SANTA MONICA BAY NATIONAL ESTUARY PROGRAM

New Zealand Mudsnail Surveys

Santa Monica Mountains

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Introduction

The highly invasive New Zealand mudsnail was first reported in the Santa Monica Mountains in 2005. The snails were collected in 4 streams during bioassessment monitoring of the Malibu Creek watershed as part of a watershed-wide monitoring program[1]. As of 2014, NZMS have been detected in 14 streams in the Santa Monica Mountains. The Bay Foundation (TBF) is currently funding research to help determine the impacts of the New Zealand mudsnails on benthic macro-invertebrates in northern Santa Monica Bay watersheds. Stakeholders, including California State Parks, Mountain Restoration Trust, National Parks Service, and Santa Monica Bay National Estuary Program (SMBNEP), are currently considering the use of biological control methods being proposed by Dr. Tom Dudley from the Riparian Invasion Research Laboratory at UC Santa Barbara. SMBNEP is also evaluating the potential uses of environmental DNA (eDNA) as an early detection method for NZMS and other aquatic invasive species.

Background

New Zealand mudsnails (NZMS*), Potamopyrgus antipodarum*, are tiny (3-5 mm), highly invasive, aquatic snails (Fig. 1). A single snail is capable of producing a colony of 40 million progeny in the course of a single year by reproducing parthenogenetically, cloning[2] (Fig. 2). Studies have documented NZMS densities in streams at more than 500,000 organisms per square meter[3]. NZMS are easily transported from stream-to-stream by hitchhiking on anything that comes in contact with an infested stream. NZMS commonly attach themselves to shoes, boots and waders, domestic and wild animals, recreational equipment such as fishing gear and bicycles, as well as boats and boat trailers.

Figure 1. New Zealand Mudsnail

New Zealand mudsnails were discovered in Idaho's Snake River in the mid-1980s, and have since spread to every western state except New Mexico. New Zealand mudsnails were first detected in the Santa Monica Mountains in the spring of 2005, in Medea Creek, part of the Malibu Creek watershed. In the fall of that same year, NZMS were collected in three additional streams in the Malibu Creek Watershed; Lindero, Las Virgenes, and Malibu Creek itself. The discovery was made during routine bioassessment monitoring conducted by the Malibu Creek Watershed Monitoring Program and Aquatic Bioassay & Consulting Laboratories, Inc[1].

Figure 2. NZMS at high density clinging to a single rock.

Following the discovery of New Zealand mudsnails in the Malibu Creek watershed, the SMBNEP hosted a mudsnail "summit" meeting in June 2006 to coordinate agency responses to the invasion. At the meeting, it was

[1] Aquatic Bioassay & Consulting Laboratories, Inc. 2006. Malibu Creek Watershed Monitoring Program, Bioassessment Monitoring, Spring/Fall 2005. Available at: www.waterboards.ca.gov/water_issues/programs/tmdl/records/region_4/2009/ref3242.pdf

[2] Alonso, A. and P. Castro-Diez. 2008. What explains the invading success of the aquatic mud snail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca)? *Hydrobiologia.* 614: 107-116.

[3] Dorgelo, J. 1987. Density fluctuations in populations (1982-1986) and biological observations of *Potamopyrgus jenkinsi* in two trophically different lakes. *Hydrobiological Bulletinn.* 21: 95-110.

determined that a presence/absence survey would need to be conducted to determine the extent of the invasion in the Santa Monica Mountains. At the summit and subsequent meetings, the agencies and groups involved in stream monitoring developed strategies to prevent the spread of NZMS to other streams and watersheds in the Santa Monica Mountains.

Three major strategy elements grew out of the June 2006 NZMS summit:

1. All the monitoring groups and agencies that collect data from fresh water streams or brackish water estuaries in the Santa Monica Mountains would cease their monitoring until the NZMS survey could be completed.
2. Before resuming stream or estuary monitoring activities, the monitoring groups would develop protocols for cleaning equipment and foot wear that would ensure NZMS were not being transported from stream-to-stream.
3. Create an NZMS warning and spread prevention sign that could be posted at the numerous recreational areas in the Santa Monica Mountains where visitors were likely to come in contact with a stream. (This would entail a message that all the groups and agencies could agree upon).

The various resource management agencies and groups that were monitoring in the area created and agreed upon the specific language to be used in the NZMS prevention signs (Appendix 1). NZMS prevention signs were created in both English and Spanish and posted strategically throughout the region. The signs are checked and replaced, if needed, annually during the surveying.

The first survey took place in 2006. The survey was conducted at 43 sites on 15 individual streams in the Santa Monica Mountains. New Zealand Mudsnails were confirmed at 14 sites on 3 different streams in the Malibu Creek watershed: Medea Creek, Malibu Creek, and Las Virgenes Creek. No mudsnails were detected outside the Malibu Creek watershed. Yearly repetition of the surveys was one of the recommendations that came from the first survey report produced in 2006.

Since the initial survey in 2006, 19 additional sites and 7 additional streams have been added for a total of 62 sites and 22 streams (Table 1). Survey sites are selected throughout the Santa Monica Mountains, with special emphasis in the Malibu Creek watershed where the presence of New Zealand mudsnails was first detected within the Santa Monica Mountains watershed. The surveys occur at locations that are frequently monitored for water quality, benthic macro-invertebrates, amphibians, or fish. Additionally, several sites frequented by recreational users such as anglers, hikers, cyclists, and equestrians are also surveyed. These sites are considered likely locations for the New Zealand Mudsnail to be spread from its known sources.

By 2009, NZMS had increased in both spatial distribution and abundance throughout the Santa Monica Mountains since their discovery in 2005[3]. In 2006, three streams and 14 sites surveyed had NZMS[4]. As of April 2009, these numbers grew to 8 streams and 27 sites.

In April 2009, staff conducted a special brief survey of two new streams based on information received about potential mudsnail colonization.

[4] Abramson, M., J. Topel, and H. Burdick. 2009. New Zealand Mudsnail Surveys July 2006, July 2007, October 2008 and April 2009 Santa Monica Mountains. *Santa Monica Bay Restoration Commission* and *Santa Monica Baykeeper.* Available at: http://mudsnails.com/Documents/NZMS%20Report%2006-April%20-09%20s.pdf

Table 1. NZMS survey sites.

