CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

MEETING OF APRIL 14 and 15, 2010
South Lake Tahoe

ITEM: **1**

SUBJECT: **PROPOSED DYE TRACER STUDY IN LAKE TAHOE**

ISSUES:

1) What regulatory action, if any, should the Lahontan Water Board take regarding a proposal to use a dye tracer in Lake Tahoe for studying surrogate dissipation and movement characteristics of a potential pesticide application to control aquatic invasive species?

2) Would a temporarily visible color plume cause a nuisance condition?

DISCUSSION:

Researchers from the US Department of Agriculture have requested to use dye in Lake Tahoe to collect information on dissipation and movement to analyze potential effects from future pesticide applications. Two species of aquatic invasive species (AIS), Curlyleaf pondweed and Eurasian watermilfoil, have infested nine marinas and more than fifteen acres of other shorezone areas over the past two decades. The proposal includes the use of a dye tracer at four sites within the Tahoe Keys (marina and lagoons), Ski Run Marina, Lakeside Marina, Emerald Bay, and near the Tahoe City dam.

The Tahoe Keys contains the densest infestations and property managers have used mechanical harvesters every season to cut the weeds back. The mechanical harvesting does not remove the invasive weeds' roots and contributes to the spread by dispersing newly cut propagules which increase the weed density each year; the annual harvesting has not been able to eradicate the invasive weeds from the Tahoe Keys. Property managers also used divers to hand pull the weeds from small patches, but this method is labor intensive and challenging because the weed density is high and smaller plants are easily missed.

Successfully removing invasive aquatic species must address the causes of the invasions and include plans to restore the habitat to bring back or encourage native species. Research efforts on AIS in Lake Tahoe have been underway since the 1990s. However, until the Asian clam infestation in 2007, there has been a lack of funding and limited importance placed on removing invasive aquatic species. The Lake Tahoe Aquatic Invasive Species Coordinating Committee and Working Group voluntarily formed in 2008 to cooperate and coordinate activities among regulators, funding agencies, public land/water management agencies, and researchers to prevent the introduction, establishment, and spread of non-native aquatic species in the Lake Tahoe Basin. The Lake Tahoe AIS Coordinating Committee, which directs the tasks of the AIS Working Group, is comprised of individuals representing eleven different entities: California Department of Fish and Game, California State Lands Commission, Lahontan Water Board, Nevada Department of Wildlife, Nevada Division of State Lands, Tahoe Resource Conservation District, Tahoe Regional Planning Agency, Tahoe Science Consortium, US Department of Agriculture, US Forest Service, US Fish and Wildlife Service. The AIS Working Group consists of representatives from the eleven entities listed above plus researchers from the University of California at Davis and the University of Nevada at Reno-Desert Research Institute.

AIS infestations reduce biological, recreational and economical values and have negative impacts upon the environment. The AIS Coordinating Committee produced a draft AIS Management Plan in June 2009 (Enclosure 1) with active participation, input, and support from Water Board staff. The AIS Management Plan describes a coordinated approach to identify existing populations of AIS, standardize monitoring and removal techniques, coordinate prevention, and educate the public about AIS.

Methods for AIS removal or control could be either mechanical, or chemical, or a combination of mechanical and chemical. At present, only mechanical methods (i.e. hand pulling, bottom barriers, suction removal, and mechanical harvesting) have been attempted to eradicate or control some infestations of AIS plants and Asian clams. Chemical methods have not been tried in Lake Tahoe because the Lahontan Basin Plan does not allow pesticides to be detected in waters of the region, essentially prohibiting the chemical methods. With the exception of a conditional variance for specific rotenone applications by the California Department of Fish and Game, the Lahontan Basin Plan currently does not allow the Board to consider an individual proposal using a chemical method for AIS control or eradication in Lake Tahoe. A proposed Basin Plan Amendment to allow use of pesticides under specific and limited circumstances is expected to be brought for Board consideration at its November 2010 meeting.

AIS source control methods, such as mandatory watercraft inspections and cleaning, have been successfully implemented at Lake Tahoe since 2009 and are a critical component of the AIS Management Plan. The AIS inspections and public education and important parts of the AIS prevention.

Researchers from the AIS Working Group need to perform a dye tracer study in Lake Tahoe to collect critical information to design and evaluate an effective chemical AIS control/eradication method without discharging any pesticide. In the absence of the dye study, researchers will be unable to develop a chemical method and evaluate the environmental effects of any proposed chemical method. As part of developing a proposal for chemical control of AIS in Lake Tahoe, an environmental analysis in accordance with the California Environmental Quality Act must be completed. An analysis of potential adverse effects of such a project within Lake Tahoe cannot be completed without the results of the dye tracer study.

Under the guidance from the Lake Tahoe AIS Working Group, researchers from the US Department of Agriculture propose to use the specific dye tracer, Rhodamine WT, for studying movement of water in specific areas, and to gain site-specific information on the retention time, dissipation and movement of a liquid substance. The dye tracer is applied in non-toxic concentrations and is a surrogate to mimic the behavior of aquatic pesticides. Rhodamine WT has been widely used as a dye tracer since the 1970s and was most recently used in California to study water movement in the Truckee River in 2008, Clear Lake in 2008, Sacramento-San Joaquin Delta in 2009, and in the Sacramento River in March 2010.

The results of this proposed study will provide an understanding of how soluble materials behave in the proposed target sites and also provide information on how small “pelagic” particles such as veligers (e.g. larvae of

Asian clams, quagga or zebra mussels) may be dispersed within the Tahoe Keys, other marinas, and offshore areas. This data will facilitate evaluations (risks, benefits) of using EPA-approved aquatic pesticides, and will add to the overall understanding of risk due to movement of invasive plants and animals in the near-shore environment.

Rhodamine WT is proposed to be injected into the water column at concentrations that are non-toxic but may be temporarily visible as a slight red tint. The Lahontan Basin Plan color objective states:

> **Color**
> *Waters shall be free of coloration that causes nuisance or adversely affects the water for beneficial uses.*

At each study site, the researchers propose to discharge up to approximately 50 gallons of Rhodamine WT dye at a concentration not to exceed 100 parts per billion (ppb). The dye concentrations are expected to dissipate and be no longer visible within minutes in areas with faster water currents and to up to 8-10 hours in areas with slower water currents. Although not visible after some dissipation, a fluorometer can detected dye concentrations as low as one part per trillion. Researchers have proposed to use the 100 ppb dye concentration in areas suspected to have stronger water currents, such as open areas, and will use lower concentrations in areas with weaker currents, such as partially enclosed marinas or lagoons. After monitoring the dye plume movement within a weaker current area, the researchers expect to reduce the dye concentration for other weak current areas to use the lowest possible concentration to detect plume movement and dissipation. Researchers anticipate being able to use a 50 ppb dye concentration or lower for the areas with weaker currents. Enclosure 2 is a photograph showing four different concentrations of Rhodamine WT in bottles: 50 ppb, 100 ppb, 200 ppb, 400 ppb. The researchers expect that, as a worst case scenario, the 50 ppb and 100 ppb dye concentrations are likely to be discernible as a slight red tint for a few minutes but will be difficult to see after a few minutes, even in the areas with weaker water currents. Rhodamine WT is commonly used at about 500 ppb, so the proposed maximum concentration is significantly less at about 100 ppb.

Researchers have proposed the dye study in specific areas, such as some enclosed marinas and certain channels and lagoons, so the dye application is limited in spatial extent. The dye study will take place in four small areas within the Tahoe Keys, two marinas and two open water locations, so the dye study will be spatially limited in extent. Because of its spatial limit and temporary duration, a visible color plume is not expected to adversely affect beneficial uses. During the dye study, the waters will be safe for swimming, fishing, and other recreational beneficial uses.

The Water Board's jurisdiction is limited to the effects of the treatment or disposal of waste on water quality and the beneficial uses of waters of the State. In addition, the Water Board has the authority to address nuisance conditions that result from the treatment or disposal of wastes that are within its jurisdiction.

A nuisance condition is defined in Water Code section 13050, subdivision (m):

> *""Nuisance" means anything which meets all of the following requirements:*
>
> *(1) Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.*
> *(2) Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted upon individuals may be unequal.*
> *(3) Occurs during, or as a result of, the treatment or disposal of wastes."*

If the dye injection is considered a "disposal of waste" in condition (3), then conditions (1) and (2), above, must be met for the color plume to cause a nuisance condition. As proposed, the plume concentrations will be non-toxic and non-injurious to health, but a possibility exists that individuals may consider a temporarily visible plume as offensive. Staff finds that the benefits of the dye study outweigh the potential concern that a color plume may be visibly offensive to some individuals for a short duration. If people find the color plume offensive, then it may be considered a nuisance and, depending on the circumstances, may or may not be subject to an enforcement action.

The Lahontan Water Board has several options for action regarding the proposed dye tracer study:

1. Adopt an individual National Pollutant Discharge Elimination System Permit to regulate the activity.

    Pros: NPDES permit will explicitly state performance criteria and monitoring and reporting requirements.

    Cons: Significant staff time (approximately 300 hours) needed to develop permit. Board would be unable to consider the permit until late Fall 2010 at the earliest, which would result in a one-year delay for the proposed study.

2. Direct the Executive Officer to impose an Order pursuant to Water Code section 13267 requiring the applicant to conduct project-specific monitoring and reporting before and after the activity commences.

    Pros: A monitoring and reporting program will ensure that pertinent and useful data is collected and reported to verify the activity does not adversely affect water quality or beneficial uses.

    Cons: Requires some staff time to develop an Order. The Order will request information concerning the nature, scope, and extent of the discharge of waste and provide monitoring criteria that we need to be able to evaluate any effect on water quality or beneficial uses as a result of the discharge of waste.

3. Take no permitting action nor require project-specific monitoring and reporting prior to commencement of the activity.

    Pros: No staff time required, so resources can be focused on other work.

    Cons: May not receive timely monitoring and reporting data to verify the activity is not adversely affecting water quality or beneficial uses.

The applicant has provided detailed information about the activity (Enclosure 3) and a monitoring and reporting plan (Enclosure 6). Staff reviewed the submitted information and requested additional information in two subsequent requests (Enclosure 4). The applicant submitted additional information in two separate emails (Enclosures 5 and 6).

Staff finds that Option 2, above, is the best course of action, based on the proposal submitted and limitations in staff resources. Choosing a specific Option does not diminish the enforcement authority of the Board if the dye study is found to adversely affect the water quality or waters to support beneficial uses.

This staff summary was circulated to interested persons and agencies on March 24, 2010.

RECOMMENDA-TION: The Executive Officer intends to proceed under Option 2, above, unless the Board directs staff to pursue another option.

Enclosures:

1. Lake Tahoe AIS Management Plan, draft June 2009
2. Photo showing different Rhodamine WT concentrations
3. Proposal to use Rhodamine WT, December 10, 2009
4. Water Board letters requesting additional information
5. Supplemental information submitted January 27, 2010
6. Supplemental information submitted March 9, 2010

Lake Tahoe Region

Aquatic Invasive Species Management Plan

CALIFORNIA - NEVADA




DRAFT

June 2009

This Aquatic Invasive Species Management Plan is part of a multi-stakeholder collaborative effort to minimize the deleterious effects of nuisance and invasive aquatic species in the Lake Tahoe Region. This specific product is authorized pursuant to Section 108 of Division C of the Consolidated Appropriations Act of 2005, Public Law 108-447 and an interagency agreement between the U.S. Army Corps of Engineers and the California Tahoe Conservancy.

US Army Corps of Engineers ®
Sacramento District

CALIFORNIA TAHOE CONSERVANCY

This product was prepared by:

TETRA TECH

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Acknowledgements

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Acronyms

AIS	Aquatic Invasive Species
ANS	Aquatic Nuisance Species
ANSTF	Aquatic Nuisance Species Task Force
BLM	Bureau of Land Management
CADPR	California Department of Parks and Recreation
CAISMP	California Aquatic Invasive Species Management Plan
CDFA	California Department of Food and Agriculture
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CDPR	California Department of Pesticide Regulation
CRWQCB	California Regional Water Quality Control Board
CSLC	California State Lands Commission
CTC	California Tahoe Conservancy
EDRR	Early detection and rapid response
EIP	Environmental Improvement Program
EMAP	Environmental Monitoring and Assessment Program
EO	Executive Order
EPA	Environmental Protection Agency
ESA	Endangered Species Act
IDA	Idaho Department of Agriculture
IPM	Integrated Pest Management
ISAC	Invasive Species Advisory Committee
LRWQCB	Lahontan Regional Water Quality Control Board
LTAISCC	Lake Tahoe Aquatic Invasive Species Coordination Committee
LTAISWG	Lake Tahoe Aquatic Invasive Species Working Group
LTFAC	Lake Tahoe Federal Advisory Committee
LTSLT	League to Save Lake Tahoe
NAC	Nevada Administrative Code
NANPCA	Nonindigenous Aquatic Nuisance Prevention and Control Act
NDA	Nevada Department of Agriculture
NDOW	Nevada Department of Wildlife
NDSL	Nevada Division of State Lands
NDSP	Nevada Division of State Parks
NEPA	National Environmental Policy Act

Acronyms cont.

NFMA	National Forest Land Management Act
NISA	National Invasive Species Act
NISC	National Invasive Species Council
NLTLPF	Nevada Lake Tahoe License Plate Fund
NRS	Nevada Revised Statutes
ONRW	Outstanding National Resource Water
PSU	Portland State University
RCD	Resource Conservation District
SNPLMA	Southern Nevada Public Land Management Act
TDC	Tahoe Divers Conservancy
TERC	Tahoe Environmental Research Center
TIE	Tahoe Interagency Executive
TKPOA	Tahoe Keys Property Owners Association
TMWQ	Truckee Meadow Water Authority
TRCD	Tahoe Resource Conservation District
TRPA	Tahoe Regional Planning Agency
TSC	Tahoe Science Consortium
UCCE	University of California Cooperative Extension
UCD	University of California, Davis
UNR	University of Nevada, Reno
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
- APHIS	Animal and Plant Health Inspection Service
- APHIS - PPQ	Animal and Plant Health Inspection Service – Plant Protection and Quarantine
- ARS	Agricultural Research Service
- NAL	National Agricultural Library
- NRCS	Natural Resource Conservation Service
- USFS - LTBMU	United States Forest Service – Lake Tahoe Basin Management Unit
USDOI	United States Department of Interior
- BLM	Bureau of Land Management
- USBOR	United States Bureau of Reclamation
- USFWS	United States Fish and Wildlife Service
- USGS	United States Geological Survey
VIP	Vessel Inspection Plan
WRP	Western Regional Panel

Glossary

Abscission point: The area of a plant where physiological changes allow for natural separation between adjacent areas of vegetation.

Accidental introduction: An introduction of nonindigenous species that occurs as the result of activities other than the purposeful or intentional introduction of the species involved, such as the transport of nonindigenous species in ballast water or in water used to transport fish, mollusks or crustaceans for aquaculture or other purposes.

Adaptive Management: Refinement of an approach (and sometimes objectives) to an environmental implementation plan that is modified based on outcome of initial results. The plan may continually be refined so that positive environmental results are achieved.

Algae bloom: A rapid increase in a population of algae in an aquatic system; usually occurs resulting from a nutrification event.

Allofragments: Fragments of vegetation produced by mechanical means such as boat propellers or mechanical harvesting.

Anoxic environment: An environment with exceedingly low levels of oxygen.

Aquaculture: The farming of freshwater or saltwater organisms including mollusks, crustaceans, and aquatic plants.

Aquascape: Aesthetic gardening in an aquatic area with aquatic species.

Aquatic species: All animals and plants as well as pathogens or parasites of aquatic animals and plants totally dependent on aquatic ecosystems for at least a portion of their life cycle (ANSTF 1994).

Aquatic invasive species (AIS): A nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters (NANPCA 1990).

Autofragments: Self-formed fragments of vegetation produced through the development of an abscission point.

