Pacific Northwest Aquatic Invasive Species Profile

Grass Carp *Ctenopharyngodon idella*

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Fish 423

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Diagnostic Information

Common Names: Grass Carp, White Amur
Kingdom: Animalia
Phylum: Chordata
Class: Actinoptergii
Order: Cyprinoformes
Family: Cyprinidae
Genus and Species: Ctenopharyngodon idella

Identification

The grass carp is a relatively large fish that possesses a similar body structure common to other carp species. It can grow up to 1.6 meters in length and weigh up to 37kg making it one of the largest members of the Cyprinidae family (Conover et al. 2007) According to Cudmore (2004) the grass carp, "is characterized by: a wide, scaleless head; subterminal or terminal mouth with simple lips; no barbels; slightly protracted upper jaw and, very short snout, its length is less than, or equal to, its eye diameter and its postorbital length is more than half its head length." Grass carps have a relatively aquadynamic body with the exception of the belly area which is curved out. The body is covered with large cycloid scales and the fins do not possess spines (Cudmore et al. 2004). Grass carp may vary in color ranging from a bright silver to black, with a dark green-brown being the middle ground. Also the Grass carp has pharyngeal teeth that are specialized for grinding up their main food source, plantlike matter (Conover et al 2007).

Since the grass carp shares many traits with other carp species they can easily be misidentified or confused. A more in depth identification key from the USGS is included in section number 8.

Figure 1: Grass carp Ctenopharyngodon idella. Top picture is of a juvenile grass carp while the bottom picture is of a full grown adult grass carp. Both pictures are from the USGS website.

Figure 2: Picture of the Pharyngeal teeth of the grass carp. Photo from the USGS website.

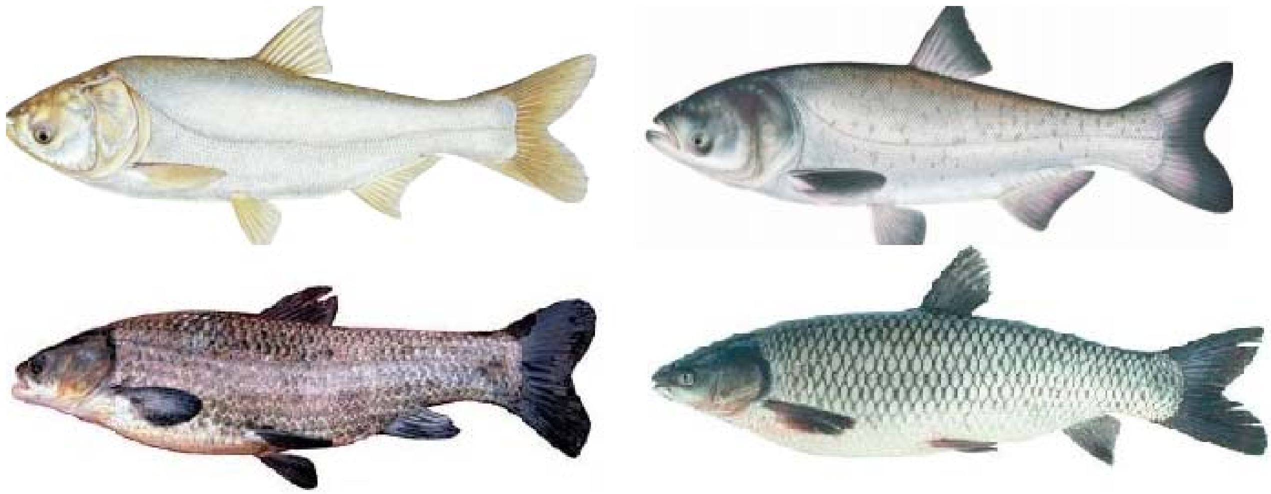


Figure 3: From top left to bottom right Silver Carp, Bighead Carp, Black Carp, Grass Carp. Top pictures from the Sea Grant website bottom two pictures from the USGS website.

