Invasive Species of the Pacific Northwest:

Green Sunfish Lepomis *cyanellus*

Derek Arterburn

FISH 423: Olden

12.5.14

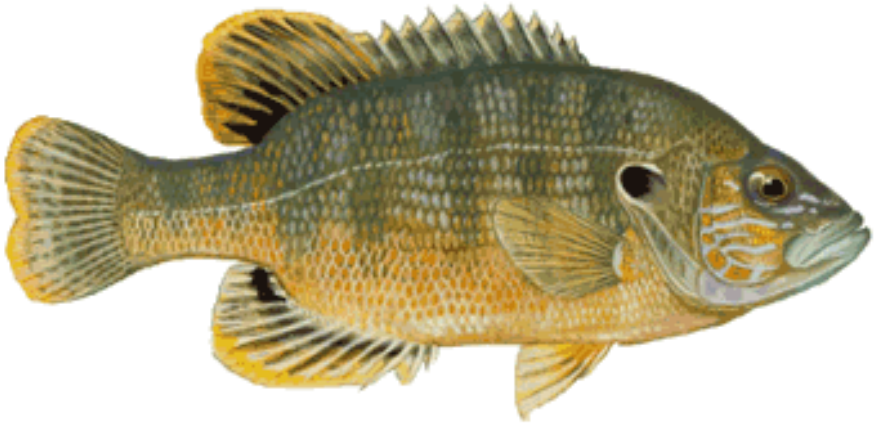

Figure 1: Adult Green sunfish Lepomis *cyanellus*. Photo from http://www.freshwater-fishing-news.com/fish-species-north-america/green-sunfish/

Classification
Order: Perciformes
Family: Centrarchidae
Genus: Lepomis
Species: *cyanellus*

Identification

Adult Green Sunfish, Lepomis *cyanellus*, commonly reach a total length of 31cm, with juveniles ranging from 12-15cm. Adult Green Sunfish have been known to reach a maximum weight of one kilogram (2.2lbs). L. *cyanellus* is a deep bodied, laterally compressed species, with a lateral line running from the operculum to the caudal peduncle. The posterior of the operculum has a characteristic dark spot relatively the same size as the eye, and the same size spot may also be found at the base of the anal and dorsal fins. The opercular flap is bordered by a white edge which runs the entire perimeter of the operculum (McGinnis 2006). The mouth on the Green Sunfish extends toward the middle portion of the eye, whereas the Blue Gill (Lepomis *macrochirus*), and Longear Sunfish (Lepomis *megalotis)*, commonly misidentified, have a significantly smaller mouth and does not run to the eye (figure 2).

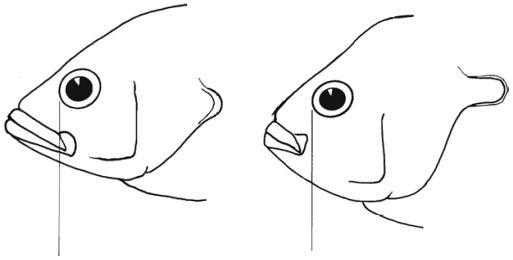

Figure 2: Relative jaw lengths of Lepomis species: left) L. cyanellus; right) L. megalotis (longear sunfish)

Lepomis *cyanellus* may have a few teeth, which can be found on the tongue. Additional distinguishing marks are the 7-12 parallel diffused dark bars running ventral to dorsal along the side of L. *cyanellus*, and the bluish-green pattern. The bluish-green coloration takes place on the mainly black/dark brown/olive body, composed of ctenoid scales, which fades to a lighter ventral color. The dark sides of L. *cyanellus* are contrast with a yellow/cream ventral coloration (Cockerell 1913). The thick caudal peduncle is without an adipose fin, and the peduncle runs to a rounded, slightly forked, homocercal caudal fin. The paired fins on Lepomis *cyanellus* are derived in orientation. The Green Sunfish has lateral placement of the pectoral fins with vertical insertion, anterior pelvic fins, and spines found on the anal and dorsal fins. Typically L. *cyanellus* has three anal spines with 9 to 11 dorsal spines. L. *cyanellus* derives its name from the iridescent blue green markings on head and sides (McGinnis 2006).