Ballast: An often water-filled device used on ships and submersibles to control buoyancy and stability.

Ballast water: Any water and associated sediments used onboard a ship to increase the draft, change the trim, regulate the stability or maintain the stress loads of the vessel.

Bathymetric: Of or relating to measurements of the depths of oceans or lakes.

Benthic (benthos): The ecological region located at the deepest level of a body of water; this includes the area around the interface between the sediment surface and water column.

Bilge: The lowest compartment on a ship or boat where water that is taken-on while floating on a water body collects and pools.

Biocontrol: The use of living organisms, such as predators, parasites and pathogens, to control pest animals (e.g., insects), weeds or diseases.

Bio-fouling: The undesirable accumulation of living or dead organisms on submersed structures (pipes, boat hulls, piers, anchors, rocks, et cetera) or other organisms.

Bivalve: Mollusks belonging to the class Bivalvia that are characterized by having a shell composed of two parts or valves.

Byssal threads: Fibers produced by bivalves that function to anchor individuals to their substrate.

Chironomid: Minute, long-legged, non-biting, two-winged flies with piercing mouthparts.

Glossary cont.

Cladocerans: Small crustaceans, commonly called water fleas, found in most freshwater habitats, including lakes, ponds, streams and rivers.

Coldwater fish: Fish species that prefer and inhabit colder waters; examples are salmonid species such as trout and salmon.

Concentration (chemistry): The density of an environmental component in a defined area.

Control: Eradicating, suppressing, reducing or managing invasive species populations, preventing spread of invasive species from areas where they are present and taking steps such as restoration of native species and habitats to reduce the effects of invasive species and to prevent further invasions.

Crustacean: A large group of mostly aquatic arthropods that includes various species such as crab, lobster, crayfish, shrimp, krill, and barnacle.

Cryptogenic species: An organism of unknown origin; may be introduced or native.

Detritus: Non-living particulate organic material derived from living organisms.

Dispersed recreation: Passive forest outdoor recreation that occurs outside of developed sites with modern facilities and where concentration use occurs.

Dreissenid: A family of small, often invasive, freshwater mussels in the phylum Mollluscа.

Ecological integrity: The extent to which an ecosystem has been altered by human behavior; an ecosystem with minimal impact from human activity has a high level of integrity; an ecosystem that has been substantially altered by human activity has a low level of integrity.

Eradicate: For the purpose of this Plan, eradication is the complete elimination of an invasive species from a specific part of the Lake Tahoe Region or the entire Region.

Established: An introduced organism with a permanent population(s), i.e., one that has the ability to reproduce and is not likely to be eliminated by humans or natural causes.

Eutrophic: A lake condition of high production associated with high phosphorus and nitrogen.

Excurrent siphon: An organ of a mollusk from which water and waste are expelled.

Exoskeleton: An external skeleton that supports and protects the body of an arthropod (invertebrate).

Exotic: Any species or other variable biological material that enters an ecosystem beyond its historic range, including such organisms transferred from one country to another. Also known as nonindigenous or non-native.

Filter feeder: An aquatic animal, such as a mussel or clam that feeds by filtering particulate organic material from water.

Fouling: An accumulation of organisms that attaches to naturally occurring and manmade submerged hard surfaces such as rocks, shells, ships, intake pipes, and other submerged equipment or machinery. Mobile organisms that may be tucked in nooks created by the larger animals are also considered part of the “fouling community”.

Genetic dilution: Genetic dilution occurs when introduced organisms add their genetic material to native populations through hybridization. This can result in populations that are less well adapted to their environment, potentially leading to the decline of those populations.

Hermaphroditic: An organism having both male and female reproductive organs; allowing the potential for self-fertilization.

Glossary cont.

Herpetofauna: A guild of vertebrates that includes amphibians and reptiles.

Host: A living animal or plant that supports parasitic animals, plants or microbes, internally or on its surface.

Incipient infestation: A small colony of an invasive species that has spread to a new area.

Indigenous: An organism that is native or naturally evolved to a specific region in which it naturally occurs.

Integrated Pest Management (IPM): A decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates) in an ecologically and economically sound manner.

Intentional introduction: All or part of the process by which a nonindigenous species is purposefully introduced into a new area.

Introduction: The intentional or unintentional escape, release, dissemination or placement of a species into a California ecosystem as a result of human activity.

Invasive species: An alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112 [Federal Register: Feb 8, 1999, Vol. 64, No. 25]). Species that establish and reproduce rapidly outside of their native range and may threaten the diversity or abundance of native species through competition for resources, predation, parasitism, hybridization with native populations, introduction of pathogens, or physical or chemical alteration of the invaded habitat. Through their impacts on natural ecosystems, agricultural and other developed lands, water delivery and flood protection systems, invasive species may also negatively affect human health and/or the economy (CDFG 2008).

Keystone species: A species whose loss would have a disproportionately large effect on its ecosystem relative to its abundance.

Limnetic zone: The area of a lake that is characterized by open surface waters away from the shore and high light penetration for primary producers.

Littoral zone: The area in an aquatic environment found between the high-water mark and the permanently submerged nearshore area.

Macroinvertebrate: An invertebrate large enough to be visible to the naked eye.

Macrophyte: An emergent, submerged or floating aquatic plant large enough to be visible to the naked eye that provides cover, substrate, and oxygen for aquatic animals.

Meso-eutrophic: A lake condition of moderately high production associated with moderately high phosphorus and nitrogen.

Metamorphs: A change in the form and often habits of an animal during normal development after the embryonic stage; also refers to the individual who is undergoing the change.

Microzooplankton: A community of zooplankton composed of animals to small to be seen with the naked eye.

Mollusks: Invertebrates belonging to the phylum Mollusca that live in diverse habitats in marine, freshwater, and terrestrial biotopes; includes gastropods (snails), clams, and mussels.

Glossary cont.

Native species: A species within its natural range or natural zone of dispersal, i.e., within the range it would or could occupy without direct or indirect introduction and/or care by humans.

Non-native or Nonindigenous species: A species that enters an ecosystem beyond its historic geographic range. Also known as exotic or alien species. Other taxa can be considered non-native or nonindigenous, such as families, genera, subspecies or varieties.

Non-point source pollution: Pollution that comes from a general, non-specific area.

Nuisance species: For the purpose of this plan, the term is synonymous with invasive species.

Oligotrophic: A lake condition of low production associated with low phosphorus and nitrogen.

Operculum (invertebrate): A hard covering used by gastropods (snails) to close the opening to their shell.

Organic (ecological): Matter that has come from a once-living organism; is capable of decay, or the product of decay; or is composed of organic compounds.

Parthenogenic: A form of reproduction in which an unfertilized egg develops into a new individual (i.e. fertilization is not required for egg development), resulting in an all female clonal population; occurs commonly among insects and some other arthropods.

Pathogen: A microbe or other organism that causes disease.

Pathway: Mode by which a species establishes and continues to exist in a new environment (Heutte and Bella 2003); often synonymous with vector, dispersal mechanism, and mode. Natural and human connections that allow movement of species or their reproductive propagules from place to place (CDFG 2008).

Pelagic zone: The zone of a water body with only water being present as the media or in space; open water.

Perennial: A plant that lives for multiple years.

Photic zone: The food-rich area of open water in a lake or ocean that is exposed to sunlight sufficient for photosynthesis to occur.

Phytoplankton: Free-floating microscopic plants (primary producers) that compose the autotrophic component of the plankton community.

Pioneer infestation: See incipient infestation.

Polytrophic: Subsisting on various types of organic material.

Propagule: Any plant material used for the purpose of plant asexual propagation.

Refugia: An area of refuge or protection from potentially change-inducing external forces.

Re-suspension: Suspending of settled sediments that have been suspended in the past.

Rhizome: A specialized plant stem that often sends out roots and shoots from its nodes for asexual reproduction.

Senesce (plant): A natural response in plants where single plant organs (e.g., leaves) or entire plants are lost as metabolically expensive nutrients are moved to surviving plant organs.

Seston: Particulate matter such as plankton, organic detritus, or inorganic particles such as silt that are suspended in water.

Spatial partitioning: A physical redistribution of competitive organisms in space.

Glossary cont.

Stakeholder: Relevant representatives from regional, state, or federal agencies, non-governmental organizations, or property owners.

Stolon: A specialized colonizing plant organ that is often a horizontal above-ground shoot that arises from an axillary bud near the base of the plant.

Substrate: The base on which an organism lives and grows.

Taxa: Groups used to classify organisms (e.g., kingdom, phylum, class, order, family, genus and species). Taxa is the plural form of taxon.

Tuber: A specialized modified plant structure that is enlarged to store nutrients.

Turion: A wintering bud of water plant that breaks off and lies submerged and dormant until the following spring, when it produces a new plantlet that floats to the surface.

Ultra-oligotrophic: A lake condition of extreme low production commonly associated with very low phosphorus and nitrogen.

Vector: The physical means or agent by which a species is transported (e.g., boat hulls, live wells, fishing gear); often synonymous with pathway, dispersal mechanism, and mode (Carlton 2001).

Veligers: Free-swimming larvae of mollusks such as clams and mussels.

Viviparous: A reproductive strategy where young are born live and free from incubation structures (i.e., live-bearing).

Watershed: The geographic area that drains to a single water body or hydrographic unit such as a lake, stream reach or estuary.

LAKE TAHOE REGION
AQUATIC INVASIVE SPECIES MANAGEMENT PLAN
CALIFORNIA AND NEVADA

Executive Summary

Lake Tahoe is designated an Outstanding National Resource Water (ONRW) under the Clean Water Act (CWA Section 106) due to its extraordinary clarity. Substantial changes to the Lake Tahoe Region's economy, pristine water quality, aesthetic value, and recreational pursuits are occurring, partly due to the harmful impacts of aquatic, non-native plants, fish, invertebrates, and other invaders. These non-native aquatic organisms are considered 'invasive' when they threaten the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependant upon such waters (NANPCA 1990), or *aquatic invasive species* (AIS) when they occur in water. AIS are commonly spread by activities such as boating, fishing, hatchery releases, and aquarium dumping. The Lake Tahoe Region is not only threatened by new introductions to Lake Tahoe from other waterbodies, but the expansion of existing populations within the lake and even as a source of AIS to nearby waterbodies.

At least 20 non-native species are established in the Lake Tahoe Region, including aquatic plants, fishes, invertebrates, and an amphibian. As examples, Eurasian watermilfoil (*Myriophyllum spicatum*; an aquatic plant) has been spreading around Lake Tahoe over the last 15-20 years, and curlyleaf pondweed (*Potamogeton crispus*; another aquatic plant) has begun to expand dramatically over the last three years. Beds of Asian clams (*Corbicula fluminea*) are larger and more common than previously known, and populations of warm water fishes such as largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus)* are expanding. Moreover, global climate change has resulted in warmer water temperature, likely facilitating the establishment of non-native plants in the nearshore environment and providing increased spawning areas for warm water fishes that compete with desirable species.

The potential economic impact to the Lake Tahoe Region caused by new AIS introductions such as quagga or zebra mussels (*Dreissena bugensis* and *D. polymorpha*, respectively) or expanding aquatic plant populations would be substantial. The combined economic impacts to recreation value, tourism spending, property values, and increased boat/pier maintenance, when evaluated over a 50 year period, is estimated at $417.5 million (present value), with an average annual equivalent value of $22.4 million per year. The largest estimated impacts would be to property values and lost tourism spending, each accounting for 38% of the total estimated AIS damages. Spending on prevention and early eradication produces a higher benefit to cost ratio than post-infestation control programs such that maximum benefits are realized through early and preemptive action.

The 2007 discovery of quagga mussels in Lake Havasu, Lake Mead, and the Colorado River Basin have prompted rapid cooperation and action by regional, bi-state, and federal agencies and non-governmental organizations in the Lake Tahoe Region. These new threats, coupled with recent studies showing high incidence of boat traffic to Lake Tahoe from these areas, have prompted a tremendous ramping up of education and outreach campaigns, new regulations to prevent accidental introduction, and increased control efforts and research on the biology and distribution of existing AIS populations. Examples of these activities include (LTAISWG 2007):

- Formation of the Lake Tahoe AIS Working Group (LTAISWG)
- Formation of the Lake Tahoe AIS Coordination Committee (LTAISCC)
- Yearly workshops organized by the LTAISWG to prioritize AIS prevention, monitoring, control, education, and research efforts
- Development and implementation of a Vessel Inspection Program at Lake Tahoe
- Deployment of portable boat washing stations
- Full-time AIS Coordinator hired by U.S. Fish and Wildlife Service (USFWS)
- Increased monitoring for invasive aquatic plants, invertebrates, and warm water fishes
- Use of diver-operated suction and benthic barriers to control invasive aquatic plants
- Evaluation of diver-operated suction and bottom barriers to control Asian clams
- Measurements of warm water fish behavior and diets in and around the Tahoe Keys
- Increased education and outreach activities
- Quagga mussel survivability studies

Despite these efforts, the Lake Tahoe Region lacks a cohesive guiding document that prioritizes objectives and identifies lead organizations, specific actions for each organization, and funding sources to combat existing and potential AIS. Also needed is further guidance that delineates appropriate, science-based regulation and monitoring that expressly deals with prevention and management of AIS. The purpose of the *Lake Tahoe Region AIS Management Plan* (the Plan) is to facilitate coordination of regional, bi-state, state, and federal programs and to guide implementation of AIS prevention, monitoring, control, education, and research in the Lake Tahoe Region.

The goals of the Plan are to:

- Prevent new introductions of AIS to the Lake Tahoe Region
- Limit the spread of existing AIS populations in the Lake Tahoe Region, by employing strategies that minimize threats to native species, and extirpate existing AIS populations when possible

- Abate harmful ecological, economic, social and public health impacts resulting from AIS

The implementation of the Plan is structured around seven objectives associated with:

A. Management plan implementation and updates

B. Coordination and collaboration

C. Prevention

D. Early detection, rapid response and monitoring

E. Long-term control and management

F. Research and information transfer

G. Laws and regulations

To meet these objectives, 23 strategies are identified with respective action items detailing how that objective will be met. The priority of each of the 95 actions included are ranked as low, medium, or high and the lead and cooperating entities are identified. Where applicable, short-term (present through 2010) priorities for action and funding source are indicated as are the long-term actions over the five year period from 2010 to 2015. In many cases, the LTAISWG or LTAISCC are named as the lead or cooperating entities. Currently, the two committees share a common chair.

The intent of the Plan is to provide more localized guidance for preventing and managing AIS in the Lake Tahoe Region and will not be in conflict with the California AIS Management Plan (CAISMP), administered by the California Department and Fish and Game (CDFG) or the anticipated plan from the state of Nevada.

At a minimum, the Plan will be reviewed once a year and revised every five years by a LTAISCC sub-committee to ensure Plan objectives, strategies and actions continue to identify and address relevant AIS issues in a timely manner. Individual components of the Plan (e.g., rapid response plans, monitoring plans, vessel inspection protocols) may be updated more frequently to fully address changing needs in the Lake Tahoe Region.

Summarized in the Plan is the background of non-native species introductions to the Lake Tahoe Region, the pathways for existing and potential AIS introductions, the types of existing and potential AIS in the Lake Tahoe Region, and short- and long-term priorities for action. Also included (as appendices) is an overview of regulations and programs, the Vessel Inspection Plan, the Small Watercraft Screening Process, an estimate of potential economic impacts from a mussel infestation at Lake Tahoe, and an overview of existing and potential AIS life histories, environmental requirements, distributions, and control methods.

1 Introduction

Numerous non-native species have been introduced worldwide intentionally (e.g., cultivars, pet trade, recreation, resource management) and accidentally (e.g., ballast water releases, hitchhikers, recreational pursuits). The nature of the relationship between non-native species and the local landscape is largely based on potential harmful impacts versus societal benefits (ISAC 2006). That is, society may deem the benefits of *purposeful* introductions of non-native species outweigh potential or realized harmful impacts. Conversely, *accidental* introductions, or especially unauthorized intentional introductions, are generally viewed as undesirable and detrimental to the local landscape.