Site ID	Name	Watershed	Year 1st Surveyed	Year Mudsnails 1st Detected
HtB-19	Arroyo Sequit	Arroyo Sequit Watershed	2006	N/O
NPSASlower	Arroyo Sequit	Arroyo Sequit Watershed	2006	N/O
NPSCHC	Cheseboro Canyon Creek	Malibu Creek Watershed	2006	N/O
NPSWQPClower	Cheseboro Canyon Creek	Malibu Creek Watershed	2006	N/O
HtB-06	Cheseboro Canyon Creek	Malibu Creek Watershed	2006	N/O
NZMS07	Cheseboro Canyon Creek	Malibu Creek Watershed	2006	N/O
NZMS04	Cold Creek	Malibu Creek Watershed	2006	2008
HtB-11	Cold Creek Middle	Malibu Creek Watershed	2006	2009-Oct
HtB-02	Cold Creek Outlet	Malibu Creek Watershed	2006	2011
HtB-03	Cold Creek Reference	Malibu Creek Watershed	2006	2014
NZMS-13	Corral Canyon Creek	Corral Canyon Watershed	2007	N/O
E5 d	Escondido Canyon Creek	Escondido Canyon Watershed	2009-April	N/O
E7 d	Escondido Canyon Creek	Escondido Canyon Watershed	2009-April	N/O
HV	Hidden Valley Creek	Malibu Creek Watershed	2007	N/O
HtB-18	LaChusa Creek	LaChusa Creek Watershed	2006	2014
NZMS01	Las Virgenes	Malibu Creek Watershed	2006	2006
NPSLVN	Las Virgenes	Malibu Creek Watershed	2006	N/O
NPSLVS	Las Virgenes	Malibu Creek Watershed	2006	2007
LV1	Las Virgenes Creek One	Malibu Creek Watershed	2006	N/O
HtB-05	Las Virgenes Creek Outlet	Malibu Creek Watershed	2006	2006
HtB-09	Las Virgenes Creek	Malibu Creek Watershed	2006	N/O
LV2	Las Virgenes Creek Two	Malibu Creek Watershed	2006	2006
NZMS-09	Las Virgenes	Malibu Creek Watershed	2007	2013
NZMS-10	Las Virgenes	Malibu Creek Watershed	2007	2007
HtB-13	Las Virgenes Middle	Malibu Creek Watershed	2006	2007
LC	Liberty Canyon Creek	Malibu Creek Watershed	2006	N/O
Liberty Lower	Liberty Canyon Creek	Malibu Creek Watershed	2007	2011
Lindero Lower	Lindero Creek	Malibu Creek Watershed	2006	2007
NZMS05	Lindero Creek	Malibu Creek Watershed	2007	2008
LIN1	Lindero Creek One	Malibu Creek Watershed	2006	2013
LIN2	Lindero Creek Two	Malibu Creek Watershed	2006	N/O
NZMS-02	Malibu Creek	Malibu Creek Watershed	2006	2006
NZMS-03	Malibu Creek	Malibu Creek Watershed	2006	2006
MAL	Malibu Creek	Malibu Creek Watershed	2006	2006
Tapia R-9	Malibu Creek	Malibu Creek Watershed	2006	2006
NZMS-15	Malibu Creek	Malibu Creek Watershed	2007	2007
HtB-01	Malibu Creek	Malibu Creek Watershed	2006	2006
HtB-15	Malibu Creek	Malibu Creek Watershed	2006	2006
HtB-12	Malibu Creek	Malibu Creek Watershed	2006	2006
NZMS06	Medea Creek	Malibu Creek Watershed	2006	2006
ML-01	Medea Creek	Malibu Creek Watershed	2006	2006
HtB-07	Medea Creek	Malibu Creek Watershed	2006	2006

MED-1	Medea Creek	Malibu Creek Watershed	2006	2006
HtB-08	Palo Comado Creek	Malibu Creek Watershed	2006	N/O
R3 d	Ramirez Canyon Creek	Ramirez Canyon Watershed	2009-April	2009-April
R4	Ramirez Canyon Creek	Ramirez Canyon Watershed	2009-April	2009-April
R4 b	Ramirez Canyon Creek	Ramirez Canyon Watershed	2009-April	2009-April
RUS	Russell Creek	Malibu Creek Watershed	2006	2009-Oct.
HtB-14	Solstice Canyon Creek	Solstice Creek Watershed	2006	2012
NZMS-11	Solstice Canyon Creek	Solstice Creek Watershed	2007	2007
NZMS-12	Solstice Canyon Creek	Solstice Creek Watershed	2007	2008
HtB-16	Stokes Canyon Creek	Malibu Creek Watershed	2006	2009-Oct
RCD-06	Topanga Creek	Topanga Creek Watershed	2006	N/O
RCD-03	Topanga Creek	Topanga Creek Watershed	2006	N/O
NZMS-14	Topanga Creek	Topanga Creek Watershed	2007	N/O
NPDTRClower	Trancas Creek	Trancas Creek Watershed	2006	2009-Oct
NPSTRCupper	Trancas Creek	Trancas Creek Watershed	2007	N/O
HtB-17	Triunfo Creek	Malibu Creek Watershed	2006	2009-Oct
TRI	Triunfo Creek	Malibu Creek Watershed	2006	2011
ML-05	Triunfo Creek	Malibu Creek Watershed	2006	2008
NPSTGP	Temescal Canyon Creek	Temescal Canyon Watershed	2007	N/O
UPR Zuma	Upper Zuma	Zuma Creek Watershed	2011	2011

*N/O never observed

Survey Method

The survey team is made up of two to seven staff from the Santa Monica Bay National Estuary Program experienced in identifying mudsnails.

Sites are surveyed a minimum of 100 yards upstream and 100 yards downstream from the point of entry at each site. Surveyors visually inspect substrate and/or woody debris. Substrate from the entire stream width, including wetted banks, is visually inspected. Multiple substrate samples are inspected throughout each site.

