Pacific Northwest Aquatic Invasive Species Profile

Fathead Minnow (*Pimephales promelas)*

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Figure 1. Fathead minnow (Image source: Utah Division of Wildlife Resources (http://wildlife.utah.gov))

Diagnostic information

Taxonomy:

Order - Cypriniformes

Family - Cyprinidae

Genus - *Pimephales*

Species - *Pimephales promelas*

*Common names***:**

Fathead minnow, blackhead minnow, crappie minnow, rosy-red minnow (red color morph variant)

Identification Key

The fathead minnow, *Pimephales promelas*, first described in 1820 by Rafinesque is a short and stout member of minnow family cyprinidae (Vandermeer 1966). Adult *P. promelas* bodies are laterally compressed and range in size from 40 to 100mm with males growing larger than females (Scott and Crossman 1973, Becker 1983). Sexual dimorphism is evident with males showing several characters not seen on females such as dark banding, possessing a dorsal pad, and development of nuptial tubercles (Ankley and Villeneuve 2006). Females may exhibit a distended belly during breaking season with an ovipositor evident slightly prior to spawning. Normal coloration of adults is dark olive to brown above the lateral stripe with an area of white below through with a black peritoneum can often be observed. During the breeding season males exhibit a darker overall color with banding sometimes present, an absence of any lateral stripe and a darkening of the head coloration to black (Becker 1983). A golden red color morph is also found however it is more common within the aquarium hobby and is rarely observed in the wild.

P. promelas has been categorized into different subspecies in the past due to minor variations in a number of morphological characters. The most notable of these was a difference in how complete the lateral line appeared and resulted in northern, southern, and eastern subspecies. Due to the nature of the variations and the high level of variability, it is accepted today that *P. promelas* is no longer broken into subspecies. A general description of the overall characters found on *P. promelas* fits most individuals closely enough for identification purposes. Since the morphological differences such as the angle of the mouth, predorsal length, or diameter of the eye have only an intermediate regional trend they can still be used to determine origin population without interfering with a correct species determination (Vandermeer 1966).

In general, the mouth of *P. promelas* is relatively small and located in a terminal position on the head. Being cyprinids they possess pharyngeal teeth which have elongate cutting surfaces, are slender and arranged in a 0-4-4-0 formula

(Stauffer et al. 1995). *P. promelas* have short, rounded snouts which do not overhang the mouth and small eyes. This combined with a flattened dorsal and pre-dorsal region of head is thought to have led to the common name of fathead minnow. The dorsal fin origin of *P. promelas* is located directly above or a bit ahead of the pelvic fin origin. There are eight rays located on both the pelvic and the dorsal fin, with the first ray being significantly shorter on the dorsal. The anal fin is comprised of 7 rays and the pectoral fin rays vary between 14 and16. The lateral line is comprised of 41 to 54 scales while being short and incomplete (Becker 1983, Nelson and Paetz 1992, Stauffer et al. 1995).

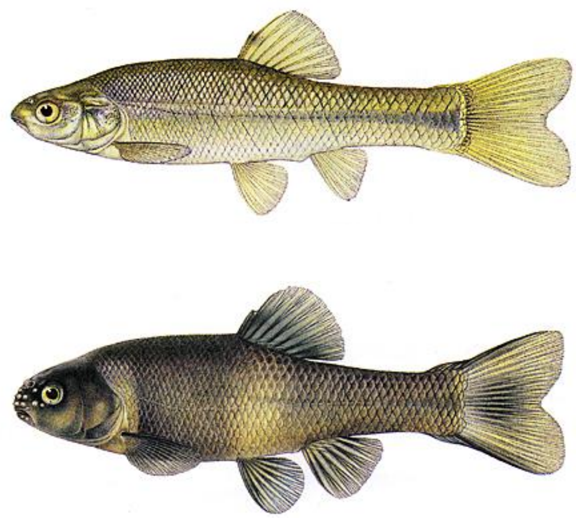

Figure 2. Fathead minnow: Female above and Male below. Illustrations by Joseph Tomelleri (Image source: University of Florida Aquatic Pathobiology Laboratory (http://aquaticpath.epi.ufl.edu/fhm))