An *invasive* species is one "that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (NISC 2008). By extension, an *aquatic* invasive species (AIS) is a "nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters" (NANPCA 1990).

The purpose of the *Lake Tahoe Region AIS Management Plan* (the Plan) is to facilitate coordination of regional, state, and federal programs and to prioritize and guide implementation of AIS prevention, monitoring, control, education, and research actions in the Lake Tahoe Region. Through Region-wide stakeholder acceptance, the Plan is an attempt to coordinate and to set timelines for these actions to preserve and protect the environmental, economic and human health in the Lake Tahoe Region.

1.1 Geographic Scope: Lake Tahoe Region

The geographic scope of the Plan is the Lake Tahoe Region (the Region) (Figure 1). As defined by the Tahoe Regional Planning Agency (TRPA) Compact, the Region is located on the California-Nevada border and includes Lake Tahoe (and approximately 6 km of the Lower Truckee River below the lake), the adjacent parts of Douglas and Washoe Counties and Carson City in Nevada and the adjacent parts of Placer and El Dorado Counties in California (TRPA Compact P.L 96-551). The Region drains 63 streams to Lake Tahoe with the Upper Truckee River being the largest. The lake's only outflow, after passing the Lake Tahoe Dam, is the Lower Truckee River at Tahoe City. Beyond the Region boundaries, the Truckee River continues to flow approximately 140 miles to its terminus at Pyramid Lake (Murphy et al. 2000; USBOR 2008). In addition to Lake Tahoe, many smaller lakes and six larger recreation lakes (Fallen Leaf, Echo, and Cascade Lakes in California; Marlette, Spooner, and Incline Lakes in Nevada) are located in the Region.

The majority of the land in the Region is owned and managed by public agencies. Approximately 80% of the public lands are managed by the U.S. Department of Agriculture -

U.S. Forest Service – Lake Tahoe Basin Management Unit (USDA-USFS-LTBMU). There are nine state parks on the California side managed by California Department of Parks and Recreation (CADPR) and the Lake Tahoe Nevada State Park managed by Nevada Division of State Parks (NDSP) on the Nevada side. Also in the Region, the California Tahoe Conservancy (CTC) owns large and small land parcels and the Nevada Division of State Lands (NDSL) owns and manages approximately 500 urban parcels. Most of the private lands are commercially held with most development is in the low lying areas near the lake. The TRPA directs land use and development issues in the Region (see Appendix A for further information on agency jurisdiction).

South Lake Tahoe, the only incorporated city in the Tahoe Basin, occupies the south shore of the lake. With respect to AIS, of note is the Tahoe Keys, also on the south shore. The Keys, as it is commonly referred to, is a residential development that includes two marinas. The residential marina is in a western channel and the commercial marina is in an eastern channel, referred to as Tahoe Keys West and Tahoe Keys East, respectively. The Tahoe Keys were constructed within the Upper Truckee Marsh in the mid-1960s when water from the Upper Truckee River was channelized and diverted to prevent flooding. The result is that surface water exchange between the Tahoe Keys and the main body of Lake Tahoe is now limited to the two channels. Water in the Keys is shallower, turbid and warmer, providing habitat for numerous AIS.

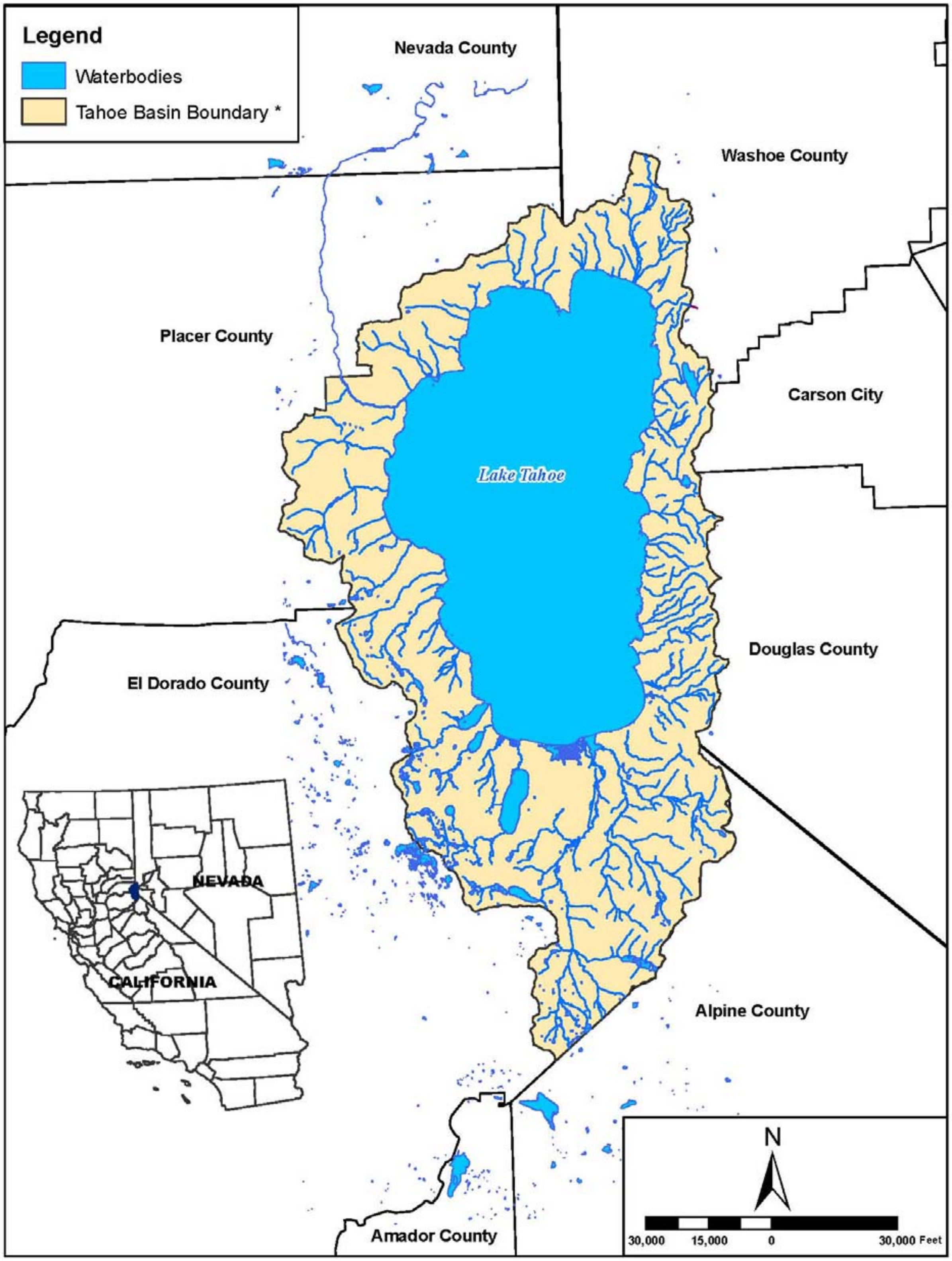

Figure 1. Lake Tahoe Region (Source: TRPA)

Lake Tahoe's water clarity is one of its most striking features. Lake Tahoe is designated an Outstanding National Resource Water (ONRW) under the federal Clean Water Act (CWA) (1972) as nominated by the California Regional Water Quality Control Board (CRWQCB). Likewise, Lake Tahoe is designated a "water of extraordinary ecological or aesthetic value" by the Nevada Division of Environmental Protection (NDEP). Lake Tahoe has a mean depth of 305 m (maximum 501 m), second only to Crater Lake (also designated an ONRW) in Oregon. Regularly recorded Secchi depths (a measurement of water transparency) have occurred in Lake Tahoe since the late 1960s. Since that time, transparency of up to 36 m has been recorded; however, it has declined up to 0.27 m $year^{-1}$ (Jassby et al. 2003) with recent measurements of 21.4 m (TERC 2008), suggesting a shift in the lake's oligotrophic status (Goldman 1974, Goldman 1988).

The ongoing decline in Lake Tahoe's water quality is a result of light scatter from fine sediment particles (primarily particles less than 16 micrometers in diameter) and light absorption by phytoplankton. The addition of nitrogen and phosphorus to Lake Tahoe contributes to phytoplankton growth. Fine sediment particles are the most dominant pollutant contributing to the impairment of lake waters, accounting for an estimated two thirds of the lake's impairment. Loss in water clarity (the vertical transmission of light penetration) has similarly decreased in Lake Tahoe, resulting in an increased shift in the lake's maximum chlorophyll depth (LRWQCB and NDEP 2007). The decline of Lake Tahoe's transparency resulted in the listing of Lake Tahoe as impaired for the transparency standard under Section 303(d) of the Clean Water Act. Lake Tahoe's 303(d) listing compelled California and Nevada to develop a Total Maximum Daily Load (TMDL) (under peer review).

Despite its relatively small watershed (812 km^2), Lake Tahoe has a surface area of approximately 500 km^2. This low watershed-to-lake ratio (1.6:1) results in a substantial amount of precipitation falling directly on Lake Tahoe, contributing to its oligotrophic status. It is a subalpine lake (elevation 1,897 m) surrounded by mountains over 1,200 m above lake level (LRWQCB and NDEP 2007). Typical surface water temperatures range from 18 to 21°C during late summer and between 4.5 to 10°C during the winter. Evidence by Coats et al. (2006); however, strongly suggest changes in the thermal structure of Lake Tahoe, possibly facilitating further colonization and expansion of AIS (UCD 2008).

1.2 EXISTING AUTHORITIES AND PROGRAMS

Numerous federal, state, and regional regulations and programs are in place in the Region, to limit the introduction and spread of AIS with no single agency or group responsible for all AIS issues. Table 1 lists the various agencies, regulations and programs associated with AIS in the Region. As an interstate AIS management plan, management actions presented in this Plan consider the overlapping jurisdictions of the States of California and Nevada as well as the areawide role of the TRPA. A comprehensive summary of regulations and programs can be found in Appendix A.

Federal authority to limit the interstate transport and importation to the U.S. of prohibited plant species is provided by the USDA -Animal and Plant Health Inspection Service-Plant Protection and Quarantine (USDA-APHIS-PPQ) (Plant Protection Act of 2000) and prohibited wildlife species authority is provided by the U.S. Fish and Wildlife Service (USFWS) (Lacey Act) (Appendix A).

In California, the California Department of Fish and Game (CDFG) is responsible for prohibited fish and wildlife resources (CCR, Title 14) and is the lead agency for the California AIS Management Plan (CAISMP). The CAISMP defines invasive species as one

> …that establish and reproduce rapidly outside of their native range and may threaten the diversity or abundance of native species through competition for resources, predation, parasitism, hybridization with native populations, introduction of pathogens, or physical or chemical alteration of the invaded habitat. Through their impacts on natural ecosystems, agricultural and other developed lands, water delivery and flood protection systems, invasive species may also negatively affect human health and/or the economy.

The purpose of the CAISMP is "to coordinate state programs, create a statewide decision-making structure and provide a shared baseline of data and agreed-upon actions so that state agencies may work together more efficiently". The CAISMP addresses numerous AIS presently established in or threatening introduction to aquatic ecosystems throughout the state. Waterbody types addressed include creeks, wetlands, rivers, bays, and coastal water habitats (CDFG 2008). The CAISMP describes vectors of concern on a statewide-scale including: commercial shipping and fishing, recreational equipment and activities, trade in live organisms (e.g., aquarium trade), construction in aquatic environments, and water delivery and diversion systems (CDFG 2008).

California Department of Fish and Game (DFG) Code §2301 allows CDFG designated staff (and other authorized state authorities, i.e., CADPR peace officers and California Department of Food and Agriculture [CDFA]) to inspect, impound or quarantine any conveyance (e.g., watercraft) that may carry dreissenid mussels (i.e., quagga and zebra mussels). CDFA is the lead agency for regulatory activities associated with noxious weeds (CAC Title 3, Sec. 3400). Also in California, the Lahontan Region Water Quality Control Board (LRWQCB) is responsible for regionwide water quality objectives as outlined in the *Water Quality Control Plan for the Lahontan Region North and South Basins* (commonly referred to as the Basin Plan; CRWQCB 2005) (see Appendix A).

In Nevada, the Nevada Department of Agriculture (NDA) is the lead agency for regulatory activities associated with noxious weeds and the Nevada Department of Wildlife (NDOW) is the lead agency for regulatory activities associated with prohibited wildlife. Under NRS Title 14 Chapter 171.123, any peace officer (e.g., NDOW Game Warden, county sheriff deputy, city police agencies) may detain a person that has committed, is committing or is about to commit a crime (e.g., possession of state listed prohibited wildlife [NAC 503.110] or plant [NAC 555.010] species). Additionally, NDOW Game Wardens (or other Nevada peace officers), as deputies of the USFWS have the authority to uphold provisions of the Lacey Act. Nevada is currently without a comprehensive AIS management plan and instead must rely on the disparate efforts of regional, state, and federal agencies. The state has, however, has completed draft guidance to prevent and monitor for AIS, particularly quagga mussel. Once a key staff position is filled with NDOW, completing and implementing the "Prevention and Disinfection Guidelines" and the "Quagga Mussel Monitoring Program" will be top priorities.

The Nevada Board of Wildlife Commissioners has set policy that clearly supports programs that would limit the introduction and impacts of undesirable aquatic species (P-33 Fisheries Management Program). The U.S. Department of Interior – Bureau of Land Management (USDOI-BLM) Nevada State Office maintains a website for their Invasive Species Initiative for reporting invasive species, but it is not specific to aquatic organisms. Likewise, efforts of the Nevada Invasive Species Council are not focused on *aquatic* invasive species. Quagga mussels have been found in Nevada lakes (e.g., Lake Mead) that are also popular destinations for Lake Tahoe visitors (Wittmann 2008). Presently there is limited mandatory boat inspection or washing for boats leaving infested waterbodies in Nevada; however, boat inspection procedures are evolving.

Specific to the Region, the TRPA, as a designated area wide planning agency under Section 208 of the federal CWA, maintains water quality measures specified in the *Water Quality Management Plan for the Lake Tahoe Basin* (208 Plan) by limiting the impacts of tourism, ranching, logging, and development on the Lake Tahoe environment and enforcing environmental thresholds.

The TRPA and its Governing Board has taken an aggressive and proactive role in preventing the introduction of new AIS to Lake Tahoe. The TRPA has the authority to inspect all boats entering Lake Tahoe for AIS or issue penalties starting at $5,000 (TRPA Code of Ordinances Chapter 79.3. B). CADPR peace officers (or other state agencies with CDFG Director approval) have the authority to enforce California DFG Code §2301 (related to dreissenid mussel inspections). As of November 1, 2008, all boat launches (public and private) without a trained inspector are closed (TRPA Code of Ordinances, Chapter 79.3.B (1) and (2)).

The TRPA defines an invasive species as:

> "…both aquatic and terrestrial, that establish and reproduce rapidly outside of their native range and may threaten the diversity or abundance of native species through competition for resources, predation, parasitism, hybridization with native populations, introduction of pathogens, or physical or chemical alteration of the invaded habitat. Through their impacts on natural ecosystems, agricultural and other developed lands, water delivery and flood protection systems, invasive species may also negatively affect human health and/or the economy (TRPA Code of Ordinances, Chapter 79.3)."