Surveyors randomly pick up rocks and/or small woody debris off the bottom of the stream, and inspected each item for the presence or absence of mudsnails. If a sample yielded suspected New Zealand mudsnail(s) but could not be confidently identified by the surveyors, NZMS were collected for visual confirmation by G. Noda (UCLA) or, if necessary, genetic analysis by M. Dybdahl (Washington State University). Samplers evaluated the abundance of NZMS using the following criteria:

Table 2. NZMS Abundance Survey Criteria

Dry	No water-unable to survey
None	No NZMS found
Low	NZMS found on less than 10% of the samples
Medium	NZMS found on more than 10% and less than 70% of samples
High	NZMS found on more than 70% of substrate samples

Figure 3. Mudsnail's right facing aperture.

Field identification of New Zealand mudsnails was based on three factors: color, size, and shell shape. Adult mudsnails have an average shell length of 3-5 mm and may vary in color, but are most commonly light brown to black. Mudsnails have conical shells with five, occasionally six, convex whorls or spirals. When held tip up, with the aperture (opening) facing the observer, the aperture is on the right and the

whorls spiral up and to the right (Fig. 3).

To prevent the unintentional spread of mudsnails during the survey, separate (non-felt bottom) waders are used at each survey location. Immediately following a site visit used waders are thoroughly cleaned off on-site using stiff bristle brushes to remove any NZMS, dirt, rocks and debris from the treads of the boots (waders) (Fig. 4). The used waders are then placed into plastic garbage bags and isolated from any clean waders to ensure cross contamination does not occur. One of the most effective methods of controlling the spread of NZMS is through freezing. In one study, Richards et al. (2004) found that 100% mortality occurred within two hours at temperatures of -3°C[5]. As a precaution used waders and brushes are placed in a chest freezer for a minimum of 48-hours after each use.

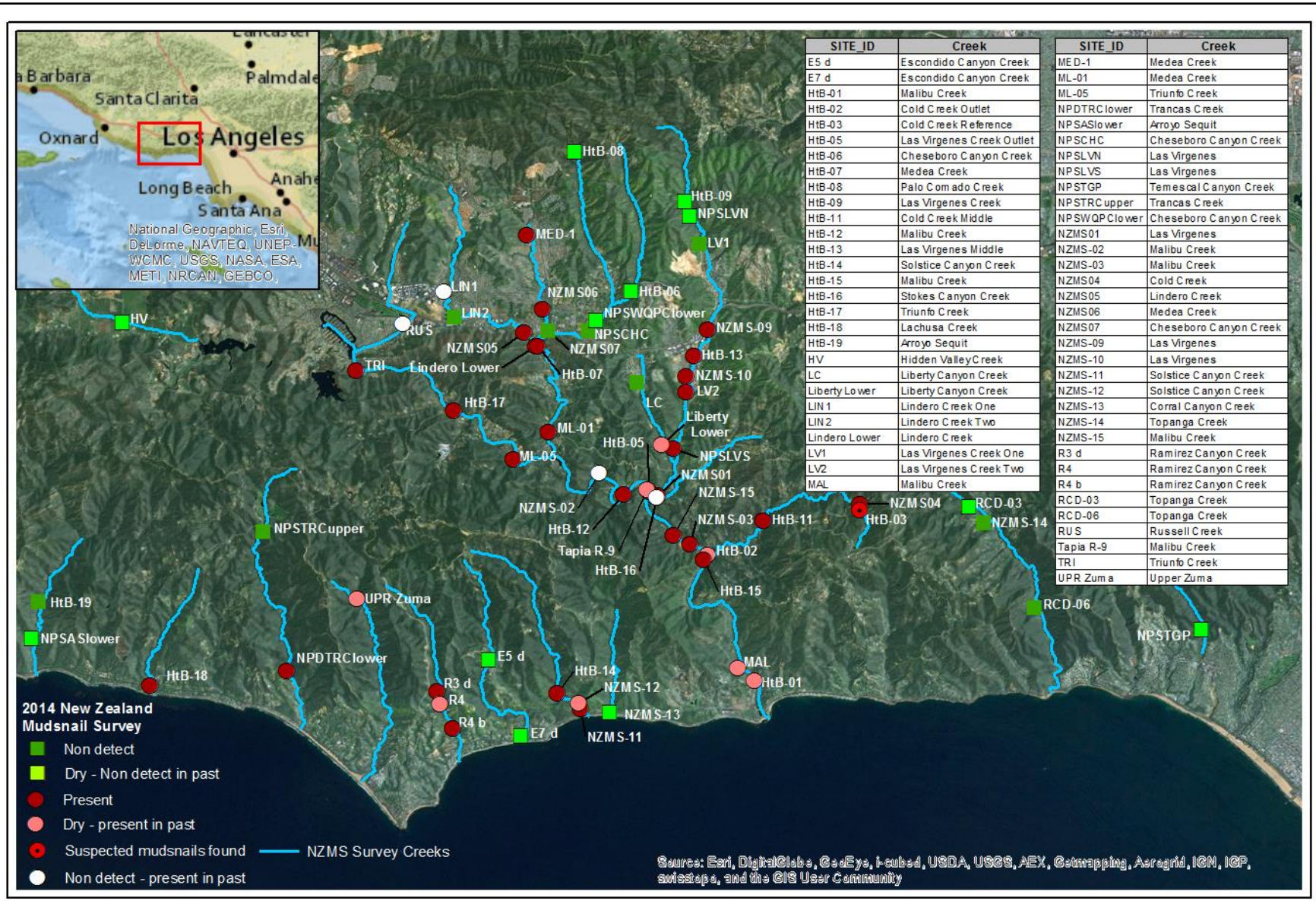
If site conditions are deemed unsafe due to any reason, including but not limited to access and wildlife, the survey team will abstain from surveying that site.

Figure 4. Wader decontamination.