Life History and Basic ecology

Life cycle

The average lifespan of the grass carp ranges anywhere from 5-11 years with a maximum recorded age of 33 years old (Cudmore 2004). After hatching from the egg, juvenile grass carp feed and grow in the lower reaches of the river they were spawned in, due to the river's flow at the time of egg dispersal (Cudmore 2004). By age one the grass carp reach 1 kg in weight and from here on can gain 2-3kg/year in temperate climates, and 4.5 kg/year in tropical climates (Conover et al. 2007). As the grass carp grow they slowly start to move upstream in their natal river (Cudmore 2004). The grass carp can mature anywhere between two and ten years old mostly based on the growth rate of the individual. Males in general mature on average one year earlier than their female counter parts (Conover 2007). The growth rate grass can be affected by a variety of factors including ambient temperature of the environment, and the density of other grass carp in the area. Studies have shown that at age 0 grass carp, ponds with higher densities had the lowest average weight and size, while the less dense ponds had larger averages, weights, and sizes (Cudmore 2004). This means depending on what environment the grass carp grows in dictates their growth rate and ultimately the age at which they mature, most likely explaining the wide range of age at maturity. After reaching maturity grass carp will spawn during spring high flows, producing up to 500,000 eggs per 5kg female (Conover 2007). After spawning, the grass carp moves out of the river and into low flow areas such as lakes until the start of fall when they return to the river to spend the winter

(Cudmore 2004). During this over wintering period the grass carp seldom feed (Cudmore 2004).

Feeding Habits

Three to four days after hatching new born grass carp start to feed on zooplankton including rotifers and protozoans, after approximately two weeks the grass carp hatchling can feed on larger prey such as daphnia and insect larvae (Cudmore 2004). At the three week mark the grass carp will begin to eat plant like material, and after about a month the grass carps diet will become exclusively aquatic plant based (Cudmore 2004). The grass carps pharyngeal teeth are perfectly design for grinding up the plant like matter that make up the bulk of the grass carp's diet. Grass carp seem to prefer eating underwater plants with larger soft leafs, but when not present the grass carp will consume more "filamentous algae" and "firmer macrophytes" such as Eurasian Millfoil (Conover 2007). In the total absence of plant like material grass carp have been known to eat detritus, smaller fish, earthworms and other invertebrates (Conover 2007). Even if these non-plant food sources are sufficient in abundance grass carp tend to lose weight when feeding on them (Cudmore 2004). In addition to this grass carps feeding habits depend heavily on the temperature of the environment. Recent studies have shown that grass carp start feeding when the temperature hits approximately 7 degrees Celsius and feed at full force when the temperature reaches 20 degrees Celsius, but they seldom feet at temperatures below 3 degrees Celsius (Cudmore 2004).

Reproductive Strategies

Maturity in grass carp seems to be controlled by temperature, requiring 1,500 to 2,000 degree days within a year to mature (Cudmore 2004). At maturity grass carp exhibit sexual dimorphism traits. Males exhibit tubercles on their dorsal and pectoral fins while females also develop tubercle and their bellies become soft and protruding (Cudmore 2004). Grass carp spawning behavior is triggered by the temperature of the surrounding water. Between 20-30 degrees Celsius is when the grass carp's spawning behavior will be triggered but they have been known to spawn at as low as 15 degrees Celsius (Cudmore 2004).

The increase in seasonal temperature normally coincides with the increased levels of flow in the rivers that grass carp reside in. This increase of flow is very important to the reproduction of grass carp, and has been shown that female grass carp will only release a portion or no eggs at all in low flow condition (Cudmore 2004). These eggs that weren't release are reabsorbed into the female's fat stores (Cudmore 2004).

The actual spawning event normally occurs in the late spring or summer in the main channel of the host river. The optimal habitat for grass carp spawning is in turbulent and fast flowing waters (Cudmore 2004). When these fast flowing habitats are not present some grass carp have been known to spawn in slower or even non-moving water (Cudmore 2004). When spawning the grass carp swims against the current with their prospective mates. Once the mating has started a courtship ritual will take place, which involves the male and female carp chasing each other (Cudmore 2004). After courtship ritual takes place fertilization occurs and the eggs are released into the strong current.

The amount of eggs a single female grass carp can produce is related to the size of the individual. Large female grass carp can produce up to two million eggs while a normal sized grass carp will produce approximately five hundred thousand eggs (Cudmore 2004). These eggs subsequently are spread across the length of the river carried by the strong currents, leading to a high dispersal rate of young.

Most grass carp individuals are diploid but in recent history scientist have developed a method to produce triploid sterile grass carp. In 1979 scientists bred a grass carp with a big head carp and as a result a high percentage of the young were triploid and sterile (Standish 1987). Even though this method produced some sterile triploid individuals there still remained some sexually viable diploid members. The growing need for consistently triploid individuals in the aquaculture industry has led to a new technique called induced polyploidy (Standish 1987). This is accomplished by either thermally or barometrically shocking eggs during the development phase (Standish 1987). These methods produce near 100% triploid individuals which are used by many companies for bio-control of aquatic plants.

