National Management and Control Plan for New Zealand Mudsnail

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Prepared for the Aquatic Nuisance Species Task Force

by the

New Zealand Mudsnail Working Group

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Executive Summary

It is the policy of the United States (U.S.) to prevent the introduction, establishment, and spread of invasive species and to eradicate and control established populations (Executive Order No.13751, 2016). Preventing the introduction, establishment, and spread of invasive species is the most cost-effective approach to protecting the ecological integrity and function of natural environments and to minimizing impacts to human health and safety, cultural resources, infrastructure, and the economy. The Aquatic Nuisance Species Task Force (ANSTF) leads development of management plans to respond to invasive species threats. In 2007, ANSTF published the first National Management and Control Plan for New Zealand Mudsnail, and this is an update of the plan.

New Zealand mudsnails (*Potamopyrgus antipodarum;* abbreviated NZMS throughout), small freshwater snails first discovered in the U.S. in 1987, remain a threat to freshwater environments of the U.S. This species is well adapted to invade; its small size, ability to withstand desiccation, asexual reproduction, and tolerance for variable conditions enable it to be carried overland and establish. In conducive environments, NZMS form dense colonies that can alter habitat and water quality, resulting in direct and indirect effects to other species and adjacent habitats. In addition, the presence of NZMS has altered management of waters for beneficial uses, including recreation restrictions, fish stocking, and mandatory decontamination of materials and equipment leaving infested waters.

Since NZMS were detected in the U.S., efforts have been taken by all levels of government and by non-governmental organizations to curtail the spread, preventing impacts to diverse environments, sensitive species, and waters for beneficial uses. Action has also been taken to refine tools and approaches to address pathways by which NZMS are spread, to investigate NZMS impacts on the ecology of invaded systems, and to explore potential tools to control and eradicate NZMS in the environment and in facilities. The greatest strides have been made in slowing the spread of NZMS, both in methodologies and management of the pathways, supported by regulatory authority and awareness and action by those working and recreating in aquatic environments.

Despite our collective efforts, NZMS have spread within the U.S. While complete containment has not been achieved, many U.S. waters remain uninvaded and are still vulnerable to the introduction and establishment of NZMS. For the protection of these waters, it is critical to continue prevention, containment, and control efforts. This plan reviews efforts to date, achievements, needs that remain unmet, and new needs. This national plan serves as a foundation for the development, implementation, and review of management plans developed at a range of geographic scopes and authorities ranging from multi-states down to local watersheds. Additionally, it identifies future actions that are needed given our progress thus far, encourages collaborations and incorporation of climate projections into future efforts, and reflects the practical constraints under which we work to conserve our natural systems.

This updated plan emphasizes the importance of preparation and investing in the development of effective interdisciplinary collaborations that leverage information, funding, and effort. Efforts led by agencies are optimized when conducted in partnership with tribes, local agencies, non-governmental organizations, and the public. This plan was developed to guide national efforts and support development and implementation of regional management plans. The overarching goals of this plan are to:

A. Protect native species, their habitats, environmental quality, and the economy from negative impacts resulting from NZMS.
B. Equip and mobilize all entities that have relevant authorities, responsibilities, and/or interests in avoiding and mitigating the spread and impacts of NZMS.
C. Establish a framework for the ANSTF to lead efforts and collaborate with States/Tribes/local agencies to respond to and minimize the impacts of NZMS.

Our collective future efforts will continue to prevent the spread of NZMS while we simultaneously work to develop and improve the tools and information necessary to respond to, contain, and manage infestations, thereby protecting aquatic environments across the U.S.

Introduction

New Zealand mudsnails (*Potamopyrgus antipodarum*; NZMS) are not native to the U.S. and cause economic and environmental harm; thus, they are considered an invasive species (Executive Order No.13751, 2016). This species was first detected in North America in the Snake River Basin (Idaho) in 1987 (Bowler 1991). A second, genetically distinct population was identified in Lake Ontario (New York) in 1991 (Zaranko et al. 1997). By 2007, NZMS were established in all the western states except New Mexico, Alaska, and Hawaii, and in Lake Ontario, Lake Superior, and Lake Erie in the Great Lakes region. Since ANSTF published the National Management and Control Plan for the New Zealand Mudsnail in 2007, the spread of NZMS has continued to be documented in the West. While the extent of spread in the Eastern U.S. appears to be less than that in the West, or less documented and reported, NZMS remain largely unreported in the Plains, Gulf, and South Atlantic states, and Alaska and Hawaii.

Justification

This revised plan is necessary to guide protection of the remaining uninfested waters of the West, Midwest, Alaska, Hawaii, and Northeastern U.S. with continued prevention efforts, containment of NZMS in infested waters and facilities, and where feasible, population suppression and eradication. While the geographic scope of the plan is focused on the continental United States and Hawaii, the objectives and actions identified herein may be applicable to the unincorporated territories and outlying islands of the U.S.

NZMS can tolerate a wide range of environmental conditions and produce many offspring, resulting in extremely dense populations when favorable conditions are present. Dense colonies of NZMS outcompete other aquatic organisms for forage and space and alter the biotic and abiotic elements of an ecosystem. Directly impacted organisms include native mollusks (snails, mussels, and clams), as well as macroinvertebrates and periphyton that support higher tropic level consumers including fish and amphibians, as well as water quality. The U.S. Fish and Wildlife Service (USFWS) 2015 New Zealand Mudsnail (*Potamopyrgus antipodarum*) Ecological Risk Screening Summary predicts that West, Midwest, and Northeast regions of the contiguous U.S. are suitable for NZMS based only on the known infested range and climate matching analysis. An updated risk assessment based on suitable water chemistry and other habitat data is needed to more accurately represent the potential range of NZMS across the U.S.

This revision reassesses, identifies, and prioritizes NZMS management actions for 2024 and beyond based on the collective knowledge and experience gained over the past 17 years. In addition, it provides the current known distribution of NZMS in the U.S. and the containment efforts that have been and continue to be taken. This plan serves as a resource for information on prevention, containment, and control for those developing prevention programs, proactively planning, or compelled to action in response to a NZMS detection. In all circumstances, responses to NZMS are optimized when tailored to the unique environmental setting and efforts are collaborative and coordinated relative to the diverse interests and authorities underlying the management of aquatic invasive species (AIS).

Summary of the Plan Goals

While important information gaps remain, our collective experience enables us to revisit and refine the 2007 plan's goals and actions to prevent the further spread of NZMS. The theme of the 2007 plan's actions were focused on identification and development of actions; this revision emphasizes the continued implementation of actions in regions where NZMS are known to be present and engagement and action in regions where NZMS have limited, or unknown, distributions. Specifically, the goals of this plan are as follows:

A. Protect native species, their habitats, environmental quality, and the economy from negative impacts resulting from NZMS.
B. Equip and mobilize all entities that have relevant authorities, responsibilities, and/or interests in avoiding and mitigating the spread and impacts of NZMS.

C. Establish a framework for the ANSTF to lead efforts and collaborate with States/Tribes/local agencies to respond to and minimize the impacts of NZMS.

Background

Biology/Natural History

Figure 1. Ventral view of a typical New Zealand mudsnail. D. Gustafson, Montana State University

NZMS (Figure 1) are gastropods (subclass Caenogastropoda) that are native to streams and lakes of New Zealand. Adult NZMS have shell lengths of 4-7 mm in invaded ranges and up to 12 millimeters in their native territory (Winterbourn 1970a). Their shells appear amber to dark brown, have three to eight whorls, and are conical and narrow in shape. In New Zealand, the species is dioecious (separate male and female sexes) and bears live young (Winterbourn 1970a, 1970b; Wallace 1978). Ova develop within the female's brood pouch and emerge into the environment as fully developed snails. Female NZMS in New Zealand may be either sexual or asexual. Asexual females develop eggs that can grow without fertilization and produce genetically identical offspring. Therefore, one female is sufficient to initiate a new clonal population. Although NZMS reproduce both sexually and asexually in New Zealand, introduced populations elsewhere thus far have been entirely clonal (Zaranko et al 1997; Dybdahl and Kane 2005).

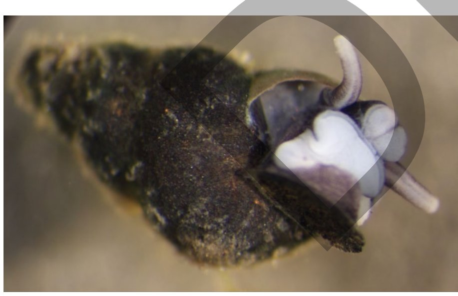

Figure 2. Juvenile female New Zealand mudsnail preserved with body and operculum relaxed. T. Jensen, California Department of Fish and Wildlife

In New Zealand, NZMS populations stem from both sexually and asexually reproducing individuals, resulting in high genetic diversity (Winterbourn 1970a). Invasive populations, however, are comprised of solely asexual clonal females (Figure 2) (Dybdahl and Lively 1995; Zaranko et al. 1997; Hershler et al. 2010). As a result, a relatively small number of clone genotypes persist in their invaded range (see Geist et al. 2022). In the U.S., there are two dominant clones, US1 and US2, and an additional seven clones have been identified (EU15, Z, AUS2, EU14, T, US1A, and US3; Donne et al. 2020; Dusting 2016; Dybdahl and Drown 2011). The US1 clone is the most widespread across the Western U.S., with clones US1A and US3 currently limited to areas of the Middle Snake River (Dybdahl and Drown 2011). US2 is prevalent throughout the Great Lakes region (Zaranko et al. 1997; Grigorovich et al. 2003; Levri et al. 2007) and was first discovered in Lake Ontario in the

1990s. The U.S. clones can be traced back to two European lineages of NZMS, with EU14 responsible for the invasion in the Great Lakes region and EU15 for the invasion in the Western U.S. (Donne et al. 2020).

Introductions of NZMS have potential for widespread colonization due to their broad environmental tolerance and opportunistic traits. NZMS occupy a broad range of habitats, including freshwater streams, lakes, springs, drainage ditches, reservoirs, estuaries, and coastal waterways. However, habitat characteristics can influence aspects of successful invasion (i.e., survival, growth rates, abundance, and distribution) (Geist et al. 2022). Additionally, clonal lineages may have either narrow or broad ecological tolerances. In New Zealand, narrow preferences often result in distinctive habitat utilization among clones (Dybdahl and Lively 1995; Fox et al. 1996; Jokela et al. 1999; Jokela et al. 2003), while one of the clones that is widely spread in Europe is broadly tolerant (Jacobsen and Forbes 1997). Thus, the invasiveness and success of this species is likely to be a function of the clone lineage present and local environmental conditions.

NZMS are tolerant of a broad range of environmental and habitat conditions. They occupy a variety of substratum types including fine sediments, large cobble, wood, vegetative mats, organic materials, and artificial substrates (Richards et al. 2001; Hall et al. 2006; Davidson et al. 2008). This species can tolerate a wide range of temperature and flow regimes, though optimal conditions for their survival and growth are apparent. For example, temperatures above and below 18° Celsius (64.4° Fahrenheit) have adverse effects on NZMS fitness (Dybdahl and Kane 2005), and flow velocities greater than 0.15 meters per second are shown to be negatively associated with NZMS population densities (Holomuzki and Biggs 2007). NZMS can persist in varying levels of salinity (LeClair and Cheng 2011) and specific conductivity; however, mid-levels of salinity and moderate-to-high levels of water hardness appear to be optimal for individual survival and growth, thus population growth (see Geist et al. 2022). NZMS population densities vary widely and are dynamic. Throughout their invaded range, reported densities have reached as high as 800,000 individuals per square meter (Dorgelo 1987; Thomsen et al. 2009). Furthermore, NZMS populations can fluctuate seasonally, with peak densities often occurring during the summer and sharp declines seen through the winter (Schreiber et al. 1998; Vinson 2004; Hall et al. 2006; Bennett et al. 2015). NZMS population fluctuations have also been documented over the long-term, at time scales of years to decades (Moore et al. 2012; Greenwood et al. 2020). The mechanisms that influence invasive NZMS populations and dynamics are likely a combination of environmental factors, clonal lineage, and other factors such as time since introduction.

Considered detritivore-herbivores, NZMS have flexible feeding strategies, utilizing algae, periphyton, leaf-litter, and other organic materials as food. As such, they can alter primary producer assemblages by reducing algal standing stock and periphyton biomass (Riley et al. 2008; Krist and Charles 2012) and altering diatom assemblages (Krist and Charles 2012). Consequently, NZMS can alter fundamental ecosystem functioning such as nitrogen cycling (Arango et al. 2009) and leaf-litter decomposition (Bovee and Tiegs 2023). NZMS affect native macroinvertebrates, particularly native gastropods, through resource competition. Negative effects on native gastropod growth rates (Riley et al. 2008) and altered foraging behavior and distribution of native macroinvertebrates have been documented (e.g., Hansen et al. 2016). Additionally, as NZMS outcompete native macroinvertebrates, the snails become dominant, leading to altered community structure and function.

Predation on NZMS by higher consumers such as aquatic invertebrates (Bennett et al. 2015) and various fish species (e.g., Vinson and Baker 2008; Bersine et al. 2008; Hellmair et al. 2011; Rakauskas et al. 2016) has been documented in multiple systems throughout their invaded range. However, the degree of NZMS consumption by higher consumers varies widely. The number of consumed NZMS found in the gut contents of fish ranges from nominal to relatively high (e.g., Hellmair et al. 2011). Thus, deliberate predation of NZMS by native consumers is unclear. Nonetheless, studies have shown that fish derive little or no energy value from eating NZMS because the snails can pass through the fish's digestive system alive and intact (Haynes et al. 1985; Bruce 2006; Vinson and Baker 2008; Rakauskas et al. 2016). In addition, the energy content of NZMS was determined to be extremely low and variable by season (Ryan 1982).

Detailed information on the biology and ecology of NZMS can be found in Appendix A of the ANSTF 2007 National Management and Control Plan for the New Zealand Mudsnail *(Potamopyrgus antipodarum)*.

Global Range

Native Range

NZMS are indigenous to New Zealand and its adjacent islands (Stewart and Chatham Islands, Winterbourn 1970b; Ponder 1988). In New Zealand, the snails have been found in nearly every aquatic habitat including large rivers, forested tributary streams, thermal springs, ponds, glacial lakes, and estuaries (Winterbourn 1970b, 1978; Towns 1979, Towns 1981; Rounick and Winterbourn 1982; Talbot and Ward 1987; Winterbourn and Ryan 1994; Scott et al. 1994). Two other species of *Potamopyrgus* (*P. estuarinus and P. pupoides*) are also present in New Zealand; however, these species are confined to brackish waters (Winterbourn 1970b).

Introduced Range

Over the past 150 years, NZMS have spread to every continent except Antarctica (Geist et al. 2022; Taybi et al. 2021). Populations originated from either the North Island of New Zealand

(Stadler et al. 2005) or Australia. During the nineteenth century, NZMS were introduced to Europe, Tasmania, and new areas of Australia (Ponder 1988). The first recorded occurrence in Europe dates to 1859 in Great Britain (Bondesen and Kaiser 1949; Ponder 1988). Ponder speculates that they may have been transported to Europe in fresh drinking water carried by ships. Bondesen and Kaiser (1949) provide a detailed account of the species' discovery in Great Britain and Western Europe.

In the twentieth century, NZMS spread to North America (Bowler 1991). Detailed biogeographical origins of early global introductions were tracked with genetics and are detailed in the 2007 New Zealand Mudsnail Management and Control Plan (ANSTF 2007). In the early twenty-first century, the species was introduced to South America but was misidentified until 2014 (Collado 2014); this decade also saw the discovery of the species in Asia (Shimada and Urabe 2003). More recently, in the last decade, the species has been found in Africa in the country of Morocco (Taybi et al. 2021), thereby occupying every habitable continent in the world (Figure 3).

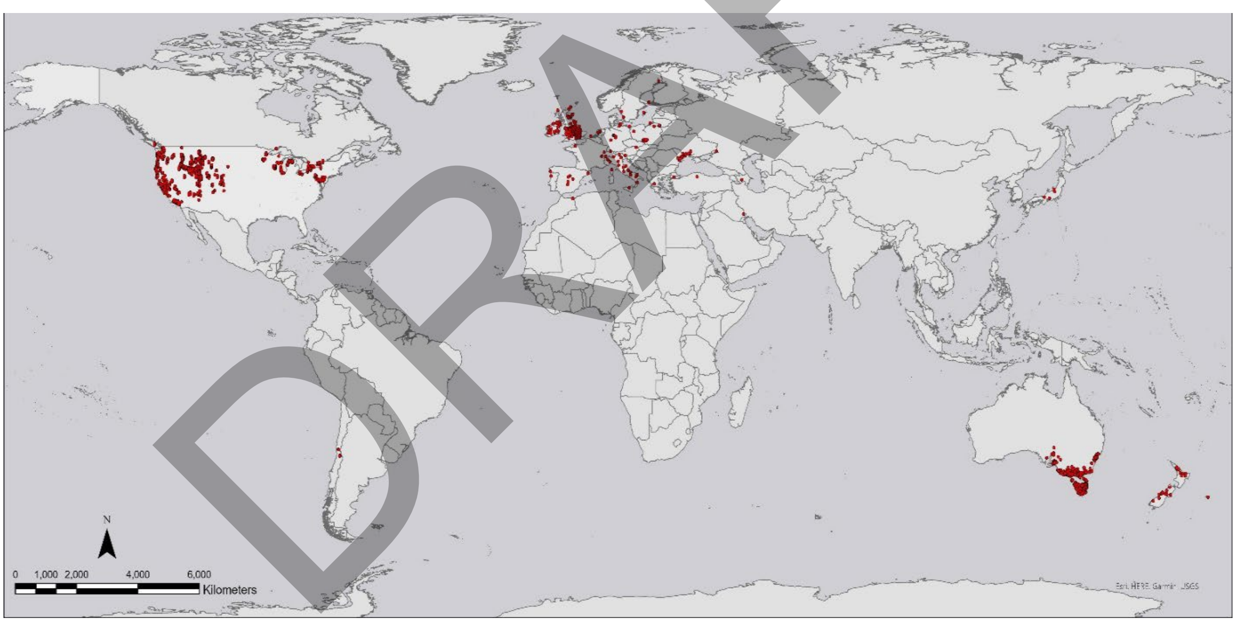

Figure 3. The approximate global distribution of New Zealand mudsnail in 2022. Data compiled from Geist et al. (2022), Taybi et al. (2021), and U.S. Geological Survey Nonindigenous Aquatic Species (2023).