Survey Results

The New Zealand Mudsnails have become well established within many streams in the Santa Monica Mountains (Fig 5). Surveys were conducted at 62 sites on 22 individual streams within the Santa Monica Mountains, of which, mudsnails have been observed at 40 sites and 14 streams since monitoring began in 2006 (Table 1). Since the April 2009 NZMS report six additional streams have become established with NZMS; LaChusa Creek, Liberty Canyon Creek, Russel Creek, Stokes Canyon Creek, Trancas Creek, and Zuma Creek.

[5] Richards, D.C., O'Connell, P and Shinn, D.C. Simple Control Method to Limit Spread of New Zealand mudsnail, Potamopyrgus antipodarum. Unpublished. Avalable at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_015233.pdf



SITE_ID	Creek
E5 d	Escondido Canyon Creek
E7 d	Escondido Canyon Creek
HtB-01	Malibu Creek
HtB-02	Cold Creek Outlet
HtB-03	Cold Creek Reference
HtB-05	Las Virgenes Creek Outlet
HtB-06	Cheseboro Canyon Creek
HtB-07	Medea Creek
HtB-08	Palo Comado Creek
HtB-09	Las Virgenes Creek
HtB-11	Cold Creek Middle
HtB-12	Malibu Creek
HtB-13	Las Virgenes Middle
HtB-14	Solstice Canyon Creek
HtB-15	Malibu Creek
HtB-16	Stokes Canyon Creek
HtB-17	Triunfo Creek
HtB-18	Lachusa Creek
HtB-19	Arroyo Sequit
HV	Hidden Valley Creek
LC	Liberty Canyon Creek
Liberty Lower	Liberty Canyon Creek
LIN1	Lindero Creek One
LIN2	Lindero Creek Two
Lindero Lower	Lindero Creek
LV1	Las Virgenes Creek One
LV2	Las Virgenes Creek Two
MAL	Malibu Creek

SITE_ID	Creek
MED-1	Medea Creek
ML-01	Medea Creek
ML-05	Triunfo Creek
NPDTRClower	Trancas Creek
NPSASlower	Arroyo Sequit
NPSCHC	Cheseboro Canyon Creek
NPSLVN	Las Virgenes
NPSLVS	Las Virgenes
NPSTGP	Temescal Canyon Creek
NPSTRCupper	Trancas Creek
NPSWQPClower	Cheseboro Canyon Creek
NZMS01	Las Virgenes
NZMS-02	Malibu Creek
NZMS-03	Malibu Creek
NZMS04	Cold Creek
NZMS05	Lindero Creek
NZMS06	Medea Creek
NZMS07	Cheseboro Canyon Creek
NZMS-09	Las Virgenes
NZMS-10	Las Virgenes
NZMS-11	Solstice Canyon Creek
NZMS-12	Solstice Canyon Creek
NZMS-13	Corral Canyon Creek
NZMS-14	Topanga Creek
NZMS-15	Malibu Creek
R3 d	Ramirez Canyon Creek
R4	Ramirez Canyon Creek
R4 b	Ramirez Canyon Creek
RCD-03	Topanga Creek
RCD-06	Topanga Creek
RUS	Russell Creek
Tapia R-9	Malibu Creek
TRI	Triunfo Creek
UPR Zuma	Upper Zuma

2014 Santa Monica Mountain New Zealand Mudsnail Survey

Figure 5. Map of surveyed streams showing presence/ absence of NZMS. Ivan Medal, TBF

Table 3. New Zealand Mudsnail Survey Results by Site 2006-2014

SITE_ID	Site Description	2006	2007	2008	April 2009	Oct. 2009	2011	2012	2013	2014
HtB-19	Arroyo Sequit-1mile N. on Mulholland Hwy. (off PCH)	none	none	none	ns	none	none	none	none	none
NPSASlower	Arroyo Sequit-Leo Carrillo campground upper crossing	dry	dry	dry	ns	dry	none	dry	dry	dry
HtB-06	Cheseboro Creek -Cheeseboro Rd. 1st gate U.S. 2nd crossing NPS	dry	dry	dry	ns	dry	dry	dry	dry	dry
NPSWQPClower	Cheseboro Creek-Old Agoura Park Colony Rd.	dry	dry	dry	ns	dry	dry	dry	dry	dry
NPSCHC	Cheseboro Creek-Canwood culvert	none	none	none	ns	none	none	dry	none	none
NZMS07	Cheseboro Creek- NW corner of Agoura Rd and Cornell Rd.	none	none	none	ns	none	none	none	none	none
HtB-03	Cold Creek-Stunt Rd. at lower gated entrance Cold Creek Reserve	none	none	none	ns	none	none	none	none	suspected low
NZMS04	Cold Creek-Public access off Stunt Rd. DS of lower entrance	none	none	low	ns	low	low	dry	med	high
HtB-11	Cold Creek-Cold Canyon Rd. M.M. 1.36 Cold Creek Midway DS	none	none	none	ns	low	high	dry	high	high
HtB-02	Cold Creek-Piuma Rd and Crater Camp Rd at the Backbone Trail	none	none	none	ns	none	high	high	dry	dry
NZMS-13	Corral Canyon Creek-Trailhead at Malibu Seafood parking lot	ns	dry	dry	ns	none	none	dry	dry	dry
E5 d	Escondido Creek added in 2009	ns	ns	ns	none	none	none	none	none	dry
E7 d	Escondido Creek added in 2009	ns	ns	ns	dry	dry	none	dry	dry	dry
HV	Hidden Valley Creek-under bridge on Potrero Rd	ns	dry	dry	ns	dry	dry	dry	dry	dry
HtB-18	LaChusa Creek-Corner of Decker Cyn Rd. and PCH	none	none	none	ns	none	ns*	ns*	ns*	high
HtB-09	Las Virgenes Creek-end of Las Virgenes Rd. SMMC Open Space	none	none	none	ns	none	none	dry	dry	none
NPSLVN	Las Virgenes Creek-Open Space 2nd crossing W of L.V. Creek	none	none	none	ns	none	none	none	dry	dry
LV1	Las Virgenes Creek-Dead end Las Virgenes Rd. gate on right side	none	none	none	ns	none	none	none	none	none
NZMS-09	Las Virgenes Creek-Lost Hills Rd. Bridge, Starbuck's parking lot	ns	none	none	ns	none	none	none	low	low
HtB-13	Las Virgenes Creek-Apts upstream of RCD Stream Restoration	none	low	med	ns	high	high	high	high	high
NZMS-10	Las Virgenes Creek-RCD Stream Restoration site Lost Hills Rd.	ns	med	high	ns	high	high	high	high	high
LV2	Las Virgenes Creek-De'Anza Park, follow path down to creek	med	high	high	ns	high	high	high	high	high
NPSLVS	Las Virgenes Creek-White Oak Farms Bridge	none	low	high	ns	high	high	high	high	high
NZMS01	Las Virgenes Creek-upstream Crags Rd. crossing MCSP	low	low	high	ns	high	high	high	high	high
HtB-05	Las Virgenes Creek-D.S. Crags Rd. crossing MCSP Trailhead	low	low	high	ns	high	high	high	high	high
LC	Liberty Canyon Creek-Dead end Liberty Cyn Rd. gate on left	none	none	none	ns	none	none	none	none	none
Liberty Lower	Liberty Canyon Creek-Horse Bridge Liberty Cyn Trail	ns	none	dry	ns	none	low	low	none	dry
LIN1	Lindero Creek-Lake Lindero Dr. field behind TJ Max	none	none	none	ns	none	none	none	low	none
LIN2	Lindero Creek-Lake Lindero Dr. spillway	none	none	none	ns	none	none	none	none	none
NZMS05	Lindero Creek-Agoura Rd. culvert	ns	none	high	ns	high	high	high	high	high
Lindero Lower	Lindero Creek-outlet into Medea Creek east of Kanan Rd.	none	high	high	ns	high	high	high	high	high
NZMS02	Malibu Creek-Lookout Trail, Logan's Run culvert U.S. Century Lake	med	high	high	ns	med	med	low	low	none
HtB-12	Malibu Creek-MCSP D.S. of Rock Pool	med	med	med	ns	low	med	low	low	low
Tapia R-9	Malibu Creek-Texas Crossing MCSP	low	low	med	ns	high	high	high	dry	dry
NZMS-15	Malibu Creek-Salvation Army Camp Bridge	ns	high	high	ns	high	high	high	med	high
NZMS03	Malibu Creek-Tapia Park U.S. of grated drain	med	high	high	ns	high	high	high	high	med
HtB-15	Malibu Creek-Malibu Cyn Rd. U.S. LA County Stream Gauge	low	low	high	ns	med	high	high	low	low
MAL	Malibu Creek-Follow trail at end of Palm Cyn Rd in Serra Retreat	low	med	high	ns	low	med	low	dry	dry
HtB-01	Malibu Creek-Cross Creek Rd. U.S. middle of Arizona Crossing	low	low	high	ns	low	med	low	dry	dry

