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Abstracts in the order of presenting. * Presenter

The New Zealand Mudsnail National Management and Control Plan – What Now?

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Federal legislation authorizes the national Aquatic Nuisance Species Task Force (ANSTF) to adopt national management and control plans for individual species or groups of species. In 2007, the ANSTF approved a New Zealand Mudsnail (NZMS) national management and control plan that was prepared by a broad-based working group. The goal of the plan is to prevent and delay the spread of NZMS, reduce their impacts, and continue to generate new information on the species and its management. Specific focal areas covered by the plan include identification of pathways of spread, detection methods, control strategies, understanding ecological and economic impacts, and increased public understanding and political support. For each focal area, the plan offers specific action item recommendations and an associated implementation table. The plan also includes extensive background information on NZMS. Many aspects of the plan are now outdated, including details on the extent of U.S. populations, coverage of available control options, and status of state regulations. Should the plan be updated? What is its role as a national compass for NZMS management? This presentation will explore these and other national coordination questions.

Risk assessment for New Zealand mudsnail (*Potamopyrgus antipodarum*) in Canada

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The New Zealand mudsnail (*Potamopyrgus antipodarum*) was identified in the Great Lakes in 1991 and, more recently, identified on the west coast of Canada in 2006. This snail possesses many traits making it well suited for invasions including a high reproductive rate, a broad range of environmental tolerances, and a number of human-mediated and natural vectors for long-distance dispersal. In some systems, this small snail reaches extremely high densities and can alter ecosystem services and trophic relationships, negatively influencing higher trophic levels. There is considerable concern about the potential ecological impacts if New Zealand mud snail spreads in Canada, especially to inland freshwater or other coastal ecosystems. Fisheries and Oceans Canada conducted a national risk assessment, including a peer-review workshop during March 2010, to determine the potential risk posed to Canadian coastal and inland waters. This assessment used an expert survey and workshop evaluate the probability of arrival, survival, reproduction, and spread and associated potential impacts to determine risk. This assessment also incorporated measures of environmental suitability from an ecological niche model and bedrock geologyto identify potential habitat. The risk assessment, based on a widespread invasion, concluded that the New Zealand mud snail generally posed low risks to most Canadian aquatic ecosystems with a moderate risk posed to freshwater biodiversity in most Canadian freshwater drainages. However, at smaller spatial scales the risk posed by this species could be much higher. Information gaps and potential research were also documented.

Biology/Genetics

The absence of genotypic diversity in a successful parthenogenetic invader

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Invasiveness might depend on the ability of genetically diverse populations of exotic species to adapt to novel environments, which suggests a paradox since exotic species are expected to lose genetic diversity when introduced. The apparent need for genetic diversity is particularly important for exotic species that lack bi-parental reproduction and genetic recombination. We used genetic marker studies to determine the genotypic diversity of invasive US populations of the clonal New Zealand mudsnail (*Potamopyrgus antipodarum*). We report here on a three-pronged survey of allozyme, microsatellite DNA, and mitochondrial DNA genetic markers of invasive populations with a focus on the western US. Combining the three types of genetic

markers, we discovered four distinct genotypes of *P. antipodarum*. These results show that only one genotype (US 1) occupied the vast majority of the western US range, and a second occurred in the Great Lakes in the eastern US (US 2). Two other genotypes occurred in the western US (US 1a and US 3), but were restricted to populations near the presumed source of invasion in the middle Snake River, ID. These results suggest that *P. antipodarum* spread across a broad geographic range in the western US from a single introduced source population, and that the populations are comprised of a single clonal lineage.