U.S. Introduction and Spread

NZMS were first documented in Western North America in 1987 from the Middle Snake River in Idaho (Bowler 1991), where the species subsequently spread up- and downstream. The exact time of arrival and source of the snails are unknown, but it has been speculated that they arrived from the commercial movement of aquaculture products such as trout eggs or live fish

(Bowler 1991; Bowler and Frest 1992). This theory is further strengthened by genetic analysis that traced the two distinct U.S. clones back to two European lineages of invasive NZMS (Donne et al. 2020).

In 1991, a population of NZMS was discovered in Lake Ontario (New York state; Zaranko et al. 1997), and multiple populations were discovered in 1995 in Arizona (Cross et al. 2010), Montana (Acy 2015), and Wyoming (Gangloff 1998). NZMS are now known to be established in 22 U.S. states, with no evidence of the presence of the species in the middle of the U.S. between the western and eastern populations, Alaska, or Hawaii (Table 1; Figure 4). There are thought to be two potential introduction sources in the West, and the early introduction to the Great Lakes is thought to be a third, independent introduction (ANSTF 2007).

Table 1. Earliest observation of New Zealand mudsnail in each of the 22 states in which they are known to occur.

State	First observed	Waterbody	Information Source
Idaho	1987	Snake River	Bowler 1991
New York	1991	Lake Ontario	Zaranko et al. 1997
Arizona	1995	Colorado River	Cross et al. 2010
Montana	1995	Madison River	Acy 2015
Wyoming	1995	Madison River, YNP	Gangloff 1998
Oregon	1997	Columbia River	Gangloff 1988
California	1999	Owens River	Hosea and Finlayson 2005
Nevada	2001	Salmon Falls Creek	USGS NAS 2024
Utah	2001	Green River	Vinson 2004
Washington	2002	Snake River	Washington Fish & Wildlife 2024
Colorado	2004	Boulder Creek	ANSTF 2007
Pennsylvania	2005	Lake Erie	Levri et al. 2007
Wisconsin	2005	St. Louis River	Wisconsin Dept of Nat Res 2024
Illinois	2006	Lake Michigan	Tiemann et al. 2022
Ohio	2006	Lake Erie	Levri et al. 2007
Minnesota	2007	Lake Superior	Minnesota Dept of Nat Res 2024
Michigan	2012	Lake Michigan	McElrath 2023
Maryland	2017	Gunpowder Falls	Maryland Dept of Nat Res 2024
New Jersey	2018	Musconetcong River	New Jersey AIS Working Grp 2024
New Mexico	2019	San Juan River	USGS NAS 2024
So. Dakota	2019	Beaver Creek	So. Dakota Game, Fish, & Parks 2020
Delaware	2021	Brandywine Creek	Delaware Invasive Species Council 2022

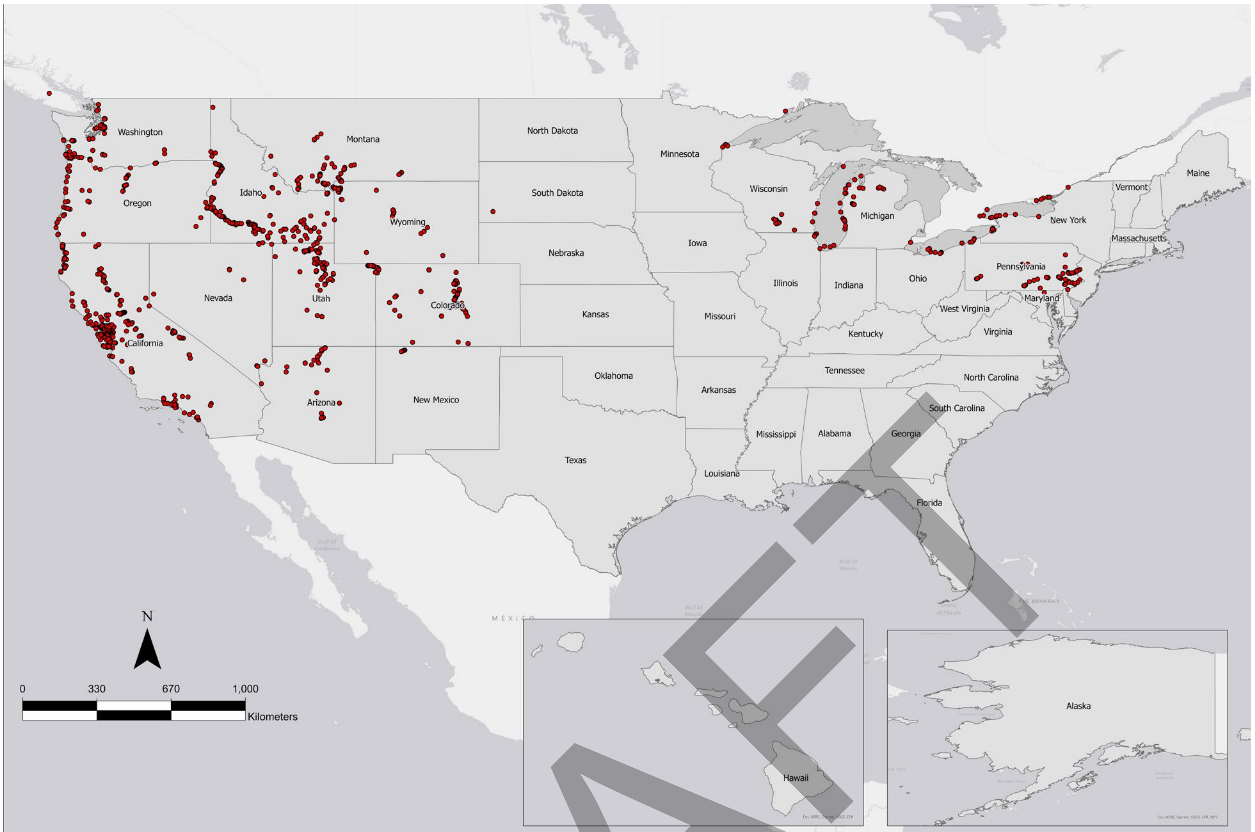

Figure 4. The approximate distribution of New Zealand mudsnail in the United States in May 2024. A dynamic distribution map can be found on the USGS Nonindigenous Aquatic Species (NAS) database website (Benson et al. 2022). Data were compiled from the NAS database (USGS NAS 2024) and Geist et al. (2022).

Pathways of Spread

As used here, "pathway" refers to the "mechanisms and processes by which non-native species are moved, intentionally or unintentionally, into a new ecosystem" (Executive Order No. 13751, 2016). NZMS are fully aquatic, so while they can naturally spread within connected waters, they are unable to disperse overland, unless aided. Physical characteristics and the behavior of NZMS likely contribute to their spread by human-mediated pathways and its own volitional movement.

Human-mediated mechanisms by which NZMS are moved present the greatest opportunity for management intervention. Because of their small size and cryptic coloration, NZMS can be picked up from a waterbody and moved, unnoticed, to another waterbody, leading to short and long leaps in the expansion of its range. NZMS can survive out of water for days and even weeks depending on moisture and humidity; they seek out moist crevasses, can close their operculum, and have a relatively hard shell, enabling them to withstand temporary drying.

The pathways by which NZMS can be picked up from a waterbody align with the many and diverse reasons humans enter waterbodies. While the spread of NZMS through human-mediated pathways presents discrete opportunities for intervention to stop further spread, range expansion via natural processes presents a much more difficult challenge.

NZMS are positively rheotactic (they move in the opposite direction of the water flow) (Haynes et al. 1985); as such, this species can expand its range upstream as well as all other directions for the point of introduction. NZMS can crawl at speeds exceeding 1 meter per hour (Richards 2002) and have been documented to move 60 meters upstream in 3 months (Adam 1942). Adults can pass alive through the digestive system of several fish species (Bondesen and Kaiser 1949, Haynes et al. 1985). Adults and juveniles may float on masses of algae (Ribi and Arter 1986) and plants (Richards et al. 2001) and on the surface tension of the water (Levri et al. 2019). Juveniles may float freely beneath the water surface without a substrate (Vareille-Morel 1983) and move with flowing water. The rate of downstream spread can be accelerated by intense flows such as flooding, and they can be spread to adjacent watersheds if high flows connect them.

Information regarding the timing and source of initial introductions of NZMS within the U.S. obscures the identification or ranking of individual pathways. However, based on knowledge of how waters are accessed and the biology and physiology of NZMS, the pathways by which NZMS spread can be identified. These include the following:

Recreational water users: Particularly when embedded in mud or attached to plant debris, NZMS may be transported on fishing gear, waders and boots (Hartzell and Macelko 2022), swimsuits and swimming toys, and even hunting dogs and horses. Hikers, backpackers, horseback riders, and bicyclists may inadvertently transfer the snail when encountering multiple stream crossings during their outings. The snail's small size allows it to be carried in small crevices that might escape detection. NZMS inadvertently distributed via live bait sales or use can be transported to new sites if bait containers or their contents are discarded in the water. Given their ability to survive in the digestive tract of fish, movement of live or dead fish between watersheds by anglers is also possible.

Natural resource management activities: Personnel involved in monitoring projects, restoration activities, and other natural resource activities that cross watersheds may transport NZMS to new waterbodies via their gear, vehicles, or clothing. Community and classroom monitoring groups can also be a pathway for spread. NZMS can live in moist environments near the edges of streams and therefore can be picked up and moved by people who are working along the edge, but not wading into, the water. Without pre-planning, field staff may not have access to facilities or equipment that allows decontamination between work sites.

Fish hatcheries and associated stocking operations: Over the past several decades NZMS have established within numerous government and private aquaculture facilities. Contamination of water supplies, the ability of NZMS to pass live through fish digestive systems (Bruce et al. 2009), and non-dedicated equipment are some ways hatcheries may be vulnerable to the introduction of NZMS into their operation. Hatcheries pose a risk for spreading NZMS through their operations of transferring live organisms, their eggs or larvae, and associated water and packing materials moved between aquaculture facilities. In addition, the stocking of fish from hatcheries with NZMS presents a significant opportunity to introduce NZMS into new environments.

Recreational watercraft and trailers: When used in NZMS infested waters, boats, canoes, kayaks, and associated gear and trailers may inadvertently pick up NZMS. NZMS may be brought onto the boat or in water taken into the ballast (particularly for jet skis and other jet-drive systems operated in shallow water), or they may cling to an exterior surface and be moved to uninfested waters. In addition, NZMS often attach themselves to aquatic macrophytes and clumps of algae. These plant materials and associated snails can be entangled on boat motors and trailers and moved between waterbodies.

In-water work and sand/gravel mining, extraction, and dredging: Any operation that entails work in aquatic environments can pick up and move NZMS. Materials that include NZMS within them may be moved during gravel extraction or dredging or incidentally on mud, sand, and other materials that are stuck to equipment. Dredges that move frequently between rivers and estuaries are a particularly high risk for spreading NZMS within a region. Maintenance of canals and ditches by landowners, ranchers, water and power agencies, and flood control personnel can also spread NZMS.

Transport by water flow: Water flow can spread NZMS within a watershed to areas where they may encounter other pathways that provide transport outside the watershed. This pathway typically varies seasonally based on flood events or periodic management of water levels in ponds and reservoirs. In lakes and ponds other species of snails have been reported to hitchhike on floating algae mats and other vegetation (Vareille-Morel 1983 and Ribi and Arter 1986 as cited in Ribi 1986, Dorgelo 1987) and float at the water's surface or cling to the underside of the surface film (Gangloff et al. 1998; Marsh 1980). Flood events in Black Earth Creek, Wisconsin, are believed to be responsible for spreading NZMS downstream (E. Voss, personal communication, June 27, 2023).

Natural movement: As noted earlier, NZMS can crawl at speeds exceeding 1 meter/hour (Richards 2002). The natural movement of NZMS enables them to spread within a watershed to areas where they may encounter other pathways that provide transport outside the watershed.

Transport by fish, wildlife, and livestock: It is already known that NZMS can survive passage through the digestive system of trout (Bruce et al. 2009). Fish could therefore serve as a more localized source of spread, particularly for species that migrate or may stray into other tributaries or watersheds. It has been suggested that waterfowl and other birds could also spread NZMS between waterbodies via feet or feathers (Boycott 1936; Talling 1951; Lassen 1975). In addition, NZMS might be spread through consumption by waterfowl, though it is unlikely a snail would pass unharmed through the gizzard (Gangloff et al. 1998). Other wildlife (particularly aquatic and semi-aquatic species like frogs, raccoons, and otters) may serve as pathways via transport on a variety of geographic scales. These snails could also be spread on the feet/hooves or fur of domestic livestock that enter streams, such as goats, sheep, cattle, or horses or wildlife such as bison, deer, and elk. Since NZMS can live in moist areas along stream banks, animals such as pet dogs that walk along riparian areas have the potential to spread them.

Aquatic pond plant and aquarium trade: The aquatic plant trade may facilitate the dispersal of NZMS and other invasive mollusks (Dickey et al. 2023; Duggan 2010; Patoka et al. 2016). For example, in 2020, a popular aquarium plant known as Marimo moss balls (the algae *Aegagropila linnaei*) distributed to retailers (brick-and-mortar and online) across the U.S. were found to harbor zebra mussels (*Dreissena polymorpha*; U.S. Fish and Wildlife Service 2020; U.S. Geological Survey 2021). A 2001 study conducted in Minnesota by the Department of Agriculture found that 40 orders placed to 34 aquatic plant vendors across the U.S. yielded 31 orders with live animal species. Sixty-five percent of these species belonged to Gastropoda, Diptera, and Hirudinea (Montz 2002; Maki and Galatowitsch 2004). Therefore, it is plausible that NZMS could be spread through the retail sale of aquatic plants and introduced into home aquaria and water gardens. If those purchased plants are discarded into waterways, or moved by flooding, wildlife, or other mechanisms, NZMS could be introduced into the natural environment. Several authors have hypothesized that initial introductions to Europe and Australia were a result of the transport of aquatic plants between Australia and botanical collections in Europe (Winterbourn 1972; Ponder 1988).

Firefighting: NZMS have the potential to spread by firefighting machinery or equipment that draws water and/or is moved from one place to another across streams and rivers to control wildland fires. Transporting large helicopter-deployed water buckets between waterbodies is also a concern. Spread could also occur through human and pack animal activity during wildland fire control operations.

Commercial shipping: Discharge of ballast water has been associated with many introductions of AIS, including snails, and is a potential pathway for NZMS introductions. Most species introduced via ballast water are those with planktonic larval dispersal, which NZMS lack, making this pathway unlikely but possible. Ballast water from foreign ports can serve as a continuing inoculation source of new NZMS clones, while ballast discharge from coastal shipping may spread snails already found in the U.S. (e.g., transport of Columbia River NZMS to other West Coast estuarine ports). Zaranko et al. (1997) suggested that this mechanism may have been responsible for the presence of NZMS in Lake Ontario. Ships can also transport NZMS that have attached to or are embedded in mud on anchors and other surfaces.

Impacts

Ecological Impacts

The ecological impacts of invasive NZMS are wide-ranging, complex, and often related to their population size. NZMS densities vary widely across their invaded range. Furthermore, cyclical boom-bust patterns of NZMS abundance are frequently observed at multiple time scales. Intra-annual variation of NZMS is often observed across their invaded range (e.g., Schreiber et al. 1998; Vinson 2004; Kerans et al. 2005; Hall et al. 2006; Bennett et al. 2015), with peak densities typically occurring during the summer followed by declines occurring throughout the winter months. Longer term population fluctuations spanning multiple years are also evident, with marked declines occurring after NZMS have achieved high densities (e.g., Moore et al. 2012; Gérard et al. 2018; Greenwood et al. 2020). The mechanisms behind such population fluctuations are largely unknown, and further research is needed to better understand NZMS population dynamics and the associated short- and long-term impacts to native ecosystems.