Variations in color and iridescence are commonly observed in females and juveniles. Females, darker in coloration, lack the intense bluish-green coloration on the sides compared to what is seen in males. As the juveniles mature they gain dark banding

Figure 3: Juvenile L. *cyanellus*. Photo credit Thomas, Bonnor, and Whiteside 2007

on their sides along with bluish-green iridescences on their body and head (figure 3). Females and juveniles are commonly found with black, orange, and white on the anal fin. Differing from the females and juveniles, the males display predominately orange coloration on the anal fin with a pronounced white boarder. A commonality among all sexually mature Green Sunfish is that they have an orange tint on the caudal, pelvic and dorsal fins.

Life History and Basic Ecology

Life cycle

After fertilization occurs, the eggs hatch after two to three days, revealing larvae about 3.5mm in total length (Taubert 1977). The vulnerable larvae avoid predation by remaining in the nest where they hatched and receive protection from the male who created the nest. Post hatching, the larvae continue to be nourished by their yolks for approximately five to seven days, after which they are able to swim and feed on top plankton. By the time the larvae are able to top feed, they have reached lengths of 6mm, and darker coloration can be found on the eyes and head. Distinguishing marks from other species of Lepomis larvae include the presence of pectoral buds after hatching, and after roughly 14 days all fins are distinguishable. Juvenile L. *cyanellus* transition to habitat where they can be found in vegetation, under rocks, and logs, where they will mature and spend much of their time as adults. Maturation of the Green Sunfish can occur as short as 7-8 months of age (Yun-Chang et al. 2008) or up to three years, depending on environmental conditions. Once sexually mature, species will reproduce multiple times over the breeding season. The average lifespan of L. cyanellus is 4-6 years in the wild, however, may live to 7-9 years in captivity.

Diet

The Green Sunfish is a highly predacious fish which feeds primarily on invertebrates. The mouth is designed for gape and suck feeding much like the rest of the Lepomis species. The Green Sunfish utilizes the maxilla bone and ligaments to sling the premaxilla forward and by doing so, creates negative pressure, effectively drawing in prey. Green Sunfish are known to prey upon a variety of fauna which include zooplankton 29%, gastropods 25%, larvae, aquatic invertebrates 27%, larvae, and small fish (Biggins 1968).

The predacious nature of the Green Sunfish provides opportunities for fishermen to apply a variety of baits to catch them. Baits commonly used by fishermen to catch L. *cyanellus* include worms, such as night crawlers, insects, small lures, and fly fishing tackle.

The Green Sunfish can be found in the aquarium trade where a similar diet is provided. In aquariums and private ponds the diet may consist of small insects such as crickets, and meal worms, or small aquatic invertebrates like shrimp. Although the preferred diet of L. *cyanellus* is invertebrates, they can take to common fish food pellets.

Environmental Optima and Tolerances

The reason for the Green Sunfish being such an invasive species relies largely on the environmental tolerances the species can inhabit. Lepomis *cyanellus* is one of the most eurythermal fish in North America and their ability to acclimate in differing thermal environments has been well documented. The temperatures in which L. *cyanellus* has been known to acclimate range from 10-35°C, with lethal temperatures of 0.2°C +/- 0.26°C to 41.3°C +/- 0.83°C (Cortemeglia & Beitinger 2008). Acclimation was also noted

to have a lower effect on lower temperature tolerances, that is, fish needed less time to acclimate to cooler temperatures compared to warm temperatures. In addition to the wide thermal tolerances of the Green Sunfish, they can also tolerate a variety of pH levels, so long as it is constant, and also differences in salinity. The Sunfish is a freshwater species, although it can tolerate brackish waters with concentrations up to 5.6 ppt (Kilby 1955).