Phenotypic variation associated with cryptic genotypic variation in Snake River NZMS

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Why some members or genotypes of a species are invasive while others are not is a major question in invasion biology. The New Zealand Mudsnail (*Potamopyrgus antipodarum*) invasion of the Western US is a prime example where only one particular genotype (US1) is found at every new invasion site. The only invaded location with multiple genotypes is the supposed origin located in the Snake River near Hagerman, Id. Here, another morphotype is found cooccuring with the highly invasive US1. What allows one genotype to spread across ten states in 25 years while the other is unable to disperse or expand its range? Isofemale lines were established from samples taken near Hagerman, Id. Allozyme gel electrophoresis was used to identify the genotype of each isofemale line and determine the frequency and distribution of each genotype. First generation juveniles were tracked until maturity. Weekly measurements of length, width, and offspring count (once at maturity) were recorded and used to calculate growth rates. Results from the electrophoresis showed multiple clonal genotypes indicating new genotypes and more genotypic overlap than previously thought. Results of the phenotypic measurements show distinct morphological differences between many of the invasive genotypes. However, at least one genotype has been found to be cryptic and does not differ morphologically from US1. Current research aims to understand *P. antipodarum* distribution, invasion patterns, and extent of cryptic genetic variation in the Snake River. Future work includes more extensive genotyping around the initial invasion site and understanding environmental and inter-genotype interactions.

Molecular detection of aquatic species in water samples using environmental DNA

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Detection of aquatic vertebrates in freshwater systems using environmental DNA (eDNA) from water samples has recently been confirmed as a sensitive and efficient tool for documenting invasive species in wetlands and a large river and canal system. The sensitivity of an eDNA test depends on the amount of DNA shed by the species and the thermal and chemical properties of the water body. False negative rates can be estimated using repeated sampling and the probability of false positives excluded by careful primer design and protocol testing using related non-target species. We are working on expanding the use of eDNA techniques, beginning by demonstrating that DNA from cryptic native amphibian species can be detected in fast-moving streams. For this test, we designed targeted primers to amplify a species-specific short DNA fragment for each of two low-density, lotic amphibian species (Idaho giant salamanders, *Dicamptodon atterimus*; Rocky Mountain tailed frogs, *Ascaphus montanus*) in northern Idaho. Using filter samples taken from 5-10 L of stream water, we efficiently recovered the targeted DNA sequences for each of these two species (field estimated at 0.16 and 0.04 individuals per m^{-2}, respectively). We estimate post-optimization laboratory costs (including labor) will be approximately $30 to test for DNA evidence of these species in a water filter sample. We found gains in efficiency of eDNA over field methods to be 20x for Idaho giant salamanders and 11x for Rocky Mountain tailed frogs; previously, researchers found gains in efficiency for Asian carp were 16 - 100x. More work is required to develop tests for additional species such as the New Zealand mudsnail; however, eDNA has the potential to be a highly sensitive and cost-efficient tool for the detection and monitoring of both invasive and native aquatic species.

Active dispersal of an aquatic invader determined by resource and flow conditions

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New Zealand mud snails, *Potampyrgus antipodarum*, (NZMS) have spread rapidly across the western United States, but little is known about mechanisms that drive their spread within invaded streams. We used a field experiment to test if upstream movement is a potential vector of NZMS spread and how this movement is modified by flow velocity and resource availability. We found movement direction and rates were related to flow velocity, while resource availability influenced the number of individuals that moved. In slow-flow treatments, individuals moved upstream at faster rates (~ 3 m/hr) than previously recorded for this species. In fast-flow treatments, most individuals were dislodged downstream and upstream movement rates were less than 2 m/hr. In low-resource treatments, individuals were more likely to move away from their initial starting locations. We suggest that upstream movement may be important in establishing new populations within local invasions and that increases in flow velocity may be an effective means to slow the upstream spread of NZMS. The surprisingly fast movements that we recorded predict greater distribution of NZMS within invaded streams than has actually occurred, which suggests that factors other than NZMS movement rate may limit population spread.

Monitoring/Disinfection

Experimental and monitoring studies of Potamopyrgus antipodarum from Piru Creek in Southern California

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The New Zealand Mud Snail (*Potamopyrgus antipodarum*) is invading streams across the western United States, including Piru Creek in the Santa Clara River watershed in Southern California. Because little is still known about the population dynamics and ecological impacts of *P. antipodarum* in our region, we collected data on the growth and development of these snails in the field, as well as conducted experiments to determine how this invasive snail affects algal resources, native invertebrates, particularly native snails from the same family (Hyrdobiidae), and native amphibians and fish, such as the endangered arroyo toad and southern California steelhead trout.