SITE_ID	Site Description	2006	2007	2008	April 2009	Oct. 2009	2011	2012	2013	2014
MED1	Medea Creek-Conifer St. under bridge on left side	high	high	high	ns	high	high	high	high	high
NZMS06	Medea Creek-Chumash Park	med	low	med	ns	low	med	low	low	low
HtB-07	Medea Creek-Cornell at Kanan Rd.	high	high	high	ns	high	med	low	high	high
ML-01	Medea Creek-outlet at Paramount Ranch	high	high	high	ns	high	high	high	high	high
HtB-08	Palo Comado Creek	dry	dry	dry	ns	dry	dry	dry	dry	dry
R3 d	Ramirez Canyon Creek added in 2009	ns	ns	ns	high	high	high	high	high	low
R4	Ramirez Canyon Creek added in 2009	ns	ns	ns	low	med	high	dry	dry	dry
R4 b	Ramirez Canyon Creek added in 2009	ns	ns	ns	low	dry	high	high	high	med
RUS	Russell Creek	none	none	none	ns	low	low	none	none	none
HtB-14	Solstice Cyn Creek-NPS U.S. wood bridge	ns	none	none	ns	none	none	low	med	med
NZMS-12	Solstice Cyn Creek-U.S. 2nd bridge	ns	none	low	ns	high	high	high	high	dry
NZMS-11	Solstice Cyn Creek-1st bridge-PCH culvert	ns	low	high	ns	high	high	high	high	high
HtB-16	Stoke Cyn Creek-100ft. D.S. of 1st bridge Crags Rd. MCSP	none	none	none	ns	low	med	low	none	none
RCD03	Topanga Creek-Old Topanga Creek Rd. at Backbone Trail	none	dry	dry	ns	none	none	dry	dry	dry
NZMS-14	Topanga Creek-behind Topanga General Store	ns	dry	dry	ns	none	none	none	dry	none
RCD06	Topanga Creek-Topanga Creek Blvd. M.M. 2.2 Stream Gauge	none	none	none	ns	none	none	none	none	none
NPSTRCupper	Trancas Creek-Encinal Rd. to Malibu Country Club, 400ft down path	ns	none	none	ns	none	none	none	none	none
NPSTRClower	Trancas Creek-Paseo Cyn Dr. through gate,500ft to end of road	none	none	dry	ns	med	high	low	low	low
TRI	Triunfo Creek-Trailhead on right side of Ridgeford Dr.	none	none	none	ns	none	low	low	low	low
HtB-17	Triunfo Creek-Corner of Kanan Rd. at Troutdale U.S. of bridge	none	none	none	ns	low	low	low	none	low
ML-05	Triunfo Creek-outlet adjacent to Green Willow	none	none	low	ns	low	low	high	low	low
NPSTGP	Temescal Cyn Creek-Temescal Gateway Park-0.52 miles at bridge	ns	none	dry	ns	none	none	dry	dry	dry
UPR Zuma	Zuma Creek	ns	ns	ns	ns	ns	high	dry	dry	dry

"ns" indicates the site was not surveyed.

*site conditions unsafe.

Malibu Creek Watershed Survey Results

The Malibu Creek watershed is made up of 12 surveyed streams and 43 survey sites. Of these 12 streams NZMS have been found at 9 streams and 32 sites, leaving 3 streams and 11 sites unaffected by mudsnails. The 9 streams that NZMS have been observed at include: Cold Creek, Las Virgenes Creek, Liberty Canyon Creek, Lindero Canyon Creek, Malibu Creek, Media Creek, Russell Creek, Stokes Canyon Creek, and Triunfo Creek. The 3 streams that NZMS have not been observed at include: Cheseboro Canyon Creek, Hidden Valley Creek, and Palo Comado Creek.