Table 1. Federal, State, and Regional Agencies, Regulations and Programs in the Lake Tahoe Region and Associated AIS Activities *

	Control	Coordination	Documentation	Education/ outreach	Eradication	Exportation	Financial Assistance	Importation	Possession	Prevention	Quarantine	Research	Technical Assistance
Federal													
Endangered Species Act of 1973	x				x								
Executive Order 13057		x											
Executive Order 13112		x		x			x			x			x
Lacey Act of 1990 (amended 1998)								x	x				
NANPCA (1990) and NISA (1996)	x	x		x			x			x		x	x
NEPA of 1970			x										
USACE		x					x					x	x
USDA	x	x		x	x		x			x		x	x
USDOI	x	x		x	x		x			x		x	x
State and Regional													
CADPR	x	x		x	x					x	x	x	x
CDFA	x	x	x	x	x	x		x	x	x			x
CDFG	x	x		x	x	x		x	x	x	x	x	x
CEQA	x		x		x					x			
CSLC	x	x					x						
CTC				x			x			x			
EIP		x					x					x	
LRWCQB (CRWQCB 2005)	x	x		x			x			x			

Table 1. cont.

	Control	Coordination	Documentation	Education/ outreach	Eradication	Exportation	Financial Assistance	Importation	Possession	Prevention	Quarantine	Research	Technical Assistance
State and Regional cont.													
LTAISCC	x	x	x	x	x					x		x	x
LTAISWG	x	x		x	x					x		x	x
LTSLT				x			x			x			
NDOW	x			x	x	x		x	x	x	x		x
NDSL		x					x						
NDSP		x		x						x			
Tahoe Area Sierra Club Group				x						x			
Tahoe Science Advisory Group		x											
TKPOA	x												
TRCD	x	x		x	x		x			x			x
TRPA	x	x	x	x	x		x	x	x	x		x	x
TSC		x		x								x	x
UCD - TERC	x			x	x					x		x	x
UNR	x				x					x		x	x

* Acronyms listed on Page iv; See Appendix A for more detailed descriptions

1.3 GAPS AND CHALLENGES

The unique ecological and political landscape of the Lake Tahoe Region presents some policy challenges that could limit the ability of resource managers to achieve management goals. For example, CDFG staff may inspect, impound or quarantine any conveyance (e.g., watercraft) that may carry dreissenid mussels (F & G Code §§ 2301). NDOW may seize as evidence any watercraft or other equipment if probable cause exists to believe that a state listed prohibited species is being imported into, transported through or possessed in Nevada (NAC 503.110). The NDEP allows for the application of U.S. Environmental Protection Agency (EPA) – approved aquatic herbicides for the control of nuisance aquatic plants. On the California side of Lake Tahoe, however, the LRWQCB's regionwide water quality objectives for pesticides, and related objectives for nondegradation and toxicity, essentially preclude direct discharges of pesticides such as aquatic herbicides (see Appendix A). The LRWQCB is currently developing a Basin Plan amendment to consider proposals for the application of aquatic pesticides in the Region. Additionally, some EPA-approved products are registered in Nevada, but not California, and vice versa (see Table 4).

With respect to the inspection of AIS vectors (e.g., motorized watercraft, kayaks, waders, et cetera), it is the responsibility of each boat launch facility to provide inspectors. TRPA-designated inspectors inspect all vessels launching at public and private boat ramps (Appendix B). Users of day-use recreation facilities (e.g., campgrounds); however, are subject to an AIS screening process for small watercraft where such sites are managed and staffed by special use permittees. Appendix C summarizes the USFS-LTBMU's AIS screening process for small watercraft, which is part of operating plan direction for special use permits.

CDFA operates 16 Border Protection Stations (BPSs) statewide to reduce the number of pest introductions to the state. Two BPSs are location in the Lake Tahoe Region: the Meyers Border Station, located in El Dorado County on U.S. Hwy 50 south of Lake Tahoe, and the Truckee Border Station, located in Nevada County on U.S. Hwy 80, five miles east of Truckee, California. Both stations currently operate 24 hours per day, seven days a week and inspect both commercial and private vehicles. Unfortunately, the stations are of limited effectiveness in preventing AIS from entering Lake Tahoe. Both stations are only structured to inspect west-bound traffic and the Meyers station is southwest of the Region. The Truckee station is located such that it inspects vessels that arrive at Lake Tahoe by way of Hwy 80, but many boats arrive from the east by other routes. The result is boaters arriving to Lake Tahoe from any direction can easily by-pass both BPSs. Conversely, west-bound boaters *leaving* Lake Tahoe are likely inspected.

1.4 PLAN OVERSIGHT

Oversight for *state* AIS management plans is typically led by a respective state resource agency (e.g., CDFG for the CAISMP); however, in the case of bi-state or regional plans, oversight is best suited to an organization capable of regulation across state jurisdictions. The TRPA, as created by California, Nevada, and the U.S. Congress has such regulatory authority (P.L. 96-551, 94, Stat. 3235). The TRPA will act as the fiscal agent, or pass-through agency, for funds associated with implementing this Plan as they have successfully demonstrated the ability to cooperatively lead and manage the $1.1 billion Environmental Improvement Program (EIP).

Efforts to improve collaboration, leverage funding, and provide peer oversight in the Region are implemented by members of the LTAISWG and/or the LTAISCC. The mission of the LTAISWG is to protect the Lake Tahoe Region from aquatic invasive species by education, research, prevention, early detection, rapid response, and control. The LTAISWG is comprised of resource managers, non-governmental organizations, researchers, and community members (Appendix D) whose participation is ratified through a Memorandum of Understanding (Appendix D, Attachment A). The LTAISCC provides direction for implementation of the Plan, and members ensure that the activities proposed in the Plan are either consistent with current agency policy or working in-house to expand or modify policies and management strategies to implement AIS activities (Appendix D, Attachment B). The LTAISCC is comprised of leaders from state and federal agencies, researchers, and other groups responsible for management, regulatory, or cultural heritage activities in the Region. TRPA staff currently participate in both the LTAISCC and the LTAISWG.

2 AIS Management Approach

The approach to managing AIS depends on a range of factors including, the species, likelihood of introduction, local and regional extent of infestation, harmful impacts, and the cost and feasibility of control/eradication. The Aquatic Nuisance Species Task Force (ANSTF) recognizes five AIS management approaches, implemented independently or in combination:

- Prevention
- Monitoring
- Control/Eradication
- Education
- Research

2.1 PREVENTION

Prevention measures encompass a range of activities such as inspection, quarantine and decontamination of watercraft, enforcement of legal authority, and strengthening the code of conduct for businesses dealing with aquatic organisms (Lodge et al. 2006). Prevention measures are used to address AIS not yet present as well as to diminish harmful impacts by reducing further spread. Inspection and decontamination of recreational equipment such as watercraft (including boats, rafts, kayaks, and float tubes), fishing gear, clothing, waders, rope, cooling tanks and live wells prevents the spread of many AIS such as dreissenid mussels, aquatic plants, and other unwanted pests.

Preventing the introduction of AIS to new waterbodies is most desirable and, fortunately, far more cost efficient compared to control and eradication efforts (Figure 1) (Leung et al. 2002; Lodge et al. 2006).

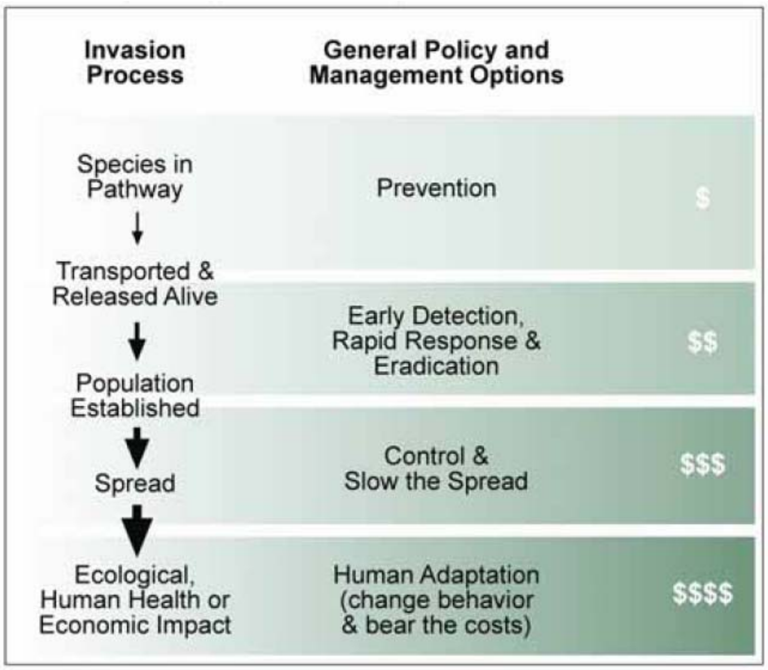

Figure 2. Model of Increasing Costs Based on Invasion Process and Management Response. From CDFG (2008) as Adapted from Lodge et al. 2006.

2.2 MONITORING

In addition to preventing the introduction of new AIS, surveying for new infestations and determining environmental thresholds improves success in control or eradication efforts. That is, early detection of new species allows for more effective rapid response outcomes such as quarantine and eradication, and more information on species distribution and biology leads to improved management with reduced impacts to native species. As an example, monitoring movement and spawning habits of warm water fishes in and around the Tahoe Keys will facilitate and improve control efforts and ameliorate their impacts to native species (Chandra et al. 2009). Conversely, the likelihood of eradicating AIS is dramatically reduced once the population(s) is widely established.

2.3 CONTROL/ERADICATION

The identification of new infestations often sparks the most attention and commands immediate resources to control or eradicate the invaders. Control of AIS implies that populations are present and small enough to curtail further increases while eradication means complete removal of the species from an area. Factors to consider when evaluating the feasibility of control or eradication measures include:

- Size of infestation (i.e., small or new populations targeted for eradication with large infestations targeted for control)
- Demonstrated history of eradication elsewhere
- Knowledge of species life history
- Potential environmental impact
- Financial support for initial and follow-up management
- Likelihood of reintroduction
- Public comment
- Current policy restrictions

Well-coordinated efforts and the availability of approved control tools increase the likelihood of a successful eradication; however, this likelihood decreases substantially as the population spreads and becomes more abundant.

Numerous methods to manage AIS are briefly summarized in the Plan and are commonly presented as single methods (e.g, physical removal of unwanted aquatic vegetation). Integrated Pest Management (IPM), however, combines a variety of management techniques with an ecosystem-based approach that minimizes the impacts to human health, the environment, non-target species, and economics. IPM efforts may include simultaneous pest management, monitoring, and the use of multiple management tactics that in the end may result in reduced pesticide use and cost (Ehler 2006). An example of IPM might include the use of a biocontrol agent to reduce vegetation followed by mechanical or manual harvesting and a benthic barrier (described in Section 3.3 Aquatic Plants).

Efforts are currently underway in Lake Tahoe to control invasive aquatic plants (Eurasian watermilfoil and curlyleaf pondweed) and research is being conducted to determine the most effective means of controlling Asian clams and warm water fishes. The control measures in use or being investigated are not presently aimed at eradication; however, these objectives may change based on research outcomes.

2.4 EDUCATION

Education is key to any effective prevention program. Based on the USFWS's Stop Aquatic Hitchhikers! campaign, the message "Clean, Drain and Dry" is now common to visitors at Lake Tahoe. The Tahoe Resource Conservation District (TRCD) delivers the campaign logo and slogan through flyers, regulatory boat launch signs, koozies, training materials, highway billboards, television advertisements, and brochures. Most importantly, the message is reinforced by watercraft inspectors at boat launches. The CDFG produced a downloadable Quagga "Not Wanted" flyer (see Appendix B for internet link) that can be printed and posted at additional locations.

Programs to educate the public about the impacts of AIS, methods to prevent introduction and further spread in the Region, and control efforts are actively underway by several organizations listed summarized in Appendix D. Other education/outreach activities currently used in the Region have included television advertisements, newspaper articles, the Tahoe Aquatic Nuisance Species Hotline (1-888-TAHO-ANS), the USFWS hotline (877-STOP-ANS), watercraft inspection trainings, presentations to public interests groups (e.g., public utility districts, chambers of commerce, property owner associations), and over Memorial Day weekend 2008, the use of CDFG's detection dogs, trained to detect quagga and zebra mussels based on odors.

2.5 RESEARCH

Research to enhance the understanding of AIS life histories, environmental thresholds, distributions, and interactions with native species is a critical component to the AIS management framework. This information allows for more effective and efficient IPM and results in reduced impacts to desirable species. Current research efforts in the Region include:

- Evaluating the effectiveness of diver-assisted suction in combination with benthic barriers to remove Asian clams
- Tracking warm water fish movement in and around the Tahoe Keys
- Determining quagga mussel survivability under low calcium conditions
- Monitoring aquatic plant distribution

2.6 ADAPTIVE MANAGEMENT

Application of these management approaches may occur singularly (e.g., control/eradication) or in combination (e.g., prevention and education). Either way, managers and researchers must continually refine their approaches, through adaptive management, to improve effectiveness. That is, through an iterative process, reduce uncertainty, maximize resources, and improve the efficacy of the management approach.

Adaptive management strategies should be utilized for future Plan revisions. In particular, the effects of climate change on AIS should be considered as new information emerges from research and control efforts (Bierwagen et al. 2008). Also, given the limited dollars that must be spread between all management approaches, it is important to evaluate the effectiveness of each. For example, researchers with the University of Minnesota Sea Grant Program found that after the Stop Aquatic Hitchhikers! campaign prevention message was reinforced through a variety of media such that boater/angler AIS awareness in Minnesota, Wisconsin, and Iowa improved dramatically as did the likelihood of taking precautionary actions (Doug Jensen, Minnesota Sea Grant, personal communication July 24, 2008). Overall, they found that information provided by watercraft inspectors at boat launches provided the most effective means of increasing AIS awareness and eliciting changes in behavior (i.e., removing AIS from trailered watercraft). This was followed by billboards and signs, targeted to non-residents in a timely manner (e.g., during holiday travel season).

3 Problem Definition and Ranking

Established and expanding populations of non-native aquatic plant and animal species are present in Lake Tahoe (Jassby et al. 2001). While some were intentionally and legally introduced, many were most likely introduced via recreational activities (e.g., boating) (Padilla et al. 1996, Johnson et al. 2001) or aquarium dumping. New and expanding populations of AIS to the Region threaten the ecological, aesthetic, and economic services so widely enjoyed. In fact, the potential economic impacts of a quagga or zebra mussel infestation at Lake Tahoe are estimated at over $22 million per year (Appendix E).

The following sections provide a background of species introductions to the Region, pathways of introduction, a brief discussion of their impacts, and a system for ranking species for management purposes. More detailed descriptions of species life histories, distribution, and control methods are proved in Appendix F.

3.1 Background

Human activities such as logging, grazing, urban development, and dam construction have occurred since the mid-1850s and have resulted in profound ecological changes to the Region including loss of biological integrity, decreased water quality, and increased fire hazard (USDA 2000, LRWQCB and NDEP 2007, Chandra et al. 2009, Raumann and Cablk 2008). To address many of these concerns, numerous programs and policies are being developed or have been implemented, for example:

- Environmental Improvement Program (EIP)
- *Regional Plan* (TRPA 2008)
- *Land and Resource Management Plan* (USFS)

- Draft total maximum daily load (TMDL) regulations for Lake Tahoe (Lahontan Region Water Quality Control Board [LRWQCB] and Nevada Division of Environmental Protection's [NDEP])
- Shorezone Ordinances (TRPA)
- *Water Quality Management Plan for the Tahoe Region* (208 Plan; TRPA)

Prior to the 1800s, the trophic structure of Lake Tahoe was relatively simple and limited to one predatory fish population, the native Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) - now extirpated from the lake. The demise of the Lahontan cutthroat trout from the Tahoe Basin is largely attributed to predation by lake trout, or mackinaw (*Salvelinus namaycush*) (introduced to Lake Tahoe for sport-fishing in 1888 [Cordone and Frantz 1966]) and by hybridization with non-native species of rainbow trout (*Oncorhynchus mykiss*). Other factors which contributed to the decline include: overexploitation by humans, dam construction on the Truckee River which prevented the migration of fish, and loss of spawning habitat (USFWS 1995 and summarized in Vander Zanden et al. 2003). Today, the historical trophic niche of the Lahontan cutthroat trout in Lake Tahoe is now occupied by lake trout (Vander Zanden et al. 2003). The establishment of mysid shrimp (*Mysis relicta*) (intentionally introduced in 1963 for game fish forage) (Linn and Frantz 1965) and lake trout also coincided with declines in native Lahontan redside (*Richardsonius egregius*) and speckled dace (*Rhinichthys osculus*) populations (Chandra et al. 2009) from the Tahoe Keys, an important rearing ground for native fishes (CDFG, unpublished data). Mysid shrimp have contributed to the shift in the Lake Tahoe's trophic structure and composition. For example, predation by mysid shrimp have played a significant role in the loss or near elimination of three pelagic cladoceran (small crustaceans) species from Lake Tahoe with an occasional reappearance during years of increased productivity (Richards et al. 1975, Goldman 1979, Byron et al.1984). Furthermore, other fish species have shifted their feeding from benthic to pelagic fish production (Vander Zanden et al. 2003).