Although L. *cyanellus* can adjust to a variety of temperatures, salinity, and pH, they are most commonly found at temperatures of 28 °C (Beitinger et al. 1975) and a pH of 6.5 – 8.5 (Stuber et al. 1982). The habitat of the Green Sunfish typically revolves around slack waters in rivers and lakes. Important habitat factors include large woody debris, rocks, and vegetation to hide in and feed around. The preferred bedload size, important in mating, is typically gravel and coarse sand which allows males to dig nests with their anal fin (Stuber et al. 1982). The males commonly dig nests roughly 30cm in diameter with nest depths ranging from 4-35cm.

Non-native distribution includes habitats such as streams and lakes. Studies largely examining the distribution and abundance of non-natives in the western U.S. obtained data on habitat preferences on a variety of stream orders (Schade & Bonor 2005). The Green Sunfish can be found in a wide variety of stream sizes, from headwater streams to those of higher order. The species has been known to inhabit stream orders of 1st and 2nd in North Carolina (Lemly DA 1985) to 4.5 ± 0.8 on a scale of 1-7 using the Strahler System (Schade & Bonor 2005). In order for a stream to increase in order, the joining of two streams of the previous level must have occurred, (ex. A combination of two 1st order streams to make a 2nd order stream). The commonality found among the habitats of L. *cyanellus* sampled was a decrease velocity of 10-25 cm/s (Kallemyn and Novotny 1977), which provides more glide and pool reaches. Of the streams sampled and specimens obtained, the percent where specimens were found ranged from 50-99% in glide and pool habitats. In addition to residing in slow moving rivers, with glides and pools, L. *cyanellus*, are also suited for life in lakes. Human disturbance where L. *cyanellus* was found in the PNW is relatively quiet, with the average human disturbance of 3.1 ± 0.4 on a scale of 1-5 (1 being intense alteration and impacted by humans).

Reproduction

Green Sunfish reproduction is highly effective, and occurs over a relatively long breeding season. The breeding season of L. *cyanellus* lasts the majority of the spring and summer, from May to August. The breeding season is mostly depended on water temperature, as common breeding temperatures range from 20-22°C (Stuber et al. 1982). Males retain their coloration throughout the year in contrast to females, which tend to get more vibrant during the breeding season. Male L. *cyanellus*, may create nests in colonies or apart from one another, but all seek preferred substrate which is easy to dig such as gravel and coarse sand. After males create their nests, they search for viable females. Once a male finds a potential female he leads the female back to his nest with sounds. Males may lure multiple females back to his nest where he can spawn with several females simultaneously. Upon arriving he begins to swim in circles around the female. The females release eggs in his nest where he fertilizes them and remains with the larvae post hatching.

Figure 4: Adult male L. *cyanellus* in spawning nest. Photo by Alan Marshall 2007

The fecundity of female Green Sunfish is largely unmatched by any other freshwater species. Females may produce 10,000 to 50,000 eggs, which are 1.0-1.4mm in diameter (Taubert 1977), depending on her size. Individuals can mate multiple times over the 4 month long breeding season. Common to most freshwater species, L. *cyanellus* lay demersal eggs, which sink to the bottom of the nest after females release them and stick to one another and/or substrate. After the eggs are deposited and fertilized, the males guard their nest and eggs. The males stay with the nest and eggs to fend off other predators such as various catfish species and also to provide the eggs with oxygen by fanning them with his anal fin. The eggs hatch to reveal larvae 4.2mm (Taubert 1977) in length after just two days, but remain in the nest for another 5-7 days until they are able to swim off and feed on plankton. As the larvae develop they can become reproductively mature in as little as 7-8 months (Yun-Chang et al. 2008) but typical age of sexual maturation occurs at 2-3 years of age. Observations have been made of L. *cyanellus*, where individuals have spawned again in just 8 days.