To date, studies have demonstrated that NZMS can impact multiple levels of biological organization, from individual species to communities and ecosystem processes. The impacts of invasive NZMS in part stem from their ability to achieve extremely high densities (Dorgelo 1987; Hall et al. 2003), affording them the ability to monopolize primary energy resources. NZMS impact periphyton abundance and community structure (Geist et al. 2022) by reducing algal standing stock (e.g., Riley et al. 2008) and altering diatom assemblages (e.g., Krist and Charles 2012). These snails can consume 75% of gross primary production in streams and dominate nutrient cycling through grazing and excretion (Hall et al. 2003; Moore et al. 2012). Their flexible feeding strategy allows NZMS to consume detrital food resources (e.g., leaf litter; Bovee and Tiegs 2023); however, their impacts on detrital processing remain largely unknown. Overall, invasive NZMS can dominate basal resources in an invaded system, which has led to record-high secondary production levels (Hall et al. 2006) and concomitant effects on native communities.

Invasive NZMS affect native macroinvertebrate community and functional structure, and the competitive ability of this species allows them to dominate the native benthic community. NZMS directly compete with native gastropods given their overlap in feeding strategies, and NZMS can outcompete and impact native snail growth rates (Riley et al. 2008; Larson and Black 2016). Furthermore, NZMS can dominate native gastropod communities (e.g., Gérard et al. 2003; Strzelec 2005; Gérard et al. 2017) and affect other native macroinvertebrate taxa distributions through competitive interference. For example, Kerans et al. (2005) observed a reduction in native macroinvertebrates colonizing experimental tiles as NZMS abundance increased, suggesting a potential to displace native invertebrates. Several other studies have documented the wide-ranging effects of invasive NZMS on native taxa and their ability to influence and/or reorganize the taxonomic and functional structure of the community.

Invading NZMS do not serve as an equivalent substitute energy source for predators relative to native prey. The hard shell and operculum of NZMS inhibit the ability of some predators to successfully digest and assimilate them. Increasingly, predation of NZMS by higher consumers in invaded systems has been documented (e.g., Vinson and Baker 2008; Bersine et al. 2008; Brenneis et al. 2011; Hellmair et al. 2011; Bennett et al. 2015). However, NZMS can pass undigested through the intestinal tracts of many fish species and have low energetic value for these secondary consumers (Haynes et al. 1985; Bruce 2006; Vinson and Baker 2008; Rakauskas et al. 2016). As invasive NZMS become incorporated into the diets of fish and other higher consumers, consequences to the consumer are likely, as is energy transfer across the food web. The extent to which these changes in community structure and energy flow can affect fish populations is poorly understood. However, if NZMS replace higher-value food resources, fish reproduction, health, and population densities could be affected. Terrestrial animals such as birds may also be affected since some interact with aquatic food webs as well. Consequently, this invader could have effects that cascade through both aquatic and terrestrial food webs (e.g., Carpenter et al. 1985).

NZMS are globally widespread, and in most instances (see Schreiber et al. 2002), they adversely affect natural aquatic communities and individual species, particularly those already imperiled (Appendix B. Federally listed species with potential to be impacted by New Zealand mudsnail). Imminent climate-level changes compound the threat to listed species by undermining the resilience of the most sensitive and vulnerable environments. The U.S. is laced with an array of unique aquatic environments ranging from tiny pools to immense rivers that are inhabited by unique native species. The health and vitality of many of these aquatic environments and the species that inhabit them are already compromised due to altered hydrology, pollution, overharvest, and other non-native species. The short and long-term impacts of NZMS are likely site-specific, and should be evaluated on a site-specific basis (Alonso et al. 2023; Greenwood et al. 2016; Greenwood et al. 2020; Moore et al. 2012; Preston et al. 2023; Riley et al. 2008).

Economic Impacts

Economic impacts associated with the introduction of NZMS are not well documented and are difficult to monetize. However, economic losses associated with impacts to recreational fisheries and costs associated with the control or eradication of NZMS at fish hatcheries have been reported throughout the invaded range of this species. In popular trout fishing streams, angler access may be restricted or temporarily closed to control the spread of NZMS. The subsequent loss of recreational activity (i.e., fewer fishing trips, loss of angler expenditures) can negatively impact local and state economies that rely on income from sport fishing and related tourism. Davis and Moeltner (2010) assessed the potential economic loss resulting from changes in fishing regulations and angler access following a hypothetical NZMS infestation in three popular trout fishing streams in the Sierra Nevada region. They found that proposed control measures such as stricter fishing regulations, winter closures, and seasonal closures could lead to economic losses ranging from 17 to 40 million dollars annually. This estimate is likely conservative given the analysis did not include other recreational activities (e.g., boating) that could be impacted by a NZMS infestation.

The introduction of NZMS into fish hatcheries is a concern because the snail can be inadvertently spread through fish stocking or other routine hatchery operations (ANSTF 2007). The establishment of NZMS within a fish hatchery could significantly increase labor and operational costs, damage equipment or infrastructure (e.g., water delivery pipes, filters, screens, and pumps), and require the facility to undergo extensive decontamination or fish depuration procedures (Bruce 2006; Oplinger et al. 2011). In extreme cases, the hatchery may be forced to suspend production, reduce production, alter stocking locations, or close completely. Montana Fish, Wildlife and Parks discovered NZMS at Bluewater State Fish Hatchery in 2022. Consequently, the hatchery euthanized nearly all largemouth bass and rainbow trout stocks to eliminate the snails' potential spread. The estimated cost of the infestation, including loss of hatchery stock and decontamination of the facility, was $225,000. Page Springs Hatchery (Cornville, AZ) detected NZMS in two raceways during a routine AIS survey in 2019. As a result, fish stocking was suspended, and Arizona Game and Fish was forced to purchase fish from other locations to meet stocking needs. Page Springs Hatchery produces 57% of trout stocked in Arizona and contributes over $185 million to the state economy (Arizona Game and Fish Department 2015). Even minor losses in hatchery production can negatively impact the angling community and local economy.

The 2007 National Management and Control Plan for the New Zealand mudsnail (ANSTF 2007) also identified biofouling as a potential impact associated with high-density NZMS populations (Colton 1942 in Zaranko et al. 1997); however, there is little recent evidence to suggest biofouling occurs other than in heavily infested fish hatcheries. Richards and Arrington (pers comm 2006) contacted over 150 water resource managers in Australia and the U.S. and found no reported impacts of NZMS to hydroelectric facilities, irrigation diversions, or municipal water supplies. More research may be needed to quantify any recent impacts of NZMS on municipal or industrial water delivery systems. Other costs associated with NZMS may include:

- Research and development expenses incurred by agency and university personnel to prevent further spread
- Monitoring the distribution and spread of this snail to determine whether sensitive native species are being placed at risk
- Additional monitoring of threatened and endangered species within the range of the NZMS invasion
- Additional efforts by agency personnel to ensure that facilities such as hatcheries do not serve as a pathway
- Additional requirements placed in permits for activities such as dredging or canal maintenance
- Additional steps and materials used by agency personnel, researchers, community monitors, and consultants to decontaminate gear
- Additional costs incurred for materials, transport, and time of public outreach and information dissemination

Human and Animal Health Impacts

Based on our current knowledge, NZMS are not considered a serious direct threat to humans or other animals; however, they may indirectly affect human and animal health by serving as a disease vector for parasites that affect human and animal health. NZMS are known to harbor parasitic trematode species (flatworms of the Class Trematoda) that affect fish, birds, mammals, and humans. The effects of the trematodes vary depending on the parasite species, host species, and environmental setting.

Worldwide, the number of parasitic trematode species has been estimated to be in the tens of thousands, and they are believed to be highly host specific. Trematodes typically require a series of two different hosts to complete their life cycle; the first host is typically a snail, and the second host is typically a vertebrate. In their native range, NZMS have been documented to be parasitized by at least 18 trematode species (Hechinger 2012); however, within their global introduced range, research has rarely documented NZMS to carry trematodes (Adema et al. 2009; Zbikowski and Zbikowska 2009; Gérard et al. 2017). Field research in the Western U.S. from 2014-2017 assessed the prevalence of trematodes in co-occurring populations of native snails and NZMS; researchers found that NZMS carried trematodes at 80% of the sites, while trematodes were far more common in native snails (Larson and Krist 2019). In contrast, research on NZMS in France identified NZMS carrying a novel trematode of unknown origin

(Gérard and Le Lannic 2003), suggesting that not all trematodes are host-specific and that NZMS have the potential to move trematodes as their invading range expands.

Trematodes of the genus *Sanguinicola* (Family Aporocotylidae) have been documented to parasitize NZMS (Gérard and Le Lannic 2003) and are known to infect fish and cause detrimental health effects including death. *Sanguinicola* species are also responsible for "swimmer's itch," an allergic reaction experienced by swimmers when the larval life stage of some species of trematodes burrow into the skin.

More work is needed to elucidate the interactions between the prevalence of parasite species in specific novel environments, parasite-host specificity, host impacts, the influences of environmental conditions now and under future climate conditions, and ultimately how NZMS might serve as an intermediary host of threats to human and animal health.

Ongoing New Zealand Mudsnail Activities

Though NZMS have continually expanded their range since their introductions, many states are in different stages of NZMS invasion. Some have yet to detect NZMS, while others have multiple and/or heavily infested waters and are working to stop their spread. Due to the broad adaptability of NZMS, all states should conduct surveillance for this invasive species regardless of the presence of any known established population. Although often used synonymously, the terms surveillance and monitoring have distinct meanings within this plan. Surveillance is defined as field surveying for the presence of NZMS before they are known to be present (pre-discovery). Monitoring is defined as field surveying for NZMS where they already known to be present in an area (post-discovery).

Many state agencies have implemented management actions for NZMS, including documenting the presence of NZMS, determining the perceived threat or impacts of infestations, and assessing budgetary and staffing limitations. These actions differ from state to state for various reasons. In addition to agency efforts, nonprofit organizations, universities, and others are actively studying and monitoring NZMS populations. For brevity and alignment with the known infested range, ongoing NZMS management activities for each state are summarized by ANSTF Regional Panels (Figure 5) to provide an overview of the current NZMS management effort in each geographic area. For states that participate in multiple panels, rather than duplicating their efforts across multiple panels, their efforts are only captured in the first panel in which they appear in the discussion below.

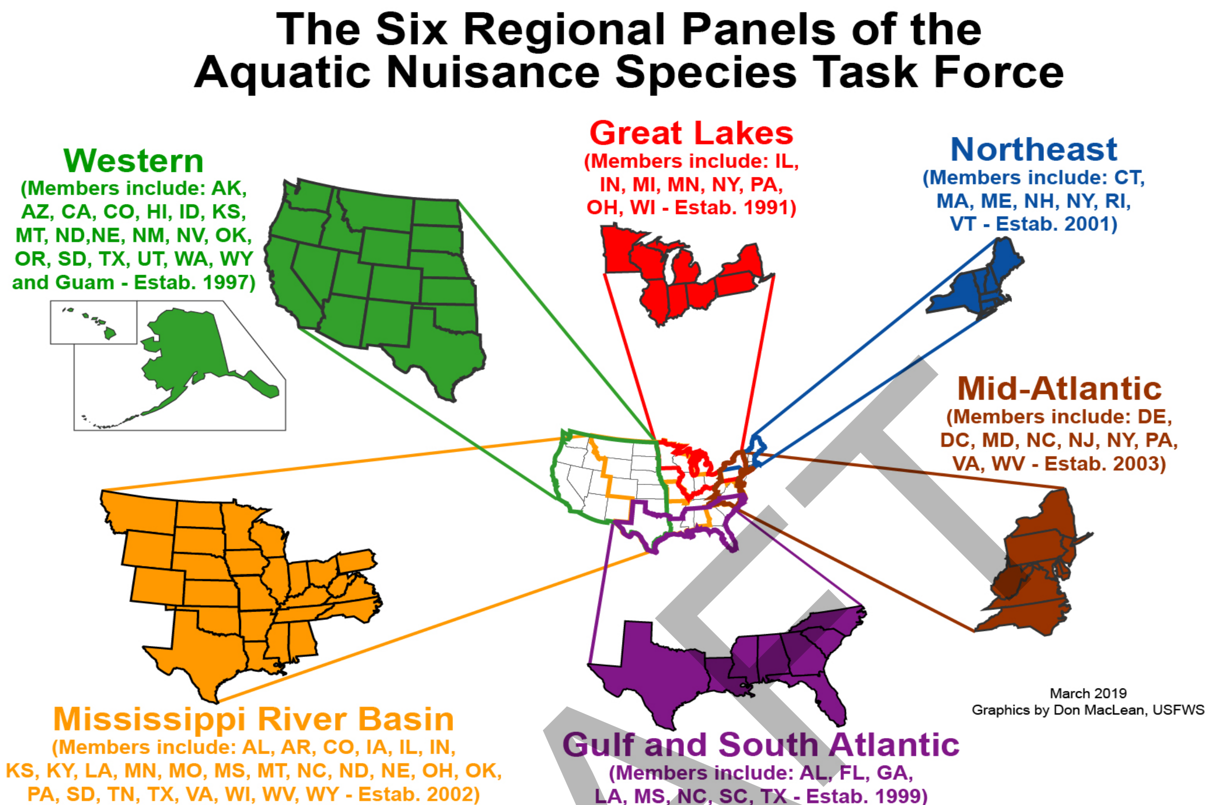

Figure 5. The Regional Panels of the Aquatic Nuisance Species Task Force showing each regional panel states and boundaries. Several states are included in multiple panels.

Western Regional Panel

AK, AZ, CA, CO, HI, ID, KS, MT, ND, NE, NM, NV, OK, OR, SD, TX, UT, WA, and WY

Due to the wide distribution of NZMS in the West, many Western Regional Panel (WRP) states have ongoing management activities for NZMS. State agencies in Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming provide educational information to the public. These efforts include posting educational signage at NZMS-infested waters, presenting information on best practice decontamination protocols for all AIS, and publishing species information pages and fact sheets on agency websites. Many western states have invasive species councils that help with AIS outreach and education efforts. In addition to education and outreach, these states conduct monitoring and early detection surveillance at waterways, including visual surveys and/or eDNA sample collection. Fish hatcheries managed by these states and those operated by U.S. Fish and Wildlife Service conduct AIS inspections for a variety of species, including NZMS. Hatcheries conduct surveillance, and if NZMS are detected, facilities implement measures to prevent spreading invasive snails to other waterways. Lastly, many of these states have watercraft inspections stations that aim to stop the spread of AIS within and between states.

The U.S. Fish and Wildlife Service published a "Rapid Response Plan for Invasive Aquatic Mussels and Snails in Alaska" in 2020 that includes NZMS. The State of Alaska banned felt-soled wading boots in 2012 for freshwater anglers and hunters to proactively minimize the introduction and transfer risk of AIS, naming NZMS, didymo, and whirling disease in their public outreach materials.

North Dakota conducts surveillance for NZMS while conducting AIS inspections, and Kansas provides information to the public. NZMS have not yet been documented in either North Dakota or Kansas.

Great Lakes Regional Panel

IL, IN, MI, MN, NY, PA, OH, and WI

The distribution of NZMS in the states comprising the Great Lakes Regional Panel (GLRP) is significant; as such, many of the states are engaged in a variety of monitoring, research, and outreach efforts. Michigan incorporates NZMS surveillance into routine fishery and bioassessment surveys. Lake Superior State University researchers are studying the ecological impacts of NZMS in Michigan. Pennsylvania posts educational signage at infested waterways and conducts surveys in popular trout fishing streams. Researchers at Pennsylvania State University are exploring how NZMS densities change within and between years and how native parasites affect NZMS in Pennsylvania, New Jersey, New York, Michigan, and Maryland. Pennsylvania Fish and Boat Commission staff and partners have been conducting visual surveys for NZMS since 2021. Surveys have occurred statewide in all major drainage basins. Pennsylvania implements educational outreach by posting signs at invaded waterways, maintaining a NZMS webpage, and posting on social media. In 2022, NZMS were detected in several Pennsylvania state fish hatcheries, which led to more intensive hatchery monitoring statewide and the activation of hatchery control plans. Wisconsin provides boot brush stations for water users at known infestation sites and other popular streams, posts educational signage at public access points, and collaborates with other organizations to train canines for detection of NZMS in sediment and water samples.

Northeast Regional Panel

CT, MA, ME, NH, NY, RI, and VT

There have been several detections of NZMS in New York, but NZMS have not been detected in any other Northeast Regional Panel state. There are no ongoing activities in the Northeast Regional Panel.

Mid-Atlantic Regional Panel

DE, DC, MD, NC, NJ, NY, PA, VA, and WV

The Mid-Atlantic Regional Panel has established populations of NZMS, but NZMS are not distributed throughout the entire area. New Jersey conducts surveillance at high-risk waterways using visual survey and eDNA methods.

Gulf and South Atlantic Regional Panel

AL, FL, GA, LA, MS, NC, SC, and TX

There are no documented populations of NZMS in any of the Gulf and South Atlantic Regional Panel (GSARP) states. Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, and Texas are aware of the NZMS threat, but these states do not implement any NZMS-specific management activities.