Based on monthly samples taken from Piru Creek In 2009-2010, we found that snail densities fluctuated between very low (less than 10 individuals /m2) following winter high flow events, to relatively high (more than 1500 individuals/m2) during spring and summer months. Juvenile forms of the snail dominated snail age classes (>50%) between March and June, but snail reproduction occurred year round. Field and laboratory experiments allowed us to examine the effects of abiotic factors on *P. antipodarum* and the effects of *P. antipodarum* on stream algal assemblages, invertebrates (native mayflies (*Centroptilum sp),* caddisflies *(Gumaga), and snails (Physella* and *Pyrgulospsis cf stearnsiana*), and Western Toad tadpoles. We found that the New Zealand Mud Snail reduced the growth and survival of native taxa by changing the abundance and composition of their shared food resource, benthic algae.

Evaluation of Virkon Aquatic toxicity and application to disinfect invasive mollusk infested field and hatchery gear

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In the western US, populations of New Zealand mudsnails (NZMS) have become established in fish hatcheries and in many aquatic systems. Resource managers want to limit the potential for transfer of invasive mollusks to new locations. Virkon Aquatic is a broad-spectrum disinfectant used in many hatchery facilities as a disinfectant on equipment for protection from bacteria, viruses and fungi. This chemical has the potential to be used in a broader context in hatchery and fishery field operations, but the appropriate dosage and duration of exposure and safety limits must be determined. We conducted experiments to determine the lethal concentration and duration of exposure for complete killing of NZMS, and quagga mussels. We evaluated bath and spray applications of Virkon Aquatic on felt, neoprene, and rubber soled wading boots infested

with NZMS. We found all life stages of NZMS were killed after a 20 minute bath exposure in 2% Virkon Aquatic. All quagga mussel veligers exposed to 0.5% Virkon Aquatic were dead after 10 minutes, and adult quagga mussels were killed after a 10 minutes bath exposure to 2% Virkon Aquatic. We estimated the toxicity of Virkon Aquatic to steelhead fry and fingerlings, and found that quantities carried over in nets or other equipment are safe. Virkon Aquatic breaks down in the presence of organic material and causes little damage to neoprene or breatheable nylon waders. Bath applications on wading gear are recommended over spray to assure killing. Virkon Aquatic is recommended for use in field and hatchery disinfection protocols.

New Zealand Mudsnails: Idaho Fish and Game Management, Rules, Monitoring, Control, Permits, Cleaning and Disinfection

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The New Zealand Mudsnail issue has been both bad and good for IDFG hatcheries and biologists. The Invasive Species law and rule brought about monitoring, development of HAACP plans and control measures, and the need for Invasive Species Transport Permits on some of our twenty two anadromous and resident hatcheries. The law and rules caused our field fisheries biologists to learn how to properly clean and disinfect their equipment. I am not as sure that the invasive species law and rules will reduce the range of NZMS in our lifetimes. This issue certainly did show that agencies and government need to think before they regulate.

Field Gear Disinfection for Monitoring Bliss Rapids Snail *(Taylorconcha serpenticola)* in Mid-Snake River Springs

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Decreasing the risk of spreading common invasive species, bacteria and parasites via infected field equipment has become an important component of aquatic sampling in Mid-Snake River spring systems. Limiting the potential ecological and economic impacts to natural springs, aquaculture, and fish hatchery facilities is paramount. Idaho Power Company (IPC) has committed to annual monitoring of the Bliss Rapids Snail (BRS) *(Taylorconcha serpenticola)* in

springs and tributaries of the Mid-Snake River to comply with license requirements issued by the Federal Energy Regulatory Commission (FERC). IPC prepared a monitoring plan (plan) after consulting with the U.S. Fish and Wildlife Service, and Idaho Fish and Game. As part of the plan IPC will monitor and evaluate changes in abundance and distribution of BRS in 12 springs and tributaries for the remainder of the Lower Salmon Falls and Bliss hydropower licenses, approximately 23 years. Given the potential for cross contamination between different water bodies during field sampling activities, IPC has included as part of the plan decontamination guidelines for limiting the spread of common invasive species.