Distribution

Global, United States & PNW

The native range of the Green Sunfish is in the Great Lakes, Hudson Bay, and Mississippi River basins from New York and Ontario west to Minnesota, South Dakota, and Wyoming, and south to the Gulf Slope drainages from Mobile Bay, Georgia and Alabama, to the Rio Grande, Texas, and the northern portion of Mexico (Page & Burr 1991). The establishment of L. *cyanellus* has occurred throughout the world (figure 6), from the United States, Asia, Africa, and Europe. The introductions which occurred in the U.S. include Alabama, Arizona, California, Colorado, Connecticut, Delaware, Washington D.C., Florida, Georgia, Hawaii, Idaho, Maine, Maryland (native in western region), Massachusetts, Michigan, Minnesota, Montana, Nevada, New Jersey, New Mexico, New York, North Carolina, North Dakota, Oregon, Pennsylvania, South Carolina, South Dakota, Utah, Virginia, Washington, West Virginia, Wyoming. The Green Sunfish can be found throughout the PNW (figure 5), with the history of introductions beginning in 1890.

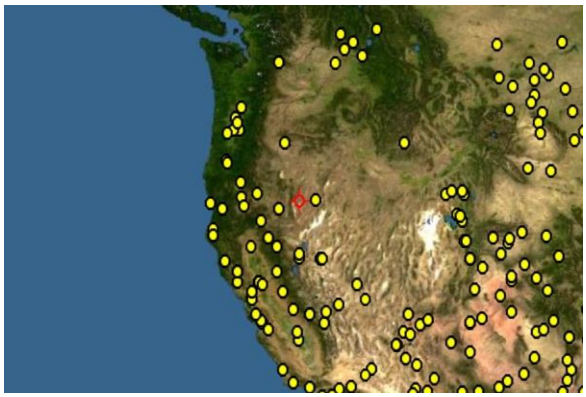

Figure 5: PNW distribution of the Green Sunfish Lepomis *cyanellus*. http://www.discoverlife.org

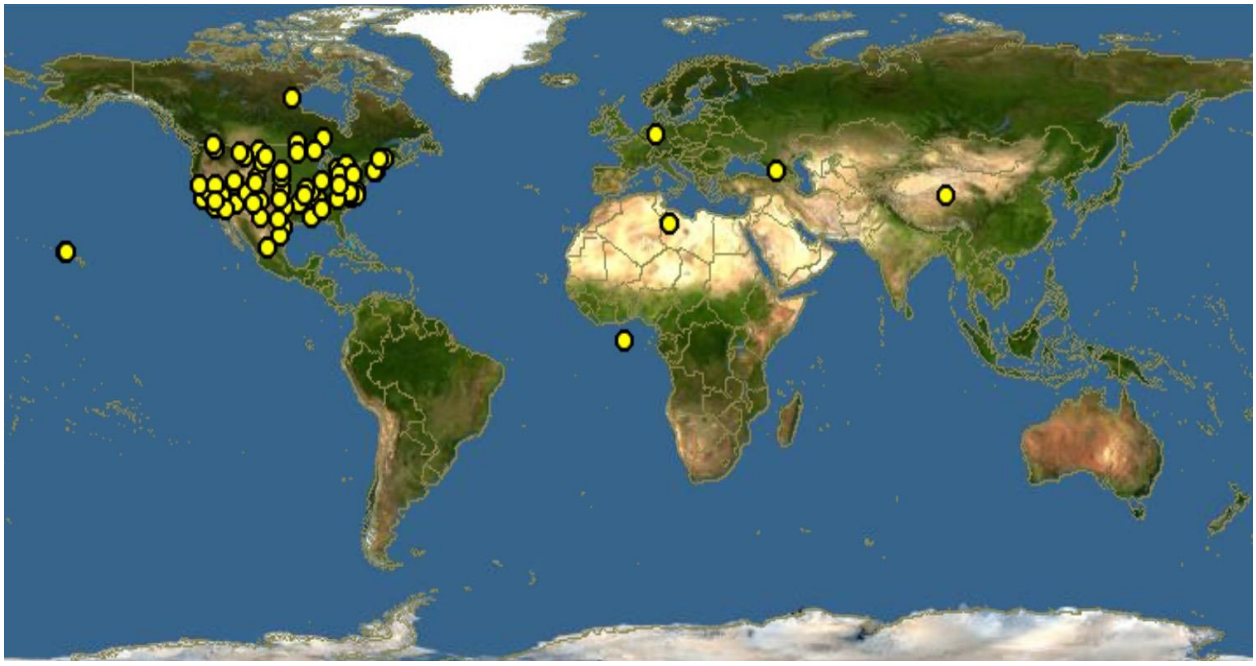

Figure 6: Global distribution of Green Sunfish Lepomis *cyanellus* http://www.discoverlife.org