Mississippi River Basin Regional Panel

AL, AR, CO, IA, IL, IN, KS, KY, LA, MN, MO, MS, MT, NC, ND, NE, OH, OK, PA, SD, TN, TX, VA, WI, WV, WY

The Mississippi River Basin Regional Panel (MRBRP) has overlapping areas with WRP, GLRP, and GSARP. Many of the Western and Great Lakes states implement various management activities as described above in the panel reviews. States that are only in the MRBRP are Iowa, Missouri, Arkansas, Kentucky, and Tennessee, and to date, these states do not implement NZMS-specific management activities.

Research on Control and Management

Despite the imminent threat posed by NZMS since they were first discovered in the U.S. in 1987, there has been modest investment in research to characterize the impacts of NZMS and only more recently efforts to control and manage infestations. An investigation to develop a parasitic trematode as a biological control agent was explored in 2010 (NOAA Project Number R/ANS-212), but while a New Zealand trematode *Microphallus* sp., was shown not to infect native Hydrobiidae, declines in NZMS populations after initial invasion reduced the need for control actions (T. Dudley, personal communication, May 1, 2024). The greatest advancements have been made in efficacy and recommendations for decontamination of personal and large equipment.

More recently, as NZMS have invaded aquaculture facilities, opportunities to test eradication or control methods on individual closed-water systems or dewaterable facilities have been possible. The outcomes of these efforts, such as dewatering, hot water washing, chemical disinfectants, and drying, are typically site-specific (not controlled experimental settings), and the outcomes are not widely published. An increase in information sharing (publications or the distribution of internal reports), regardless of the successfulness, would be beneficial for others to learn from and advance upon. Even fewer open-water control and management efforts have been undertaken, which is not surprising given the challenges and limitations of acceptable tools for management in open-water systems. Management of NZMS in Capitol Lake (Olympia, Washington) is one well-documented effort with accessible information (LeClair and Cheng 2011). Management goals for Capitol Lake have been modified and refined based on the outcomes of their management efforts, which underscores the importance of investing in post-action monitoring.

Policies and Authorities

This summary addresses federal and state laws, regulations, plans, and policies that directly relate to NZMS, either specifically or generally. It does not include other AIS prevention requirements such as ballast water regulations that relate to NZMS indirectly. As laws, regulations, plans, and policies are subject to change, they should be validated before relying on the information contained herein.

Federal

NZMS are not listed as “injurious wildlife” in the federal Lacey Act (18 U.S.C. 42; 50 CFR Part 16), and therefore, their importation into the U.S. is not prohibited.

A key federal provision that has been applied to NZMS invasions is Executive Order 13112, which was signed by President Clinton in 1999. This policy prevents federal agencies from authorizing, funding, or carrying out actions that are “likely to cause or promote the introduction or spread of invasive species” (except under certain conditions). It has been the basis for NZMS prevention and control programs at federal fish hatcheries, federally funded state fish hatcheries, and other facilities.

In 2016, Executive Order 13112 was amended by Executive Order 13751, establishing the policy of the U.S. to prevent the introduction, establishment, and spread of invasive species as well as to eradicate and control populations of invasive species that are established. In addition, the Order renewed the commitment of federal agencies and the National Invasive Species Council to continue their leadership in prevention and coordination efforts and further expanded that directive to include more progressive, coordinated action and leadership.

State

State authorities regulating the importation, transport, possession, and/or release of NZMS range from none to complete prohibition (Appendix A). Those states that do have laws take a variety of approaches, including regulating specifically named species, regulating lists of named species, or prohibiting all undefined/unnamed species. All regulatory approaches can be equally effective and enforceable to manage NZMS introduction and spread; however, the primary management constraint is often a lack of adequate staffing to inspect for or interdict the movement of NZMS and thereby intervene to enforce the laws.

State laws applicable to regulating NZMS are summarized in Appendix A. A simple comparison of key words across laws is inadequate to assess whether a state's laws collectively cover authority to prevent the introduction and spread of NZMS. A more nuanced assessment performed only by that jurisdiction may be necessary to determine whether their interpretation of the laws, penalties, regulation, and enforcement of those laws is adequate. For example, a jurisdiction may prohibit "possession" but not also explicitly prohibit "introduction." It can be argued that "possession" is a prerequisite for an "introduction," and therefore "possession" is adequate unto itself. The purpose of this table is to demonstrate the variety of approaches across states and to identify opportunities for strengthening laws to prevent further introduction and spread of NZMS within and across states.

In the U.S., states that regulate importation, possession, and transport of NZMS (species specific) include Alaska, Arkansas, Arizona, California, Colorado, Connecticut, Idaho, Iowa, Kansas, Maryland, Minnesota, Montana, Nevada, New York, North Dakota, Oregon, Texas, Utah, Virginia, Washington, Wisconsin, and Wyoming. States with general aquatic invasive species regulations that apply to NZMS, but do not name NZMS specifically, include Alabama, North Carolina, Pennsylvania, South Dakota, Florida, and Kentucky. States that do not regulate NZMS but address the species in their state aquatic nuisance/invasive species management plans include Mississippi, Indiana, and Kentucky.

While ineffective in the absence of compliance and enforcement, laws are an important component of preventing the introduction and spread of AIS. NZMS are spread across jurisdictional authorities; therefore, the most comprehensive regulatory approach, which also maximizes enforceability, is a suite of complementary federal and state laws that prohibit the possession and transport of NZMS within and across state lines. A prohibition on moving NZMS across state lines is particularly important because not every state has a law prohibiting the possession and transport of NZMS.

Goals and Objectives of the Plan

Since publication of the 2007 plan, considerable investments have been made to prevent the spread of NZMS within the U.S., and continued action is needed. To reiterate, the goals of this plan are:

A. Protect native species, their habitats, environmental quality, and the economy from negative impacts resulting from NZMS.
B. Equip and mobilize all entities that have relevant authorities, responsibilities, and/or interests in avoiding and mitigating the spread and impacts of NZMS.
C. Establish a framework for the ANSTF to lead efforts and collaborate with States/Tribes/local agencies to respond to and minimize the impacts of NZMS.

The plan goals are multipart and interdisciplinary. Therefore, multiple objectives are necessary to achieve each goal. Each objective is described, and specific strategies and actions are identified, and all actions are detailed in corresponding implementation tables. The objectives that support the three goals of the plan are:

1. Preventing Introduction and Secondary Spread
2. Monitoring and Surveillance
3. Rapid Response to New Detections
4. Management of in situ NZMS Infestations
5. Education and Outreach
6. Implementation, Information, and Data Management

Working towards each objective is key to fulfilling the goals of the plan. In addition to addressing NZMS, many of these objectives, strategies, and actions contribute to addressing other unmet AIS prevention, containment, and management needs.

Objectives

Based on a reassessment of pathways by which NZMS can be introduced and spread, the suite of tools and information currently available, and known ongoing activities, this plan lays out future objectives, strategies, and actions that are needed, and prioritizes those needs and estimates the cost of implementation. These actions were developed with a 5-year planning horizon; however none would be obsolete beyond that anticipated plan horizon. The following objectives, strategies, and actions range from general to specific, discrete to long-term, no/low cost to significant cost, and appropriateness for implementation by a range of organizations. Successful implementation of some actions may require national leadership while others can be completed by state, Tribal, local, and even non-governmental organizations at a national or regional scale. Recommended actions are described in the text and summarized in the implementation tables for each objective along with short term needs, long term needs, deliverable, estimated cost, and relative cost.

Objective 1. Preventing Introduction and Secondary Spread

Preventing the spread of NZMS requires an investment in planning. The significant upside to this investment is that it is the most cost-effective management strategy and avoids ongoing costs to manage an infestation and irreparable impacts to natural resources. The prevention efforts described herein may just apply to NZMS, but more often, they also prevent the spread of many other AIS across multiple pathways. For example, posting educational signage at infested waters may address the pathways of recreational watercraft/trailer users as well as general water users and shoreline anglers. Other methods are more pathway-specific, such as including AIS decontamination best practices for heavy equipment in permits. Overall, preventing the spread is key because once NZMS are introduced, there are limited tools for NZMS containment and eradication.

An important planning tool for AIS prevention is Hazard Analysis and Critical Control Point (HACCP) planning, which is a structured process used to assess activities, identify potential risks throughout the course of carrying out that activity, and proactively identify actions to mitigate the potential risks associated with the activity (Britton et al. 2019; Minnesota Sea Grant 2004). The HACCP management system was originally developed for food safety during production and processing, but the same principles can be applied to natural resource management. In this context, invasive species are framed as a "risk"; all opportunities by which they could be introduced or spread ("pathways") are proactively identified, and preventative measures are incorporated into the activity. Development and implementation of HACCP plans for NZMS specifically, as well as for activities likely to transport NZMS, can significantly reduce their spread.

Strategy 1.1 Implement pathway-specific management actions to address recreational equipment

Recreationalists engaged in a variety of in-water activities pose a great risk of spreading NZMS by way of their equipment. This includes angling, swimming, hiking/exploring, gold panning, and any other activity where gear (including footwear) comes into contact with multiple bodies of water. Further research is needed to evaluate the efficacy and applicability of cleaning and decontamination options to address the risk of spread by specific user groups. The results of this research will inform the development of user group-specific cleaning and decontamination recommendations/requirements.

To address recreational equipment:

- Develop and promote implementation of cleaning protocols for various types of equipment (Action 1.1.a)

- Provide resources to the public to facilitate field cleaning of gear (bristle brushes, dunk buckets, wash stations, wash kits; Action 1.1.b)
- Partner with national recreational organizations and retailers to promote NZMS prevention and containment (Action 1.1.c)
- Conduct research to evaluate the efficacy and applicability of cleaning options to address the risk of spread by specific user groups (Action 1.1.d)

Strategy 1.2 Implement pathway-specific management actions to address professionals working in aquatic environments

While working in the environment to protect natural resources, natural resource management professionals can inadvertently spread NZMS. This potential extends beyond natural resource managers and includes all those who work in aquatic environments, including lake managers, law enforcement officers, or those involved with construction activities. HACCP plans, standard operating procedures, and policies for the decontamination of field gear and equipment between waterbodies should be developed and implemented. Furthermore, opportunistic surveillance for NZMS while doing work for any purpose in aquatic environments should be adopted.

To address professionals working in aquatic environments:

- Incorporate equipment decontamination requirements for any activities in waterbodies (Action 1.2.a)

Strategy 1.3 Implement pathway-specific management actions to address fish production, stocking, and translocation

The operation of fish hatcheries, inclusive of the risk of NZMS entering hatcheries by way of water sources, broodstock, and equipment, and leaving hatcheries by way of equipment and in the digestive system of stocked fish, presents the opportunity to introduce NZMS into new watersheds immediately connected to the hatchery as well as to distant stocking sites. Hatcheries should develop HACCP plans to identify the points at which NZMS could be introduced to the system. In addition, when fish are moved within the environment for conservation purposes there is the potential to move NZMS to uninfested waters. Further research is needed to inform measures to prevent fish production operations and translocations from spreading NZMS. Results of this research will help inform fisheries management decision making.

To address fish production, stocking, and translocations:

- Develop HACCP plans for each hatchery (Action 1.3.a). Each hatchery should develop site-specific HACCP plans that include the following: dedicating separate equipment and gear for each hatchery and field use; decontaminating equipment and gear; regularly inspecting the facility and axillary operations for NZMS/AIS; and documenting the inspections (including non-detections).
- Develop standardized NZMS inspection protocol for hatcheries (Action 1.3.b) Surveillance at hatcheries will inform the need for operational changes should NZMS be present. For facilities with known NZMS infestations, operations should be modified to minimize the potential for release/spread of NZMS by way of water releases, fish movement, and all other operations. Additionally, fish from facilities where NZMS are already present should only be released at sites where NZMS are already present. When possible, as hatchery facilities are built, upgraded, or replaced, they should be designed to reduce the risk of colonization by AIS and conducive to monitoring and decontamination if colonization occurs.
- Conduct NZMS/AIS inspections at all hatcheries (Action 1.3.c)
- Conduct research to determine which fish species consume NZMS and, if so, the transit time through their gastrointestinal tract (Action 1.3.d)

Strategy 1.4 Implement pathway-specific management actions to address recreational watercraft and trailer*s*

Recreational watercraft (inclusive of motorized and non-motorized) and trailers have the potential to move NZMS from infested waters. Engagement of this important user group to implement the principles of "Clean Drain Dry" will require regional implementation. "Clean Drain Dry" is currently the national message that encourages boaters to prevent the spread of all AIS. This message, or any subsequent AIS messaging that replaces it in the future, should be adopted and promoted.

To address recreational watercraft and trailers:

- Promote implementation of "Clean Drain Dry" (Action 1.4.a)

Strategy 1.5 Implement pathway-specific management actions to address commercial activities

The commercial activities category is broadly inclusive of any activity that is partially (along the edge of or transiently into a waterbody) or entirely (submerged or floating on a waterbody) associated with aquatic environments and the removal of material from aquatic environments. Often, commercial activities in aquatic environments require some form of permitting (e.g., construction, chartered travel, special events, livestock,). Permitting authority is an opportunity to prevent NZMS spread by requiring prevention actions (best management practices). To protect the environment, mandatory requirements, or conditions relevant to preventing AIS should be imposed, when possible, by federal, state, or local agencies.

Sand/gravel mining, extraction, and dredging is another commercial activity that has the potential to remove NZMS from an infested location and deposit them in a new location. The spread of NZMS via this pathway can be prevented through the following: permit conditions; restrictions on work or the removal of materials from infested waters; requirements for NZMS-/AIS-free materials when depositing materials into aquatic environments; the development of cleaning methods for source materials; cleaning of equipment prior to and after use in waterbodies; and closing areas with NZMS to mining, extraction, and dredging.

Aquatic plant collection and trade can spread NZMS, with the greatest likelihood of spread occurring among the pond plant industry and hobbyists. Actions that can prevent this pathway include encouraging organizations responsible for inspecting shipments to watch for NZMS; developing stronger inspection and quarantine requirements for shipments of aquarium and water garden organisms accompanied by requirements for the disposal of contaminated shipments; and conducting outreach to retailers and wholesalers who may purchase aquatic plants.

To address commercial activities:

- Create prohibitions for the import, possession, and/or release of NZMS/AIS (Action 1.5.a)

Strategy 1.6 Implement pathway-specific management actions to address firefighting activities

Firefighting equipment that crosses watersheds as well as tanker trucks and aircraft that draw water from NZMS-positive water sources have the potential to spread NZMS to uninfested waters. Preventive actions include making information available to firefighting entities on identifying positive AIS waterbodies; developing contingency plans to only draw water from those waterbodies when alternative sources are not available; and decontaminating equipment after use.

To address firefighting activities:

- Collaborate with firefighting organizations to communicate locations of NZMS positive waters and encourage contingency planning (Action 1.6.a)

Objective 2. Monitoring and Surveillance

Monitoring and surveillance are critical components of all invasive species management, and the methods, frequency, and intensity can vary depending on whether the purpose is surveillance or monitoring known infestations. There are three main purposes for NZMS monitoring and surveillance: 1) surveillance to inform subsequent rapid response efforts; 2) monitoring known infestations to document population changes or expansion of NZMS within a system; and 3) characterizing ecosystem impacts within invaded systems. Early detection coupled with rapid response is a foundation of invasive species management that prevents the spread of unwanted organisms such as NZMS. Timely surveillance ensures that NZMS are detected soon after introduction, enabling prompt action to contain them within an infested area and ideally eradicate the population.

NZMS can occur in all types of lentic (still) and lotic (moving) waters and substrates, including silt, sand, gravel, cobbles, boulders, leaf litter, organic detritus, algae, and aquatic macrophytes as well as any other type of stable substrate (natural or artificial). With such a wide variety of habitats capable of being invaded, no single surveillance method is applicable in all situations. See Appendix C for options for surveillance methods.

Strategy 2.1 Conduct surveillance in each state

Surveillance involving qualitative sampling techniques for the presence/absence of NZMS is all that is required. Detection is the first priority and is best achieved with visual inspection surveys or eDNA sampling followed up with visual inspections. These methods should aim to maximize efficiency so that surveys can be conducted at as many sites or waterbodies as possible starting with the highest priority waterbodies. Priority locations are likely adjacent or connected to current, documented NZMS populations, popular public use areas, or sensitive environments. Priority locations should be selected with input from the lead state management agency. The visual inspection survey method for NZMS outlined in Tank et al. 2021 is an excellent reference for implementing cost-effective surveillance for NZMS. Following a positive detection of NZMS, response measures should be taken that align with agency goals and the established rapid response plan (see Objective 3. Rapid Response to New Detections).

It is best to get as many groups involved in early detection surveillance as possible. State natural resource agencies should be conducting surveillance and encouraging other organizations to be on the lookout for NZMS. Any groups or individuals working near water, including community scientists, can conduct visual surveys due to the simplicity and speed of the method.

Surveillance should also be conducted at hatcheries on a routine basis (see Objective 1. Preventing Introduction and Secondary Spread) as part of facility-specific HACCP plans. Surveillance at hatcheries should be conducted at least quarterly, consistent with a standardized national protocol, or in absence of that, a protocol developed by staff both knowledgeable in hatchery operation and AIS.