Environmental Optima and Tolerance

The grass carp are considered to be a temperate or subtropical species and are normally found in the range of 20-65 degrees north latitude (Conover et al. 2007). The grass carp can put up with a relatively high range of temperatures differing between the grass carp's life stages. At the adult stage grass carp can tolerate 0-33 degrees Celsius, and at 38 degree Celsius there are high rates of mortality (Cudmore 2004). Strangely enough the thermal maximum for fry is higher than the adults at 33-41 degrees Celsius and lower at the yearling stage which is 35-36 degrees Celsius (Cudmore 2004). On the lower end of the temperature spectrum grass carp can tolerate 2-3 hours of exposure to 0 degrees Celsius before significant mortality occurs, but the grass carp eggs will not hatch in temperatures lower than 18 degrees Celsius (Cudmore 2004).

Grass carp are also very tolerant of low oxygen levels and high levels of salinity. Adult grass carp are able to tolerate as low as .2mg/l oxygen concentrations (Cudmore 2004). Also grass carp are not normally found in salt water environments their ability to cope with high salinity is very impressive. Studies have shown that grass carp adults can easily tolerate 17.5 ppt. salinity concentrations, and can even survive in 100ppt. environment for many days at a time (Cudmore 2004).

Biotic Associations

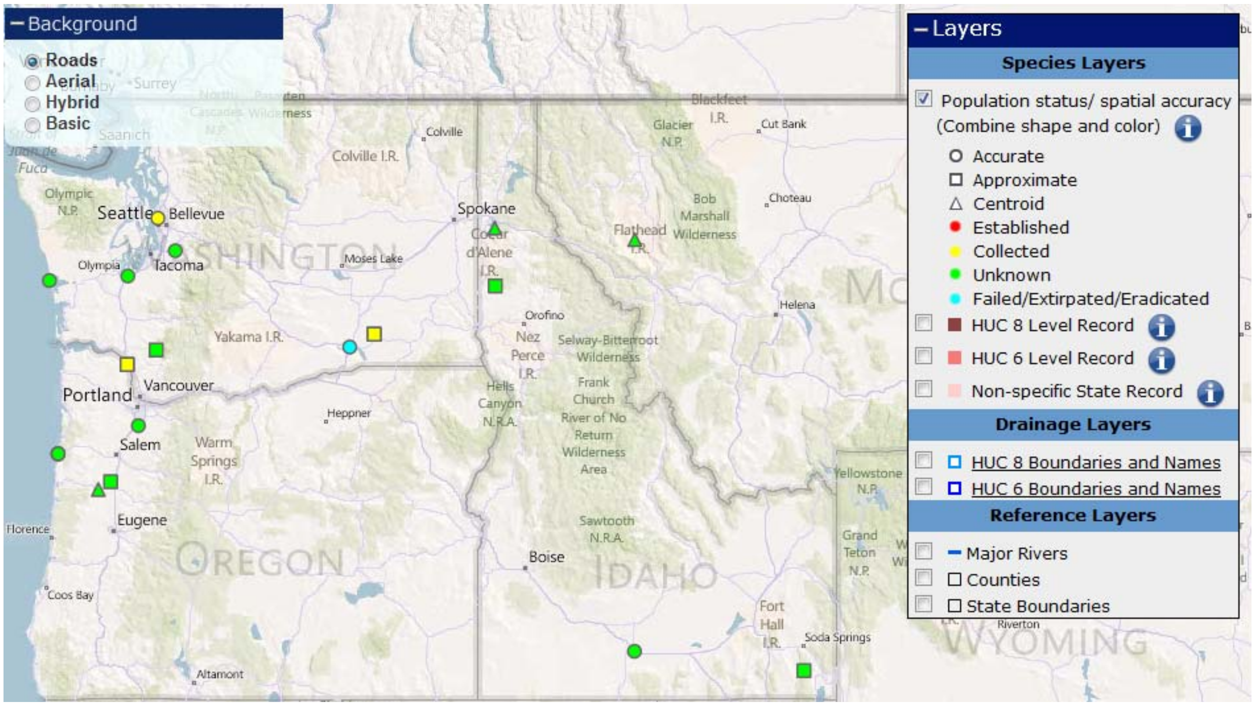
The grass carp is associated with many diseases and pathogens including; Capillaria catostomi, Spiroxys, Metacercarial custs, Dactylogyrus, Trichodonella, Bothriocephalis opsarochthydis, Cyrptobia brandchialis,Trichondia, Camallanus, Aeromonas, Hexamita, Apiosoma, External fungus, Spheres, Lernaea elegans, Ich, Clinostomum companatum, Gyrodactylus, Gold shiner virus, Ambiphyra, Proteocephalus, Flexibar columnaris, Trichophyra, Ichtyobodo, Chloromyxum, Cryptobia agitans, IPN-like virus (Wahington 1990). All of these associated pathogens except for the Asian tapeworm either appear in other fish in the region or pose little to no threat to native fish populations. The Asian tapeworm problem can be held in check by not importing any grass carp under eight inches in length (Washington 1990). Recently there has been a discovery of an American grass carp reo virus. This virus is in the same family as gold shiner virus but it is supposedly genetically unique within the family (Wang et al 2011). Wang et al. (2011) believes that susceptibility of grass carp to this virus maybe be genetically linked. The reovirus kills it victims through hemorrhagic shock which causes bleeding throughout the victim's body. The reovirus seems to be only deadly to grass and black carp, and has wreaked havoc on China's carp aquaculture industry (Su et al. 2009). This virus has also been found in healthy gold shiners in the US, but with none of the negative side effects.

