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Select Research Findings on the New Zealand Mudsnail (*Potamopyrgus antipodarum*)

The New Zealand mudsnail (*Potamopyrgus antipodarum)* was first discovered in the middle Snake River, Idaho in the mid-1980s and has rapidly spread throughout the western U.S. It is a parthenogenetic (clonal) livebearer with a high reproductive potential.

Potamopyrgus antipodarum has been shown to appreciably alter primary production in some streams. Research to date has shown decreases in native macroinvertebrate populations in several rivers where the New Zealand mudsnail (NZMS) has been introduced. These impacts have generated much concern about the potential impacts that *P. antipodarum* may have on native species, fisheries and aquatic ecosystems in the western U.S. Its spread into new systems is considered to be primarily human caused.

Unintentional transport by people is probably the primary vector for the spread of NZMS. Mature specimens average 5mm in length and juveniles are much smaller making them difficult to notice on gear. On damp substratum at temperatures of 20-25º C survival rates of over 50% at 20 days and some individuals up to 50 days have been observed (Winterbourn 1970). This ability to survive for days out of water combined with the parthenogenetic nature of NZMS makes waders, boots and other equipment that contacts infested waters a high risk vector for spreading populations to new areas.

<u>Known locations of mudsnail colonization in CA:</u>

- In January 2004 they were found in the Lower Calaveras River – Mormon Slough in an eleven mile stretch.
- In December 2003 they were found in the Lower Mokelumne River; in a five mile stretch below Comanche Dam.
- In October 2003 they were found in Lower Putah Creek inhabiting a mile-long stretch
- In 2000 they were discovered in the Owens River (Eastern CA) and are now found in Hot Creek near the Hatchery.

<u>Controlling the spread of mudsnails:</u>

- Initial findings on NZMS bleach tolerance tests by Medhurst and Herbst (2003) suggest that gear exposed to mudsnail infested waters can be decontaminated by immersion in a 10% bleach solution for 1 hour. Personal observations by Medhurst (2003) suggest that putting gear in a freezer for 6-8 hours will kill all attached NZMS.
- Putting gear in water maintained at 130ºF for 5 minutes will result in 100% NZMS mortality (Medhurst 2003).
- NZMS do not survive freezing or desiccation at high temperatures with low humidity (Richards et al. Unpublished). At all temperatures larger NZMSs generally survive desiccation longer than do small NZMSs (Richards et al. Unpublished). For all sizes of NZMS mortality rates increase at higher temperatures and longer exposure times (Richards et al. Unpublished).

- Bioassays conducted by Montana Fish Wildlife and Parks (FWP) indicated that Bayluscide (active ingredient ethanolamine salt of niclosamide) may be an appropriate chemical treatment for NZMS, in a limited area. The bioassays found that Bayluscide killed 100% of test snails exposed to at least 48 exposure units[1] of Bayluscide (MFWP 2002**).**
- A minimum of eight-hour exposure to Bayluscide[2] (at a concentration of 4mg/L), followed by a clean-water period, results in 100% mortality (Clancey 2002).
- Chlorine does not appear to kill NZMS well at any concentration, within 60 seconds (Dwyer 2001). Copper sulfate showed some mortality at 100 and 1,000 mg/L (Dwyer 2001).
- Carefully regulating the stocking of fish can prevent further spread of NZMS (Yundt 2003).
- Fencing off a portion of a ditch can be used to restrict access by wading anglers and cows thereby limiting spread (Clancey 2001).

<u>Vectors and pathways for introduction:</u>

- Sometime between 1985 and 1987 NZMSs were probably introduced to Hagerman, Idaho with rainbow trout imported from New Zealand for aquaculture (Shinn 2001). The NZMSs were probably transported from the Snake River to the Yellowstone area by anglers using neoprene waders and boats (Shinn 2001).
- Hatchery transplants, contaminated fishing equipment, boats and trailers are likely vectors for the spread of NZMS (Chapman 2003). Other potential vectors include migratory birds, bait, the aquarium pet trade and the aquatic plant trade (Chapman 2003).
- In Utah NZMSs have primarily been found in regulated rivers and popular trout fisheries, but Vinson (2003) cautions that this may be based on where the researchers have looked for snails.
- NZMSs can raft on vegetation and can remain alive on the shoes of anglers for twenty-four hours, with small snails drying out quicker (Mahony 2001).
- Vectors of spread appear to be ballast water, boaters, and anglers, although fish and birds may also contribute to the spread (Dwyer 2001).