A qualitative sampling protocol for presence/absence of New Zealand mudsnails; a guide to finding a needle in a haystack

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Quantitative sampling for invertebrates in flowing water systems frequently requires the total removal or disturbance of substrate to extract species for the purposes of identification and enumeration. These methods, which include the use of cores, kick nets, grab samplers, and quadrats, are hard work, time-consuming and unsuited to the task of rapidly determining presence/absence of a single species such as the New Zealand mudsnail (NZMS). This is especially true at the early stages of an invasion when densities can be less than 100/m2. The zig-zag technique describe here is well suited to determining presence/absence of NZMS and is simple enough that it can easily be taught to natural resource personnel who may not have rigorous background in stream invertebrates or even sampling in aquatic habitats. It requires no additional gear beyond a vial and a pair of waders and can be performed by a single individual. While this technique does not allow for the collection of any additional information beyond this binary presence/absence index it is simple and straightforward enough that it allows for widespread opportunistic sampling of NZMS presence by personnel performing other field investigations.

Management Tools

The introduction of *Potamopyrgus antipodarum* (Gray, 1843) (New Zealand mudsnail) to Capitol Lake, Olympia, Washington: An Overview

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Capitol Lake, Olympia, Washington was created in 1951 when an earthen dam with a concrete spillway and gates was constructed at the outlet of the Deschutes River estuary, which is located at the southern end of Budd Inlet in Puget Sound. The artificial lake served two purposes, to eradicate the "eyesore" of tidal mudflats and to create a refection pool for the State Capitol building. The lake is managed by the Washington Department of General Administration as part of the Capitol Campus in downtown Olympia. New Zealand mudsnails were discovered in Capitol Lake in October 2009. This is the first known introduction of New Zealand mudsnails to the interior of Washington State. An emergency response workgroup of local stakeholders was created to address the introduction and possible eradication of the New Zealand mudsnails from Capitol Lake. The Washington Invasive Species Council is coordinating the workgroup. Capitol Lake was immediately closed to public use post the discovery of the snails. Surveys were conducted to establish the extent of the introduction. A variety of control methods have been tested, but no large scale eradication effort has been conducted, to date due to the complexities of using such methods in an urban environment and in Puget Sound.

Experimental removal of New Zealand mudsnails in an Idaho spring creek.

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We tested the effectiveness of a dredgeless sediment vacuum, called the Sand Wand (www.streamsidesystems.com), to remove New Zealand mudsnails (NZMS) from an Idaho spring creek. The Sand Wand uses a combination of variable water jets and suction to remove surface and subsurface sediments. The material is then discharged to an off-water location. We used a before-after-control-impact design to evaluate effectiveness on removing NZMS and to evaluate the impact on non-target organisms such as native stream insects. We found that the Sand Wand greatly reduced NZMS abundance but did not eradicate NZMS. We also found that the Sand Wand had minimal non-target impacts on stream insect emergence and leaf-litter decomposition rate.

Can copper-based substrates be used to protect hatcheries from invasion by the New Zealand mudsnail (*Potamopyrgus antipodarum*)?