Current Geographic Distribution

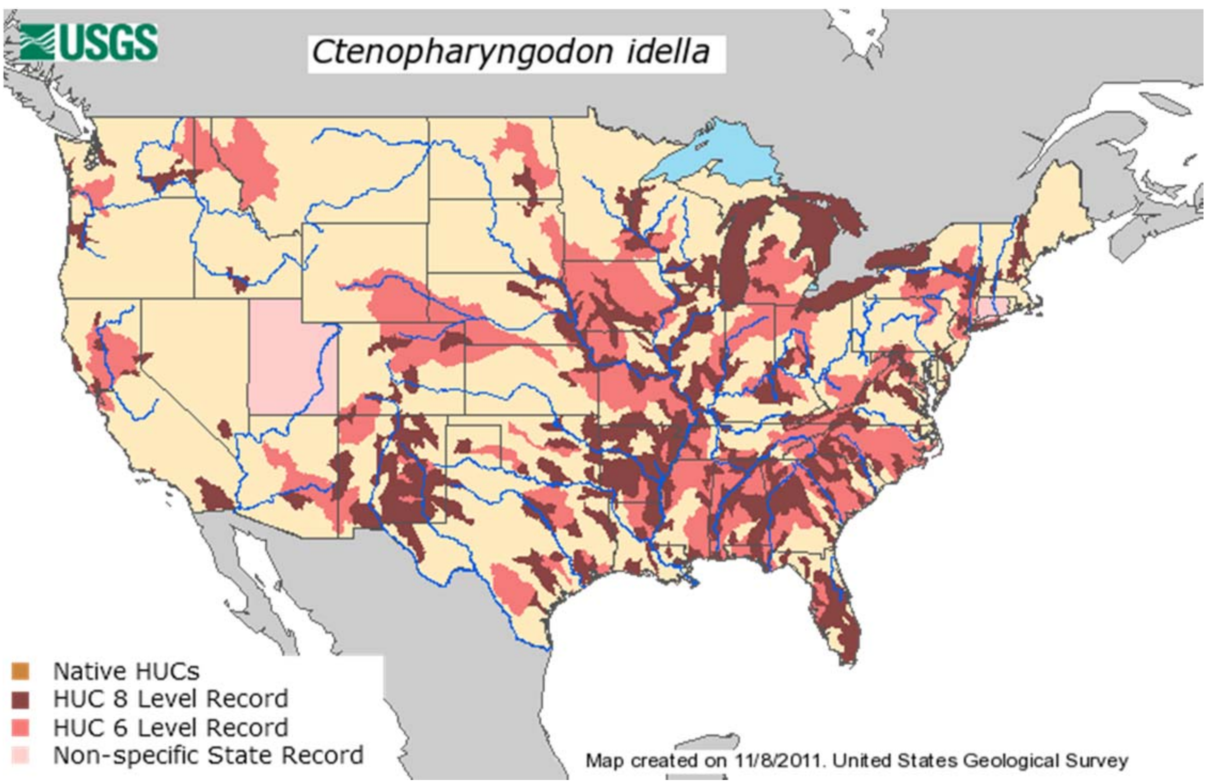
Distribution in the Pacific Northwest and the United States

Grass carp are widely distributed throughout the continental United States. Grass carp is present in all the states except Alaska, Rhode Island, Maine, Vermont, and Montana (Conover et al. 2007). Their wide distribution most likely is due to both legal and illegal stocking for use as bio-control for submerged macrophytes.