Invasion Process

Pathways, Vectors and Routes of Introduction

The vector by which the Green Sunfish was introduced into much of America was primarily through intentional efforts of fish services. The introduction of L. *cyanellus*, was largely done in the early 1900's for recreational fishing expanding from its native distribution, toward the east and west coasts. Common placement of L. *cyanellus* was primarily lakes, although stocking did occur in rivers. The Pacific Northwest is no exemption to this, the introductions were done for the same reason, of fish stocking, due to the aggressive nature when take bait, and the fight they put up (Schade & Bonar 2005). They are largely seen as a nuisance fish among anglers with no large recreational benefits, and prevent fishermen from targeting other desirable species. The benefit anglers do receive from Green Sunfish is in the application of live bait. If the Green Sunfish are already present in the body of water they are currently fishing, they may be used as live bait. Contrary to many species that are used as live bait, L. *cyanellus* can be transported from one body of water to another in Kansas.

In addition to the historical stocking of Green Sunfish for recreation, the species can easily be found in the aquarium trade. L. *cyanellus*, was available to purchase for $6 - $12 (http://www.zimmermansfish.com/ http://jonahsaquarium.com/JonahSite/fishlist.htm). The aquarium sites visited did not mention the potential invasiveness of L. *cyanellus*, negative impacts, and no

restrictions were applied to purchasers who live in banned states, such as Florida.

Unintentional introduction of the Green Sunfish occurred when it was accidentally released into Hawaii. Bluegills, Lepomis *macrochirus*, are commonly stocked for aesthetics in ponds, and also readily hybridize with Green Sunfish. The stocking of Bluegill Sunfish had preceded the establishment of the Green Sunfish. It is thought that L. *cyanellus* was accidentally was incorporated with Bluegills, as stock contaminate, a very similar species when comparing morphological observations.

Factors Influencing Establishment & Spread

Factors associated with spread and establishment of L. *cyanellus*, outside of the great fecundity, include the habitat in which they were stocked, river or lake, and the amount of propagules released. Due to the wide tolerances of environmental conditions, habitat suitability of the Green Sunfish plays a lesser role in establishment.

Although the environmental suitability of L. *cyanellus* is broad, the homing ability and lack of spread keeps populations localized in streams (Gatz 2007). The locality of Green Sunfish after mark and recapture events yielded results that showed the majority of fish stayed within the same 20m section of the stream with initial capture in the spring and recapture in late summer. Compared to the control samples, the sunfish displaced 400 or 1,000m displayed the greatest tendency for homing (45%), the second greatest movement all the way home (31%), followed by no movement (18%), and the least tendency was movement away from the initial sight of capture once displaced (6%). This has beneficial implications to aspects in which management might try and control L. *cyanellus*, as they tend to have a greater tendency of staying in the same location or return to a location in which they are established.

Economical & Ecological Impacts

The Green Sunfish produces little economic damage, but can have large effects on native wildlife. Lepomis *cyanellus* undergoes little management pressure across the U.S. with no direct economic cost utilized in prevention or elimination for the fish in non-native habitats. There are however, negative impacts that are contrast with the relatively few beneficial aspects of Green Sunfish introduction. Biotic impacts associated with introductions of L. *cyanellus* vary from parasites, available nesting habitat, predator prey interactions, most of which arising from the intense fecundity.

One of the most negative associations with the introduction of Green Sunfish is the affect it has on Bass populations. Largemouth Bass (Micropterus *salmoides*) were commonly stocked in the PNW during the 1900's, at the same time as Green Sunfish. The bass interact with sunfish in predator prey relationships, where both species feed on one another (Biggins 1968). Largemouth bass have been known to feed on eggs, larvae, and juvenile Green Sunfish. Largemouth bass occur in many lakes in Washington, and in Oregon so interactions are mostly dependent on the limited Green Sunfish introductions.