In general, fishery workers and other resource professionals that work in aquatic systems should be recruited to conduct surveillance for NZMS, or minimally trained in NZMS identification, how to collect samples, and who to submit samples to for species identification. However, a more effective strategy may be to engage high-level resource management professionals who have the authority to direct their staff to conduct surveys. High-level institutional commitments are more likely to result in ongoing efforts and not cease if individual employees vacate positions.

Further research is needed to understand the probability of detection under varying environmental conditions and to refine early detection methods like environmental DNA. Results of this research will support the development of surveillance programs provide additional methods for early detection surveillance, and promote confidence in surveillance results.

To ensure increased field surveillance is promptly translated to reportable results:

- Encourage state agencies to conduct surveillance and report confirmed detections to USGS NAS database (Action 2.1.a)
- Form a working group of regional invertebrate/NZMS experts (Action 2.1.b)
- Develop a key of aquatic snails with an emphasis on lookalikes and non-native snails (Action 2.1.c)
- Establish a process and written protocol for confirming NZMS identification (Action 2.1.d)
- Engage watershed groups and government agencies collecting benthic invertebrate samples to collaborate on NZMS surveillance (Action 2.1.e)
- Conduct research to determine the probability of detection under varying scenarios (substrates, ecoregions, sampling methods, sampling designs) (Action 2.1.f)
- Conduct research to refine early detection methods (e.g., environmental DNA) (Action 2.1.g)

- Conduct research on NZMS biology and habitat suitability to prioritize surveillance efforts (2.1.h)
- Perform a nationwide ecological risk assessment that includes climate and water quality parameters using latest science on suitability (Action 2.1.i)

Strategy 2.2 Monitor established NZMS populations

Both quantitative and qualitative sampling techniques may be used to document NZMS population spread within watersheds. Qualitative sampling techniques are appropriate to detect the presence of NZMS in new locations within a system where they are already established. Quantitative sampling techniques allow for abundance estimates of NZMS populations and can be implemented to track changes in populations over time. Monitoring population expansion can help identify the pathways of spread in the system and in turn help direct management actions to address and interrupt those pathways.

Determining the impacts of established NZMS populations requires a well thought out study design and appropriate methodology for quantitative sampling for NZMS, other organisms, and the environment. NZMS sampling techniques should be selected based on habitat, collection goals, and specific substrates. In addition to NZMS monitoring, monitoring for other invertebrates and water quality may help determine ecosystem impacts and response over time.

To understand regional NZMS populations:

- Systematically monitor established NZMS populations (Action 2.2.a)

Strategy 2.3 Monitor ecosystem impacts

There is published research of NZMS impacts within local ecosystems at various locations around the U.S. However, the information does not fully encompass the wide variety of ecosystems, species, and natural processes, and therefore is inadequate for predicting potential impacts in a variety of ecosystems.

To fully understand the ecosystem impacts of NZMS:

- Conduct research to understand the short and long-term changes in ecosystem function resulting from NZMS infestations (Action 2.3.a)
- Conduct research to determine NZMS impacts to sensitive/at-risk fish and invertebrate species and their critical habitat (Action 2.3.b)

Objective 3. Rapid Response to New Detections

An effective and swift "rapid response" following the detection of a new population of NZMS is the product of pre-planning. Pre-planning should be coordinated among agencies with management authority and vested interests. Furthermore, the rapid response plan should define the parameters that trigger a rapid response; identify who will coordinate the response; define short- and long-term actions; and assign those actions to appropriate agencies, Tribes, and partners. A rapid response serves to contain NZMS within an infested area, suppress the increase of the population, and/or take action to eradicate it. All of these goals should be paired with actions to prevent NZMS from moving out of the area by pathways that contact infested waters.

States with AIS management plans may already have a model rapid response plan/framework that identifies a specific process and actions based on state, federal, local agency, Tribe, and partner coordination. States with an invasive species/AIS council may coordinate with that entity as necessary and define roles and responsibilities as appropriate. States without an AIS management plan or invasive species council should prepare to respond to NZMS/AIS detections in a format appropriate to their jurisdictional and capacities but inclusive of the same elements found in an AIS management plan. Those elements include establishing partnerships, defining authorities, and identifying specific representatives responsible for leading and making decisions. In the absence of clear authorities, the establishment of a process whereby decisions will be made may meet the need. The Federal Emergency Management Agency's Incident Command System is a readily accessible framework that applies very well to AIS response. Other organizations, such as Tribes, private entities, or local agencies, with the responsibility of managing waterbodies and waterways should develop and implement a rapid response plan that covers their specific jurisdiction and include state and federal agencies as partners.

One critical aspect of planning is anticipating possible scenarios before they happen. States and organizations can be ready to respond to new detections, including the determination of which action(s), if any, will be taken following a detection. These actions will differ based on the state, region, and area, but the one constant is having forethought in planning before NZMS detections arise. Rapid response planning is about preparedness to avoid chaotic reactive efforts. Planning, conducting surveillance, and effectively responding are the foundations of the Early Detection-Rapid Response paradigm.

Strategy 3.1 Develop and test a rapid response plan, and be prepared to implement it

NZMS rapid response plans should be created in partnership with other entities that will be involved with implementation. These plans should define the roles and responsibilities of those entities, determine what level of rapid response is appropriate for detections, and develop a response timeline. Each organization should commit to what resources they will contribute towards a rapid response. Keep in mind that rapid response plans should be actionable and achievable and need not be overly complex. Testing the applicability of a plan can help identify gaps and improve actual responses. Once a plan is complete, ongoing coordination with key implementing entities and partners should occur to reaffirm commitments and maintain engagement of designated points of contact. Lastly, programmatic environmental coverage for typical rapid response actions is necessary to ensure actions funded and/or implemented by federal agencies can be implemented quickly.

Ideally every waterbody would be surveyed for NZMS, and every new detection would trigger a rapid response. However, because resources are limited and responses to every detection are not possible, waters should be prioritized for NZMS response. Priorities may be based on factors deemed most important by each jurisdiction/managing authority, such as risk of introduction or further spread, implications of an infestation, uniqueness of environmental setting (such as sensitive species, recreational value), or other factors. In addition, response actions should be defined that will be taken for each priority level if NZMS are detected. For example, actions could include shifting outreach priorities, choosing not to stock fish into infested waters, or closing infested waterways to the public.

To be prepared to respond to new detections:

- Publish a rapid response template (Action 3.1.a)
- Develop a nationwide, programmatic NEPA review covering rapid response to AIS (Action 3.1.b)
- Develop State NZMS rapid response plan (Action 3.1.c)
- Develop watershed-specific NZMS rapid response plan (Action 3.1.d)
- Develop individual waterbody/facility rapid response plan (Action 3.1.e)

Objective 4. Management of in situ NZMS Infestations

There are known established infestations of NZMS in the Western and Eastern regions of the U.S., and future monitoring will likely reveal new established infestations that do not warrant a rapid response. Managers of infested waters must decide what actions to take in response, if any, to reduce the abundance of NZMS within an infested area (control) or eliminate NZMS from an infested area (e.g. facilities and closed water systems).

Control or eradication is necessary to protect other waters because every new waterbody that is infested with NZMS is a new potential source to infest other waters, both those nearby and distant. Regardless of which management goal is chosen, efforts to prevent NZMS from spreading outside of an infested area (containment) should occur in conjunction with planning and implementation of control or eradication efforts.

Control efforts are best achieved by developing a site-specific plan. If a rapid response was enacted to immediately address an infestation, the response can transition into a program with the purpose of ongoing containment/management. In small, isolated waters or at facilities, eradication may be a realistic goal; however, for large or interconnected waters that cannot be effectively treated, in locations where treatment would have unacceptable incidental impacts, or if there would be an ongoing potential for reinfestation, eradication may not be feasible. When eradication is not a realistic goal, a well-developed and executed containment plan coupled with population control may provide the best management option to minimize impacts and prevent further spread. Before implementing any strategy, it is important to consider the trade-offs that may occur (such as effects on non-target organisms, reduced access to the resource during and after a treatment, etc.) and the long- or short-term availability of resources (funds/staffing) to implement the effort.

Strategy 4.1 Develop and implement containment strategies
To prevent further spread from an established population, containment is a necessary component of managing any NZMS infestation. In absence of containment actions being defined as part of a rapid response to a new NZMS detection, a plan that defines containment should be developed and implemented for each infested waterbody/facility. The containment plan would identify the pathways by which NZMS could be moved from the waterbody or facility and what efforts can be taken to prevent NZMS from being moved out of the infested area. All situations will be unique given their environmental setting and prevailing constraints. Actions can range from outreach and education and promoting voluntary compliance to highly regulated and mandatory controls such as inspections of equipment or waterbody closures, and active containment. The true costs of NZMS containment, environmental, and recreational impacts are variable and challenging to quantify, however, they provide justification to gain support for action.

There are several active containment methods available including hydrocyclonic separation (Nielson et al. 2012), copper plate installation (Myrick and Conlin 2011; Hoyer and Myrick 2012), electric barrier installation (Oplinger et al. 2011), artificial turbulence, and artificial barriers. The method(s) that should be selected is the one that minimizes harm and is most effective.

To implement effective containment:

- Develop and implement a plan to contain NZMS within each infested water/facility (Action 4.1.a)
- Conduct an economic analysis to estimate the cost of managing an infestation plus the loss of ecosystem services (Action 4.1.b)

Strategy 4.2 Eradication and/or control

Eradication of NZMS populations is the ideal, yet likely most difficult outcome to achieve in managing NZMS. Eradication of NZMS has been attempted in facilities and open-water infestations and has proved challenging to achieve in both scenarios. Many of these eradication attempts have resulted in incomplete mortality of a population. While a failed eradication falls short of the intended goal, the effort can still be viewed as a successful control action, as it may reduce a population and thereby decrease the number of NZMS that can potentially be moved out of the infested area. A NZMS population that is drastically reduced may repopulate very quickly, but it is also possible that it will take several years, if ever, to return to the same level of infestation. The short- and long-term results of control actions are likely to vary by site.

The chemical and environment management eradication/control methods that have been employed previously are varied and should be considered site-specific. Manipulating physical conditions in a facility or the environment may offer a more benign approach to eliminating or reducing the number of NZMS in an infested area. These modifications may also offer the advantage of being applied consistently over the infested area. Any eradication or control effort should thoroughly consider the specific site conditions, desired outcome, applicable laws and regulations and chemical product label, and be implemented following a predetermined site-specific plan. Examples of chemical and physical options include hydrogen peroxide (Oplinger and Wagner 2009; Oplinger and Wagner 2015), bayluscide (Francis-Floyd et al. 1997; McMillin and Trumbo 2009), copper sulfate (Oliver et al. 2021), commercially available cleaners (Schisler et al. 2008; Oplinger and Wagner 2009; Stout et al. 2016), air drying (Alonso and Castro-Diez 2012; Richards et al. 2004), and freezing (Cheng and LeClair 2011). The applicability and efficacy of hot water, steam, and flame treatments should be explored.

In absence of eradication/control actions being defined as part of a rapid response to a new NZMS detection, a plan defining the management goal (eradication or control) and the actions to achieve that goal should be developed and implemented for each infested water and facility. Population monitoring should be a component of every eradication/control effort, as well as criteria by which progress, or success can be assessed. Periodically, the outcomes of the efforts should be assessed, goals reassessed, and efforts adjusted as appropriate.

To implement effective control and eradication:

- Develop and implement a plan to eradicate or control NZMS within infested waters and facilities (Action 4.2.a)
- Conduct research to evaluate the efficacy and feasibility of treatment options (chemical, physical removal, environmental modification) under various management contexts (open water and enclosed/facilities) (Action 4.2.b)

Objective 5. Education and Outreach

A successful effort to prevent, contain, and control NZMS will only be possible if an effective outreach and education campaign is developed and implemented. Any successful communication effort begins with a plan that establishes who the target audiences are, what the desired outcome is from these audiences, where these audiences will be reached, and how to reach them. Four primary audiences have been identified to be targeted with NZMS outreach efforts: resource allocators, agency administrators, natural resource management implementers, and the public. Each of these groups has unique messaging needs; as such, messages should be tailored for each group to ensure the greatest possibility of success.

Education and outreach efforts also must recognize that unlike invasive species with long and well-defined histories of major economic and ecological impacts (e.g., zebra mussels), NZMS impacts may “underwhelm” many audiences. Species impacts will vary between location, habitat, water conditions, temperature, and other co-existing organisms. Furthermore, many of the economic impacts of NZMS are more related to management actions to prevent spread (e.g., hatchery closures) than to the direct effects of the snails (i.e., those impacts would not exist if efforts to control the snails ceased). These factors may result in challenging “so what?” questions from target audiences, particularly those that seek answers in simple “sound bites.” Education and outreach messages will need to find a balance between providing sufficient information to explain why concern still exists (such as explanation of lag times and food web connections) versus losing audiences with too much information. Additionally, there needs to be a balance between overly exaggerating the risks versus failure to convince audiences that they should be concerned. Many of the education and outreach needs are relevant across audiences.

Strategy 5.1 Engage resource allocators

Resource allocators are those key individuals that can provide the financial and human resources needed to advance this effort (e.g., legislators). These individuals are (typically) not scientists and do not want to receive detailed specifics about the organism. Rather, they are concerned about how NZMS fit into a larger picture. Resource allocators want to know what the threat is, what the consequences of various actions are, what environmental and economic impacts the species might have, how it will affect the public, and why the species should be prioritized. To effectively reach this audience, outreach messaging needs to directly address their concerns and be delivered in a brief fashion, usually through a personal contact.

To engage resource allocators:

- Develop a GIS-based, interactive online map (e.g. ESRI storymap) to share with primary audiences (Action 5.1.a)

Strategy 5.2 Engage agency administrators

Agency administrators are another important group to directly target for outreach. These administrators are often resource allocators but also have the role of establishing priorities and policies for their agencies. These individuals need to be fully informed about NZMS before there is a need to respond. Agency administrators expect more detailed information than resource allocators that is inclusive of management options and strategies. Finally, agency administrators should be encouraged to commit to take action to secure the full cooperation of their implementation staff. Proactively preparing messaging to engage agency administrators will ensure you are prepared when the opportunity arises.

To engage agency administrators:

- Develop messaging defining what is at risk and necessary resources for action (Action 5.2.a)

Strategy 5.3 Engage natural resource management implementers

Natural resource management implementers are those individuals that work in aquatic and terrestrial environments. These individuals might be biologists, researchers, wardens, or others that undertake the actions identified as part of the strategy. The outreach goal for this group is twofold: 1) ensure that they understand and adopt any protocols that are established; 2) enlist these individuals as additional communicators to the public. Outreach strategies should be carefully crafted to ensure their enthusiastic support. First, this audience must be educated about the threat to the resource. They must clearly understand all aspects of identification, spread, control, and prevention. Finally, they must be prepared to share their knowledge with others. Most implementers need more information than any of the other target audiences previously mentioned. They need to understand the impacts and threats, pathways of spread, life history of the organism, methods of control, any cleaning or disinfection protocols, and how they can help or hurt the effort. They will need fact sheets, clearly defined protocols, research results, information on support resources, and outreach materials for public distribution.

To engage natural resource management implementers:

- Develop national messaging for adoption across states (5.3.a)
- Modernize messaging to include contemporary environmental concerns and modernize communication channels (5.3.b)
- Partner with other sectors to increase engagement in NZMS management (5.3.c)
- Host an annual survey blitz to promote surveillance by agencies and the public (5.3.d)

Strategy 5.4 Engage the public

The public includes everyone not otherwise captured on one of the three audiences defined above. The public is highly diverse with respect to their knowledge about environmental issues, personal values around the protection of natural resources, and participation in outdoor recreation. Because outdoor recreationists are the segment of the public having the greatest potential for spreading NZMS, concerted efforts are needed to reach them. Outreach messaging should focus on the adoption and sustained practice of preventative actions as a routine part of their recreational activities.

To maximize recreationist's engagement, messages, content, and communication channels should be tailored to individual user groups. Information that is specific to the user's activities and interests is more likely to resonate and spur action. Messages can be conveyed to individuals through a variety of outlets such as signs at recreational access points and various media platforms, or to groups through organizations. Partnering with organizations that work within watersheds or with user-specific groups leverages the power of trusted messengers in reaching the target audiences. In addition, public opportunities to participate in on the ground efforts, such as a national survey blitz or community scientist efforts, will cultivate an individual's connection to and investment in the natural resources around them.

To engage the public:

- Post NZMS signs at infested and high-priority waters to educate users (5.4.a)
- Develop user-specific outreach materials to connect the issue with their interests (5.4.b)
- Partner with NGOs to coordinate outreach and education activities (5.4.c)

Objective 6. Implementation, Information, and Data Management

Implementation of the goals, objectives, strategies, and actions defined in this plan would be more likely if there was oversight at a national level. In addition, oversight would ensure managers would have reliable access to information and expertise, a single repository for data on the known distribution of NZMS, past and recent developments in management options, and the latest outreach and education materials to adapt to their needs. Coordination will enable managers to make informed management decisions and address needs within their respective jurisdictions.

Strategy 6.1 Coordination

National oversight of the implementation of this plan will ensure efforts are prioritized and coordinated, and progress is tracked. This oversight will ensure consistency where appropriate, and that the outputs of everyone's collective efforts remain accessible to all involved, and the public.