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There is evidence to suggest that lining the insides of hatchery effluent pipes with copper-based substrates could reduce the risk of invasion by the New Zealand mudsnail (*Potamopyrgus antipodarum*). However, before this type design can be recommended for wide-scale use, it is important that we understand how several key physicochemical parameters effect deterrent performance. The goal of this project was to evaluate the relative ability of four types of copper-based materials (copper sheet, copper mesh, copper-based ablative anti-fouling paint, and copper-based non-ablative anti-fouling paint) to serve as effective mudsnail *contact* deterrents across a range of water temperatures (8 - 24° C), hardness (75 - 300 mg/L), pH (6 - 8.5), fouling (0 - 10 wks of exposure), and water velocity (0 - 33 cm/s) levels. Five distinct experiments were conducted during 2009-10 at the Colorado State University Foothills Fisheries Laboratory to evaluate the effect of each physicochemical variable on the mudsnail deterrent performance of the four materials. Overall, copper mesh and sheet were the most effective materials in terms of limiting the crawling distance of the mudsnail ($p < 0.05$). In contrast to the paint treatments, the deterrent performance of the mesh and sheet treatments were unaffected by temperature or fouling. These results suggest deterrents constructed of copper mesh or sheet could provide a

satisfactory level of protection against mudsnail invasion. Design considerations and integration of solid copper materials with other types of barriers designs are discussed.

Reducing the Spread of New Zealand Mud Snails: Risk of Stocking Fish from Infested Hatcheries and Description of a Removal Project at a Utah Hatchery

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New Zealand mud snails *Potamopyrgus antipodarum* (NZMS) are a non-native mollusk that threaten fisheries throughout western North America. Because fish stocking can help spread NZMS, it is essential that actions are taken to prevent the establishment of NZMS in hatcheries. In this presentation, I will discuss the effects that NZMS have had on operations at the Loa State Fish Hatchery (Utah Division of Wildlife). I will detail how the establishment of NZMS in the hatchery has affected the management of Loa and how operational changes at Loa have had a "trickle-down" effect on other hatcheries. In addition, I will present the results from research that has determined the specific risk associated with the stocking of fish from Loa. Based on studies that have determined the proportion of NZMS that can survive passage through the digestive tract of rainbow trout *Oncorhynchus mykiss* and the prevalence of NZMS in the diets of fish at the hatchery, I estimate that on average, one live NZMS is added to the wild for every 3,800 fish stocked from the hatchery. Finally, I will discuss the results of experiments that have determined the toxicity of iodine, formalin, hydrogen peroxide, potassium permanganate, Roccal D-Plus, benzethonium chloride, benzalkonium chloride, and Stepanquat 50 NF to NZMS and will discuss a project that utilized hydrogen peroxide and benzalkonium chloride to remove NZMS from the hatchery. This project successfully removed >95% of NZMS from Loa. The removal procedure described is inexpensive and can be adapted for use in other hatcheries.

Modeling water and small particle residence times in two rearing units used for intensive culture of steelhead trout *Oncorhynchus mykiss* in Idaho

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Dworshak National Fish Hatchery rears large quantities of steelhead trout *Oncorhynchus mykiss* that are integral to conservation hatchery supplementation programs in the Snake River system. Concerns about settleable solids in rearing units due to low velocities and hydraulic dead zones led hatchery managers to convert two rectangular circulating Burrows ponds (BP), into experimental mixed-cell raceways (MCR). The MCR uses directed water flow to create discrete units with a circular counter current over centrally placed drains. We measured velocity, hydraulic residence time (HRT) and particle removal efficiency on a BP and a MCR to compare the two rearing systems. We used acoustic Doppler velocimetry to measure water velocities, introduced a salt tracer measuring conductivity at discharge to model HRT, and plastic beads were introduced to simulate typical particles of feces and waste feed. We found the MCR exhibited more homogenous velocity distribution, more mixing, and a higher average velocity than the BP. Vectors revealed well-defined, counter-rotating cells in the MCR. Particle removal in the MCR was 99.8% after 20 minutes compared to 6.1% from the BP after 50 minutes. The larger, more homogeneous velocities in the MCR are desirable for uniform water quality and optimal fish growth. Although the HRT tests did not reveal dead zones, the efficiency of particle removal validated observations of accumulated solids in production BP that are often associated with bacterial growth and frequency of cleaning. Bead tests confirmed visual observations that the MCR is an efficient system to remove solids.