In addition to the predator prey interactions with L. cyanellus the sunfish has been known to be one of the hosts for a parasitic worm, which can then be transmitted to Largemouth Bass (Richardson & Richardson 2009). Experimental data yielded 33% infection rate in Largemouth Bass, where Leptorhynchoides thecatus adults (figure 7) had been establish in 100 Green Sunfish. The parasitic worm causes significant abdominal swelling and thickening of the ceca in fish it infects

(Buron and Nickol 1994). Although the hookworm cannot be transmitted to people, the hooked snout can cause serious damage to the intestines of fish.

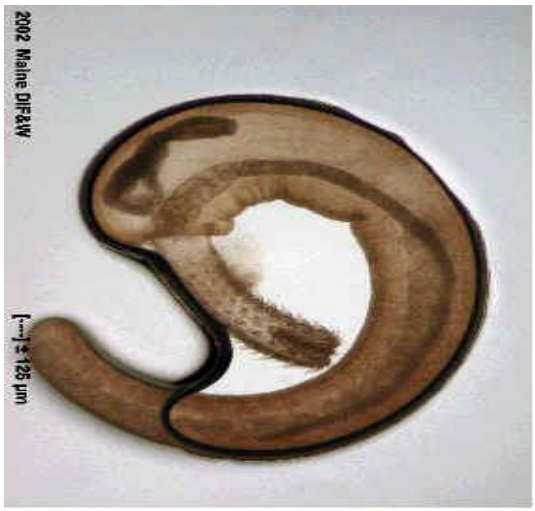

Figure 7: Adult Leptorhynchoides thecatus from the intestines of a largemouth bass **http://www.state.me.us/ifw/fishing/health/vol4issue9.htm**

Besides the negative impacts regarding predator prey interactions and parasite associations to L. *cyanellus*, positive outcomes have been documented for the Northern Redfin Shiner (Notropis umbratilis cyanocephalus), when the two share habitat (Hunter & Wisby 1961). The mating season of Green Sunfish and the Redfin Shiner occurs over the same period, and even though the Shiners are considerably smaller, they utilize the Green Sunfish nests. Over the breeding season, male Shiners occasionally created dense swarms and as a female moved through the group, males pursued her and spawn over the nest. The male Sunfish displayed effort to fend off his nest to other male Sunfish, but did not regard swarms of Shiners. Male Green Sunfish did not eat the eggs of the Shiners, and the survivorship of the Shiner eggs deposited in the nest may be greater due to the parental care provided by the male Green Sunfish.

Despite the positive effects with Northern Redfin Shiner, L. *cyanellus* can have negative implications during prolonged drought or when introduced to small tributaries. Green Sunfish's establishment in a Californian river was facilitated during a prolonged drought (Beche et al. 2009). Contrary to the increase in abundance of Green Sunfish, the native fish were least abundant during the 5 year drought, when the Sunfish was becoming established, with highest native abundance taking place during wet periods. Of key importance was that Green Sunfish rose to population levels which successfully sustained themselves during normal and high flow events; revealing that habitat suitability models should account for possible areas of establishment given that climate fluctuations may increase in frequency and magnitude. Further ecological impacts regard headwaters where L. *cyanellus* has negative impacts on native fish. In 1st and 2nd order streams where the species is introduced they typically undergo rapid biomass and increase in abundance which overwhelm coexisting species (Lemly 1985). Upon removal of L. *cyanellus* the native biomass increased and more than made up for the loss of the Sunfish, after just two years. The removal of the Green Sunfish shows the species hinders native fish abundance and biomass, which is primarily thought to be done through predation on native juveniles.

The Green Sunfish is one of the most successful species of the Lepomis genus given the array of environmental conditions it can inhabit, and hybridization may complicate any management efforts. Common hybridization with other Lepomis species include mating with Bluegill Lepomis *macrochirus* (figure 8), Pumpkin Seed Lepomis *gibbosus* (figure 9), and

Longear Lepomis *megalotis* (figure 10). Hybridization between L. *cyanellus* and the other species, commonly leads to misidentification, and complicate management efforts, as seen in Hawaii.