For effective coordination:

- It is recommended that an advisory group is formed to oversee the National New Zealand Mudsnail Management Plan implementation and adaptive management of objectives, strategies, and actions (Action 6.1.a)

Strategy 6.2 Information Management

To effectively address NZMS, states, watershed managers, and councils need to be able to access information and contact NZMS experts. The information needs to be readily accessible. Online resources would include published site-specific management plans, open-access scientific articles, fact sheets, identification guides, outreach and education materials, snail identification guides, a list of expert contacts, and other useful resources for states and partners to access. These resources would be especially useful for states that have emerging NZMS detection reports or are looking to start NZMS management efforts.

To increase information management:

- Assemble a "living list" of experts to be a resource for questions and information and include each expert's area of expertise (6.2.a)
- Identify a host to create, organize, and maintain an electronic library (6.2.b)

Strategy 6.3 Data Management

State agencies, invasive species councils, and watershed managers need access to data on the national distribution of NZMS to inform management efforts. USGS NAS maintains national distribution maps on invasive species, including NZMS. State AIS coordinators should be engaged in confirming the species identification prior to any new detections being published on the NAS website. Universities, nonprofit organizations, and the public can all submit NZMS reports and contribute to the distribution mapping effort.

The sophisticated mapping capability of the USGS NAS database allows for easy input of new detections and provides a dynamic, up-to-date, and interactive range map for the species. The NAS database is the central repository for non-native aquatic species data and tracks species occurrences across the U.S. and its territories from the 1800s to present. Each occurrence in the NAS database is represented by a point that provides a description of the site and estimates of abundance if that information was reported with the detection report. The USGS NAS website will serve as the master database for publishing NZMS detections and mapping the national distribution. This central repository will provide states and watershed managers the most comprehensive source of information on reported detections across the U.S. of not only NZMS but all AIS. Having a master database will help with prevention and management activities and provide insight into invasion patterns, abundance, and range limitations. The NAS database gathers data from a variety of sources, including reports from managers and scientists, data harvests from scientific journals, and museums. All data from community science reports, other databases, and news reports are independently verified.

For effective data management:

- Promote NAS website as the central reporting website for detections of NZMS (6.3.a)

Plan Oversight and Evaluation

The goals of this national management plan are to protect natural ecosystems, the environment, and the economy from the negative impacts of NZMS, equip and mobilize organizations to take action to prevent the spread of NZMS and respond to new detections, contain and control infestations, and facilitate coordination and collaboration among all levels of government, Tribes, and non-governmental organizations through leadership at a national level. Among the highest priority actions of this plan is the formation of an advisory committee that will be responsible for overseeing implementation of this plan, tracking completion of actions, providing accessible platforms for information sharing, garnering fiscal support, and leading implementation of actions that can only be undertaken by agencies with specific roles and authorities.

The primary metric for assessing implementation of this plan is tracking the completion of the prioritized recommended actions. Some actions have discrete deliverables, while implementation of others will be diffuse and ongoing. Completion of these ongoing actions will be more difficult to characterize and track, and the advisory committee will be best suited to determine how implementation of ongoing actions are appropriately characterized. The advisory committee would report annually to the ANSTF on progress made in implementation of the plan.

This plan identifies several high-priority research needs aimed at better understanding the impacts of NZMS and expanding the suite of tools available to manage NZMS. While this plan was developed with a 5-year horizon, it is possible the outcomes of this research, or other factors not contemplated in this plan, may warrant revisiting the objectives and actions herein. In either case, a concerted effort to revisit the plan goals, objectives, and strategies should be undertaken as warranted, and under the leadership of the advisory committee. Many of the actions include publications as deliverables marking their completion. These publications, and products of other actions, should be readily available to anyone who is interested. These products will promote collaboration and economize efforts across organizations. The advisory committee would also be key in creation and maintenance of internet-based information hubs.

Implementation Tables

The following tables summarize all of the actions described within each of the six objectives. Each action is assigned a qualitative priority of high, medium, or low based on its contribution to achieving the plan goals and objectives and/or the dependance of it for the implementation of other high priority actions. Where applicable, short and long-term needs necessary to implement the action are identified. A benchmark for declaring the action complete is defined under completion criteria. When possible, the cost to complete the action is estimated (2024 dollars) based on estimated hours necessary to complete the action multiplied by the hourly labor rate of an appropriate classification. To aid a higher-level view of costs across all actions, a relative cost was assigned to each ($0 - $10,000 = $, $10,001 - $100,000 = $$, $100,001 - $500,000 = $$$, and >$500,001 = $$$$).

Objective 1 Implementation Table. Preventing Introduction and Secondary Spread

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
1.1 Address recreational equipment	a. Develop and promote implementation of cleaning protocols for various types of equipment	High	Review published literature on techniques and efficacy for cleaning and develop a protocol	Distribute protocol in various forms and revise protocol as more effective techniques are developed	Published cleaning protocol	$48,000	$$
1.1 Address recreational equipment	b. Provide resources to the public to facilitate field cleaning of gear (bristle brushes, dunk buckets, wash stations, wash kits,)	High	Identify locations for brushing or cleaning stations, prioritizing high-risk waterbodies	Purchase, install, and maintain stations	Functional cleaning station maintained over time	$450 per location	$
1.1 Address recreational equipment	c. Partner with national recreational organizations and retailers to promote NZMS prevention and containment	Medium	Identify the organization and a point of contact for each appropriate organization	Maintain ongoing partnerships	Messaging is in partner's consumer information	Unknown; scope dependent	$
1.1 Address recreational equipment	d. Conduct research to evaluate the efficacy and applicability of cleaning options to address the risk of spread by specific user groups	Low	Define products, equipment, and study design	Perform the research	Published research	Unknown	$-$$

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
1.2 Address professionals working in aquatic environments	a. Incorporate equipment decontamination requirements for any activities in waterbodies	Low	None	Permitting agencies require decontamination as conditions to permits for work in aquatic environments. Where no regulatory authority exists, promote voluntary action	Agencies adopting the inclusion of decontamination requirements in permitted activities	$2,400	$
1.3 Address fish production, stocking, and translocation	a. Develop HACCP plans for each hatchery	High	Identify federal point(s) of contact to provide technical assistance on HACCP plan development	Develop HACCP plans and implement them in perpetuity in hatchery operations	Completed HACCP plans for each hatchery and implementation of HACCP at control points	$2,400 per hatchery per year	$
1.3 Address fish production, stocking, and translocation	b. Develop standardized NZMS inspection protocol for hatcheries	Medium	Convene working group to draft an inspection protocol for all types of hatcheries	Finalize and distribute inspection protocol	Publish standardized inspection protocol	$96,000	$$
1.3 Address fish production, stocking, and translocation	c. Conduct NZMS/AIS inspections at all hatcheries	High	None	Implement at least quarterly inspections per the protocol	Completed hatchery NZMS/AIS inspections	$2,400 per hatchery per year	$
1.3 Address fish production and stocking	d. Conduct research to determine which fish species consume NZMS and, if so, the transit time through their gastrointestinal tract	Medium	Identify which fish species to research based on the hatcheries that already have NZMS	Perform the research	Published research	Unknown	$-$$
1.4 Address recreational motorized watercraft and trailers	a. Promote implementation of "Clean Drain Dry"	Low	Identify gaps in outreach and ensure the tools are available to motorized watercraft users and water managers	Implement actions to address gaps in outreach	Ongoing promotion of messaging	$4,800	$

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
1.5 Address commercial activities	a. Create prohibitions for the import, possession, and/or release of NZMS/AIS	High	Create enforceable laws/regulations/rules that prohibit AIS from being moved across state lines	Promote enforcement and education on laws/regulations/rules	Development, implementation, and enforcement of laws/regulations/rules	Unknown; scope dependent	$$$$
1.6 Address firefighting activities	a. Collaborate with firefighting organizations to communicate locations of NZMS-positive waters and encourage contingency planning	Low	Assess current operation and maintenance procedures for risk of spread	Implementation of avoidance and prevention measures by firefighters	Implementation of avoidance and prevention measures	Unknown; scope dependent	$$

Objective 2 Implementation Table. Monitoring and Surveillance

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
2.1 Conduct surveillance in each state	a. Encourage state agencies to conduct surveillance and report confirmed detections to USGS NAS database	High	Dedicate resources to conduct surveillance; determine where surveillance efforts should be focused; train staff to conduct surveillance	Document all results (presence and absence)	Completion of surveys and reports of confirmed detections to USGS NAS	$400 per survey	$
2.1 Conduct surveillance in each state	b. Form a working group of regional invertebrate/NZMS experts	High	Create the list of expert contacts by state/regional panel	Develop snail identification tools and processes	Establishment of working group and list of working group members	$8,000	$
2.1 Conduct surveillance in each state	c. Develop a key of aquatic snails with an emphasis on lookalikes and non-native snails	Low	Completion of Objective 2, Strategy 2.1, Action B	Distribute key to states, organizations, and public	Development and distribution of a snail identification key	$25,000	$$
2.1 Conduct surveillance in each state	d. Establish a process and written protocol for confirming NZMS identification	High	Completion of Objective 2, Strategy 2.1, Action B	Implementation of process and written protocol	Development and distribution of written protocol	$25,000	$$
2.1 Conduct surveillance in each state	e. Engage watershed groups and government agencies collecting benthic invertebrate samples to collaborate on NZMS surveillance	Low	Identify other groups and agencies involved with invertebrates; contact organizations and educate them about NZMS	Maintain contact and support organizations conducting surveillance that includes NZMS	Commitment from other monitoring groups to include surveillance for and reporting of NZMS detections.	$5,000	$
2.1 Conduct surveillance in each state	f. Conduct research to determine the probability of detection under varying scenarios (substrates, ecoregions, sampling methods, sampling designs)	Low	Define conditions, methods, and study design	Perform the research	Published research	Unknown	$-$$

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
2.1 Conduct surveillance in each state	g. Conduct research to refine early detection methods (e.g., environmental DNA)	Medium	None	Perform the research	Published research	Unknown	$$
2.1 Conduct surveillance in each state	h. Conduct research on NZMS biology and habitat suitability to prioritize surveillance efforts	Low	Identify research questions and study design; Perform the research	Prioritize surveillance based on the results of the research	Published research	Unknown	$-$$
2.1 Conduct surveillance in each state	i. Perform a nationwide ecological risk assessment that includes climate and water quality parameters using latest science on suitability	High	Gather information on limiting conditions, environmental conditions, and projected future climate conditions to inform the risk assessment	Evaluate data and prepare the risk assessment	Published risk assessment to aid states in prioritizing waters	$40,000	$$
2.2 Monitor established NZMS populations	a. Systematically monitor established NZMS populations	Low	Select infested waters to monitor and develop a monitoring plan based on desired goals and outcomes	Commit resources for the duration and intensity as defined in the monitoring plan	Completion of systematic monitoring and sharing of results	Unknown; scope dependent	$$
2.3 Monitor ecosystem impacts	a. Conduct research to understand the short and long-term changes in ecosystem function resulting from NZMS infestations	High	Identify research locations and study design	Perform the research	Published research	Unknown	$$
2.3 Monitor ecosystem impacts	b. Conduct research to determine NZMS impacts to sensitive/at-risk fish and invertebrate species and their critical habitat	High	Identify research locations, species, and study design	Perform the research	Published research	Unknown	$$

Objective 3 Implementation Table. Rapid Response to New Detections

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
3.1 Rapid response planning	a. Publish a rapid response plan template	High	Develop template and distribute to all organizations involved with NZMS management	Annually review template and update as necessary	Published rapid response plan template	$50,000	$$
3.1 Rapid response planning	b. Develop a nationwide, programmatic NEPA review covering rapid response to AIS	High	Identify the suite of likely rapid response actions	Complete the NEPA process	Completed programmatic NEPA review for rapid response actions	Unknown	$$$
3.1 Rapid response planning	c. Develop State NZMS rapid response plan	Medium	Engage all entities with authority or interests in managing NZMS and form a working group	Annually review rapid response plan and update as necessary	Published state NZMS rapid response plan	$50,000 per State	$$
3.1 Rapid response planning	d. Develop watershed-specific NZMS rapid response plan	Medium	Engage all entities with authority or interests in managing NZMS in that watershed and form a working group	Annually review rapid response plan and update as necessary	Published watershed-specific NZMS rapid response plan	$50,000 per watershed	$$
3.1 Rapid response planning	e. Develop individual waterbody/facility rapid response plan	Low	Compile a list of waterbodies and facilities for each state; incorporate input from the working group on the decisions	Determine management effort for each waterbody/facility	List of waterbody/facilities by state with response actions described	$50,000 per waterbody/ facility	$$

Objective 4 Implementation Table. Management of in situ NZMS Infestations

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
4.1 Containment	a. Develop and implement a plan to contain NZMS within each infested water/facility	Medium	Completion of Objective 2, Strategy 2.1, Actions A-E	None	Development of a site-specific plan and implementation of actions to manage pathways	$0-$100,000	$-$$
4.1 Containment	b. Conduct an economic analysis to estimate the cost of managing an infestation plus the loss of ecosystem services	Low	Identify a location(s) for a case study	Perform the analysis	Published economic analysis	Unknown	$$
4.2 Eradication and/or control	a. Develop and implement a plan to eradicate or control NZMS within each infested waters and facilities	Medium	Completion of Objective 2, Strategy 2.1, Actions A-E	None	Development of site-specific plan and implementation of eradication/control actions	Unknown; scope dependent	$$$
4.2 Eradication and/or control	b. Conduct research to evaluate the efficacy and feasibility of treatment options (e.g., chemical, physical removal, environmental modification) under various management contexts (open water and enclosed/facilities,)	Low	Determine study design	Perform the research	Published research	Unknown	$$

Objective 5 Implementation Table. Education and Outreach

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
5.1 Engage resource allocators	a. Develop a GIS-based, interactive online map (e.g. ESRI storymap) to share with primary audiences	Low	Identify an editor and draft an ESRI storymap using USGS NAS data	Edit map as new NZMS information becomes available or changes	Published ESRI storymap	$6,000	$
5.2 Engage agency administrators	a. Develop messaging defining what is at risk and necessary resources for action	Low	Assess NZMS status and needs within respective jurisdiction	None	Finalized messaging for current and future administrators	$25,000	$$
5.3 Engage natural resource management implementers	a. Develop national messaging for adoption across states	Low	Form working group and secure expertise to develop national NZMS messaging	Everyone involved in NZMS management consistently promote messaging	Finalized messaging and adoption by states	$500,000	$$$
5.3 Engage natural resource management implementers	b. Modernize messaging to include contemporary environmental concerns and modernize communication channels	Medium	Review published research on environmental effects of NZMS and identify modern communication channels optimal for reaching target audiences	Revisit messaging annually to adopt new communication channels	Finalized updated messaging	$50,000 initial	$$
5.3 Engage natural resource management implementers	c. Partner with other sectors to increase engagement in NZMS management	Low	Engage other professions and educate them on NZMS threat and management	Check in with contacts to maintain their engagement and provide support as needed	Establishment and maintaining relationships with other professionals	$1,000 per contact	$
5.3 Engage natural resource management implementers	d. Host an annual survey blitz to promote surveillance by agencies and the public	Low	Assemble small working group to determine survey blitz details and advertise survey blitz to all organizations involved with NZMS and the public	Annually host the event	Annual hosted survey	$100,000	$$

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
5.4 Engage the public	a. Post NZMS signs at infested and high-priority waters to educate users	High	Determine where signs should be posted; design and order signs or use existing designs	Monitor signage for damage or replacement	Signage installed at infested waters	$350 per location	$
5.4 Engage the public	b. Develop user-specific outreach materials that connect the issue to their interests	Medium	Identify an appropriate service provider	None	Tailored outreach materials developed for user groups	$200,000	$$$
5.4 Engage the public	c. Partner with NGOs to coordinate outreach and education activities	High	Build relationship with NGOs and identify outreach and education opportunities	Maintain relationship with NGOs and provide support as needed	Coordinated outreach and education	Unknown; scope dependent	$$

Objective 6 Implementation Table. Implementation, Information, and Data Management

Strategy	Actions	Priority	Short-term Needs	Long-term Needs	Deliverable	Estimated Costs	Relative Costs
6.1 Coordination	a. It is recommended that an advisory group is formed to oversee the National New Zealand Mudsnail Management Plan implementation and adaptive management of objectives, strategies, and actions	High	Form the advisory group	Oversee the advisory group to adaptively manage implementation the objectives, strategies, and actions of the plan	Formed advisory group		
6.2 Information Management	a. Assemble a "living list" of experts to be a resource for questions and information and include each expert's area of expertise	Medium	Identify people willing to be points of contact	Annually revisit the "living list" to update	A contact list of NZMS experts and their area(s) of expertise	$5,000	$
6.2 Information Management	b. Identify a host to create, organize, and maintain an electronic library	High	Identify a library host; gather and organize NZMS documents; upload and allow state agencies and water managers to access and use	Maintain the host function and ongoing additions	Available electronic library	$24,200 first year; $19,200 per year thereaf ter	$$
6.3 Data Management	a. Promote NAS website as the central reporting website for detections of NZMS	High	None	Promotion of ongoing reporting of detections and subscriptions to NAS database automated alerts	All states reporting to NAS website	$1,000	$

Summary

New Zealand mudsnails (NZMS) are present in the West and Northeast, however much of the U.S. appears uninvaded. Therefore, it is important to continue to maintain the prevention efforts that have likely reduced their spread. Implementation of the actions identified in this plan support Executive Order No. 13751, protecting the unique environments and species dependent on them throughout the U.S., human and animal health, and the economy. The actions identified in this plan will continue to prevent the introduction of NZMS, prevent their spread from infested waters, and reduce the impacts of established populations. Greater surveillance and monitoring for NZMS will provide a better picture of their range, enable containment and population suppression, and increase our understanding of their impacts to invaded waterbodies. Many of the actions in this plan build on our past and current efforts, and advance needed additional action. While some actions require leadership by specific agencies, many others can be advanced by Tribes, partners, and the public, as everyone who works within or around freshwater plays a critical role in preventing the spread of NZMS.