Life-history and Basic Ecology

Life Cycle:

The life span of *P. promelas* is relatively short with a maximum age of around 5 found for adults in extremely stable populations with a maximum age of around two and a half being more commonly observed (Danylchuk and Tonn 2006). Newly hatched fry grow rapidly and if food stocks are plentiful can reach maturity the same year (Becker 1983). This occurrence is rare as it depends on temperatures being optimal combined with a number of other factors being favorable and the average individual will not mature until the second summer after hatching. This delay in might also be in part due to decreased growth during winter months however it should be noted that the younger fish in a population grow at a faster rate compared to older more mature fish which can lead to early spawning events once conditions reach the correct levels (Markus 1934). Males tend to grow at a faster rate and to a greater size than females of the same generation with both maturing within 4-5 months in ideal conditions (Becker 1983, Ankley and Villeneuve 2006).

Feeding Habits:

P. promelas is an omnivore which consumes a wide range foods including both plants and animals within whatever ecosystem it is found. Being an opportunistic feeder allows for continued growth throughout multiple seasons without being heavy dependent on another species population levels. Common prey items include insects, fish eggs and larvae, zooplankton, various crustaceans, algae, and detritus (Scott and Crossman 1973, Held and Peterka 1974, Abrahams 1996). It has been observed that in some locations the prey preference of *P. promelas* varies from month to month and can be tied to the ecology of the location changing (Becker 1983). The larger and more mature an individual is, the larger the diet varies. In some cases this is due to competition among conspecifics or native species and sometimes it is influenced by the overall abundance of prey choices (Held and Peterka 1974, Abrahams 1996, Seegert et al. 2014). There are also cases where competition exists between fatheads and young waterfowl species in the same area (Duffy 1998).

Reproductive Strategies:

The reproduction of *P. promelas* is well studied as it is an important bait fish in many parts of the US as well as providing an ideal model for toxicology research (Markus 1934, Ankley and Villeneuve 2006). The breeding season is thought to be dependent on both temperature and the photoperiod however more support for a minimum change to the photoperiod is needed to begin the spawning process has been gathered (Becker 1983). After starting the breeding process temperature appears to be more important as the hatch and survival rates are tied closely to optimal temperatures being reached (Markus 1934, Becker 1983, Stauffer et al. 1995).

About a month before spawning the males begin to develop secondary sexual characteristics such as tubercles on the head, development of a spongy dorsal pad and a dynamic color shift to a darker overall shade with more pronounced banding and the visual lateral line disappearing (Markus 1934). This coincides with females becoming distended with eggs as the spawning period of early May though mid-August approaches (Flicking 1969, Becker 1983, Divino and Tonn 2007). Spawning substrate preferences vary depending on location however eggs are preferentially laid on the underside of a hard surface such as a stone, log, or in artificial settings a hard tile (Becker 1983). Males clear the surface of any algae or debris using a combination of the developed tubercles and dorsal pad prior to the female laying eggs (McMillan and Smith 1974, Smith and Murphy 1974). The dorsal pad in particular may be crucial to this cleaning procedure as it may aid egg attachment and survival or act as a chemical maker to guide the female (Becker 1983).

During preparation of the nesting site and continuing after its completion, the male actively defends it against all intrusion aside from certain gravid females (Becker 1983). Once a nest has been established, the male courts females in various fashions ranging from simply allowing a female into the vicinity to actively seeing out and leading a chosen female to the location (Becker

1983). The eggs laid are buoyant and adhesive so that they stick to each other and the cleared location. One female can lay 80 to 370 eggs at a time and because multiple females can spawn multiple times per season at intervals of 3 to 4 days between spawning event and the number of eggs within a single nest has been found to reach as high as 12,000 (Markus 1934, Watanabe et al. 2007). It has also been found that females preferentially spawn in nests which already contain eggs (Stauffer et al. 1995).