Figure 8: Hybrid Bluegill Lepomis *macrochirus* and Green Lepomis *cyanellus* Sunfish. Photo credit John Lyons.

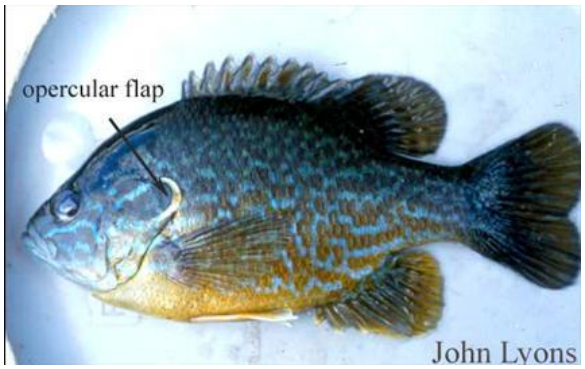

Figure 9: Hybrid Pumpkinseed Lepomis *gibbosus* and Green Lepomis *cyanellus* Sunfish. Photo credit John Lyons.

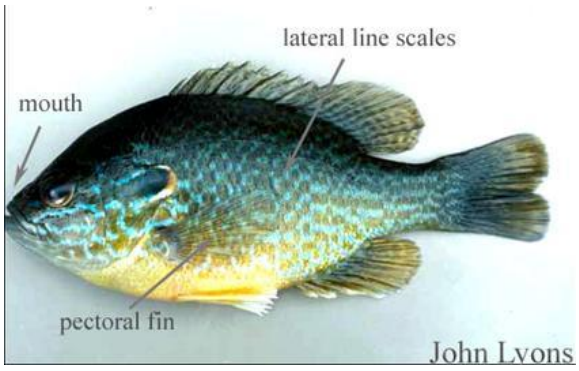

Figure 10: Hybrid Longear Lepomis *megalotis* and Green Lepomis *cyanellus* Sunfish. Photo credit John Lyons

Control Methods

Minor efforts and resources go into the management of L. *cyanellus*, outside of the state who have banned the species. One state who has management outlines in place is New Jersey. If Green Sunfish are caught or found in the state, Fish and Wildlife require anglers to destroy and report any caught individuals.

The Green Sunfish species is extremely difficult to control once established and successful eradication are hard to accomplish. Eradication is typically achieved by draining ponds and/or applying chemical toxins such as Rotenone. If draining or applying toxins is not appropriate, such as in a stream or a large lake, trapping methods may provide some relief. Depending on presence of other species, applications of destroying spawning grounds and exposure to predators by vegetation removal may be applied.

Management Objectives & Current Research

Little management efforts and current research is being completed on L. *cyanellus*. The work that has been performed describes the ability of the Green

Sunfish to metabolize and excrete contaminated food with ['4C] hexachlorobenzene (HCB) (Sanborn et al. 1977). The contaminant is known to cause porphyria, accululation of natural chemicals in the body, and increased risk of cancer (To-Figueras et al. 1997). In L. *cyanellus* concentrations of highest residues were in the digestion tract with the lowest accumulation in skeletal muscle. The muscle tissue was also able to clear most rapidly for a given exposure concentration.

Literature Cited

Beche, L.A; Connors, P.G; Resh V.H; Merenlender A.M; 2009; Resilience of fishes and invertebrates to Prolonged Drought in Two California Streams; Ecography; 32; 5; 778-88

Beitinger, T.L; Magnuson, J.J; Neil, W.H; Shaffer. W.R; 1975; Behavioural thermoregulation and activity patterns in the green sunfish, Lepomis cyanellus; Animal Behaviour; 23; 222-229

Biggins, R. G; 1968; Centrarchid Feeding Interactions in a Small Desert Impoundment; University of Arizona, Tucson; MS Thesis

Buron, I; Nickol, B, B; 1994; Histopathological effects of the acanthocephalan *Leptorhynchoides thecatus* in the ceca of the green sunfish, *Lepomis cyanellus*; Transactions of the American Microscopical Society; 133; 2; 161-168