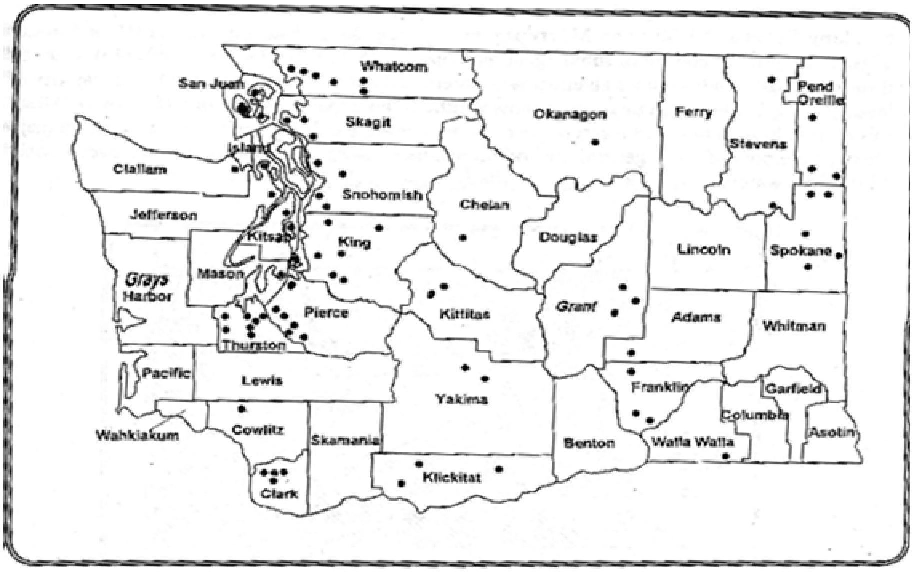
The largest populations in the state of Washington are in the form of triploid stocking. Map 3 shows the certified stocking areas for triploid grass carp in the state of Washington from 1990-1996. These legal stockings have been known to have escapees during times of flooding. Other than these triploid stockings there has been confirmed sighting of grass carp in the snake and Columbia River (Loch et al 1997). The grass carp were seen and identified making their way through fish passages at dams along the Columbia and Snake rivers (Loch et al. 1997) The few individuals that were captured and tested were found to be triploid (loch et al. 1997). Even though the ones captured were triploid, there is evidence of illegal stocking of diploids in the region. This could potentially lead to a much bigger problem since triploid male grass carp can fertilize diploid female grass carp eggs (Standish 1987).



Map 1: Map of Grass carp Distribution in the Pacific Northwest, photo from the USGS website.



Map 2: Map of Grass Carp Distribution in the United States, photo from the USGS website.



Map 3: Map of Certified Triploid Grass Carp Sites in Washington State 1990-1995, photo from (Bonar et al 1996)

History of Invasiveness

Grass carp first came to the United States in 1963, for the purpose of evaluating their usefulness as a biological control for aquatic macrophytes (Conover et al. 2007). The first fish were kept in a fish farming experiment station in Arkansas (Conover et al. 2007). These individuals eventually matured and the first captive breeding of grass carp in the United States occurred in 1966 (Conover et al. 2007). During this spawning and rearing event many grass carp fry escaped captivity, becoming the first wave of invaders. According to Guillory and Gasaway (1978) (as cited in Conover 2007) the first stocking of grass carp in a body of water with access to a stream system occurred in 1971. In this same year the Arkansas Game and Fish commission began supplying other states with grass carp further increasing its distribution (Conover et al. 2007). Following these events event grass carp was widely marketed, with little or no restrictions, for almost ten years. In the late 1970s many states banned the importation of grass carp, but by this time grass carp had already invaded the state of Arkansas and many of the surrounding waterways and states (Conover et al 2007).

Invasion Process

Pathway, Vectors and Routes of Introduction

There are many ways in which grass carp are moved or introduced in the United States, but by far the largest factor is its use as a bio-control for aquatic macrophytes. This vector was how grass carp originally came to the United stated and is directly responsible for the majority of invasive grass carp populations. The grass carp that are stocked to control plant levels, escape through either flooding events or connected waterways, and the subsequently colonize larger rivers.