Cheseboro Canyon Creek is made up of 4 survey sites. All sites have been absent of mudsnails since monitoring began in 2006 however 2 sites (NPSWQPClower, HtB-06) have been dry during every monitoring event since 2006.

Hidden Valley Creek consists of 1 survey site (HV). This site has been dry during every monitoring event since it was first surveyed in 2007.

Palo Comado Creek consists of 1 survey site (HtB-08). This site has been dry during every monitoring event since 2006.

Cold Creek consists of 4 survey sites. Two of the sites have increased mudsnail in abundance. One site (NZMS04) was low from 2008 to 2011, dry in 2012, medium in 2013, and high in 2014. The second site (HtB-11) went from low in 2009 to high in 2011. This site was dry in 2012, but mudsnails were found in high abundance in 2013 and 2014. Mudsnails were first observed at a third site (HtB-02) in high abundance in 2011 to 2012. The site was dry in 2013 and 2014. Two snails that closely resemble NZMS (Figure 6) were collected at the fourth site (HtB 03) in 2014.

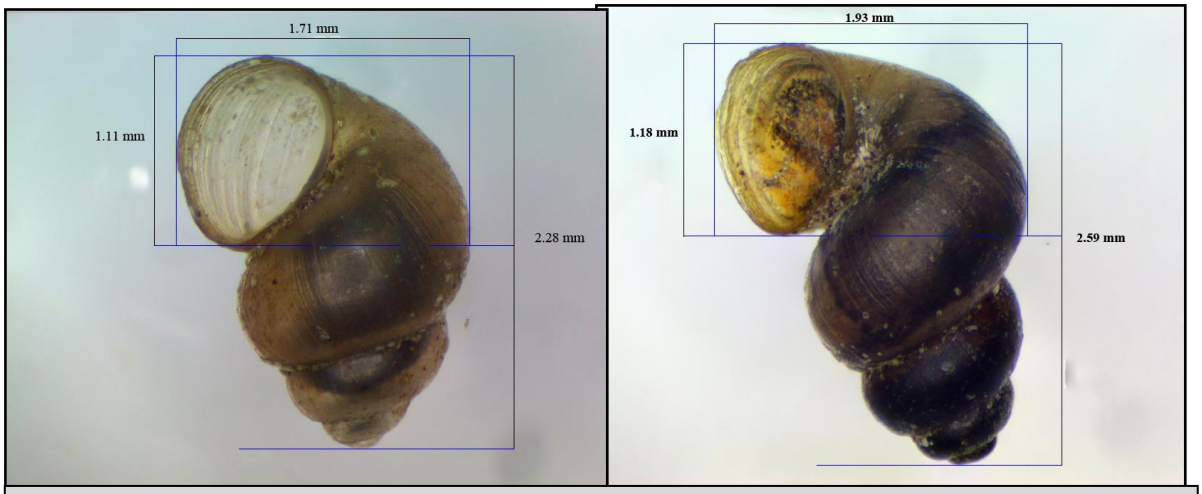


Figure 6. Two suspected NZMS discovered at Cold Creek Reference site (HtB 03) in 2014.

Las Virgenes Creek consists of 10 survey sites, 7 at which mudsnails have been observed. At 6 of the sites (HtB-13, NZMS-10, LV2, NPSLVS, NZMS01, HtB-05) mudsnails have been present in high abundance every survey year from 2009 to 2014. Mudsnails were observed at one site (NZMS-09) in low abundance in 2013 and 2014.

Liberty Canyon Creek consists of 2 survey sites, 1 at which mudsnails have been observed. Mudsnails have been observed in low abundance in 2011 and 2012 at the Liberty Lower site, in 2013 none were detected and in 2014 this site was dry.

Lindero Canyon Creek consists of 4 survey sites, 3 at which mudsnails have been observed. The City of Calabasas takes benthic macro-invertebrate samples and in 2005 identified NZMS at two sites (LIN1, LIN2) however no NZMS were ever identified by the survey team at either of these sites until 2013 when mudsnails were observed for the first time in low abundance at LIN1, in 2014 no mudsnails were found at this site despite water being present. The two other sites (NZMS05, Lindero Lower) have had a high abundance of mudsnails since 2008.

Malibu Creek consists of 8 survey sites of which all are positive for mudsnails. All sites show fluctuation in mudsnail abundance throughout the years with the exception of Tapia R-9 which has increased in abundance from low in 2006 and 2007, to medium in 2008, to high from 2009 to 2012; the site was dry in 2013 and 2014.

Media Creek consists of 4 survey sites all of which are positive for mudsnails. Two sites (MED1, ML-01) have consistently remained high in mudsnail abundance since surveying began in 2006, while the other two sites (NZMS06, HtB-07) have fluctuated in abundance throughout the years.

Russell Creek consists of1 survey site (RUS). Mudsnails were observed at this site in low abundance in 2009 and 2011 with no further observations of mudsnails from 2012 to 2014 despite water being present.

Stokes Canyon Creek consists of 1 survey site (HtB-16) which is positive for mudsnails. Mudsnails were first observed here in October 2009 in low abundance and then fluctuated from medium abundance in 2011, to low abundance in 2012, and have not been observed at this site in 2013 or 2014, despite water being present.

Triunfo Creek consists of 3 survey sites, all of which are positive for mudsnails. Mudsnails were observed at one site (TRI) for the first time in 2011 in low abundance; this site has remained low in abundance through 2014. Mudsnails were observed at another site (HtB-17) in low abundance since 2009 with the exception of 2013 when no mudsnails were detected, despite water being present. At the third site (ML-05) mudsnails have remained low in abundance since 2008 with the exception of 2012 when mudsnails were high in abundance.