<u>Vectors and pathways for spread once present in a stream:</u>

- NZMS do not spread smoothly upstream, but "hopscotch" suggesting that a vector is spreading the mudsnails (Dybdahl 2003).
- Findings from a study conducted on the eastern Snake River of Idaho suggest that NZMS mostly spread through vegetation and edges of the faster-flowing waters and then move into new habitats, particularly vegetated ones (Richards, et al. 2001). NZMSs were also observed to be more likely to detach from substrate due to flow or disturbance then was a native snail (*Taylorconcha serpenticola*) (Richards, et al. 2001).

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[1] An exposure unit is determined by multiplying an exposure Bayluscide concentration, in mg/l (ppm) by the number of hours or exposure. An example is 4mg/l x 12 hours of exposure = 48 exposure units.
[2] The active ingredient in Bayluscide is the ethanolamine salt of niclosamide ($C_{13}H_8Cl_2N_2O_4$) [MFWP 2001].

- Stream velocities over 0.6 m/s can be expected to facilitate the passive distribution of NZMS.At a stream velocity of 0.6 m/s all NZMS will detach (Lysne 2003). The NZMS appear to have a greater attachment velocity then endemic (to Idaho) snails (Lysne 2003).
- NZMS have been observed rafting on vegetation mats and have been timed actively dispersing on flat substrates at a rate of 1m/h (Richards et al. 2001).
- Live NZMS have been documented passing through live brown trout within twenty-four hours (Dwyer 2001).

Microclimate and habitat preference:

- NZMS secondary production can be high in lake outlets because concentrated nutrients are focused for the filter feeding assemblage at the lake outlet (Hall et al. In Preparation).
- It is possible that algal based ecosystems have the potential for higher production rates of NZMS then detritus based ecosystems (Hall et al. In Preparation).
- In the upper Owens River NZMSs have been found in the densest patches near Crowley Lake (Noda 2002).
- The Greater Yellowstone Ecosystem NZMS clone may be a river clone since it failed to colonize Hebgen Lake and some small streams (Dybdahl 2003).
- Vegetated areas with slower water velocity seem to provide refuge for small NZMS and may act as nurseries (Richards et al. 2001).
- NZMS frequently burrow into sand substrate, where they probably consume epipsammic algae (Holomuzki 2003).

Fecundity:

- NZMSs are ovoviviparous[3] and brood sizes can be up to 80 snails per female (Hall et al. In preparation). In three streams of Yellowstone National Park (Firehole River, Gibbon River and Polecat Creek) fecundity rates tended to be a function of shell size and not a function of water temperature. Large NZMSs produced 0.1 to 1.3 daughters per day (Hall et al. In preparation).
- In three streams of Yellowstone National Park (Firehole River, Gibbon River and Polecat Creek) the annual total growth rate of NZMS was about as fast as the average of the entire native invertebrate assemblage (Hall et al. In preparation).

Densities observed:

- A study conducted in the eastern Snake River Plain of Idaho found that NZMS had the highest density, of three snail species examined, in all habitat types examined. Densities of NZMS were lowest in areas with the highest stream velocities (Richards, et al. 2001).
- NZMS densities may vary on a seasonal basis. A survey in the upper Madison River, MT found that NZMS abundance was highest in summer and decreased significantly in the spring (Kerans 2001). In Firehole River and Nez Perce Creek

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[3] Ovoviviparous - producing eggs that develop within the maternal body (as of various fishes or reptiles) and hatch within or immediately after extrusion from the parent (Merriam-Webster Online 2003).