More recent AIS introductions to Lake Tahoe include non-native warm water fish (largemouth bass and bluegill, aquatic plants (Eurasian watermilfoil and curlyleaf pondweed) and invertebrates (Asian clams). Many of these AIS are found within isolated areas of Lake Tahoe (e.g., marinas and embayments) and in the Tahoe Keys. In fact, the largest populations of AIS are found in or near the Tahoe Keys along the south shore; however, populations are present and rapidly expanding to other regions of Lake Tahoe. Efforts to identify expanding populations are currently underway by numerous researchers from the LTAISWG.

The January 2007 confirmation of quagga mussels in Lake Mead, Nevada marked the first population of dreissenid mussels west of the 100th Meridian. This population also served as a wake-up call to resource managers, researchers, boaters, and marina operators throughout the Region because boats are commonly trailered between Lake Mead and Lake Tahoe (Wittmann 2008).

3.2 Pathways of Introduction

While AIS can be transported naturally, for example, seeds can be transported on currents and fish can move up and down streams, human activities are a common vector for transporting AIS. Thus, the potential for AIS colonization depends as much on suitable environmental conditions as the frequency the waterbody is exposed to human activities. Unwanted species hitchhike via a myriad of human-driven pathways including recreational activities, the aquarium trade, commercial shipping, intentional stocking, and resource management activities (Cooke et al. 2005, CDFG 2008). The potential for new AIS introductions is especially worrisome as boats arrive to the Region from AIS-infected water bodies such as Lake Havasu, Lake Mead, and the Colorado River Basin (Wittmann 2008). Additionally, in August 2008 a mussel-contaminated boat was intercepted and quarantined prior to launching at Lake Tahoe.

Recreational Activities

Recreational activities involving watercraft (including motor boats, personal watercraft, kayaks, canoes, float tubes, et cetera) and/or fishing are the most likely vectors for the introduction of AIS to the Region (inter-Region) and among waterbodies within the Region (intra-Region). Currently, TRPA Code 79.3 B(2) states that "all watercraft, motorized and non-motorized, including but not limited to boats, personal watercraft, kayaks, canoes and rafts, shall be subject to an inspection prior to launching into the waters of the Lake Tahoe Region to detect the presence, and prevent the introduction, of aquatic invasive species". While the establishment of AIS is largely determined by factors such as environmental requirements, food availability, and predators, the movement of AIS between waterbodies is determined by similarities in recreational pursuits, possibly even more than waterbody proximity. For example, the likelihood may be greater that New Zealand mudsnails (*Potamopyrgus antipodarum*) would be introduced from one fly-fishing stream to another (from fishing gear such as float tubes, felt-soled waders) rather than a fly-angler introducing mudsnails to Lake Tahoe. Conversely, a power boat contaminated with quagga mussels would not be the most likely vector for mussels to a lake without a boat launch.

Inter-Region AIS Introductions

During the 1998 boating season, there were approximately 99,300 power boat trips from launches at Lake Tahoe (Hagler-Bailly 1999). Most AIS exposure to Lake Tahoe is due to recreational boats that are more likely to move between waterbodies with similar recreational opportunities rather than smaller waterbodies that may be closer. During the summers of 2005 and 2006, Wittmann (2008) conducted recreational boater surveys at seven boat launches around Lake Tahoe. Boaters were asked about their boat use, visitation frequency, areas visited at Lake Tahoe, cleaning practices/habits, and AIS awareness. A visual inspection was also conducted. Of the 778 boaters surveyed, about 300 users had visited about 20 other waterbodies within a week (some of which are listed in Table 2). During the same survey, she found that 265 originated from waters with AIS and that three of those waterbodies contained quagga mussels (Lake Mead, Colorado River, and Lake Havasu). She also found that 117 boats that were leaving Lake Tahoe had aquatic plants (native and non-native) entrained on boating equipment when exiting the lake and that 82.1% of boaters surveyed "never" conduct as much as a visual inspection of their equipment for AIS after use.

Table 2. Inter-Region Recreational Waterbodies

Waterbody	Boat Launch	Fishing	Non-motorized	Rafting
Inter-Region Waterbodies				
Lake Berryessa, CA	x	x	x	
Boca Reservoir, CA	x	x	x	
Colorado River, NV	x	x	x	x
Donner Lake, CA	x	x	x	
Folsom Lake, CA	x	x	x	
Lake Havasu, AZ	x	x	x	
Lahontan Reservoir, NV	x	x	x	
Lake Mead, NV	x	x	x	
Pyramid Lake, NV	x	x	x	
Sacramento-San Joaquin Delta, CA*	x	x	x	
Lake Shasta , CA	x	x	x	
Stampede Reservoir, CA	x	x	x	
Topaz Lake, CA-NV	x	x	x	
* At least 84 non-native species are found in the freshwater portions of the San Francisco Bay and Delta ecosystem; Source: Cohen and Carlton. 1998.				

Intra-Region AIS Introductions

In addition to Lake Tahoe, seven other important recreational waterbodies are located in the Region (Table 3). These waterbodies not only provide further opportunities for AIS introduction *to* Lake Tahoe but they risk invasion by Eurasian watermilfoil, curlyleaf pondweed and Asian clams *from* Lake Tahoe.

Table 3. Intra- Region Recreational Waterbodies

Waterbody	Boat Launch	Fishing	Non-motorized	Rafting
Lake Tahoe, CA-NV	x	x	x	
Cascade Lake, CA		x	x	
Echo Lake, CA	x	x	x	
Fallen Leaf Lake, CA	x	x	x	
Incline Lake, NV		x		
Lower Truckee River, CA*	x	x	x	x
Marlette Lake, NV		x		
Spooner Lake, NV		x		
*Only the first 6 km of the Lower Trucker River below the dam at Lake Tahoe is considered in the Lake Tahoe Region				

Cascade Lake lies south of Emerald Bay and has no public boat launch and much of the shoreline access is privately held. Echo Lake, south-west of South Lake Tahoe, has a public boat launch operated by Echo Lake Chalet under a USFS-LTBMU special use permit. The gated boat launch is closed when a trained inspector is not available. Game fishes present in Echo Lake include rainbow, brook and Lahontan cutthroat trout. Most of the shoreline at Fallen Leaf Lake is publicly held by the USFS-LTBMU. From the northern shore of Fallen Leaf Lake, Taylor Creek runs directly to Lake Tahoe. Game fishes present in Fallen Leaf Lake include lake, rainbow, Lahontan cutthroat, brook and brown trout and Kokanee. Incline Lake is on the Third Creek drainage, located between Mount Rose and Incline Village on the north side of Lake Tahoe. The lake, along with the 750 acres surrounding it, was controlled by the Incline Lake Corporation until summer 2008 when ownership was transferred to the USFS-LTBMU. The land will be jointly managed by the USFS-LTMBU and the USFS-Humboldt-Toiyabe National Forest. Many of the 63 streams that drain to Lake Tahoe are popular for recreational activities, including fishing and rafting. Only the first 6 km of the Lower Truckee River is technically considered in the Lake Tahoe Region; however, its popularity for rafting and fly fishing leave it particularly vulnerable to New Zealand mudsnail introduction and establishment. Marlette Lake, located in the Lake Tahoe Nevada State Park northeast of Lake Tahoe, is closed to motorized watercraft. Game fishes in Marlette Lake include brook trout, Lahontan cutthroat trout, and rainbow trout. The lake is currently managed as a brood lake for rainbow and cutthroat trout which provide eggs for NDOW hatcheries. Spooner Lake, south of Marlette Lake and also in the State Park, has no boat launch facilities but is open to catch and keep trout fishing with a five trout limit. Due to their limited or restricted boat access, Marlette and Spooner Lakes may be at greater risk of AIS introduction via contaminated waders and float tubes.

Aquascaping and the Aquarium Trade

The use of aquatic plants in outdoor water features is increasing in popularity. Many species associated with this industry are non-native to the U.S. and often problematic in natural environments. Increasing internet sales have facilitated the widespread distribution of many federal and state listed prohibited species (Kay and Hoyle 2001). Education and outreach efforts directed to the aquascaping and aquarium trades have increased. Programs such as the ANSTF's partnership program, Habitattitude™, and Sea Grant campaigns encourage the selection of non-invasive or regionally native plants and the construction of water features away from natural waterways. Despite these efforts, the spread of invasive aquatic plants continues, most likely due to lack of enforcement or inadequate stewardship.

Dumping of non-native live bait is prohibited in Lake Tahoe, a measure that most likely prevents the further spread of unwanted fish species. The use of live bait in Lake Tahoe and its tributaries in Carson City and Douglas and Washoe Counties is only allowed for the following species: Lahontan redside shiner, tui chub (*Gila bicolor*), Tahoe sucker (*Catasomus tahoesis*), Lahontan mountain sucker (*Catostomus platyhynchus*), Paiute sculpin (*Cottus beldingii*) and Lahontan speckled dace (NDOW 2008). Fish used as live bait may only be taken from, and must be native to, Lake Tahoe and its tributaries.

Resource Management Activities

Many non-native species are intentionally introduced, but others are unintentionally introduced through resource management activities such as fish stocking or habitat enhancement projects. Hitchhikers in early development stages (i.e., egg, larvae, or seed) can easily be transported on equipment (e.g., water sampling devices, nets, waders, and shovels) or in water (e.g., fish enhancement projects, revegetation projects for riparian or submersed vegetation) by unknowing workers.

Nearshore Construction Activities

Shoreline construction and maintenance activities such as the removal, replacement or repair of docks, moorings, marinas, and other structures may result in the introduction of harmful AIS if contaminated equipment is used. Again, TRPA Code 79.3 B(2) requires all watercraft, motorized and non-motorized, be inspected prior to launching into the waters of the Region. Thus, inspection and decontamination requirements are extended to construction equipment.

Wildfire Suppression Activities

Wildfires threaten not only the forest ecosystem of the Region, but homes and commercial structures. The Angora Fire, located in the southwestern portion of the Region, burned over 3,000 acres, nearly 300 homes and 67 commercial buildings in 2007. To control these fires, the USFS-LTBMU and other private and state firefighters commonly use aerial and ground-based drafting/dipping methods from nearby waterbodies. This involves the use of slings, buckets, suction hoses, and holding tanks to remove and transport water to fires. The USFS-LTBMU developed Resource Guidelines for Wildfire Suppression to help conserve natural resources, including reducing the likelihood of AIS transport from fire suppression activities. The AIS pertinent guidelines include:

- Decontaminate water conveyance equipment (slings, buckets, suction hoses, holding tanks) before and after use. Disinfect internal tanks by applying either a rinse of 5% solution of Quat 128 or Sparquat 256 or high pressure water applied at 140 degrees F or hotter. Do not pump treated water into any stream or lake, or on areas where it can migrate into any waterbody.
- Remove water at least 1000 ft. from the shoreline in Lake Tahoe and 500 ft. from the shoreline in Emerald Bay in order to avoid coming in contact with aquatic weeds (Eurasian watermilfoil and curlyleaf pondweed) from water withdrawal equipment (i.e., buckets and/or suction hoses).
- Only remove water out of 1 site once committed to a specific water body unless conveyance systems are decontaminated before removing water from an alternate site.

For management consistency, these AIS fire suppression guidelines are available for use by other state, county and municipal agencies who have responsibility for wildfire suppression. The important consideration for wildfire suppression is, where possible; avoid removing water from areas with known AIS, such as Eurasian watermilfoil and curlyleaf pondweed.

3.3 Non-native Species Present or Threatening Lake Tahoe

At least 20 known non-native aquatic species, including plants, fish, invertebrates, and an amphibian are established in the Region. Many of these non-native species were purposefully and legally introduced (i.e., as a managed game fishery), but others were introduced illegally, for example, through recreational activities, the aquarium trade, or resource management activities such as habitat enhancement projects.

Aquatic Plants

Dense growth of invasive aquatic plants impede water flow, disrupt navigation, discourage recreational activities, deleteriously affect water quality, and reduce plant diversity (Smith and Barko 1990, Frodge et al. 1991, Boylen et al. 1999, Mullin et al. 2000). Non-native aquatic plants known to occur in Lake Tahoe include Eurasian watermilfoil and curlyleaf pondweed. These rooted plants "pump" nutrients from the sediment to the overlying water column (Carignan and Kalff 1980; Granéli and Solander 1988; Walter et al. 2000) and may be contributing to increased phytoplankton and reductions in water clarity at Lake Tahoe. The ability of a plant to spread and become invasive is strongly driven by factors such as its propagule type (e.g., seed, stem fragment, tuber, turion, stolon, rhizome), propagule number, and ability to withstand harsh conditions and optimize limited resources (e.g., light and nutrients) (Haynes 1988).

Eurasian watermilfoil was likely introduced to Lake Tahoe in the 1960s to early 1970s when the Tahoe Keys were developed; however, paleolimnological data do not fully support this (Kim and Rejmánková 2001). Confirmation of Eurasian watermilfoil in Lake Tahoe was made in 1995 by the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS) during a vegetation survey (Anderson 2007) (Figure 3). First observations of curlyleaf pondweed in Lake

Tahoe were made in 2003 with populations concentrated in the south basin, near the Tahoe Keys. As of 2006 its range had extended northeastward to the Lakeside Marina (Anderson 2007) and, as recently as summer 2008, coverage in the Tahoe Keys had expanded substantially (Lars Anderson, USDA-ARS, personal communication, June 3, 2008). While native plant species such as Andean milfoil (*M. quitense*), Canadian waterweed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*) and leafy pondweed (*Potamogeton foliosus*) are found in Lake Tahoe, Eurasian watermilfoil and curlyleaf pondweed dominate the submersed aquatic plant community (Anderson 2007). Surprisingly, prior to 1995, only one published reference to "*Myriophyllum* sp." (near Ward Creek and Tahoe City) has been documented (Flint and Goldman 1975) and all other evidence for aquatic plant distribution and species is anecdotal (Lars Anderson, USDA-ARS, May 14, 2009).