Other Santa Monica Mountain Watersheds Survey Results

Ten additional streams and 19 additional survey sites in the Santa Monica Mountains that are outside of the Malibu Creek watershed are surveyed. Of these 10 streams NZMS have been observed at 5 streams and 9 sites, leaving 5 streams and 10 sites where NZMS have not been detected. The 5 streams NZMS have been observed at include: LaChusa Canyon Creek, Ramirez Canyon Creek, Solstice Canyon Creek, Trancas Canyon Creek, and Zuma Creek. The 5 streams NZMS have not been observed at include: Arroyo Sequit Creek, Corral Canyon Creek, Escondido Creek, Temescal Canyon Creek, and Topanga Creek.

LaChusa Canyon Creek consists of 1 site (HtB-18) which is positive for mudsnails. Mudsnails were originally detected here by Heal the Bay from a June 2012 sample; however this site was not surveyed from 2011 to 2013 due to unsafe conditions for the survey team. Surveys resumed in 2014, and mudsnails were detected in high abundance.

Ramirez Canyon Creek consists of 3 survey sites, all of which are positive for mudsnails. One site (R3 d) has had a high abundance of mudsnails since April 2009 with the exception of 2014 when mudsnail abundance was low. Another site (R4) has increased in mudsnail abundance from low in April 2009 to medium in October 2009 to high in 2011 and was dry in 2012, 2013, and 2014. The other site (R4 b) fluctuated in mudsnail abundance from low in April 2009 to high in 2011, 2012, and 2013, it was dry in October 2009, and medium in 2014.

Solstice Canyon Creek consists of 3 survey sites, all of which are positive for mudsnails. In 2012 mudsnail were first observed in low abundance at one site (HtB-14) and then increased to medium abundance in 2013 and 2014. Another site (NZMS-12) increased in mudsnail abundance from low in 2008 to high in 2009 and remains high through 2013; the site was dry in 2014. The other site (NZMS-11) has been high in mudsnail abundance since 2008 after they were first observed in low abundance in 2007.

Trancas Creek consists of 2 sites, one site (NPSTRClower) is positive for mudsnails. Mudsnails were first detected at this site in October 2009 in medium abundance. The abundance then fluctuated from high in 2011, to low in 2012, 2013, and 2014.

Zuma Creek consists of 1 site. This site was added to the survey in 2011 and mudsnails were observed there in high abundance. The site has been dry from 2012 to 2014.

Field Notes

Although mudsnails observed during the survey appeared to be far more abundant near the banks (stream margins) in relatively shallow areas with a moderate flow, they were observed under almost all stream conditions that the survey team encountered.

Very few mudsnails were found on soft bottom habitat (i.e., mud) although they were noted on almost every other type of substrate, including rocks, woody debris, and trash. Mudsnails were also observed on floating or submerged algal mats and plants. Mudsnails were not commonly found in concrete channels or culverts.

Discussion

New Zealand Mudsnails have increased in both spatial distribution and abundance since the last survey report in April 2009. In 2011, one additional site (UPR Zuma) in a new stream, Zuma Creek, was added to the monitoring sites. NZMS have been observed, for the first time, at this new site along with 13 other sites (HtB-11, HtB-02, HtB-03, HtB-18, NZMS-09, Liberty Lower, LIN 1, RUS, HtB-14, HtB-16, NPDTRClower, HtB-17, TRI), since the April 2009 NZMS report (Table 3). In October 2009, 31 sites in 11 streams were positive for the presence of NZMS. In 2011, 36 sites in 13 streams were positive for NZMS. In 2012, 32 sites in 11 streams were positive for NZMS. In 2013, 29 sites in 9 streams were positive for mudsnails. In 2014, 29 sites in 10 streams were positive for NZMS. Although it may seem that the presence of mudsnails is decreasing this may be misleading. The decreased numbers of positive sites and streams may be due to many sites and streams being dry (Table 4). In October 2009 there were 7 dry sites, in 2011 there were 4 dry sites, in 2012 there were 15 dry sites, in 2013 there were 17 dry sites, and in 2014 there were 19 dry sites.

Table 4. New Zealand Mudsnail Overall Survey Results 2006-2013

	2006	2007	2008	April 2009	Oct. 2009	2011	2012	2013	2014
Total # sites	44	56	56	5	61	61	61	61	62
Total # streams	16	19	19	2	21	21	21	21	22
# dry sites	4	8	11	1	7	4	15	17	19
# positive sites	14	20	24	3	31	36	32	29	29
# sites "none"	26	28	21	1	23	21	14	14	14
# sites "low"	6	9	3	2	10	6	12	9	10
# sites "med"	5	3	4	0	4	7	0	3	3
# sites "high"	3	8	17	1	17	23	20	17	16
# positive streams	3	5	7	1	11	13	10	9	10

NZMS are positively rheotactic (moving upstream against the current) crawling at speeds greater than 1 m/hour (Richards 2002)[6] and can travel up to 60 m upstream in 3 months (Zaranko et al. 1997)[7]. The New Zealand Mudsnail surveys have shown that NZMS made their way upstream at Solstice Canyon Creek and Triunfo Creek. It is expected that they will continue to expand their distribution, and will eventually make their way upstream at Liberty Canyon Creek and Trancas Creek.

Cold Creek Preserve (Upper Cold Creek HtB-03) is used as a reference condition site in the Santa Monica Mountains for water quality and benthic macro-invertebrates. It was hoped that the site posed a physical barrier to NZMS due to the presence of a pipe outfall under Stunt Rd. with a drop of several feet into a pool, separating the site from the lower Cold Creek sites. In 2011, this site was closed to the public to prevent the accidental spread of mudsnails; the site remained open to researchers. This decision was made by the Mountain Restoration Trust (MRT) after mudsnails were discovered during SMB NEP's annual surveys at the three lower Cold Creek sites.

In 2014, two suspected mudsnails (Figure 6) were collected at the Upper Cold Creek site in a small pool, just upstream of where the trail crosses the stream. Because the samples could not be positively identified, the MRT has temporarily closed the site to all activities until additional sampling can be performed and the presence or absence of NZMS can be confirmed.