Cockerell, T.D.A; 1913; Observations on Fish Scales; Government Printing Office; Issue 779

Cortemeglia, C; Beitinger, T.L; 2008; Temperature Tolerance of Green Sunfish (Lepomis Cyanellus); Texas Journal of Science; Volume: 60; 3; 179-188

Gatz, A.J; 2007; Homing Ability of Displaced Stream-Dwelling Green Sunfish; Journal of Freshwater Ecology; Volume: 22; 3; 403-409

Hunter, J.R; Wisby, W.J; 1961; Utilization of the nests of green sunfish (Lepomis cyanellus) by the Redfin Shiner (Notropis umbratilis cyanocephalus); Copeia; 1; 113-115

Kallemyn, L.W; Novotny, J.F; 1977; Fish and fish food organisms in various habitats of the Missouri River in South Dakota, Nebraska, and Iowa, U.S. Department of Fish and Wildlife Service; 100

Kilby, J.D; 1955; The fishes of two gulf coast marsh areas of Flordia; Tulane Studies in Zoology; 2:175-247

Lemly D.A; 1985; Suppression of Native Fish Populations by Green Sunfish in First Order Streams of Piedmont North Carolina; Transactions of the American Fisheries Society; 114; 5

McGinnis, S.M; 2006; Field Guide to Freshwater Fishes of California; University of California Press

Richardson, D.J; Richardson K.E; 2009; Transmission of Paratenic Leptorhynchoides thecatus (Acanthocephala) from Green Sunfish (Lepomis cyanellus) to Largemouth Bass (Micropterus salmoides) Comparative Parasitology; Volume: 76 Issue: 2 Pages: 290-292

Sanborn, J.R; Childers, W.F; Hansen, L.G; 1977; Uptake and Elimination of [14C]hexachlorobenzene (HCB) by the Green Sunfish, Lepomis *cyanellus* Raf., After Feeding Contaminated Food; Journal of Agriculture and Food Chemistry; 25; 3; 551-553

Schade, C.B.; Bonar, S.A; 2005; Distribution and Abundance of Nonnative Fishes in Streams of the Western United States; North American Journal of Fisheries Management; Volume 25; 4

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982. Habitat suitability index models: Green sunfish. U.S. Dept. Int. Fish Wildlife Service 28 pp.

Taubert, B.D; 1977; Early Morphological Development of the Green Sunfish, Lepomis cyanellus, and its separation from other larval Lepomis species; Transactions of the American Fisheries Society; 106; 5; 445-448

To-Figueras, J; Sal, M; Otero, R; Barrot, Carme; Santiago-Salva, M; Rodamilans, M; Herrero, C; Grimalt, J; Sunyer, J; 1997; Metabolism of Hexachlorobenzene in Humans: Association between Serum Levels and Urinary Metabolites in a Highly Exposed Population; Environmental Health Perspectives; 78-83

Yun-Chang, C; Wen-Sheng, L; Hao-Ran, L; 2008; Gonadal Development in Green Sunfish, Lepomis cyanellus: A Histological Study; Chinese Journal of Zoology; 43; 1; 88-95

Other Key Sources

http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=380

http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=168132

http://eol.org/pages/207660/details

http://www.seagrant.wisc.edu/home/Default.aspx?tabid=605&FishID=64

http://www.discoverlife.org/mp/20m?kind=Lepomis+cyanellus&guide=Fish&cl=US/MA/Middlesex/Carlisle

http://aqualandpetsplus.com/Oddballs,%20Sunfish.htm

http://animaldiversity.org/accounts/Lepomis_cyanellus/#56955960e846c9a70fa0338ba9c11820

http://jonahsaquarium.com/JonahSite/fishlist.htm

http://www.zimmermansfish.com/

Contacts

Washington Invasive Species Council
Wendy Brown
Executive Coordinator
(360) 902-3088
E-mail:InvasiveSpecies@rco.wa.gov

Washington Department of Fish and Wildlife
Allen Pleus
ANS Coordinator
(360) 902-2724
Allen.Pleus@dfw.wa.gov