Once eggs are present within the nesting site the male continues to protect the area and guard the eggs from potential predators. On top of egg predators such as crayfish or other small bodied fishes there are threats from conspecifics as well (Kusch and Chivers 2004, Rehage et al. 2005, Martinovic-Weigelt et al. 2012). Cannibalism by both female and other male fatheads is likewise a threat, so much so that males will defend the nest even against females that may be trying to spawn in the nest (Divino and Tonn 2008). Large predator fish in the local area can have hugely detrimental effects on the ability of males to protect the eggs as the males are less aggressively positioned and if driven away from the nest, they take longer to return (Jones and Paszkowski 1997, Kusch and Chivers 2004). Aside from guarding the nesting site, males act as curators for the eggs. By agitating the water surrounding the nest sediment is prevented from accumulating and by directly picking out and removing eggs which have turned white or developed a fungus on them the males protect the healthy eggs until they can hatch (Becker 1983).

Eggs hatch 5 to 7 days after being laid in water that is 25°C and the newly emerged fry are between 4.75 and 5.2mm in length (Markus 1934). Young fathead fry grow rapidly and remain in close proximity to the nest until the yolk-sac has been completely absorbed (Markus 1934). Growth after the yolk-sac is gone depends greatly on the abundance of suitable food nearby. Higher concentrations of zooplankton or smaller algal food sources in combination with warmer temperatures can facilitate rapid growth which results in fish maturing and spawning the same season they are hatched (Becker 1983). Because fatheads can undergo such rapid development their ability to recover from disturbances where already established can be high. This also acts to increase the ability of fatheads to move into an area and rapidly develop a sizeable population within a relatively short time span (Becker 1983).

Environmental Optima and Tolerances:

P. promelas prefer slow moving water with fine substrate and numerous hard objects or vegetation to hide within as they are not the strongest of swimmers however no preference is found for either clear nor turbid waters (Becker 1983, Stauffer et al. 1995, Ward et al. 2003). Fatheads have the ability to survive a wide range of water conditions which can lead to them infiltrating small water bodies where other small fish would parish (Scott and Crossman 1973).

The upper temperature tolerance of *P. promelas* is 33°C (91.5°F) while the lower is 2°C (35.6°F) with a preferred temperature of 22.6°C (72.7°F) found (Becker 1983, Danylchuk and Tonn 2006). This wide range of temperatures along with the lack of need for specific water quality parameters allows fatheads to move into many different types of habitats and establish where other species have failed (Becker 1983, Marchetti et al. 2004, Danylchuk and Tonn 2006). In northern states where winter hypoxia becomes an issue, fathead minnows have proven to be very successful at establishing or re-establishing populations when there is an absence of larger piscivores (Jones and Paszkowski 1997, Danylchuk and Tonn 2006).

Biotic associations:

Within both the native and the extended range in which *P. promelas* has established there is often close association with various other small-bodied fishes (Scott and Crossman 1973, Becker 1983, Zimmer et al. 2002). Some of the inter species interactions are beneficial while others can be extremely detrimental to one or both species. Many of the negative interactions occur when direct completion for resources or predation occurs between fatheads and other native species (Markle and Dunsmoor 2007, Pearson and Goater 2009). In areas where they are not native, fatheads can become abundant leading to detrimental effects on in species that require hosts for some part of their life cycle (Johnson et al. 2012). In some localized instances, predators can have an impact on smaller minnows while larger more mature individuals are not affected (Mirza and Chivers 2003).

P. promelas is also host to a wide range of parasites and may have high infestation rates even when other closely associated fish species have low rates of infection (Scott and Crossman 1973). There have been observed instances where fathead minnow larvae become infested with a parasite shortly after hatching. In one specific case a microsporidian, Glugea pimephale, was found on 2-3 week post hatch fish and the infected individuals exhibited impaired swimming ability compared to non-infected fish (Forest et al. 2009). Because *P. promelas* have the ability to spread out to areas in which they are not native, the risk of carrying a potentially new parasite with them is present.

