes, Family Centrarchidae, Genus Lepomis, Species gulosus.

Common name

There have been over 16 common names given to *Lepomis gulosus*, however the most recognized common names for this species are warmouth, warmouth bass and goggle-eye. Warmouth is currently the accepted common name for *Lepomis gulosus* after the American Fisheries Society Committee on Common and Scientific Names of Fishes designated this the common name in 1948 (Larimore 1957).

Basic identification key

Although individuals can vary in coloration and size between populations, warmouth are generally darkly colored, and tend to be thick bodied relative to other sunfish (Larimore, 1957). They are very similar to rock bass, yet can be differentiated by the presence of three spines rather than six spines in the anal fin (Larimore, 1957). Warmouth have a black spot on their opercular flap, with 3 to 5 red or purple streaks across their eyes and operculum (Ross, 2001). Warmouth are the only species in the genus *Lepomis* with teeth present on the tongue (Page and Burr, 1991). Warmouth also have a mouth that is roughly twice the size of similar related species of the same size (Larimore, 1957).

Life-history and basic ecology

Life cycle

Warmouth are able to grow to a large size in comparison to other related sunfishes (Edwards, 1997). The largest adult found in research scenarios was 170 mm SL, however, they have been recorded as large as approximately 189 mm SL (284 mm TL) (Carlander, 1977). Individuals generally will reach maturity in their second year, at a size of 50 to 67 SL (75 to 100 mm TL) (Edwards, 1997). Size, rather than age, has been found to be the driving factor in maturation rather than age (Larimore, 1957). The maximum lifespan recorded for warmouth was 8 years, yet averaged roughly 3 years in Texas aquatic environments (Edwards, 1997). Warmouth are oviparous, externally fertilizing and guarding eggs until they become free swimming juveniles.

Feeding habits

Warmouth tend to feed on small fishes, crayfish, larval aquatic insects, and isopods (Layzer and Clady, 1991). They are “sit and wait” or ambush predators, utilizing cover as a mechanism to hide, and quickly darting out to capture the unsuspecting prey (Edwards, 1997). Warmouth are gape and suck feeders, utilizing opercular flaps to create suction and capture prey (Edwards, 1997). Although similar in external appearance, warmouth have mouths that are roughly twice the size of similar *Lepomis* species, allowing for the capture of larger prey

(Larimore, 1957). Warmouth feed in both the pelagic and benthic zones of bodies of water, and have different compositions of prey based on size and location (Becker, 1983).

Reproductive strategies

Warmouth spawn over a period of several months, and their germ cells do not go through the cycle of maturation all at once (Larimore, 1957). Rather, small groups of germ cells develop and are spawned at at various times throughout the spawning season (Larimore, 1957). Spawning seems to be size dependent in warmouth, in a field study, larger specimens (> 5.4 inches) all matured, whereas in smaller specimens (3.5 to 5.4 inches), a considerable proportion failed to mature (Larimore, 1957). Reproduction in warmouth is assumed to take place between early march through July, as freshly hatched warmouth individuals have been found between March and July (Edwards, 1997). Although there is likely variation based on local attributes of the environment and population, the onset of reproductive development has been recorded as occurring when the water temperature rises above 4.5 degrees Celsius, and spawning has been recorded as occurring at 21.1 degrees Celsius (Ross, 2001).

Fecundity has been difficult to measure in warmouth due to their long spawning season, multiple spawning events, and the small size of their eggs (Larimore, 1957). However it is known that fecundity in warmouths may be reduced when the population is overcrowded, or in the presence of unfavorable weather conditions (Larimore, 1957). When poor conditions are present, mature eggs can be reabsorbed by the ovaries rather than spawned (Larimore, 1957). Overall, warmouth are generally considered to have a fairly low reproductive potential in comparison to other related sunfish species (Tomelleri and Eberle, 1990).

Prior to reproduction, males will build nest sites by performing sweeping motions with their tails at suitable locations, which tend to be near stumps, rocks, vegetation, or other types of cover (Edwards, 1997) (Larimore, 1957). Only mature males will build nest sites and will do so even without the presence of a female (Larimore, 1957). Courtship has been observed as aggressive behavior towards other males and the luring of a female into the nest site (Larimore, 1957). Females will only allow themselves to be courted into nest sites when they are ready to lay their eggs (Larimore, 1957). Males change to a bright yellow color with red eyes, whereas females do not appear to to change colors during the process of reproduction. The color changes in males have been recorded as happening as quickly as in 5 to 10 seconds (Larimore, 1957).