Successful management of NZMS requires collaboration between governmental, Tribal, and non-governmental organizations. With many states and watersheds at different stages of invasion, sharing knowledge and communicating lessons learned is instrumental in stopping the spread of NZMS. Substantial research has been conducted since the publication of the 2007 plan, which supports the current framework of national NZMS management. This plan identifies research needs that will help fill in the gaps and establish a solid foundation for management. With our collective efforts, we will continue to prevent the spread of NZMS while simultaneously working to develop and improve our tools and information necessary to respond to, contain, and manage infestations, thereby protecting aquatic environments across the U.S.

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Appendices

Appendix A. State laws applicable to preventing the introduction and spread of New Zealand mudsnail

State laws range from comprehensive prohibition (key terms being illegal to "import," "possess," "transport," and "release") to no restrictions. Among the states with laws, the wording of each law varies and may include some but not all key words. This fact does not de facto make these laws insufficient if they only include prohibition of "release;" however, when coupled with prohibitions on importation, possession, and transport, there is greater opportunity to regulate pathways by which New Zealand mudsnail spread. This table summarizes the laws by state to demonstrate the variety of approaches and to identify opportunities for strengthening laws to prevent further introduction and spread of New Zealand mudsnail within and across states.

State	Prohibit NZMS importation?*	Prohibit NZMS possession?*	Prohibit NZMS release?*	Applicable law(s)
Alabama	No	No	Yes	Alabama 220-2-.129 Public Water Stocking
Alaska	Yes	Yes	Yes	5 Alaska Administrative Code (ACC) Section 41.075
Arizona	Yes	Yes	Yes	A.R.S. Section 17-255: AIS Interdiction Act; AAC R12-4-406
Arkansas	Yes	Yes	Yes	Arkansas Code of Regulations 26.13, Addendum J1.01 and J1.03, Reg 26.12
California	Yes	Yes	Yes	California Code of Regulations Title 14, Section 671; California Fish and Game Code Section 6400
Colorado	Yes	Yes	Yes	Colorado Revised Statutes 33 and 35; and Chapter P-8 – Aquatic Nuisance Species
Connecticut	Yes	Yes	Yes	Conn. Agencies Regs 26-55-5
Delaware	No	No	No	None
Florida	No data found	No data found	No data found	No data found
Georgia	Yes	Yes	Yes	GA Board Rule 391-4-8-.05; Official Code of Georgia, Title 27, CH 5, Section 27-5-7; Section 27-1-2
Hawaii	No data found	No data found	No data found	No data found
Idaho	Yes	No	Yes	02.06.09 – 123 – Rules Governing Invasive Species and Noxious Weeds, Exempt Species
Illinois	No	No	No	None
Indiana	No	No	No	None

State	Prohibit NZMS importation?*	Prohibit NZMS possession?*	Prohibit NZMS release?*	Applicable law(s)
Iowa	Yes	Yes	Yes	Iowa Code 456A.37; Iowa Administrative Rule 571.90
Kansas	Yes	Yes	Yes	Kansas Administrative Regulations 115-18-10
Kentucky	Yes	Yes	Yes	301 KAR 1:122
Louisiana	No	No	Yes	LA R.S. 318; LA R.S. 319
Maine	No	No	No	None
Maryland	Yes	Yes	Yes	Code of Maryland Regulations, Title 08, Subtitle 02, Chapter 08.02.19, Section 08.02.19.04
Massachusetts	No	Yes	Yes	AIS Transportation Law
Michigan	Yes	Yes	Yes	Part 413. Transgenic and Nonnative Organisms, Natural Resources and Environmental Protection Act 451 of 1994, as amended
Minnesota	Yes	Yes	Yes	Minnesota Administrative Rules – 6216.0250, Subp 4
Mississippi	No	No	No	NZMS are listed as a “prohibited” species in the state AIS plan; no legal status
Missouri	No	No	No	None
Montana	No	Yes	No	Rule 12.6.22; Rule 12.6.2215; Rule 12.6.2201; Rule 12.6.2220
Nebraska	Yes	Yes	Yes	Nebraska Admin Code, Title 163, Ch 2, Sec 012, Subp 012.02
Nevada	Yes	Yes	Yes	NRS Title 45 – Wildlife NRS 503.597 – Chapter 503 and AB167 Aquatic Invasive Species Act
New Hampshire	Yes	Yes	Yes	CHAPTER Fis 800; Statutory Authority: RSA 207:14, RSA 211:62-e, RSA 211:64 and RSA 212:25
New Jersey	No data found	No data found	No data found	No data found
New Mexico	No data found	No data found	No data found	No data found
New York	Yes	Yes	Yes	NY Codes, Rules and Regulations – Title 6, Chapter V, Subchapter C, Part 575.3
North Carolina	No	No	No	None
North Dakota	Yes	Yes	No	North Dakota Century Code 20.1-17-06
Ohio	Yes	Yes	No	Ohio Administrative Code 1501:31-19-01
Oklahoma	No	No	Yes	OK Admin Code 800:20-2-3
Oregon	Yes	Yes	No	Oregon Secretary of State – Chapter 635, Div 56, sec 0040

State	Prohibit NZMS importation?*	Prohibit NZMS possession?*	Prohibit NZMS release?*	Applicable law(s)
Pennsylvania	No	No	Yes	58 Pa. Code Chapter 71a
Rhode Island	Yes	Yes	No	Rhode Is. Code of Regs. Title 250, Ch 40, SubC 05. Part 3.17, Sec A-1 b.
South Carolina	Yes	Yes	Yes	Title 50, Chapter 16 – Importation of Wildlife
South Dakota	Yes	Yes	No	South Dakota Codified Laws – Title 41, Chapter 13A, Section 41-13A-2
Tennessee	Yes	Yes	Yes	Tennessee Code Annotated 70-4-401, 70-4-403, 40-4-412
Texas	Yes	Yes	Yes	Parks and Wildlife Code Sec. 66.007 and Texas Administrative Code Title 31 Ch 57.113(b)(1)
Utah	Yes	Yes	Yes	Utah Admin. Code R657-3-22-2(o)
Vermont	Yes	Yes	No	10 VSA 1454; 10 V.S.A. § 4709
Virginia	Yes	Yes	Yes	Code of Virginia. Article 7. Nonindigenous ANS Act 29.1-574 Prohibitions Admin Code – 4VAC15-20-210 A(2)a A.
Washington	Yes	Yes	Yes	Washington Administrative Code 220-640-050 and Revised Code of Washington 77.135.040
West Virginia	Yes	Yes	Yes	West Virginia Code (20-1-2, 20-2-13, 20-2-64)
Wisconsin	Yes	Yes	Yes	Wisconsin Administrative Code NR 40
Wyoming	Yes	Yes	Yes	Wyoming State Statue Title 23, Chapter 4, Article 202 and Wyoming Chapter 62

*** Unless otherwise authorized**

Appendix B. Federally listed species with potential to be impacted by New Zealand mudsnail

If New Zealand mudsnail were to invade the freshwater habitats of sensitive species, it would likely present an additional challenge to their recovery. The following Federally-listed species may be affected by the introduction of New Zealand mudsnail into their range. This list includes listed species as of July 2023 that spend all or a portion of their lives in freshwater environments.

Amphibians	Common Name	USFWS Region	ESA Listing Status
Ambystoma californiense	California tiger salamander	8	Endangered
Ambystoma cingulatum	Frosted Flatwoods salamander	4	Threatened
Ambystoma macrodactylum croceum	Santa Cruz long-toed salamander	8	Endangered
Ambystoma mavortium stebbinsi	Sonoran tiger salamander	2	Endangered
Anaxyrus baxteri	Wyoming toad	6	Endangered
Anaxyrus californicus	Arroyo (=arroyo southwestern) toad	8	Endangered
Anaxyrus canorus	Yosemite toad	8	Threatened
Anaxyrus williamsi	Dixie Valley toad	8	Endangered
Bufo houstonensis	Houston toad	2	Endangered
Cryptobranchus alleganiensis alleganiensis	Eastern hellbender	3	Endangered
Cryptobranchus alleganiensis bishopi	Ozark hellbender	3	Endangered
Eurycea chisholmensis	Salado salamander	2	Threatened
Eurycea nana	San Marcos salamander	2	Threatened
Eurycea naufragia	Georgetown salamander	2	Threatened
Eurycea rathbuni	Texas blind salamander	2	Endangered
Eurycea sosorum	Barton Springs salamander	2	Endangered
Eurycea tonkawae	Jollyville Plateau salamander	2	Threatened
Eurycea waterlooensis	Austin blind salamander	2	Endangered
Necturus alabamensis	Black warrior (=Sipsey Fork) waterdog	4	Endangered
Necturus lewisi	Neuse River waterdog	4	Threatened
Peltophryne lemur	Puerto Rican crested toad	4	Threatened
Rana chiricahuensis	Chiricahua leopard frog	2	Threatened
Rana draytonii	California red-legged frog	8	Threatened

Rana muscosa	Mountain yellow-legged frog	8	Endangered
Rana pretiosa	Oregon spotted frog	1	Threatened
Rana sevosa	dusky gopher frog	4	Endangered
Rana sierrae	Sierra Nevada yellow-legged frog	8	Endangered
Clams	**Common Name**	**USFWS Region**	**ESA Listing Status**
Alasmidonta atropurpurea	Cumberland elktoe	4	Endangered
Alasmidonta heterodon	Dwarf wedgemussel	5	Endangered
Alasmidonta raveneliana	Appalachian elktoe	4	Endangered
Amblema neislerii	Fat threeridge (mussel)	4	Endangered
Arcidens wheeleri	Ouachita rock pocketbook	2	Endangered
Cumberlandia monodonta	Spectaclecase (mussel)	3	Endangered
Cyprogenia stegaria	Fanshell	4	Endangered
Dromus dromas	Dromedary pearlymussel	4	Endangered
Elliptio chipolaensis	Chipola slabshell	4	Threatened
Elliptio lanceolata	Yellow lance	4	Threatened
Elliptio spinosa	Altamaha Spinymussel	4	Endangered
Elliptoideus sloatianus	Purple bankclimber (mussel)	4	Threatened
Epioblasma brevidens	Cumberlandian combshell	4	Endangered
Epioblasma capsaeformis	Oyster mussel	4	Endangered
Epioblasma florentina curtisii	Curtis pearlymussel	3	Endangered
Epioblasma florentina florentina	Yellow blossom (pearlymussel)	4	Endangered
Epioblasma florentina walkeri (=E. walkeri)	Tan riffleshell	4	Endangered
Epioblasma metastriata	Upland combshell	4	Endangered
Epioblasma obliquata	Purple Cat's paw (=Purple Cat's paw pearlymussel)	3	Endangered
Epioblasma othcaloogensis	Southern acornshell	4	Endangered
Epioblasma penita	Southern combshell	4	Endangered
Epioblasma perobliqua	White catspaw (pearlymussel)	3	Endangered
Epioblasma rangiana	Northern riffleshell	5	Endangered
Epioblasma torulosa gubernaculum	Green blossom (pearlymussel)	4	Endangered

Epioblasma torulosa torulosa	Tubercled blossom (pearlymussel)	4	Endangered
Epioblasma triquetra	Snuffbox mussel	3	Endangered
Epioblasma turgidula	Turgid blossom (pearlymussel)	4	Endangered
Fusconaia burkei	Tapered pigtoe	4	Threatened
Fusconaia cor	Shiny pigtoe	4	Endangered
Fusconaia cuneolus	Finerayed pigtoe	4	Endangered
Fusconaia escambia	Narrow pigtoe	4	Threatened
Fusconaia masoni	Atlantic pigtoe	4	Threatened
Fusconaia subrotunda	Longsolid	4	Threatened
Hamiota altilis	Finelined pocketbook	4	Threatened
Hamiota australis	Southern sandshell	4	Threatened
Hamiota perovalis	Orangenacre mucket	4	Threatened
Hamiota subangulata	Shinyrayed pocketbook	4	Endangered
Hemistena lata	Cracking pearlymussel	4	Endangered
Lampsilis abrupta	Pink mucket (pearlymussel)	3	Endangered
Lampsilis higginsii	Higgins eye (pearlymussel)	3	Endangered
Lampsilis powellii	Arkansas fatmucket	4	Threatened
Lampsilis rafinesqueana	Neosho mucket	4	Endangered
Lampsilis streckeri	Speckled pocketbook	4	Endangered
Lampsilis virescens	Alabama lampmussel	4	Endangered
Lasmigona decorata	Carolina heelsplitter	4	Endangered
Lemiox rimosus	Birdwing pearlymussel	4	Endangered
Leptodea leptodon	Scaleshell mussel	3	Endangered
Margaritifera hembeli	Louisiana pearlshell	4	Threatened
Margaritifera marrianae	Alabama pearlshell	4	Endangered
Medionidus acutissimus	Alabama moccasinshell	4	Threatened
Medionidus parvulus	Coosa moccasinshell	4	Endangered
Medionidus penicillatus	Gulf moccasinshell	4	Endangered
Medionidus simpsonianus	Ochlockonee moccasinshell	4	Endangered
Medionidus walkeri	Suwannee moccasinshell	4	Threatened
Obovaria choctawensis	Choctaw bean	4	Endangered

Obovaria retusa	Ring pink (mussel)	4	Endangered
Obovaria subrotunda	Round hickorynut	4	Threatened
Parvaspina collina	James spinymussel	5	Endangered
Parvaspina steinstansana	Tar River spinymussel	4	Endangered
Pegias fabula	Littlewing pearlymussel	4	Endangered
Plethobasus cicatricosus	White wartyback (pearlymussel)	4	Endangered
Plethobasus cooperianus	Orangefoot pimpleback (pearlymussel)	4	Endangered
Plethobasus cyphyus	Sheepnose mussel	3	Endangered
Pleurobema athearni	Canoe Creek clubshell	4	Endangered
Pleurobema clava	Clubshell	5	Endangered
Pleurobema curtum	Black clubshell	4	Endangered
Pleurobema decisum	Southern clubshell	4	Endangered
Pleurobema furvum	Dark pigtoe	4	Endangered
Pleurobema georgianum	Southern pigtoe	4	Endangered
Pleurobema hanleyianum	Georgia pigtoe	4	Endangered
Pleurobema marshalli	Flat pigtoe	4	Endangered
Pleurobema perovatum	Ovate clubshell	4	Endangered
Pleurobema plenum	Rough pigtoe	4	Endangered
Pleurobema pyriforme	Oval pigtoe	4	Endangered
Pleurobema strodeanum	Fuzzy pigtoe	4	Threatened
Pleurobema taitianum	Heavy pigtoe	4	Endangered
Pleuronaia dolabelloides	Slabside pearlymussel	4	Endangered
Pleuronaia gibber	Cumberland pigtoe	4	Endangered
Popenaias popeii	Texas hornshell	2	Endangered
Potamilus capax	Fat pocketbook	4	Endangered
Potamilus inflatus	Inflated heelsplitter	4	Threatened
Ptychobranchus greenii	Triangular kidneyshell	4	Endangered
Ptychobranchus jonesi	Southern kidneyshell	4	Endangered
Ptychobranchus subtentus	Fluted kidneyshell	4	Endangered
Quadrula cylindrica cylindrica	Rabbitsfoot	4	Threatened
Quadrula cylindrica strigillata	Rough rabbitsfoot	5	Endangered

Quadrula fragosa	Winged mapleleaf	3	Endangered
Quadrula stapes	Stirrupshell	4	Endangered
Reginaia rotulata	Round ebonyshell	4	Endangered
Theliderma intermedia	Cumberland monkeyface (pearlymussel)	4	Endangered
Theliderma sparsa	Appalachian monkeyface (pearlymussel)	5	Endangered
Toxolasma cylindrellus	Pale lilliput (pearlymussel)	4	Endangered
Villosa fabalis	Rayed bean	3	Endangered
Villosa perpurpurea	Purple bean	5	Endangered
Villosa trabalis	Cumberland bean (pearlymussel)	4	Endangered
Crustaceans	**Common Name**	**USFWS Region**	**ESA Listing Status**
Antrolana lira	Madison cave isopod	5	Threatened
Cambarus aculabrum	Benton County cave crayfish	4	Endangered
Cambarus callainus	Big Sandy crayfish	5	Threatened
Cambarus cracens	Slenderclaw crayfish	4	Endangered
Cambarus veteranus	Guyandotte River crayfish	5	Endangered
Cambarus zophonastes	Hell Creek cave crayfish	4	Endangered
Gammarus acherondytes	Illinois cave amphipod	3	Endangered
Gammarus desperatus	Noel's amphipod	2	Endangered
Gammarus hyalleloides	Diminutive amphipod	2	Endangered
Gammarus pecos	Pecos amphipod	2	Endangered
Lirceus usdagalun	Lee County cave isopod	5	Endangered
Orconectes shoupi	Nashville crayfish	4	Endangered
Pacifastacus fortis	Shasta crayfish	8	Endangered
Palaemonetes cummingi	Squirrel Chimney cave shrimp	4	Threatened
Palaemonias alabamae	Alabama cave shrimp	4	Endangered
Palaemonias ganteri	Kentucky cave shrimp	4	Endangered
Procambarus econfinae	Panama City crayfish	4	Threatened
Procaris hawaiana	Anchialine pool shrimp	1	Endangered
Spelaeorchestia koloana	Kauai cave amphipod	1	Endangered
Stygobromus (=Stygonectes) pecki	Peck's cave amphipod	2	Endangered