Biosecurity Framework and Methods to Protect Aquaculture Facilities against Invasive Mollusks

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Invasive mollusks such as New Zealand mudsnails pose risks to aquaculture facilities that produce fish used in mitigation, supplementation, food production, or recreation. Many species of invasive mollusks can flourish within and surrounding aquaculture facilities because of their constant temperature and flow and enhanced nutritional resources. In addition, human activities associated with aquaculture facilities can increase the likelihood of transporting invasive mollusks to other locations. We provide a framework and decision tree to evaluate and characterize risks at a facility, and provide measures that can be used to disinfect water sources, facilities, and transport systems. In this process, the manager assesses vectors, vehicles, and water sources likely to introduce or transport invasive mollusks. Monitoring programs are essential tools to use in and surrounding facilities to determine the risk of invasion. Various options can be used for mollusk removal including hydrocyclone filtration, mixed-cell rearing units, depuration strategies, and various barriers. Management alternatives must also consider local regulatory infrastructure, concerns and limitations. Synthesis of the current methods and research results and management options are imperative for facility managers to adequately assess and control mollusk infestations.

Limits to NZMS Populations

Potamopyrgus antipodarum (Gray, 1843) (New Zealand mudsnail) at Capitol Lake, Olympia, Washington: Surveys, Containment, and Control of the Introduction

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The New Zealand mudsnail (NZMS) was first detected in the Puget Sound region at Capitol Lake, Olympia, Washington by Bert Bartleson (Olympia) on October 22, 2009 and confirmed by Ed Johannes on November 15th. As a result, U. S. Fish & Wildlife Service (USFWS), Washington Department of Fish & Wildlife (WDFW), and Washington Department of General Administration (GA) jointly assessed the situation and came up with a plan to close public access to the lake, inform the public and other government agencies of the introduction, conduct surveys

to determine the extent of the introduction, and to research ways to contain or control the introduction. In 2009, Kevin Aitkin (USFWS) and Allen Pleus (WDFW) conducted spot surveys for NZMS in Capitol Lake and its tributaries and WDFW decontaminated a local fish hatchery. Additional wading surveys of Capitol Lake were conducted by WDFW in 2009. GA conducted controlled drawdowns of Capitol Lake in 2009, 2010, and 2011, so WDFW could study the impact of exposure to freezing temperatures and from refilling Capitol Lake with salt water on the NZMS population. Deixis Consultants assisted in the 2009 freeze effects study. A detailed survey for NZMS in mapped water bodies within a 5-mile radius of Capitol Lake was initiated by the Washington Invasive Species Council and conducted by Deixis Consultants from August to September, 2010.

Thermal Limits to Range Expansion of NZMS in A Highly Used Recreational Drainage in the Intermountain west

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Following the discovery of New Zealand mudsnails, *Potomopyrgus antipodarum,* in the world-renown Silver Creek watershed in Idaho, we investigated the distribution and seasonal dynamics of the snail populations over two years (2004 – 2006). Despite extensive fishing and recreational activities in the watershed, the infestations of snails appeared to have not increased in extent. We monitored and correlated measures of water temperatures and other physico-chemical factors with distribution and relative densities of *P. antipodarum*. As with other published studies, densities of *P. antipodarum* were highest during summer months, but the distribution was patchy. We found that near-to-below freezing winter water temperatures in localized reaches of the watershed increased colony mortality and caused local extirpations. Winter refuges for *P. antipodarum* were located associated with groundwater releases, or impoundments that served to dampen the temperature extremes. We speculate that the population has remained restricted because thermal conditions are not conducive to year-round survival and growth. We recommend continued monitoring and awareness of the population in light of potential watershed alterations.