After the spawning event, males stay at the nest site to guard and fan the eggs (Larimore, 1957). Upon hatching, larvae are limited in movement, absorbing their yolk sac over a period of around 4 days (Larimore, 1957). Warmouth larvae will

begin to feed by 7 days after hatching, and will die of starvation in 10 to 11 days after hatching in the absence of feeding (Larimore, 1957). Male warmouth will guard the fry for around a week after the fry become free swimming (Robinson and Buchanan, 1988). Survival of recruits is related to the density and composition of their environment (Larimore, 1957). Not only are juvenile warmouth eaten by larger fish, they will also feed on freshly hatched warmouth, eating as many as 12 in 5 minutes in a laboratory study (Larimore, 1957). Survival of young warmouth tends to peak in summer months, as dense aquatic vegetation provides protection from predators (Larimore, 1957).

Environmental optima and tolerances

Warmouth are generally solitary, and often inhabit sluggish waters (Edwards, 1997). Evidence suggests that they prefer muddy substrates, with high densities of detritus and beds of vegetation (Edwards, 1997). Habitats utilized by the warmouth contain many types of cover, including brush-piles, stumps, and even human induced forms of structure such as discarded tires and barrels (Edwards, 2007). These structures are utilized as refuge from predators in young and moderate sized individuals (Larimore, 1957).

Warmouth are often found in turbid water, yet appear to prefer clear water with thick vegetation (Gatz and Adams, 1994). Although they may prefer clear water over turbid waters, they have been recorded as having a higher occurrence in turbid waters (Larimore, 1957). Warmouth have been recorded having a larger tolerance for turbid water conditions than other sunfish, and may exploit this environment as a means to reduce competition with other similar species.

Generally, warmouth tend to inhabit impoundments, mostly backwater with adequate sources of cover (Edwards, 1997). Warmouth are considered the ecological equivalent of the green sunfish (*Lepomis cyanellus*), yet tend to inhabit larger streams and river with suitable habitats than the green sunfish (Layzer and Clady, 1991). Field observations have found that small warmouth tend to remain in shallow weed beds or dense cover, likely to maximize food and protection (Larimore, 1957). Whereas larger warmouth specimens spend more time in deeper water (Larimore, 1957).

Warmouth have the potential to survive in lower dissolved oxygen concentrations than other similar sunfish species. In a field study where both bluegill and warmouth individuals were collected and placed in tanks with no compressed air supply, nearly all of the 50 bluegill died shortly, whereas all of the 23 warmouth collected were still in good condition (Larimore, 1957). Warmouth have also been recorded in brackish water up to 4.1 ppt (Carlander, 1977). They seem to exhibit some level of salinity tolerance as they are abundant where they were introduced in the saline water of the lower Colorado River (Minckley, 1973)

Biotic associations (pathogens, parasites, and commensals)

Studies have found extreme seasonal fluctuations in number of parasites and the percentage of warmouth infested (Larimore, 1957). They appear to have a wide susceptibility to multiple types of parasites, one study found 22 different species of parasites from a sample of 58 warmouth (Larimore, 1957). Older warmouth tend to have larger, and more diverse parasites than smaller warmouth (Cloutman, 1975)