Stygobromus hayi	Hay's Spring amphipod	5	Endangered
Syncaris pacifica	California freshwater shrimp	8	Endangered
Thermosphaeroma thermophilus	Socorro isopod	2	Endangered
Vetericaris chaceorum	Anchialine pool shrimp	1	Endangered

Fishes	**Common Name**	**USFWS Region**	**ESA Listing Status**
Acipenser oxyrinchus (=oxyrhynchus) desotoi	Gulf sturgeon	4	Threatened
Acipenser transmontanus	White sturgeon	1	Endangered
Amblyopsis rosae	Ozark cavefish	4	Threatened
Catostomus discobolus yarrowi	Zuni bluehead sucker	2	Endangered
Catostomus santaanae	Santa Ana sucker	8	Threatened
Catostomus warnerensis	Warner sucker	1	Threatened
Chasmistes brevirostris	Shortnose sucker	8	Endangered
Chasmistes cujus	Cui-ui	8	Endangered
Chasmistes liorus	June sucker	6	Threatened
Chrosomus saylori	Laurel dace	4	Endangered
Cottus paulus (=pygmaeus)	Pygmy sculpin	4	Threatened
Cottus specus	Grotto sculpin	3	Endangered
Crenichthys baileyi baileyi	White River springfish	8	Endangered
Crenichthys baileyi grandis	Hiko White River springfish	8	Endangered
Crenichthys nevadae	Railroad Valley springfish	8	Threatened
Crystallaria cincotta	Diamond darter	5	Endangered
Cyprinella caerulea	Blue shiner	4	Threatened
Cyprinella formosa	Beautiful shiner	2	Threatened
Cyprinodon bovinus	Leon Springs pupfish	2	Endangered
Cyprinodon diabolis	Devils Hole pupfish	8	Endangered
Cyprinodon elegans	Comanche Springs pupfish	2	Endangered
Cyprinodon macularius	Desert pupfish	2	Endangered
Cyprinodon nevadensis mionectes	Ash Meadows Amargosa pupfish	8	Endangered
Cyprinodon nevadensis pectoralis	Warm Springs pupfish	8	Endangered

Cyprinodon radiosus	Owens pupfish	8	Endangered
Deltistes luxatus	Lost River sucker	8	Endangered
Dionda diaboli	Devils River minnow	2	Threatened
Elassoma alabamae	Spring pygmy sunfish	4	Threatened
Empetrichthys latos	Pahrump poolfish	8	Endangered
Eremichthys acros	Desert dace	8	Threatened
Erimonax monachus	Spotfin chub	4	Threatened
Erimystax cahni	Slender chub	4	Threatened
Etheostoma akatulo	bluemask darter	4	Endangered
Etheostoma boschungi	Slackwater darter	4	Threatened
Etheostoma chermocki	Vermilion darter	4	Endangered
Etheostoma chienense	Relict darter	4	Endangered
Etheostoma etowahae	Etowah darter	4	Endangered
Etheostoma fonticola	Fountain darter	2	Endangered
Etheostoma moorei	Yellowcheek darter	4	Endangered
Etheostoma nianguae	Niangua darter	3	Threatened
Etheostoma nuchale	Watercress darter	4	Endangered
Etheostoma okaloosae	Okaloosa darter	4	Threatened
Etheostoma osburni	Candy darter	5	Endangered
Etheostoma percnurum	Duskytail darter	4	Endangered
Etheostoma phytophilum	Rush darter	4	Endangered
Etheostoma rubrum	Bayou darter	4	Threatened
Etheostoma scotti	Cherokee darter	4	Threatened
Etheostoma sellare	Maryland darter	5	Endangered
Etheostoma spilotum	Kentucky arrow darter	4	Threatened
Etheostoma susanae	Cumberland darter	4	Endangered
Etheostoma trisella	Trispot darter	4	Threatened
Etheostoma wapiti	Boulder darter	4	Endangered
Eucyclogobius newberryi	Tidewater goby	8	Endangered
Fundulus julisia	Barrens topminnow	4	Endangered
Gambusia gaigei	Big Bend gambusia	2	Endangered

Gambusia georgei	San Marcos gambusia	2	Endangered
Gambusia heterochir	Clear Creek gambusia	2	Endangered
Gambusia nobilis	Pecos gambusia	2	Endangered
Gasterosteus aculeatus williamsoni	Unarmored threespine stickleback	8	Endangered
Gila bicolor ssp.	Hutton tui chub	1	Threatened
Gila bicolor ssp. mohavensis	Mohave tui chub	8	Endangered
Gila bicolor ssp. snyderi	Owens tui Chub	8	Endangered
Gila cypha	Humpback chub	6	Threatened
Gila ditaenia	Sonora chub	2	Threatened
Gila elegans	Bonytail	6	Endangered
Gila intermedia	Gila chub	2	Endangered
Gila nigrescens	Chihuahua chub	2	Threatened
Gila purpurea	Yaqui chub	2	Endangered
Gila robusta jordani	Pahranagat roundtail chub	8	Endangered
Gila seminuda (=robusta)	Virgin River chub	6	Endangered
Hybognathus amarus	Rio Grande silvery minnow	2	Endangered
Hypomesus transpacificus	Delta smelt	8	Threatened
Ictalurus pricei	Yaqui catfish	2	Threatened
Lepidomeda albivallis	White River spinedace	8	Endangered
Lepidomeda mollispinis pratensis	Big Spring spinedace	8	Threatened
Lepidomeda vittata	Little Colorado spinedace	2	Threatened
Macrhybopsis tetranema	Peppered chub	2	Endangered
Meda fulgida	Spikedace	2	Endangered
Menidia extensa	Waccamaw silverside	4	Threatened
Moapa coriacea	Moapa dace	8	Endangered
Notropis albizonatus	Palezone shiner	4	Endangered
Notropis buccula	Smalleye shiner	2	Endangered
Notropis cahabae	Cahaba shiner	4	Endangered
Notropis girardi	Arkansas River shiner	2	Threatened
Notropis mekistocholas	Cape Fear shiner	4	Endangered
Notropis oxyrhynchus	Sharpnose shiner	2	Endangered

Notropis simus pecosensis	Pecos bluntnose shiner	2	Threatened
Notropis topeka (=tristis)	Topeka shiner	6	Endangered
Noturus baileyi	Smoky madtom	4	Endangered
Noturus crypticus	Chucky madtom	4	Endangered
Noturus flavipinnis	Yellowfin madtom	4	Threatened
Noturus furiosus	Carolina madtom	4	Endangered
Noturus munitus	Frecklebelly madtom	4	Threatened
Noturus placidus	Neosho madtom	6	Threatened
Noturus stanauli	Pygmy madtom	4	Endangered
Noturus trautmani	Scioto madtom	3	Endangered
Oncorhynchus aguabonita whitei	Little Kern golden trout	8	Threatened
Oncorhynchus apache	Apache trout	2	Threatened
Oncorhynchus clarkii henshawi	Lahontan cutthroat trout	8	Threatened
Oncorhynchus clarkii seleniris	Paiute cutthroat trout	8	Threatened
Oncorhynchus clarkii stomias	Greenback cutthroat trout	6	Threatened
Oncorhynchus gilae	Gila trout	2	Threatened
Percina antesella	Amber darter	4	Endangered
Percina aurolineata	Goldline darter	4	Threatened
Percina aurora	Pearl darter	4	Threatened
Percina jenkinsi	Conasauga logperch	4	Endangered
Percina pantherina	Leopard darter	2	Threatened
Percina rex	Roanoke logperch	5	Endangered
Percina williamsi	Sickle darter	4	Threatened
Phoxinus cumberlandensis	Blackside dace	4	Threatened
Plagopterus argentissimus	Woundfin	6	Endangered
Poeciliopsis occidentalis	Gila topminnow (incl. Yaqui)	2	Endangered
Ptychocheilus lucius	Colorado pikeminnow	6	Endangered
Rhinichthys osculus lethoporus	Independence Valley speckled dace	8	Endangered
Rhinichthys osculus nevadensis	Ash Meadows speckled dace	8	Endangered
Rhinichthys osculus oligoporus	Clover Valley speckled dace	8	Endangered
Rhinichthys osculus thermalis	Kendall Warm Springs dace	6	Endangered

Salmo salar	Atlantic salmon	5	Endangered
Salvelinus confluentus	Bull trout	1	Threatened
Scaphirhynchus albus	Pallid sturgeon	6	Endangered
Scaphirhynchus platorynchus	Shovelnose sturgeon	6	Threatened
Scaphirhynchus suttkusi	Alabama sturgeon	4	Endangered
Speoplatyrhinus poulsoni	Alabama cavefish	4	Endangered
Tiaroga cobitis	Loach minnow	2	Endangered
Xyrauchen texanus	Razorback sucker	6	Endangered
Insects	**Common Name**	**USFWS Region**	**ESA Listing Status**
Ambrysus amargosus	Ash Meadows naucorid	8	Threatened
Brychius hungerfordi	Hungerford's crawling water beetle	3	Endangered
Heterelmis comalensis	Comal Springs riffle beetle	2	Endangered
Ischnura luta	Rota blue damselfly	1	Endangered
Lednia tumana	Meltwater lednian stonefly	6	Threatened
Megalagrion leptodemas	Crimson Hawaiian damselfly	1	Endangered
Megalagrion nesiotes	Flying earwig Hawaiian damselfly	1	Endangered
Megalagrion nigrohamatum nigrolineatum	Blackline Hawaiian damselfly	1	Endangered
Megalagrion oceanicum	Oceanic Hawaiian damselfly	1	Endangered
Megalagrion pacificum	Pacific Hawaiian damselfly	1	Endangered
Megalagrion xanthomelas	Orangeblack Hawaiian damselfly	1	Endangered
Pyrgus ruralis lagunae	Laguna Mountains skipper	8	Endangered
Somatochlora hineana	Hine's emerald dragonfly	3	Endangered
Stygoparnus comalensis	Comal Springs dryopid beetle	2	Endangered
Zapada glacier	Western glacier stonefly	6	Threatened
Snails	**Common Name**	**USFWS Region**	**ESA Listing Status**
Antrobia culveri	Tumbling Creek cavesnail	3	Endangered
Assiminea pecos	Pecos assiminea snail	2	Endangered
Athearnia anthonyi	Anthony's riversnail	4	Endangered
Campeloma decampi	Slender campeloma	4	Endangered

Elimia crenatella	Lacy elimia (snail)	4	Threatened
Erinna newcombi	Newcomb's snail	1	Threatened
Juturnia kosteri	Koster's springsnail	2	Endangered
Lanx sp.	Banbury Springs limpet	1	Endangered
Leptoxis ampla	Round rocksnail	4	Threatened
Leptoxis foremani	Interrupted (=Georgia) rocksnail	4	Endangered
Leptoxis plicata	Plicate rocksnail	4	Endangered
Leptoxis taeniata	Painted rocksnail	4	Threatened
Lepyrium showalteri	Flat pebblesnail	4	Endangered
Lioplax cyclostomaformis	Cylindrical lioplax (snail)	4	Endangered
Marstonia ogmorhaphe	Royal marstonia (snail)	4	Endangered
Marstonia pachyta	Armored snail	4	Endangered
Physa natricina	Snake River physa snail	1	Endangered
Pleurocera foremani	Rough hornsnail	4	Endangered
Pseudotryonia adamantina	Diamond Tryonia	2	Endangered
Pyrgulopsis bernardina	San Bernardino springsnail	2	Threatened
Pyrgulopsis bruneauensis	Bruneau Hot springsnail	1	Endangered
Pyrgulopsis chupaderae	Chupadera springsnail	2	Endangered
Pyrgulopsis neomexicana	Socorro springsnail	2	Endangered
Pyrgulopsis roswellensis	Roswell springsnail	2	Endangered
Pyrgulopsis texana	Phantom springsnail	2	Endangered
Pyrgulopsis trivialis	Three Forks springsnail	2	Endangered
Taylorconcha serpenticola	Bliss Rapids snail	1	Threatened
Tryonia alamosae	Alamosa springsnail	2	Endangered
Tryonia cheatumi	Phantom Tryonia	2	Endangered
Tryonia circumstriata (=stocktonensis)	Gonzales tryonia	2	Endangered
Tulotoma magnifica	Tulotoma snail	4	Threatened

Appendix C. Surveillance Methods

When developing a surveillance program, the purpose of sampling, environmental setting, and necessary resources (labor for sample collection and analysis, equipment) should be considered. As with any early detection surveillance, where the goal is detecting few organisms in a vast environment, no sampling method can guarantee detecting NZMS when they are present. As such, failing to detect NZMS at a site does not prove absence. Failure to detect the presence of NZMS when they are present (Type 1 Error) may be because there are very few snails, there are few due to sub-optimal environmental suitability, or the distribution is localized and was outside of the search area. To improve the likelihood of detection if NZMS are present, the number of transects within the area of interest and/or the temporal frequency of surveys should be increased.

NZMS density and location can vary dramatically seasonally. Typically, NZMS densities are highest in late summer and early autumn but can vary with location (Richards et al. 2001; Richards 2004; Kerans et al. 2005). NZMS presence can also vary seasonally around food availability and other physical and chemical factors. A locality with NZMS in one season may not have them in another season; therefore, monitoring efforts should not varied to maximize detection.

Numerous sampling methods have been used to detect NZMS (Table 1). Methods including Surber and Hess samplers, kick-nets, Ponar grabs, snorkeling, SCUBA, hand-picking, suction dredging, eDNA, and colonization samplers or traps (Merritt and Cummins 1996). Once collected, an invertebrate sample can be analyzed immediately or preserved for future analysis. The samples generated by many of these conventional invertebrate sampling methods are typically highly diverse, containing many types of organisms and organic and inorganic debris, and require considerable time and effort to analyze.

Table 1. Comparison between NZMS sampling methods

Sampling Methods	Habitat	Qualitative	Quantitative	Relative cost *	Reference
Visual detection (walking surveys, snorkeling, SCUBA, or hand- picking)	Lentic/Lotic	Yes	No	$	Tank et al. 2021
Kick net	Lotic	No	Yes	$$	Merritt and Cummins 1996

Sampling Methods	Habitat	Qualitative	Quantitative	Relative cost *	Reference
Hess sampler	Lotic	No	Yes	$$	Merritt and Cummins 1996
Surber sampler	Lotic	No	Yes	$$	Merritt and Cummins 1996
Ponar grab sampler	Lentic	No	Yes	$$	Merritt and Cummins 1996
Environmental DNA	Lentic/Lotic	Yes	Yes	$$$	Goldberg et al. 2013; Thomas et al. 2019; Ponce et al. 2021; Woodell et al. 2021

***to collect and analyze sample**

If the purpose of surveillance is only for NZMS detection, the most cost effective and comparably reliable approach is targeted surface surveys. While NZMS are very small, close examination of suitable habitat generally reveals their presence. Survey sites should target high-use access points because they are often the point of introduction from external sources and can be a point of deposition for NZMS picked up within that waterbody as users exit. While actual methodology may vary depending on the environmental setting, a basic model recommendation for an effective surface survey is a team of two or more people wading up to knee-deep along a 50-meter transect along a no- to low-flow margin of a waterbody. The surveyors spend 20 minutes within the transect picking up and examining the undersides of submerged rocks, vegetation, wood debris, leaf litter, or other substrate surfaces (Tank et al. 2021). Only suspect NZMS are collected and brought back to the lab for identification. The benefits to this approach are that no specialized equipment or training is needed, little if any equipment needs to be decontaminated (only rubber boots), and the effort results in discrete samples that can be analyzed very quickly.

Because many small snails look similar, identification of suspect NZMS should be made under magnification (dissecting microscope) by an expert experienced in NZMS identification and knowledgeable of other native and non-native snails with similar morphology. A minimum of 20 suspect organisms should be collected and stored in 95% ethanol and confirmed with an established protocol for microscopic or molecular identification. All suspect NZMS samples should be confirmed in coordination with the state invasive species program. All confirmed NZMS detections should be reported to the U.S. Geological Service Nonindigenous Aquatic Species (USGS NAS) database and state database, if applicable, in a timely manner. Anyone working to manage invasive species should subscribe to NAS database notifications to be alerted about new NZMS detections reported by others. Reporting new detections will contribute to a nationwide mapping effort and help manage pathways of spread.