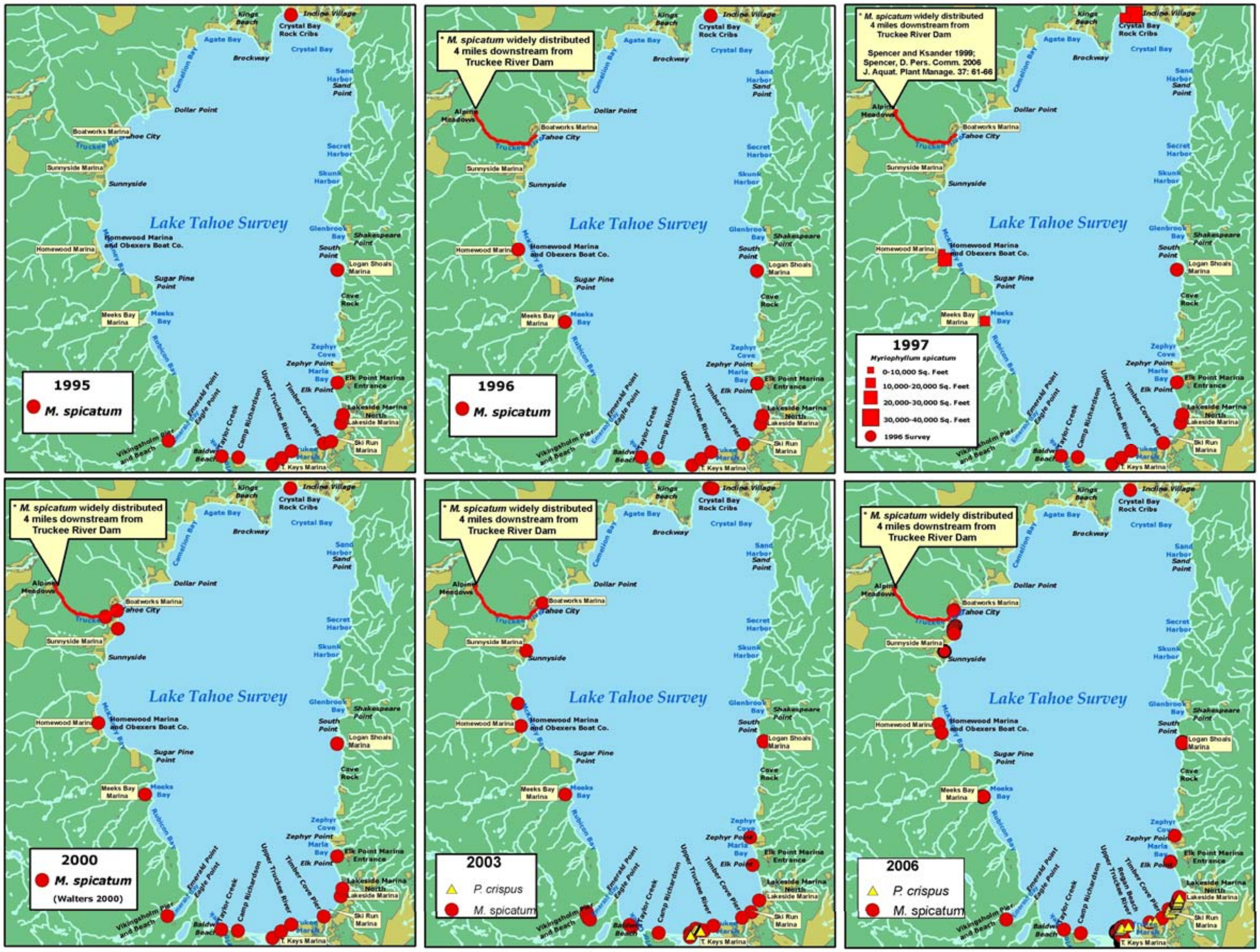

Figure 3. Distribution of curlyleaf pondweed (*P. crispus*) and Eurasian watermilfoil (*M. spicatum*) in Lake Tahoe from 1995 to 2006 (Anderson 2007)

Factors such as light penetration, wave energy, sediment texture, slope, and water temperature all influence submersed plant distribution (Duarte and Kalff 1986, Hudon et al. 2000). Depth information at Lake Tahoe has been shown to be the most comprehensive variable (i.e., easily mapped and readily available information) for predicting plant distribution. To determine the potential habitat available for submersed aquatic plants, we assumed a survival depth of approximately 11 m (Sheldon and Boylen 1977, Chambers and Kalff 1985, Schwarz and Howard-Williams 2000). This represents the maximum depth under most natural conditions. Within this depth range, there are approximately 4,600 surface hectares of available habitat for submersed aquatic plants in Lake Tahoe, including the Tahoe Keys area (Figure 4). Areas of high energy (due to wind and waves), steep slopes, and poor substrate such as large boulders (e.g., north of Cave Rock to South Point, entrance to Emerald Bay) are unlikely to support submersed plant growth, regardless of depth. Conversely, the leeward (west side) and isolated embayments and marinas are more likely to support aquatic plant growth. More research is needed to better quantify the potential distribution of aquatic plants in Lake Tahoe.

Figure 4. Potential distribution of submersed plants (e.g., curlyleaf pondweed and Eurasian watermilfoil) in Lake Tahoe

Control/Eradication Methods for Invasive Aquatic Plants

Controlling or eradicating unwanted aquatic vegetation may be accomplished using the methods outlined below, or some combination such as IPM. The following sources were consulted to summarize aquatic plant control technologies: Gibbons et al. (1999), Madsen (2000), Cooke et al. (2005), and Washington Department of Ecology (2008).

Physical and Cultural Methods

Methods to physically control unwanted aquatic plants include: hand-pulling and hand-pulling with diver-assisted suction, deployment of benthic barriers, water level drawdown, and the use of tools such as cutters, rakes, or hooks. Many of these physical methods; however, typically produce plant fragments capable of sprouting. Diver-operated suction is used to facilitate the removal of plants and plant fragments following hand-pulling. Similar to vacuuming, the plant material and sediment are suctioned during hand-pulling then transported to the surface. The sediment is sifted through a screen and the vegetation is retained for disposal. This method can allow for selective removal of unwanted vegetation, may be used near boat docks, and is environmentally favorable. Increased turbidity can temporarily result from diver-assisted suction, and reduce diver visibility. While an effective means of controlling invasive aquatic plants, vegetative hibernacula such as tubers, turions, and root crowns may remain in the sediment allowing for reinfestation.

Hand-pulling of aquatic plants is most effective in shallow water where the bottom is within reach. In deeper water, tools and/or snorkel or SCUBA gear will most likely be needed. Physical methods of plant removal are best for smaller areas as it is very labor intensive. Because plant fragments form using many physical methods, it is important to have a system in place to contain the fragments (e.g., suction device, booms around the boat, person to hand net the fragments, et cetera), have an off-site location for disposal away from water sources, and to understand the biology of the plants being harvested as many are capable of spreading by vegetative fragments.

Bottom barriers, also called benthic screens, control rooted aquatic plants by covering the vegetation with materials such as sand, gravel, burlap, plastic, or woven synthetic fibers thereby preventing light penetration. These barriers can be used at various depths but will most likely require divers for many applications, for example in deep water or around boat docks and piers. Flexible, non-porous materials require anchoring due to gas buildup from decomposing plant material. Bottom barriers were installed at Lake Tahoe during the summer of 2008 - in a boat slip at Lakeside Marina, near the shoreline at Ski Run and in Emerald Bay. Post-treatment observations in Emerald Bay indicate few plants survived; however, the success of barriers in Emerald Bay is limited by diverse topography, boulders, logs, and other woody debris, such that hand-pulling and diver-assisted suction is required in many areas.

The advantages of bottom barriers are that a variety of rooted plants, particularly new infestations may be controlled and they are considered environmentally favorable.

Disadvantages include maintenance, cost of material, limited to flat areas or those with little change in slope and no obstructions (i.e., logs, boulders, large rocks, et cetera), and cost of installation if commercial services are used. Maintenance is critical as plants can send lateral branches from under the barrier, improper anchoring can lead to ballooning of the material, and sediment deposition over the barrier can exacerbate barrier decomposition (e.g., for burlap). Lastly, barriers may lead to temporary impacts to benthic organisms.

In general, the advantages of physical control methods are: they are inexpensive, allow for selective removal, are simple, and are environmentally favorable. Disadvantages for physical control methods are: labor intensive effort and plant fragments need to be removed to prevent further spread. Additionally, water may become turbid and limit visibility particularly when pulling plants that have large or deep rhizomes or roots. Operations may require acquisition of permits and water quality monitoring for diver-assisted suction removal and bottom barrier placement and removal. Monitoring needs are likely to be evaluated on a case by case basis by the LRWQCB.

Water level drawdown may be used to expose plants to extreme desiccation, heat, or cold long enough to kill them. Water drawdown may be more acceptable than chemical control and provide opportunities for maintenance of other structures such as boat docks, fish screens, dams or installing bottom barriers. Frequent and/or prolonged drawdowns are often required for substantial reduction or elimination of unwanted vegetation. Water drawdown is not a selective plant eradication strategy and may encourage the growth of unwanted vegetation, particularly plants that can survive desiccation (e.g., hydrilla tubers [Doyle and Smart 2001]). This method of plant control is more applicable for use in reservoirs, irrigation canals and other areas where water level control structures are present and is not considered a viable method for controlling invasive aquatic plants in Lake Tahoe.

Mechanical Methods

Mechanical control devices typically "mow" the upper portions of a plant canopy (up to about 5 ft. below the water surface) using a mechanized cutter. The scale of mechanical controls ranges from portable boat-mounted to barge-like devices. Fragment recovery is critical to prevent further spread and can be accomplished using a net for boat-mounted devices. For larger harvesters, a conveyor belt system may be used to offload harvested vegetation to a barge where plants are deposited on shore or contained for transport off-site.

The advantages of mechanical control are that open water access is immediately provided and it is environmentally favorable. The disadvantages are that cost varies greatly between small boat-mounted cutters and large-scale harvesters. The latter have to be either transported from elsewhere, or purchased for use within the same waterbody. The prevailing disadvantages are that plants are allowed to return, there is no selective control, and plant fragments can be released and expand the in-lake population.

Weed cutting and harvesting are not currently regulated in the Tahoe Region, however there are concerns about the improper disposal of plant fragments that could spread infestations and release nutrients upon decay. Additionally, the operation and maintenance of weed harvesters should be sufficient to prevent leakage of mechanical fluids. Regulatory agencies (i.e., LRWQCB or TRPA) *may* require that a plant disposal plan and an operations and maintenance plan be in place prior to project commencement.

Biocontrol Methods

Biocontrol is the use of one organism (generally host-specific) to control another. The control agent works by impacting the reproduction or growth of the host. Because the presence of the host organism is required for the biocontrol agent, this method used alone will provide control, but not eradication. Biocontrol methods may, however, be used as part of an integrated pest management (IPM) plan to increase efficacy.

The advantage of biocontrol agents is that public perception is generally favorable and the perception is further improved when the proposed agent is native. Additionally, while biocontrol agents will not effectively eradicate unwanted vegetation, they can control plants to more acceptable levels, allowing for native vegetation to thrive or leave plants susceptible to other control methods using IPM. Biocontrol agent stocking rates are difficult to predict especially in novel environments.

The native North American weevil (*Euhrychiopsis lecontei*) has been shown to be an effective biocontrol agent against Eurasian watermilfoil (Newman et al. 1996, Creed 1998). Weevil larvae damage milfoil plants by mining through the stem during their development (Mazzei et al. 1999). The result can be substantial loss in stem and root biomass without the need for mechanical removal. The optimal stocking rate of weevils has been estimated at two to four weevils per stem (Newman and Biesboer 2000); however, damage to the plant depends on factors such as water temperature, disease, and plant health (Newman et al. 1998, Mazzei et al. 1999, Spencer and Ksander 2004). Weevils have been considered for use in Lake Tahoe; however, it is unlikely that viable populations of the insects would establish at Lake Tahoe due to lack of suitable over-wintering habitat, shoreline development, expense, and because Eurasian watermilfoil does not commonly reach the water surface (due in part to high boat traffic) (Lars Anderson, USDA-ARS, personal communication June 3, 2008).

Chemical Methods

Aquatic herbicides registered by the United States Environmental Protection Agency (USEPA) may be used to control and in some cases, eradicate unwanted vegetation. Herbicide selection is based on factors such as plant species, waterbody function (e.g., drinking water, recreation, aesthetics or irrigation), presence of native and/or federal/state listed species, public perception, and other considerations. Aquatic herbicides are typically discussed in terms of their mode of action and selectivity. Aquatic herbicides used to control curlyleaf pondweed and Eurasian watermilfoil include early season application of endothall (Netherland et al. 2000), or the use of diquat or fluridone (Table 4).

Disadvantages of chemical control methods include restrictions to swimming, drinking water, and fishing and potential impacts to non-target plants. Additionally, the use of chemical controls may require extensive water quality monitoring that could increase overall program costs. In the Lake Tahoe Basin, water quality objectives for pesticides, and related objectives for non-degradation and toxicity, essentially preclude direct discharges of pesticides such as aquatic herbicides (California Regional Water Quality Control Board Lahontan Region 2005; TRPA Water Quality Management Plan for the Tahoe Basin; see Appendix A).

Table 4. Aquatic Herbicides Registered in by California Department of Pesticide Regulation (CDPR), Nevada Department of Agriculture (NDA) and/or the U.S. Environmental Protection Agency (USEPA)

Active Ingredient	Controls	CDPR	NDA	USEPA
2, 4-D (butoxy-ethyl-ester [BEE])	Eurasian watermilfoil		✓	✓
2, 4-D (dimethylamine salt [DMA])	Eurasian watermilfoil	✓	✓	✓
Carfentrazone-ethyl	Eurasian watermilfoil		✓	✓
Copper (elemental)	Eurasian watermilfoil	✓	✓	✓
Copper (chelated)	Curlyleaf pondweed Eurasian watermilfoil	✓	✓	✓
Diquat dibromide	Curlyleaf pondweed	✓	✓	✓
Endothall (dipotassium salt)	Curlyleaf pondweed Eurasian watermilfoil	✓	✓	✓
Fluridone	Curlyleaf pondweed Eurasian watermilfoil	✓	✓	✓
Penoxsulam	Curlyleaf pondweed Eurasian watermilfoil	✓	anticipated	✓
Triclopyr (triethylamine [TEA])	Curlyleaf pondweed Eurasian watermilfoil	✓	✓	✓
Acid Blue 0 Acid Yellow 23	Curlyleaf pondweed Eurasian watermilfoil	✓	✓	✓

Resource managers at Lake Tahoe have employed various non-chemical methods to reduce invasive aquatic plants, including physical, mechanical, and cultural. Physical methods have included diver-assisted suction and bottom barriers. The Tahoe Divers Conservancy (TDC) recently began an Aquatic Plant Research Diver Certification with the objective of training divers to remove rooted vegetation in a manner that would minimize increases in turbidity from re-suspension of fines from the bottom substrate. Mechanical harvesting is used in the Tahoe Keys to remove Eurasian watermilfoil and curlyleaf pondweed. Four harvesters are operated 40 hours per week from June to October to control vegetation (Harry Dotson, TKPOA personal communication, July 10, 2008). Long-distance water circulation systems (SolarBees) were installed in the east basin of the Tahoe Keys for about three years to reduce the impacts of Eurasian watermilfoil but have since been removed due to no perceived success and data are not readily available.

A mesocosm study was conducted by researchers from the USDA-ARS using plants (Eurasian watermilfoil), sediments and water from Lake Tahoe (more specifically Tallac Lagoon). The purpose was to evaluate the efficacy of endothall, triclopyr, and fluridone in controlling Eurasian watermilfoil. They found that Eurasian watermilfoil from Lake Tahoe exposed to EPA-approved herbicides showed similar susceptibility to those test elsewhere in the U.S.

Warm Water Fishes

In the mid to late 1970's and again in the late 1980's, a variety of warm water fish species were found in the nearshore environment of Lake Tahoe (Reuter and Miller 2000). These illegal introductions are thought to be the result of anglers eager to catch these fish. Prior to that, native minnows were abundant while warm water fish were rarely found around the lake. By the end of the decade however, largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) were common to the Tahoe Keys. The change in fish structure was confirmed by fishing guides operating out of the Tahoe Keys. Within a decade they could no longer collect minnows from certain marinas commonly used as bait during fishing charters on the lake. The quick reduction in native fish abundance has raised concern while at the same time suitable habitat for non-native fishes in the nearshore environment increases (i.e., expansion of aquatic weed beds), further reducing food web efficiency and decreasing biodiversity of fish assemblages (MacRae and Jackson 2001).

Until recently, the distribution of warm water fishes beyond the Tahoe Keys was largely unknown, but a survey by Kamerath et al. (2008) found non-native fish species, including bluegill, largemouth bass, brown bullhead (*Ameiurus nebulosus*), black crappie (*Pomoxis nigromaculatus*), gold fish (*Carassius auratus auratus*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*) at 12 of 21 sites around Lake Tahoe (Figure 5). It is believed that increased water temperatures have extended the amount of habitat available for warm water fishes to spawn (Chandra et al. 2009).