Distribution

P. promelas has a native range that is widely distributed throughout North America from Northern Mexico into Canada (Scott and Crossman 1973, Becker 1983, Nelson and Paetz 1992). They are most abundantly found throughout the Mississippi watershed and great lakes region (Stauffer et al. 1995). The presumed geographic range extends east to the Appalachians and west into parts of Montana to the north and small portions of Arizona in the south (Vandermeer 1966). The wide dispersal pattern of fathead minnows is in part due to the ability to survive and reproduce in many different water parameters across different regions (Scott and Crossman 1973). This widespread dispersal also led to several sub spices being recognized throughout history based on characters that seemed to differentiate between Northern, Southern, and Eastern populations (Vandermeer 1966).

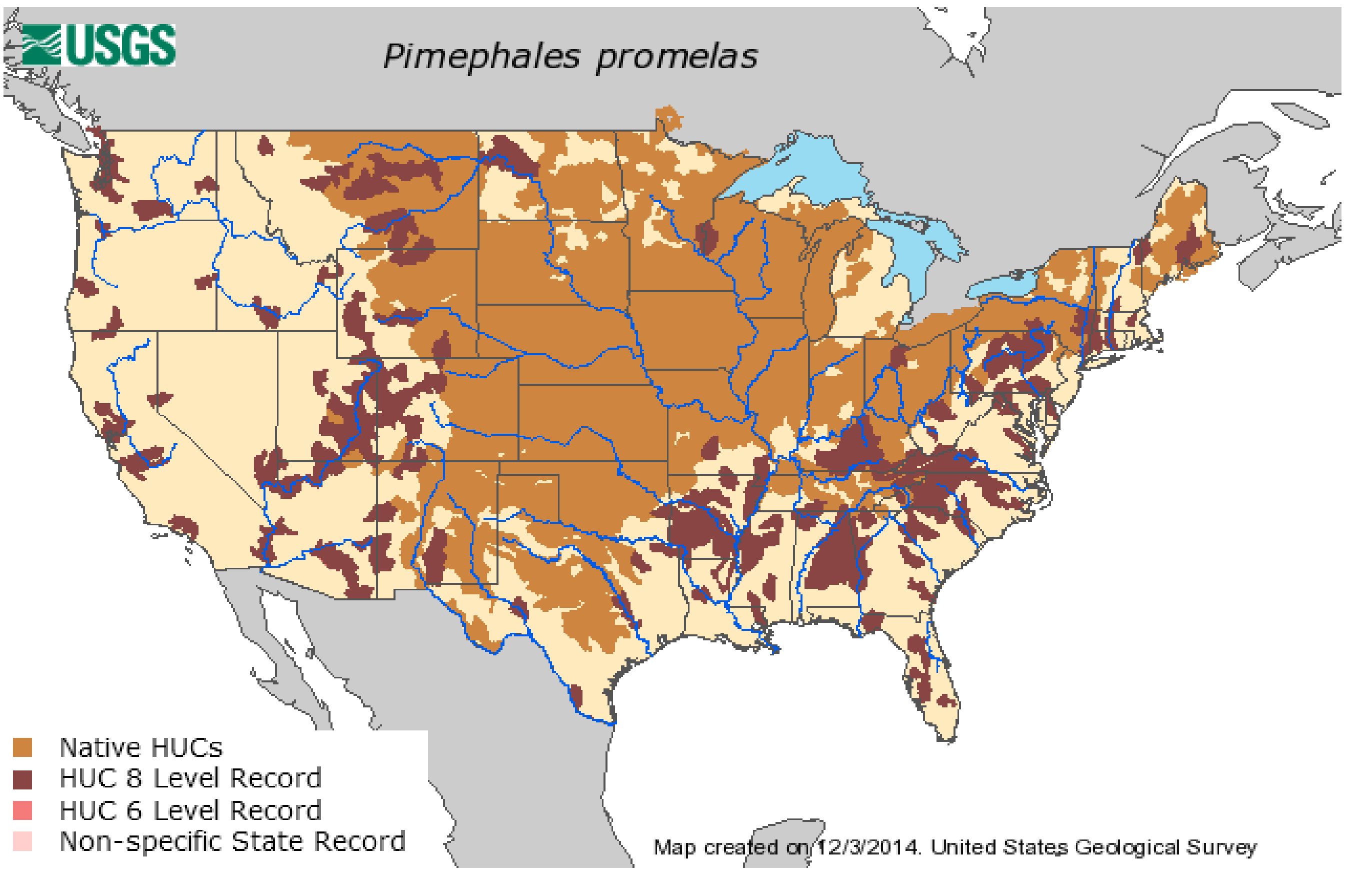

Figure 3. Map showing native range of fathead minnows within the United States (Native HUCs) along with other established locations (Image source: U.S. Geological Survey (http://www.usgs.gov))

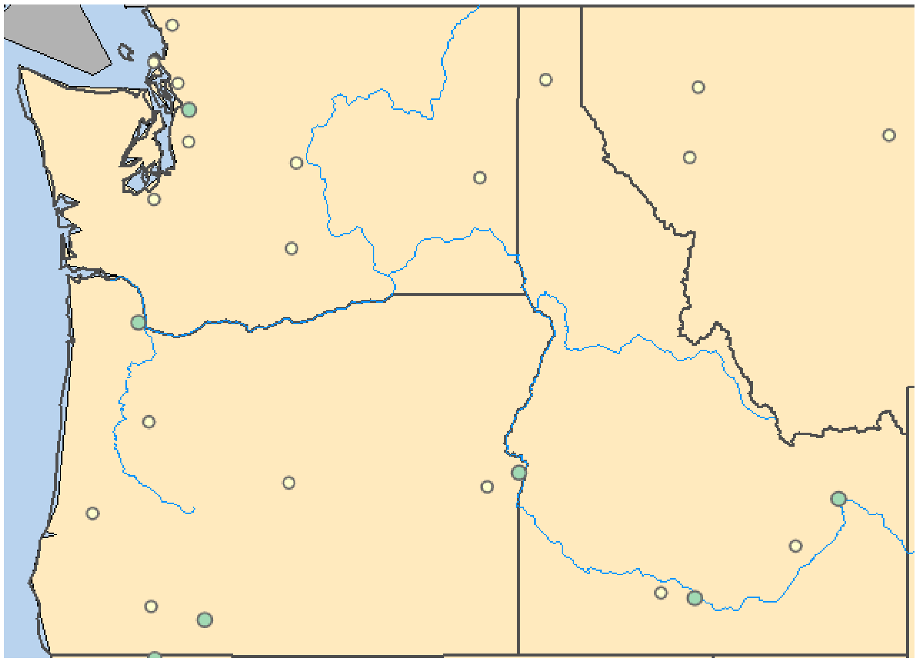

Figure 4. Map of all reported fathead minnow locations within the Northwest region of the US. Note that reports vary from 1 (yellow points) to a range of 2-5 (larger blue-green points) however no implication of abundance is made. (Image source: U.S. Geological Survey (http://www.usgs.gov))

History of Invasiveness

Invasion Process

Throughout the United States fathead minnows have been widely introduced through both intentional and unintentional release events since their discovery (Schade and Bonar 2005, Ankley and Villeneuve 2006). Widely used as a bait or forage fish in much of their native range, fathead minnows have been cultivated throughout time. Currently *P. promelas* is an important species within the realm of toxicology research (Aldea and Allen-Gil 2005, Ankley and Villeneuve 2006). Because of its hardy nature, there is also demand for fathead minnows in bioassay uses across the US as it can be a good indicator of current ecological conditions (Simon and Markle 1997). Fathead minnows have been cultivated for both laboratory use and for sale within the aquarium hobby (Clemment and Stone 2004, Gordon et al. 2014). The increased demand for fathead minnows outside of their native range has led to many of the introduction events that have occurred and creates increased risk of future introductions.