One of the smaller vectors of introduction that still may have a large impact is the illegal stocking of diploid grass carp. This type of stocking can result in the escape of reproductively viable grass carp individuals which could be the start of a local invasion. Another vector with a less chance of individuals escaping is the live sea food trade. Grass carp is eaten and raise by aquaculture in China, so some individuals from china may want to eat grass carp in the US. This would result in the illegal shipping of live individual from China, or local Asian markets stocking live carp in the store. The only chance for escape would be during the shipping and transportation phase. If these imports were legal the specimens would most likely be triploid and of no threat, but if they are obtained through illegal measures they could well be diploid. The final vector would be ritualistic/ religious release. This vector poses the same threat as the previous one with the exception of the fish being freed at the end.

Factors Influencing Establishment and Spread

The grass carp has many attributes which may aid it in establishing populations and spread to new environments. First and foremost the grass carp has a high environmental tolerance temperature, ranging from 0-38 degrees, oxygen levels, as low as .2 mg/l, and salinity, up to 100ppt (Cudmore 2004). In addition to it wide range of tolerances it also has a diverse diet of plants, and when plants aren't available it has been known to eat fishes and invertebrates (Conover et al. 2007). These fish are also very long lived and large, living as long as 33 years, and can grow to be over 40kg (Cudmore 2004). This large size at adulthood means few if any predators in their introduced range. Finally their high fecundity plays a major factor on their ability to establish and spread. On average a grass carp can produce 500,000 in a year and up to 2,000,000 on higher end (Cudmore 2004). Due to where these eggs are released, in fast flowing rapid, they can be dispersed an astounding distance, up to 180km from spawning site (Cudmore 2004).

Potential Ecological and Economic Impacts

The grass carp's diet consists of approximately 95% plant material, this means that anywhere the grass carp invades there will be significant pressure on local aquatic macrophyte. If there is a sufficient amount of grass carp there is a chance of extirpation of the present plant species. Studies have shown that removal of marcophytes by grass carp can result in adverse effects on the ecosystem, such as loss of nursery habitat for fish and loss of a source of forage for birds such as ducks (Conover et al. 2007). It has also been documented that grass carp will consume the roots of bank plant when other food is not available, this in turn kills the plant and reduces the riparian cover and the bank stability (Conover et al. 2007). In addition to these effects, grass carp have been known to increase the turbidity and alkalinity of water through their feeding process (Cudmore 2004). Studies have also shown that areas where grass carp were present had increased levels of dissolved nutrients (Cudmore 2004). These large disturbances to and ecosystem could possible destabilize the system resulting in a nonfunctioning environment.

Management Strategies

The approach of grass carp management seems less focused on eradicating the already present populations of grass carp, and more focused on the prevention of the spread of grass carp. According to Standish et al (1987) there are four general approaches states use for grass carp management. 1. Some states allow all grass carp types into the state these are the states that already have established grass carp populations. 2. States that allow the use of only triploid grass carp these are the states that have the greatest need for aquatic plant control. 3. States that prohibit grass carp except for experimentation. And 4. States that prohibit grass carp all together. Currently the state of Washington falls under the second category (Conover et al. 2004). There is also a great emphasis on correct identification and differential on in coming triploid grass carp. Finally in the state of Washington there is a certification process that all triploid grass carp introduction must go through before being put into action. If grass carp populations ever became a problem introduction of triploids into fertile populations and use of grass carp reovirus may prove to be effective. For a more comprehensive management plan for all Asian carps see Conover et al. (2007).

Works Cited

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Wang, L., Su, J., Peng, L., Heng, J., & Chen, L. (October 01, 2011). Genomic structure of grass carp Mx2 and the association of its polymorphisms with susceptibility/resistance to grass carp reovirus. *Molecular Immunology, 49,* 359-366.

Washington (State). (1990). *Grass carp use in Washington*. Olympia, Wash.: Washington Dept. of Wildlife, Fisheries Management Division.

Other Key Sources Of Information

http://fl.biology.usgs.gov/Carp_ID/html/key_to_species.html (Identification Key)
http://www.usgs.gov/
http://www.seagrant.noaa.gov/

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Current Research

Currently a lot of attention is being paid, especially in china, to the emergence of grass carp reovirus. In china the grass carp aquaculture is a rather large industry since the Chinese consume grass carp and use them in religious ceremonies. Some grass carp facilities suffered up to 80% fry mortality due to the reovirus (Su et al. 2009). Currently many Chinese scientist are researching why some grass carp are resistant to the disease and why others aren't. Some have concluded that there is a genetic trait that predisposes some grass carp to be resistant to the reovirus (Wang et al. 2011). A more thorough coverage of the topic can be found in both Su et al. 2009 and Wang et al. 2011.