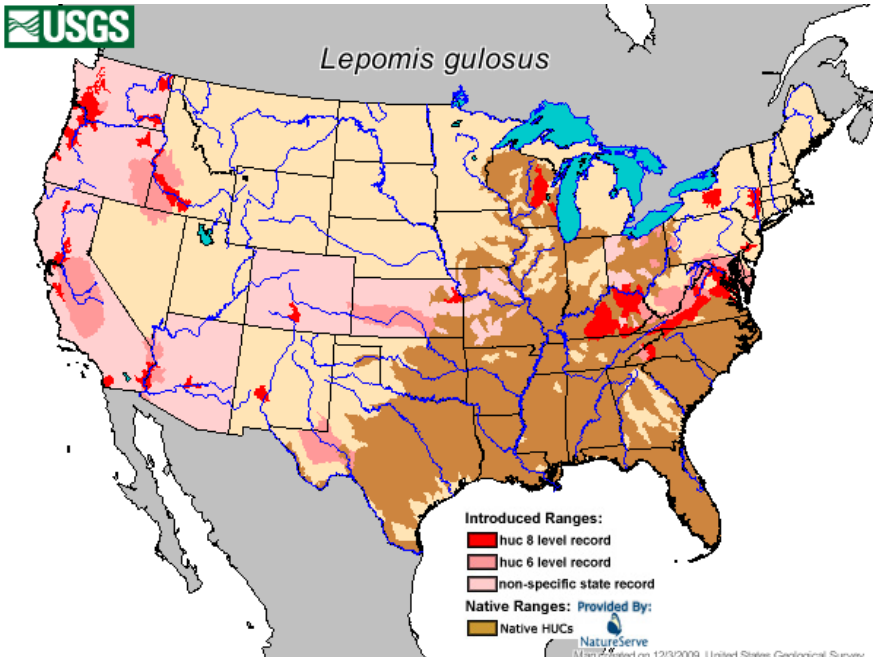

Figure 1: Distribution of nonindigenous occurrences across the United States. The brown shaded area represents the native range of warmouth, and the light pink states are states that have recorded nonindigenous warmouth populations at a non specific level. Pink and red shaded areas represent reports of nonindigenous populations of warmouth in that area.

Current geographic distribution

Warmouth have a native range from the Great Lakes and Mississippi River basins from western Pennsylvania to Minnesota, and south to the Gulf of Mexico (Page and Burr, 1991). They are also found in Atlantic and Gulf slope drainage's from Virginia to the Rio Grande in Texas and New Mexico (Page and Burr, 1991)

Distribution in the PNW and the United States (map)

Records indicate that warmouth have been likely been introduced in 20 states across the US. They have been introduced to Arizona, California, Colorado, Delaware, Idaho, Indiana, Kansas, Kentucky, Maryland, Missouri, Nevada, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, Virginia, Washington and Wisconsin (USGS, 2006).

History of invasiveness

Warmouth were introduced outside of their native range in the late 19th century and early 20th century (USGS, 2006). In the United States, warmouth distribution was originally restricted to locations in the central and eastern regions (Figure 1). Although potential impacts of warmouth introductions have been proposed, there is little record of the impacts this species

has had on invaded regions.

Pathways, vectors and routes of introduction

Stocking has been the primary pathway in which warmouth introductions have occurred, primarily intentional introductions for sport fishing (USGS, 2006). Warmouth are considered excellent sport fish as they respond well to many types of bait, are powerful for their size and fight well, and are good for eating (Larimore, 1957). Warmouth also do not overcrowd ponds and become stunted in size like many other sunfish species, which add to

Figure 2: The Columbia River Basin.

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their appeal for sport fishing.

It is likely that warmouth have also been accidentally introduced through contamination of intentional bluegill (*L. macrochirus*) or bass (*Micropterus sp*.) stocking, as was recorded in Arizona (Minckley, 1973). Stocking for conservation has also introduced warmouth outside their native range (USGS, 2006). Introduction in eastern Wisconsin were likely caused by fish rescue operations in the late 19th century and early 20th century, which transplanted stranded fish from the Mississippi River to other locations (USGS, 2006). Currently, newly recorded occurrences of warmouth are likely either old introductions that had yet to be discovered, or the results of illegal stocking by anglers. Although regulated government sponsored stocking no longer occurs, fishermen who desire warmouth for their recreational value may continue to transplant these fish to new locations despite legal consequences (USGS, 2006).

Warmouth are excellent for laboratory studies as they are easy to handle and robust enough to stay alive in transportation (Larimore, 1957). They also will feed on a large variety of foods, and will nest and spawn in captivity relatively easily (Larimore, 1957). This may have facilitated scientific research activities to be a possible pathway of introduction. If they were released to the wild from laboratories or managed to escape to a watershed, they could have been introduced to non-indigenous areas. However, this pathway is likely to have had little effect on their current distribution in comparison to stocking, as propagule pressure would likely be very low in comparison. Their robust nature in captivity may have also facilitated aquarium pet trade to be a possible pathway of

introductions. However, this pathway also is unlikely to have affected introductions relative to stocking, as propagule pressure would be presumably low for this pathway.