Within the Pacific Northwest fathead minnows were introduced for both bait and forage fish in some areas while promoted as an ideal bioassay subject in others (Simon and Markle 1997). Available data show that the first established populations specifically within the state of Washington occurred in the early 1990’s (Wydoski and Whitney 2003). These early releases were for forage and populations have subsequently become established in several lakes and rivers since (Wydoski and Whitney 2003). Due to the temperature tolerances being within that of Washington states waters and preference of fathead minnows to establish within slow moving streams there is a high likelihood that more introductions have occurred since 2003.

Potential Impacts:

According to the latest IUCN, *P. promelas* populations are stable throughout all established ranges and they are classified as a species of least concern (NatureServe 2013). This determination was based on the large range in which they can be found, large overall population size and lack of major threats on a range-wide scale (NatureServe 2013). Although the overall consensus seems to be that there is no broad threat from continued outward establishment, some research has been done to determine whether or not fathead minnows have a detrimental effect on a more localized scale. The majority of these studies have focused on interspecific completion between *P. promelas* and the already established native species.

P. promelas are relatively small bodied fish and thus tend to consume a large variety of small insect or zooplankton species (Scott and Crossman 1973, Held and Peterka 1974, Abrahams 1996). When introduced to a new environment this varied diet can put them in direct competition with native species due to similar life cycle needs or biological similarities and in some cases this competition can exist between fathead minnows and other taxa such as waterfowl (Duffy 1998, Ward et al. 2003). Forced interactions between species can have the side effect of increasing diet diversity within fish populations and on occasion this has been shown to increase growth rates or morphological variations for one or both species involved (Abrahams 1996). The complex nature of interactions between many different species makes it hard to say for certain that fathead minnows cause negative reactions in native species populations however at least on a localized level there are detrimental effects found once *P. promelas* becomes established (Zimmer et al. 2002, Markle and Dunsmoor 2007, Pearson and Goater 2009).

Native species can also have impacts on populations of fathead minnows which limit the rate or range of establishment. Because the creation and defense of a nesting site is critically important to the spawning cycle of fathead minnows, minor disturbances in nesting behaviors can led to major morphological or behavioral shifts (Divino and Tonn 2008). An example where this occurs is when fatheads are located in the same area as larger piscivores such as pike. One study showed that when large predators are present, even if direct predation does not reduce population numbers, the nest guarding behavior exhibited by males is altered (Jones and Paszkowski 1997). An example of morphological changes in hatchlings comes from a study where it was shown that moderate crayfish predation was positively correlated with smaller sizes and length of developmental period in subsequent hatchings (Kusch and Chivers 2004).

Control Methods

P. promelas are widely introduced into areas outside of their native range by governmental agencies seeking to increase bait or forage fish levels (Brown 1971, Becker 1983, Wydoski and Whitney 2003). The literature on eradication methods or studies detailing removal strategies is understandable small given the overall outlook by many that fatheads pose relatively little risk of harming areas into which they are placed. A large portion of the scientific information available about them deals with how they are used in toxicology studies or as measurements of ecosystem recovery after a disturbance (Ankley and Villeneuve 2006, Beatty et al. 2009). Since *P. promelas* is listed as a species of least concern by IUCN there is little incentive for large scale studies to be done on potential impacts or current impacts of large numbers being released into non-native areas (NatureServe 2013).

The one way in which possible control methods are being researched is due to spill over from research on other cyprinids or invasive fish species. It has been widely recognized that that non-native species moving into a new area present a risk to natives (Schade and Bonar 2005). Recent research into eradication methods such as the use of electric currents to kill off early life stages focused on cyprinids in particular shows how hard it might be to target species at that base level (Nutile et al. 2012). Often times the research shows that it can be extremely hard to eliminate non-natives once they enter the system and an ecosystem wide recovery plan might be a better choice than species targeted management (Tyus and Saunders 2000).

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