Assessing the safety and efficacy of biological control of the New Zealand Mud Snail

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Classical biological control is a possible management strategy for the invasive New Zealand Mud Snail (NZMS; *Potamopyrgus antipodarum*). The first step in assessing a prospective control agent is to evaluate its safety and efficacy. We have initiated a research program examining the safety and efficacy of specialized castrating trematode parasite of NZMS. Concerning efficacy, we conducted a survey of NZMS and its trematode parasites throughout its native range—the North and South Islands of New Zealand. This provides information on whether the parasite can regulate snail populations. Also concerning efficacy, we have been cultivating the parasite in North American NZMS. Regarding safety, we have been conducting non-target exposure experiments and performed a survey of NZMS and native snails in another invaded area—southwestern Australia. We have also initiated studies on the pathological impacts of the parasite to final host birds. I will share preliminary findings from this ongoing research that can inform downstream management decisions.

New Zealand mudsnails as leaf litter decomposers

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Invasive species have been known to change trophic dynamics and alter ecosystem function. Until recently, the invasive New Zealand mudsnail (*Potamopyrgus anitpodarum)* has largely been studied as a consumer of periphyton, algae and diatoms. This study aims to consider the snails' role as decomposers and (1) determine if New Zealand mudsnails accelerate the rate of leaf litter decomposition and (2) determine how mudsnail density alters decomposition. Leaf litter bags containing air-dried White Alder (*Alnus rhombifolia*) leaves were placed in an invaded California stream and the snails' had restricted access to half of the bags. Subsets of the bags for each treatment were removed weekly, for one month, and the abundance and biomass of invertebrates were quantified. Using non-linear regression analysis, we found that there was a significant difference in leaf decay rates between treatments. Leaf litter that was exposed to snails lost 30% of its mass over 28 days, but treatments where the snails' access to the leaf litter was reduced lost only 15% of leaf litter mass. The abundance of non-mudsnail invertebrates in each treatment did not differ over the course of the experiment. This suggests that native

invertebrates are playing a smaller role in the breakdown and decomposition of riparian leaf litter in areas where New Zealand mudsnails have invaded. Initial results suggest that snail density may significantly contribute to litter decomposition. A second study, where snail densities varied in bags containing *A. rhombifolia* leaves, further supported these these findings.

The roles of productivity and diversity in mediating dominance of an invasive freshwater snail

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According to long-standing theory, native diversity should limit the ability of species to invade and dominate. However, the importance of biotic resistance in repelling invasions remains controversial and it appears that high resource availability (i.e. high productivity) has the ability to neutralize competitive effects from native community members. Here, we tested whether production, diversity or both, influenced dominance of an invasive freshwater snail. The New Zealand mud snail, *Potamopyrgus antipodarum*, dominates macro-invertebrate communities in some western U.S. streams, but constitutes only a small portion of the community in other streams. Thus, we quantified relative abundance of *Potamopyrgus* across eleven streams in northwestern Wyoming. In addition, we measured primary production, native macro-invertebrate diversity and other supplementary variables. We found that primary production and macro-invertebrate diversity were both highly variable across streams. In addition, the dominance of *Potamopyrgus* was also highly variable, with the abundance (relative and absolute) of *Potamopyrgus* highest in the most productive stream. These results suggest that primary production might be more important than native community diversity in predicting success of *Potamopyrgus*.

What is driving the sudden collapse of New Zealand mudsnails in the West?

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Populations of New Zealand mudsnails (NZMS) that are widely established have rapidly collapsed to low densities in many western streams. These declines have not been linked to any direct management action. Flow variability, food and nutrient limitation, parasites, and predation have been posited as drivers of these spontaneous collapses, but are untested because rapid declines are rare events that are seldom studied. Data that do exist are largely anecdotal and describe NZMS occurrence rather than demographic variability over time. We used a retrospective analysis constructed from occurrence data, anecdotal observations, and ecology first principles to discriminate among drivers of the recent NZMS crash in multiple streams in the western North America. Retrospective inferences are valuable because they can eliminate hypotheses that lack strong support and identify the kinds of data needed to test the remaining hypotheses. Greater insight on the processes that drive sudden collapses may provide opportunities to identify cost-effective strategies to remove or reduce the density of invasive species.