Canals and artificial waterways have also been a pathway for introductions. It is likely that the artificial Fox-Wisconsin Canal at Portage, which connects the Mississippi and Great Lakes allowed for warmouth to invade the Wolf and Fox systems in Wisconsin (Becker ,1983). Warmouth have also established in the Columbia river and been able to subsequently spread to across the basin, which covers much of the Pacific Northwest (Figure 2).

Factors influencing establishment and spread

Warmouth had difficulty establishing a population in a lake overcrowded with other sunfish species (Larimore, 1957). Warmouth have also been found to produce much smaller populations when introduced to lakes with established populations of predators, such as the large mouth bass. Therefore, the abundance and biotic composition of the region of introduction will affect the likelihood of establishment. Warmouth tend to be more sedentary than other sunfish species, which may cause the spread to be relatively slow (Gatz and Adams, 1994). Canals and artificial water ways also have facilitated the spread on warmouth to new locations (Becker, 1983). Warmouth depend on vegetative shallow habitats, and therefore are very unlikely to establish without this habitat (COSEWIC, 2005). Increasing global temperatures have allowed for warmouth to recently colonize Canada (COSEWIC, 2005). Since temperature currently also limits the distribution of warmouth within Canada, it should be utilized as a factor to determine likelihood of establishment in new locations (COSEWIC, 2005). The successful establishment of the Columbia river has allowed for warmouth to expand over a wide geographic range of connected waters (USGS, 2006). Warmouth have established in most of the areas introduced (USGS, 2006). However, their spread has been relatively slower than many other species (USGS, 2006), likely due to the necessity for specialized habitats, and limiting biotic and environmental factors.

Potential ecological and/or economic impacts

In the early 20th century, warmouth were a commercial fish in North Carolina, being caught in nets and sold year round (Larimore, 1957). However nowadays they have little commercial value, as they are relatively small in comparison to other food species (Larimore, 1957). Warmouth do not tend to overcrowd ponds, and evidence has shown that reproduction will slow or stop in response to population density (Larimore, 1957). Therefore, in terms of ecological damage they are not likely to cause ecosystem level impacts, which are the biggest concern in invasive species management. Although the exact ecological impact of warmouth is not measured, introduced sunfish as a whole have been blamed for the

decline of native ranid frogs and tiger salamander in California. In addition, southern toad (*Bufo terrestris*) tadpoles reduce activity when exposed to chemical cues of warmouth (Pearl, 2003). Although warmouth have been included in multi-species studies determining impacts of nonnative species, these studies generally conclude that the impact of warmouth is negligible relative to other introduced species (Dill, 1997) (Pearl, 2003).

It is possible for warmouth to hybridize with other *Lepomis* species (Childers, 1971). In the Pacific Northwest, this has the potential to threaten green sunfish, a native species. Hybrids of warmouth and green sunfish are able to continually breed successfully, further threatening native populations (Childers, 1971). Although actual rates of hybridization in nature are unknown, introduced warmouth have the potential to alter the genetic composition of native *Lepomis* species.

Management strategies and control methods

The stocking of warmouth no longer takes place, which has likely minimized the additional invasions to novel locations (USGS, 2006). In addition, it is illegal to buy or sell game fish in most states, which has limited further introductions of warmouth (USGS, 2006). Other than the cessation of intentional stocking, no evidence of effort to control the spread of warmouth have been recorded, which is likely due to the relatively small population sizes these fish exhibit in the wild, and effort being focused on invasive species with a larger impact. New occurrences of warmouth have slowed since intentional stocking has stopped, with the only new occurrences after 2000 being in California, Oregon and Washington. These new occurrences are likely a combination of continuing spread through the Columbia River Basin, and illegal stocking by sport fishermen.

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Expert contact information in PNW

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Current research and management efforts

Currently very little effort is being put into managing warmouth as an invasive species. In Washington state, warmouth are not listed by WDFW as an aquatic nuisance species. In Canada, warmouth are actually listed for protection as “special concern”, as populations have been exhibiting negative trends (COSEWIC, 2005). Although warmouth have invaded the Columbia River basin, introduced smallmouth and largemouth bass have a much larger impact (USGS, 2006) (Sanderson, 2009). In some locations of the Columbia River basin, smallmouth bass have been recorded as consuming as much as 35% of out migrating native salmon , and of replacing the native pike minnow (Sanderson, 2009). Therefore, there is little evidence for gearing management effort towards warmouth as their relative impact is much smaller than other introduced species.