The potential for biological control is currently being evaluated in the Santa Monica Mountains for New Zealand mudsnails by Dr. Tom Dudley from the Riparian Invasion Research Laboratory at UC Santa Barbara.[8] The method of biocontrol being proposed is a trematode parasite. In January 2014, Dr. Dudley presented his research at a meeting of agencies and interested groups. The outcome of this meeting indicated that additional research is needed to determine the impacts of NZMS before biocontrol efforts are pursued.

Examining changes in benthic macro-invertebrate (BMI) communities over time is important to assess the impacts of invasive New Zealand mudsnails before biological control efforts are pursued. Heal the Bay (HtB) has data on BMI communities from multiple steams pre- and post-invasion by NZMS as well as data on NZMS abundance, allowing them to assess the impacts of NZMS. With financial assistance from The Bay Foundation, HtB will assess impacts of NZMS on the benthic macro-invertebrate community from Medea, Malibu, Las Virgenes, Solstice, Cold, and Triunfo Creeks. A preliminary analysis shows that mayflies (genus *Baetis*) may be negatively impacted by NZMS, while nine other BMI groups may not be negatively impacted by NZMS.

Steelhead trout are an important endangered fish that were historically found in the Santa Monica Mountains. Efforts to restore the population by removing barriers are underway. However, Vinson and Baker (2008) have shown that NZMS are a poor food source for trout[9]. If trout restoration efforts are going to succeed it is critical that appropriate food sources are available. To ensure the success of trout restoration efforts it is important to assess the impacts of invasive NZMS on BMI communities.

The 2009 mudsnail survey report recommended that the Los Angeles Regional Water Quality Control Board place specific streams on the State's 303(d) list (waters not meeting water quality standards or not supporting

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[6] Richards, D.C. 2002. The New Zealand mudsnail invades. *Aquatic Nuisance Species Digest*. 4(4): 42-44.

[7] Zaranko, D. T., D. G. Farara, and F. G. Thompson. 1997. Another exotic Mollusk in the Laurentian Great Lakes: the New Zealand native NZ mudsnail (Gray 1843) Gastropoda, Hydrobiidae). *Canadian Journal of Fisheries and Aquatic Sciences.* 54: 809-814.

[8] University of California, Santa Barbara. 2012. RIVRLAB Riparian Invasion Research Laboratory. Available at: http://rivrlab.msi.ucsb.edu/invasive-species/new-zealand-mud-snail

[9] Vinson, M.R. and M.A. Baker. 2008. Poor growth of rainbow trout fed New Zealand mud snails *Potamopyrgus antipodarum. North American Journal of Fisheries Management*. 28(3): 701-709.

their designated uses) for invasive species. Las Virgenes Creek, Malibu Creek, Solstice Creek, portions of Lindero Creek, and Medea Creek have since been placed on the list as impaired by aquatic invasive species. The 303(d) listing initiates the development of a Total Maximum Daily Load (TMDL), or another regulatory program, to address the impairment. A TMDL is a calculated maximum amount of a pollutant or impairment that a waterbody can receive and still meet water quality standards.

The Santa Monica Bay National Estuary Program (SMB NEP) is currently evaluating the possibility of changing monitoring sites. Site selection will be based on past criteria as well as survey results. Sites that are consistently dry or high in abundance may be surveyed once every two years. Additional sites may be added. When the severe drought subsides surveys will be conducted at all the sites.

We are also evaluating the potential uses of environmental DNA (eDNA) as an early detection method for NZMS and other aquatic invasives. Recent research indicates that this method can detect extremely low densities of NZMS and other invasive species in a cost effective manner.

Recommendations

To reduce further spread of the invasive New Zealand Mudsnail the SMB NEP make the following recommendations:

1. All agencies should review their monitoring protocols and make alterations to the protocols as needed to prevent the spread of NZMS. Ensure all personnel including staff, volunteers, and any accompanying parties are following the protocols to help prevent the accidental spread of NZMS. Train all new personnel on the proper protocols and ensure they understand the importance of following the protocol to help prevent the spread of NZMS.

2. Repeat the mudsnail presence/absence and abundance surveys into the future.

3. Compare pre- and post-establishment water quality data to evaluate the impacts of NZMS and prioritize the need for implementing control methods.

4. Ensure NZMS prevention signs (English and Spanish) are clearly displayed at all access points to streams throughout the Santa Monica Mountains.

5. That the State Water Resource Control Board and the Los Angeles Regional Board place the following streams on the state 303(d) list as impaired for aquatic invasive species: Cold Creek, Trancas Creek, Zuma Creek, Triunfo Creek, LaChusa Canyon Creek, and Ramirez Canyon Creek.

6. Evaluate the potential uses of environmental DNA (eDNA) as an early detection method for NZMS and other aquatic invasive species.

7. Continue research into the efficacy of biocontrol.

Appendix 1: New Zealand Mudsnail Prevention Sign (English)

WARNING

New Zealand Mudsnails Threaten Native Wildlife

YOU CAN STOP THEIR SPREAD!

New Zealand mudsnails are INVASIVE aquatic snails. They take over habitat that supports native wildlife, including endangered species.

Mudsnails can take over an entire creek. A single snail can result in a colony of more than 40 million snails in just one year.

New Zealand mudsnails can be as small as a grain of sand or up to 1/8 inch. They are typically brown or black.

Prevent the spread of New Zealand mudsnails!

AVOID CONTACT WITH WATER

However, if your activities include water contact, please follow these simple steps to reduce the chances of spreading this invader to another stream:

(1) Don't be a CARRIER!

Avoid transferring anything wet (sandals, boots, waders, bikes and other sports gear, pets and horses) from stream to stream.

(2) Keep it DRY!

After every trip to a stream or lake, remove all mud and debris, visually inspect, and completely dry your belongings. If possible do ONE of the following:
-Put all wet items in the dryer on high heat for a minimum of 2 hours.
-Freeze wet items overnight.
-Air dry your belongings at temperatures of at least 85°F for 48 hours.

HELP PROTECT OUR CREEKS AND STREAMS.

IT ONLY TAKES ONE SNAIL TO INFEST A WATERBODY!

bay restoration foundation

Visit WWW.MUDSNAILS.COM for more information