densities were high in the fall, dropped off in the spring and were high again in the summer (Kerans 2001).
- NZMS growth is unaffected by the presence of other taxa (Holomuzki 2003).
- NZMSs are not self-limiting from density dependent effects (Dybdahl 2003).
- Up to 48,000 snails/m^2 in the upper Owens River watershed (Noda 2003).
- Densities in Darlington Ditch, Montana peaked at 25,000 snails/m^2 (Cada 2003).
- NZMS densities up to 500,000 snails/m^2 have been found in the middle Snake River (Richards, David C. 2003).
- In the Greater Yellowstone Ecosystem NZMS are the dominant benthic macroinvertebrate in several rivers attaining densities of 550,000 snails/m^2 (Riley 2002).
- Densities at a site above Hebgen Lake have been fairly stable for three years at 2,000 to 6,000 snails/m^2 (Pickett 2002).
- In the Owens River NZMS densities of about 10,000 snails/m^2 have been observed (Becker 2001).
- In three streams within Yellowstone National Park (Firehole River, Gibbon River and Polecat Creek) NZMS density has been observed at a maximum in summer and a minimum in the winter (Hall et al. In Preparation). The highest observed density was in Polecat Creek with over 500,000 snails/m^2 at maximum (Hall et al. In Preparation).

<u>Growth:</u>
- Biomass specific growth rates for NZMS were found to be a function of snail size class and mean temperature [(1/d) = 0.0775 - 0.0293 (size mm) + 0.0024 (temperature °C)] (Hall et al. In preparation).
- Growth is a function of shell size and temperature, but shell size is the best (r^2 = 0.59) predictor of growth [smaller snails grow faster] (Hall et al. In preparation). Annual production varied from 194 g/m^2/y to 24 g/m^2/y (Hall et al. In preparation).
- In July of 2001 NZMS production was 1.5 g/m^2/d in Polecat Creek (highest production) [Hall et al. In preparation]. Production of native invertebrate assemblages was much lower then for NZMS in each stream ranging from 8-35% of combined production (Hall et al. In preparation).
- When compared to other taxon, NZMSs ranged from 6.5-40 times more productive, depending on the particular stream sampled (Hall et al. In preparation).
- Average water temperatures as low as 7º C (45º F) did not prevent survivorship, growth or reproduction of NZMS in the greater Yellowstone Area (Dybdahl 2003).
- NZMS do not appear to be self limiting from density effects (Dybdahl 2003).

<u>Documented impacts:</u>
- NZMS out compete the threatened Bliss Rapid snail (*Taylorconcha serpenticola*) in the Snake River (Richards 2003).

- NZMS decrease densities of other macroinvertebrates, and therefore food available to fish (Cada 2003). Research is inconclusive on whether or not fish will eat NZMS in the wild (Cada 2003).
- Fish avoid eating NZMS and prefer other macroinvertebrates that are negatively impacted by NZMS. There was a trend of decreased growth of fish (brown trout, sculpin, white sucker and longnose dace) in high NZMS density areas, particularly for sculpins (Cada 2003).
- Dwyer (2001) has found NZMS abundant in whitefish stomachs, but not in trout stomachs. Cada's data suggest that wild fish avoid eating NZMS.
- In the Hagerman Valley - Snake/Salmon River area the replacement of a dominant keystone algae (*Cladophora glomerata*), with a less nutrient dependent algae, has been correlated with the introduction of NZMS (Shinn 2002).
- NZMSs have also been associated with an increase in algal biomass. Possibly the NZMSs are fertilizing the periphytic algae by excreting ammonia (Riley 2002).
- In Darlington Ditch, of the Madison River drainage, NZMS have been associated with decreases in the densities of macroinvertebrate assemblages. NZMSs also probably compete for resources with other macroinvertebrates, and this competition varies over the year (highest in November, lowest in June) [Cada 2002].
- A study in Darlington Ditch, MT found that the presence of NZMSs does not cause other macroinvertebrate species to shift habitats (Kerans 2002). Kerans (2002) stated that the long term effect of NZMS presence on baetids[4] will probably be negative, but other species may be able to "hold their own".
- In communities with established populations of NZMS (Darlington Ditch) composition of invertebrate communities included about half NZMS and midges[5] were found to be much higher in sites without NZMS (Cada 2001).
- In Montana the average aquatic macroinvertebrate assemblage shows that about 1/4 to 1/2 of the community consists of mudsnails (Kerans 2001). There was also a negative correlation between NZMS and members of the mayfly, stonefly, and caddis fly taxa (Kerans 2001).
- In three Yellowstone Rivers NZMS had among the highest secondary production rates ever measured for a river animal. In different rivers the NZMS population accounted for 65-92% of total invertebrate production, strongly indicating food web alteration (Hall et al. In Preparation).