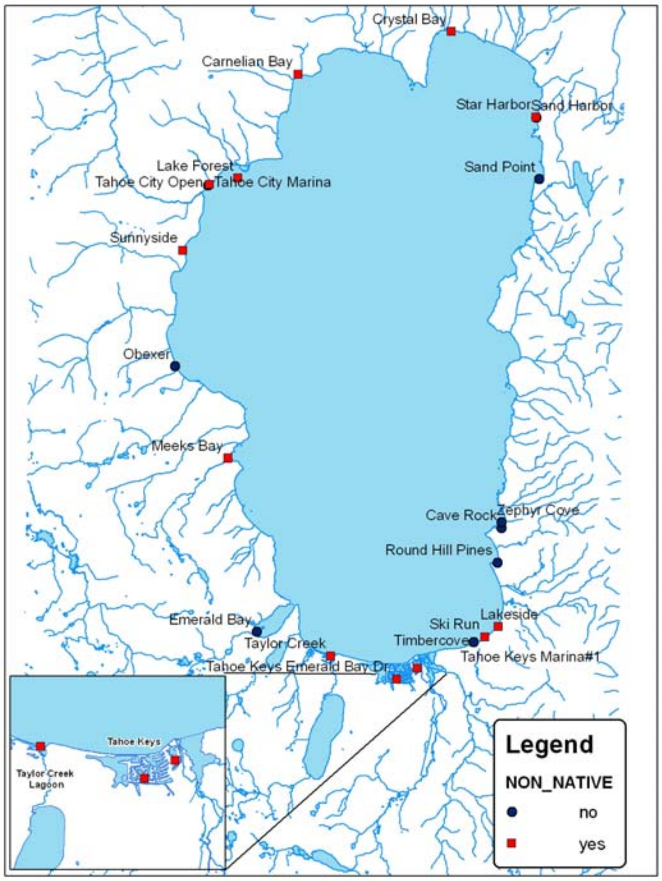

Figure 5. Survey locations with (indicated by "yes") and without (indicated by "no") non-native warm water fishes May-November 2006 (modified from Kamerath et al. 2008)

University of Nevada - Reno (UNR) and University of California – Davis (UCD) researchers recently investigated the distribution, relative abundance, and diets of warm water fishes within Lake Tahoe and, more specifically, whether they are moving out of the Tahoe Keys (Chandra et al. 2009). Additionally, they monitored temperature changes in the nearshore environment to determine where and when adequate spawning conditions are present. The objectives of their work were to determine whether the Tahoe Keys could serve as a source population of warm water fishes to the rest of the lake, and to identify management periods to reduce deleterious impacts to native fishes. Nearshore temperature data suggests that all monitored sites are thermally suitable for largemouth bass, bluegill, and likely other warm water fishes and that bass migrate out of the Tahoe Keys in early to mid summer. Based on the shift in largemouth diet to piscivory at two to four years (8.0 to 12.0 cm), Chandra et al. (2009) recommend largemouth bass removal, optimally every two years, to minimize predation pressure and competition with native fishes.

Control/Eradication Methods for Invasive Fishes

Examples of non-chemical methods to control unwanted warm-water fishes include, fyke nets, gill nets, or minnow traps. These efforts are more efficacious in smaller waterbodies and require repeat visits (Closs et al. 2003). Electro-fishing and seines may be used to control invasive fish, however evidence from Lake Davis, CA and Browns Pond, CA suggest these methods have limited impact for controlling northern pike and grass carp, respectively. Biological control methods include increasing predators such as largemouth bass. To facilitate the eradication of bluegill from Lake Biwa, Japan, the government is calling on its citizens to "catch-and-eat" the nuisance non-native species.

Chemical methods to control warm water fishes include the plant-derived piscicide, rotenone. Rotenone acts by inhibiting oxygen uptake through the gills, resulting in suffocation. Rotenone is non-selective, meaning it will kill all fish within the target tolerance level as well as other aquatic organisms such as invertebrates; however, there is usually recovery of benthic organisms over time (Mangum and Madrigal 1999; Melaas et al 2001). Different fish species can tolerate different levels of exposure thus application rates are based on target-species tolerance. Oftentimes, applications are made in combination with a significant drawdown or area isolation. Following rotenone application, potassium permanganate may be used to neutralize the effects of rotenone. Typically, a concerted effort is made to salvage as many native fish species as possible prior to the application of a piscicide.

At present, warm water fishes are not being controlled in Lake Tahoe; however, as part of Southern Nevada Public Land Management Act (SNPLMA) Round 8, 9, and 10 Capital Projects, research led by the Tahoe Keys Subcommittee (as part of the LTAISWG) will study the effects of experimental aquatic weed removal on localized warm-water fish populations. Target areas will be based on projections of overlapping habitat use by native fish species.

Given the evidence that largemouth bass migrate out of the Tahoe Keys and that widespread nearshore habitat is available for spawning, UNR and UCD researchers recommend that temperature monitoring at least once a week at marina and non-marina locations with the goal of targeting management activities to when movement and spread of non-native fishes are most likely to occur (Chandra et al. 2008). That is, removal efforts should precede maximum water temperatures of the season to prevent spawning and spread of non-native fishes. As a result, the majority of efforts aimed at controlling non-native spread should be conducted in June and July with follow up in October, or when water in marinas become colder than exposed, open-water sites.

Rotenone use in Lake Tahoe is not currently prohibited per say, but applications must be reviewed on a case by case basis, meet a series of conditions, and are subject to approval by the Executive Officer of the LRWQCB. Simplification of this approval process, or easing of requirements, would require an amendment to the Basin Plan which is currently being evaluated.

Other Species

The establishment of non-native aquatic invertebrates and other vertebrates such as amphibians has the potential of severely impacting new environments. Invasive invertebrates present in Lake Tahoe include the Asian clam, signal crayfish (*Pacifastacus leniusculus)*, mysid shrimp, and gill maggot (*Salmincola californiensis)* (Kamerath et al. submitted). Invasive invertebrates threatening introduction to the Lake Tahoe Region include quagga and zebra mussels, New Zealand mudsnails, and spiny Waterflea (*Bythotrephes longimanus)*. Bullfrog (*Rana catesbeiana*) is also present in the Region.

The Asian clam is a small (~1-25 mm) bio-fouling filter-feeder capable of dominating benthic invertebrate communities Karatayev et al. 2003). The Asian clam usually occurs in high densities (thousands per square meter) (Gottfried and Osborne 1982, McMahon 1983, Stites et al. 1995) and accumulation of dead shells in large beds exemplifies its rapid life cycle (see Hackley et al. 2008 for images). Asian clam beds increase the nutrient load in the water column through excretion of organic wastes (elevated levels of nitrogen and phosphorus) and by re-suspending sediments, resulting in decreased water clarity from algal growth in nearshore areas (Chandra and Wittmann unpublished data). In addition to concerns about the direct impacts of Asian clams to the Lake Tahoe ecosystem, researchers are concerned that their presence may facilitate a dreissenid mussel invasion by increasing localized calcium concentrations in clam beds (Hackley et al. 2008). Research is underway in Lake Tahoe to test this hypothesis (Chandra and Wittmann unpublished data and see Appendix F).

Known occurrences of Asian clams in or near the Region include Lake Tahoe, Pyramid Lake, and the Lower Truckee River. Asian clams were observed during a 2002 survey of Lake Tahoe's south shore, revealing a small population that could have been present since the late 1990s (survey by Sudeep Chandra, UNR). During a 2008 survey of Lake Tahoe's south shore, beds were found in 4 to 40 m of water with densities ranging from zero to < 100 individuals m^2 up while others had >2000 individuals per m^2 (Wittmann et al. 2008) (Figure 6). Additional surveys for Asian clams are anticipated using an autonomous underwater vehicle (AUV) called the "Gavia" (http://gavia.is/) which will be used to take high resolution photography of the lake bottom to look for surficial clam shells as an indicator of live Asian clam presence. In areas where clam shells are sensed, ground truthing via benthic grab sampling and/or SCUBA or snorkel diving will be used. The AUV will also be able to sense chlorophyll levels via an externally attached, continuously sampling fluorometer.

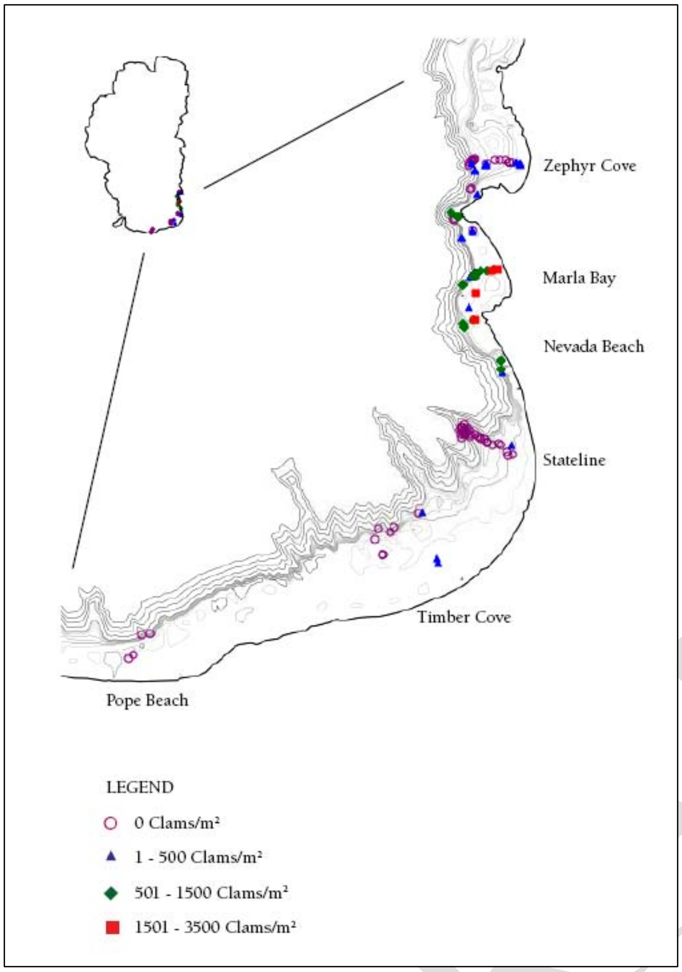

Figure 6. Asian clams densities from discrete locations in Lake Tahoe July – October 2008 (Wittmann et al. 2008)

Quagga and zebra mussels (dreissenid mussels) are two of the biggest threats to North America's freshwater ecosystems, and their presence often results in irrecoverable ecological damage with fiscal impacts of over $1 billion annually for control efforts in the U.S. (Pimentel et al. 2001). They grow in dense populations that encrust pipes, impede water movement, and colonize on other organisms (e.g., turtles, native mussels, crayfish, aquatic plants, et cetera) and structures (e.g., piers, docks, pilings, rope, anchors, et cetera.). Dreissenid mussels are filter-feeders, commonly found in high flow areas such as pipes, intake structures, and pumps which can substantially reduce their flow efficiency, forcing expensive maintenance of pipes and other water conveyance structures. Dreissenid mussels are essentially impossible to eradicate once they become established.

Dreissenid mussels can filter about 1 L of water per day, primarily consuming phytoplankton but also other suspended material including bacteria, silt, and microzooplankton (USGS 2008). This results in transfer of substantial portions of the phytoplankton biomass from overlying surface water into the benthos, thereby increasing water clarity (Edwards et al. 2005). This can result in increased, and possibly toxic, blue-green algae blooms, which in turn increase odor problems. Increased water clarity can also allow for more light for the growth of submersed aquatic plants.

Colonization is common to areas where suspended organics (e.g., shoreline areas) or re-suspension from wave action occurs (Tuchman et al. 2004). These natural disturbances of nutrient rich sediments or aggregation of phytoplankton in higher densities at the shoreline support higher densities of dreissenid mussels. Ultra-oligotrophic waterbodies with non-point source nutrient runoff entering from shoreline development may also support increased mussel populations, resulting in locally-dense phytoplankton growth as nutrients are expelled directly from invasive bivalve excrement (Higgins et al. 2008).

No known populations of dreissenid mussels were known west of the 100th Meridian until January 2007 when quagga mussels were found in Lake Mead, Nevada. Since then, zebra mussels have been found in San Justo Reservoir, San Benito County, California and quagga mussels are present in waters in southern California, Nevada, and Arizona (Figure 7). More specifically, quagga mussels are present in the Lower Colorado River lakes (Lake Mohave AZ/NV; Lake Havasu, CA/AZ; Copper Basin Reservoir, CA), at the Nevada State Fish Hatchery (Lake Mead), and at the Willow Beach National Fish Hatchery (Lake Mohave, AZ). Most recently, dreissenid larvae were found in the Big Thompson Water Project which serves nearly 800,000 water users in northern Colorado. Within the Big Thompson Water Project, both quagga and zebra mussel larvae are currently in Grand Lake while only quagga mussel are found in Lake Granby and Shadow Mountain, Pueblo, and Willow Creek Reservoirs.

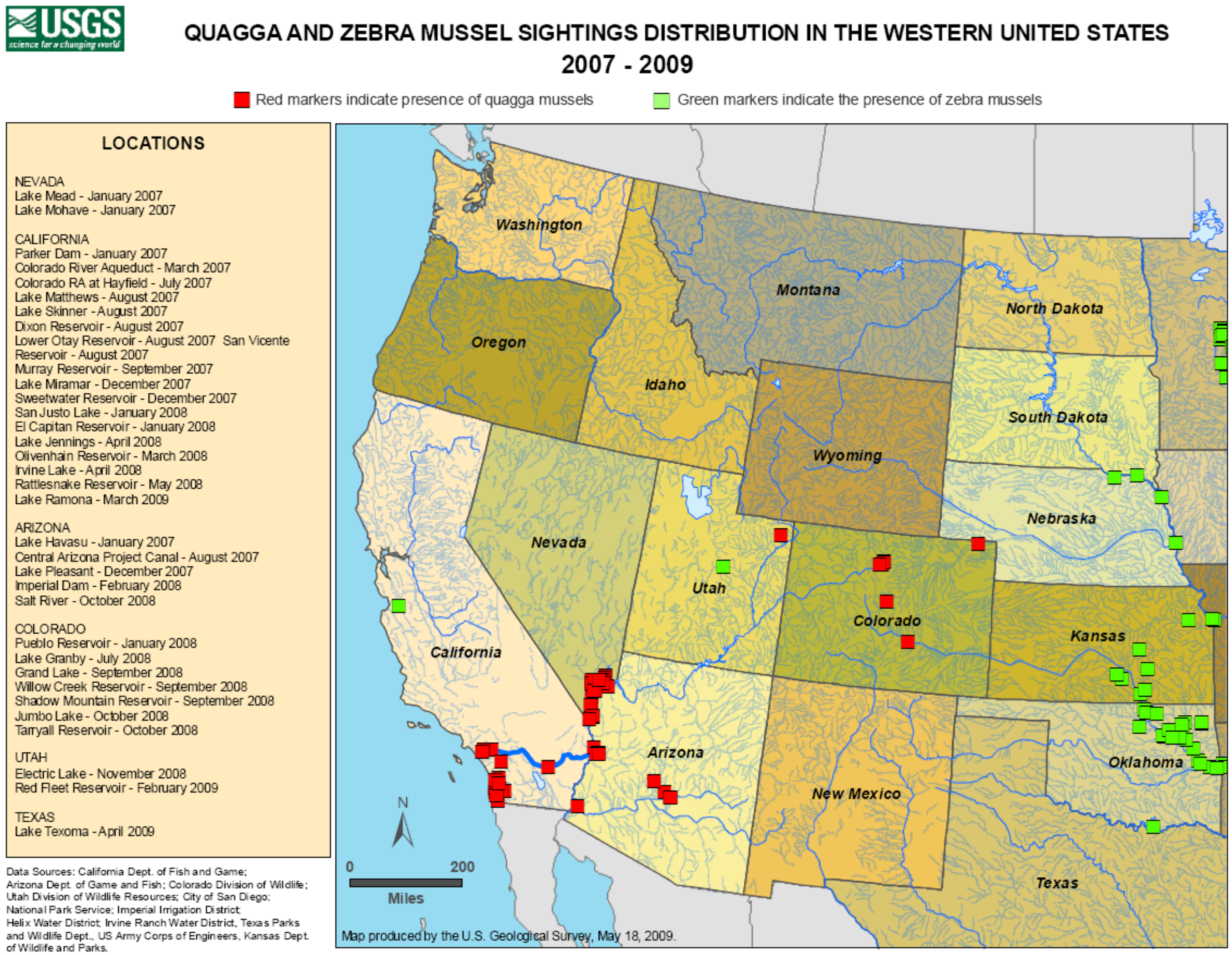

Figure 7. Distribution of quagga and zebra mussels in the western U.S. (http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/maps/southwest_quagga.pdf. Accessed May 18, 2009)

Quagga mussels colonize in higher abundance at greater depths (130 m) and colder water than zebra mussels (110 m) suggesting the quagga mussel is better adapted to cold-water than the zebra mussel (Mills et al. 1996). This observation highlights an interrelationship between water depth and level of disturbance where deeper water habitat tends to have largely undisturbed substrate composed of silty-sand, while shallower habitat is frequently affected by wave action (Mills et al. 1996). These differences have resulted in the spatial partitioning of the two species (Cohen 2007) along multiple environmental gradients, underscoring the importance for considering these relationships at all life stages.