Potential impacts:

- NZMS are potentially hosts for fish parasites such as the eye fluke (*Diplostomum spathaceum*), which is a parasite that has snail, fish and bird hosts (Staton 2003).
- NZMS populations on the Oregon coast inhabit important anadromous fish habitats and they may compete with critical prey species for juvenile salmon (Chapman 2003).

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[4] Baetidae is a family of may flies (Order: Ephemeroptera). http://www.duluthstreams.org/understanding/bugs_ephem.html

[5] Midges are insects that have an aquatic juvenile stage (Ohio State University Extension Fact Sheet, 2003).

- In the tailwater area of Lake Powell fish production has been low for a few years; there are large numbers of fish, but they are not growing well (Anderson 2002). These effects have been correlated with the introduction of the NZMS (Anderson 2002). Anderson (2002) also mentioned that a terrestrial ecologist has noted fewer dabbling ducks in the area of NZMS introduction. <u>He cautions that these findings are only anecdotal.</u>
- Grazing by NZMSs may decrease food availability, causing competition with other grazers (Cada 2002).
- NZMS may impact native ecosystems through direct competition for resources or interference since the NZMS population can become so dense. NZMS may also lower resident fish production if their invasion depresses the native invertebrate biomass (Hall et al. In Preparation).

<u>Predators and parasites:</u>

- Starved crayfish (*Pacifasticus sp.*) have been observed to consume NZMS in a laboratory setting (Lysne 2003). The crayfish were more likely to consume another snail (*Valvata utahensis*), but the difference was not statistically significant (Lysne 2003).
- NZMS have also been found in the stomachs of brown trout and suckers, demonstrating that the fish eat snails (Dwyer 2001). Close to 85% of mudsnails can survive in the stomachs of trout for 2.5 hours and some may survive as long as 5 hours in trout stomachs (Dwyer 2001).
- In the native range of NZMS, trematode parasites (*Microphallus sp.*) sterilize the snails, but trematodes are selective in parasitism to specific NZMS clones (Emblidge and Dybdahl 2003).
- One author said that given the assumption that all western U.S. populations of NZMS originate from a single clone, the clone should be susceptible to some parasite, probably a nematode (Dybdahl 2001).

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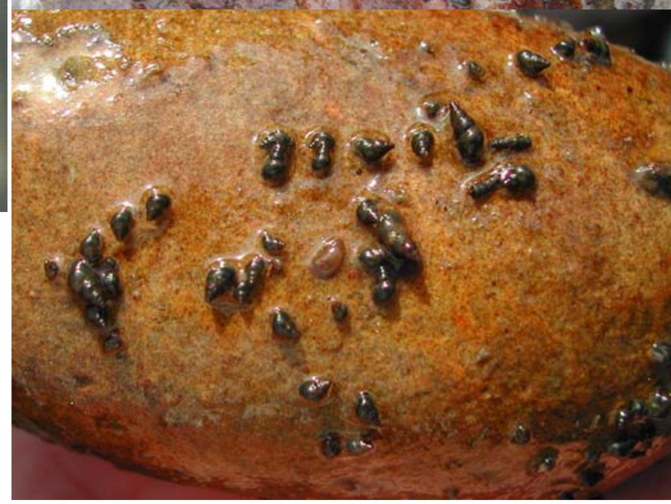
Identification:

Photos by D.L. Gustafson



Operculum: NZMS has an operculum to block the shell aperture which protects the snail from desiccation and predation. This operculum is easily seen on live snails, but the operculum is lost from dead shells and it is normally withdrawn beyond view in shells that are directly preserved in alcohol or formalin.

Color: Light to dark brown shell. Encrusted shells can be any color.

Size: Almost all western populations reach a mature size near 5 mm.

Shape: The shell is rather elongate compared to most western species and dextral (opening to the mudsnail's right). A full grown shell normally has **5 or 6 whorls**.

Keel: A weak keel may be present about mid whorl, but many populations lack this keel entirely. This keel is not present on any native western snails.

For additional ID information, please visit:
http://www.esg.montana.edu/aim/mollusca/nzms/id.html

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