Optimal conditions represented by convergences of multiple environmental gradients determine the success of this species and have been noted by their proliferation and spatial extent of distribution in some systems. Based on a maximum colonization depth of 130 m potential quagga and zebra mussel habitat in Lake Tahoe is shown in Figure 8.

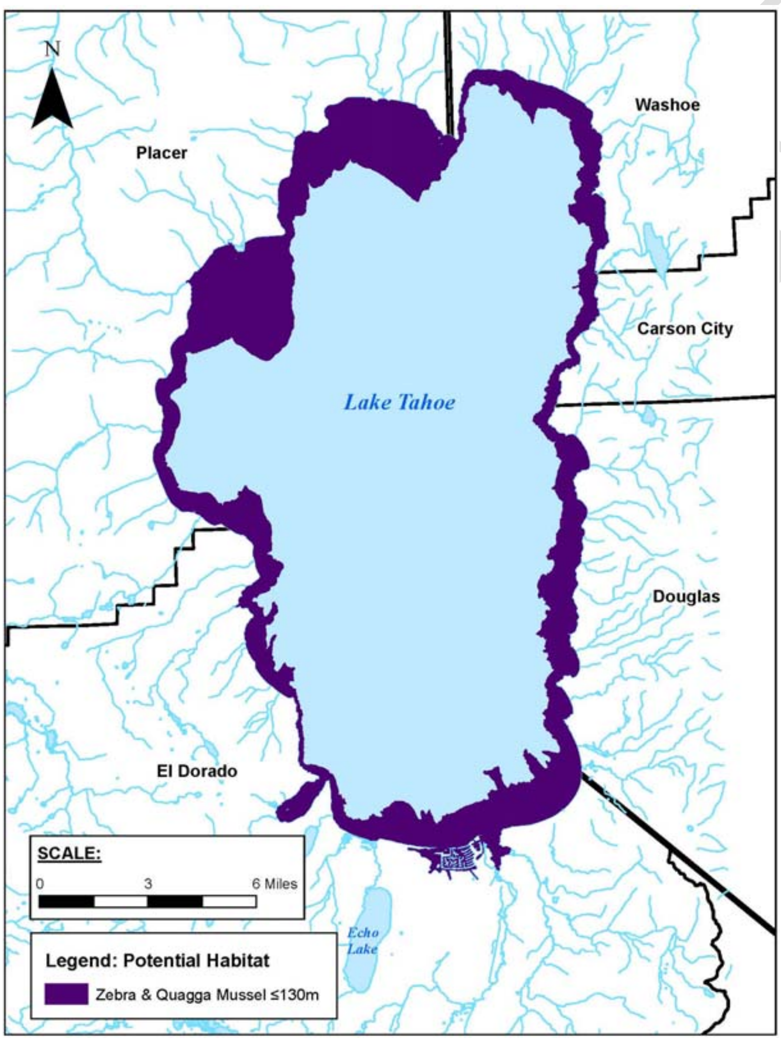

Figure 8. Potential quagga and zebra mussel habitat in Lake Tahoe, assuming survival depth ≤130 meters

Control/Eradication Methods for Other Species

Asian clams

In general, limited success has been achieved in controlling Asian clams. Similar to dreissenid mussels, chemical control of Asian clams is similarly difficult and involves the use of chlorine or bromine to control juveniles. In Lake Tahoe, research is currently underway to manage Asian clams. A four-phase program has begun that involves 1) field testing of removal options, 2) evaluation of strategies, 3) implementation, and 4) long-term monitoring (Wittmann et al. 2009). The first phase involves evaluating the effectiveness 1) diver-operated suction, 2) the installation of benthic barriers, and 3) a combination of the two.

Dreissenid mussels

There are no widely accepted physical methods to substantially control or eradicate invasive invertebrates. Physical removal of dreissenid mussels from structures such as intake screen, trash grates, and cooling units may be accomplished by using pressure washing with water or dewatering structures and allowing them to dry (USACE 2009). Such physical methods, however, are only practical where water levels can be manipulated such as irrigation canals or hydropower facilities with redundant infrastructure to allow off-line cleaning. Methods of controlling dreissenid mussels from pipes include: physical pigging, manual cleaning, exposure to temperature that exceed thermal optima, or desiccation of viable life stages.

Physical pigging involves use of a tool (physical inspection gage; PIG) that is propelled through a pipeline and scrubs the interior with abrasive brushes removing attached mussels. This method of cleaning is a corrective measure and not a preventive measure. Manual cleaning can include use of pressure washers or abrasive brushes to remove the invading mussels. Manual cleaning is useful when the mussels are visible such as on the outside of boat hulls, docks, and natural surfaces that may be immersed in affected waterways and subsequently removed or exposed for a period of time. Exposure of dreissenid mussels to heated water over 38 ^{o}C is also effective in eradicating the adult life stage. Heated water is introduced into piping and exposes the invading mussels for a period of time. Return of the heated water to a lake is blended with lake water to reduce temperatures and lessen thermal impacts to receiving water biota. This is a non-chemical method for control the mussels and can be used on a periodic basis for maintenance of water conveyance structures and pumping equipment. Enclosed areas colonized by invasive mussels can be exposed to radiation by microwaves that heat surrounding water resulting in the same effect from exposure to pre-heated water.

A microbial pesticide is currently being investigated to control dreissenid mussels (Molloy 2002). Exposure of veliger or adult stages of dreissenid mussels to a biotoxin in the bacteria *Pseudomonas fluorescens* strain CL145A (Pf-CL145A) results in 70 to 100% mortality. Efficacy of the biotoxin is achieved by destroying the mussel's digestive system from both live and dead bacterium cells. Ingestion of the cells does not stimulate valves to shut as the bacteria resemble food normally filtered by the mussel. Limitations for use of this biological control method include achieving effective concentrations of bacteria in open water whereas use in enclosed piping represents a controlled environment for application. Non-target tests on *Daphnia magna* (a microscopic crustacean) indicate non-lethal effects from the bacterium. Efforts are currently underway to improve its formulation for commercial products sales. In March 2009, a private company requested registration for a new active ingredient from the EPA for this microbial pesticide. The product is anticipated for commercial availability as soon as early 2010.

To prevent bio-fouling organisms such as dreissenid mussels from attaching to aquatic structures, antifouling building materials and repellents are available. Building materials include: copper, galvanized iron, aluminum, acrylic, Teflon, vinyl, pressure-treated wood, black steel, pine, polypropylene, asbestos, stainless steel, and polyvinyl chloride (PVC) (Kilgour and Mackie 1993). Products that can be applied to surfaces include, antifouling coatings containing cuprous oxide that repel zebra and quagga mussels, foul-release coatings that minimizes byssal thread attachment, and thermal spray coatings that work by slowly releasing metals ions (Boelman et al. 1996). In the Tahoe Region, the use of antifouling coatings are restricted according to the Water Quality Management Plan for the Lake Tahoe Basin (208 Plan) and the Basin Plan, both summarized in Appendix A.

Several methods for chemical control of dreissenid mussels have been used, including use of chlorine, potassium permanganate, bromine, ozone, and molluscicides (Shaw 2004; Maguire and Sykes 2004). These treatments, however, are normally introduced to intake pipes and colonization locations for zebra and quagga mussels. Otherwise, achieving effective concentrations in open water proves to be unachievable without harming other biota on a localized basis. The only known zebra mussel eradication to date occurred in Millbrook Quarry in Virginia. The small (5 ha) quarry was widely used for recreational diving which may have been the zebra mussel vector. Eradication was achieved using potassium chloride solution which is currently an unacceptable method in the Tahoe Region. No successful eradication of quagga mussels has been documented in North America (http://www.100thmeridian.org/).

New Zealand mudsnails

Research on a trematode parasite, *Microphallus* sp. as biocontrol agent for New Zealand mudsnails is currently underway (Fromme and Dybdhal 2006). No experimental methods will be considered for immediate implementation by this Plan.

The *National Management and Control Plan for the New Zealand Mudsnail* provides valuable information on vectors, pathways, and decontamination procedures that includes the following for waders and other equipment (NZMMCPWG 2007):

- Cleaning all mud and debris from boots, waders and gear with a stiff brush
- Putting fishing gear in a freezer for 6-8 hours

- Putting fishing gear in water maintained at 120°F for a at least 5 minutes will eliminate New Zealand mudsnails (Dwyer et al. 2003; Medhurst 2003; Robyn Draheim, Portland State University, March 19, 2009) (mudsnails can survive at 110°F)
- Dry fishing gear at 84-86°F for at least 24 hours or at 104°F for at least two hours (gear may be brushed with a stiff bristled brush prior to drying).

Bullfrogs

To control adult bullfrogs, a variety of methods may be deployed, including shooting, spears/gigs, bow and arrow, clubs, nets, traps, angling, and by hand (GISD 2008). They tend to be extremely shy, but can be caught by use of a strong spotlight at night and collected by hand or alternatively can be shot. Collecting egg masses using a bilge pump can be an effective adjunct control method (Govindarajulu 2004). Targeting egg searches to areas where male bullfrogs are heard calling during the night may improve the probability of detecting egg masses (Govindarajulu 2004). Incomplete removal of eggs or larvae, however, can inadvertently increase the growth and survival of the remaining individuals and cause an increase in the population (Govindarajulu 2004).

Bullfrogs can also be controlled by ringing the aquatic areas where they are established with reptile-proof fencing to catch neonates and placing traps in terrestrial areas to catch dispersing adults. The tadpoles take two years to metamorphose (tadpoles in most of North America over-winter at least once and some over-winter multiple years, whereas tadpoles in the southern U.S. are known to metamorphose in the same year that they were hatched). Other attempts to control this species have been made (see: Wright 1996; Pauli et al. 1999), but no primary alternative has been identified.

Direct removal of bullfrog is often very difficult and typically unsuccessful due to their high fecundity rate, high dispersal capability, opportunistic diet, and the complex habitats in which they are often associated. Habitat manipulation, in association with direct removal efforts, could prove more successful. Maret et al. (2006) used a method of draining and drying ponds to eliminate bullfrogs. Because bullfrogs overwinter as larvae and are dependant on permanent water for growth, this method has shown some success. Doubletree et al. (2003) used models to determine necessary draining intervals to reduce numbers. Their model suggests that direct removal of adults in combination with periodic drying (approximately every two years) could allow native amphibians the opportunity to reestablish. Although this could be successful, it is undetermined how periodic draining would impact other native species that also rely on a permanent water source.

3.4 Non-native Species Types

Similar to the CAISMP, species management types/categories were developed to facilitate the prioritization of management objectives (Table 5). This system will be used to categorize non-native species in the Region and those threatening introduction. Table 6 lists the estimated dates of species introduction (if present), known pathway of introduction, and applicable state and federal pest ratings (hereafter all species referred to by common name).

Table 5. Non-native Species Management Types

Species Management Type	Current Management Response
Type 1 Not yet detected in the Region	Prevention Monitoring Education
Type 2 Limited in extent with operational control* options	Monitoring Control/Eradication
Type 3 Established with operational control* options	Prevention Monitoring Control/Eradication Education Research
Type 4 Established but no operational control* options	Monitoring Research
Type 5 Unknown invasion potential	Prevention Research
Type 6 Legal introduction	Education Research

*Operational control refers to legal and permitted control and eradication methods, e.g., hand-removal of aquatic plants, diver-assisted suction for Asian clam removal.

Table 6. Non-native Species Presently In or Threatening the Lake Tahoe Region.

Group	Common name	Scientific name	In Tahoe Region (since)	Pathway	Applicable Pest Rating
Type 1: Not yet detected in the Region					
Aquatic Plants	Brazilian egeria	*Egeria densa*	N	AT, RA	CDFA “C” NRS 503.597
	Fanwort	*Cabomba caroliniana*	U	AT	CDFA “Q” NRS 503.597
	Giant salvinia	*Salvinia molesta*	N	AT	CDFA “A” NDA “A” Federal NRS 503.597
	Hydrilla	*Hydrilla verticillata*	N	AT, RA	CDFA “A” NDA “A” Federal NRS 503.597
	Oxygen weed	*Lagarosiphon major*	N	AT	CDFA “Q” Federal
	Parrot feather	*Myriophyllum aquaticum*	U	AT	NRS 503.597
	S. American spongeplant	*Limnobium laevigatum*	N	AT, RA	CDFA “A” NRS 503.597
	Water chestnut	*Trapa natans*	N	AT	NRS 503.597
	Yellow flag iris	*Iris pseudacorus*	N	AT	NRS 503.597
	Yellow floating heart	*Nymphoides peltata*	N	AT	NRS 503.597
Fishes	Northern pike	*Esox lucius*	N	ISI	CDFG NRS 503.597 NAC 503.110

Table 6 cont.

Group	Common name	Scientific name	In Tahoe Region (since)	Pathway	Applicable Pest Rating
	Smallmouth bass	*Micropterus dolomieui*	U (attempted introduction in 1895)	ISI	NRS 503.597 NAC 503.060
	Mosquitofish	*Gambusia affinis*	U	RM	CDFG NRS 503.597
Other Species	New Zealand mudsnail	*Potamopyrgus antipodarum*	U	RA	CDFG NRS 503.597 NAC 503.110
	Quagga mussel	*Dreissena bugensis*	N	RA	CDFG NRS 503.597 NAC 503.110
	Spiny waterflea	*Bythotrephes longimanus*	N	RA	NRS 503.597
	Zebra mussel	*Dreissena polymorpha*	N	RA	CDFG US NRS 503.597 NAC 503.110
Type 2: Limited in extent with operational control options					
Aquatic Plants	Curlyleaf pondweed	*Potamogeton crispus*	Y[1] (2003)	RA	NRS 503.597
Fishes*	-	-	-	-	-
Other Species	Bullfrog	*Rana catesbeiana*	Y[1] (late 1940s)	AT, RM	NRS 503.597
Type 3: Established with operational control options					
Aquatic Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Y[1] (early-1990s)	RA	CDFA “A” NDA “A” NRS 503.597

Table 6 cont.

Group	Common name	Scientific name	In Tahoe Region (since)	Pathway	Applicable Pest Rating
Fishes	Black crappie	*Pomoxis nigromaculatus*	Y[1] (late 1980s)	ISI	NRS 503.597 NAC 503.060
	Bluegill	*Lepomis macrochirus*	Y[1] (late 1980s)	ISI	NRS 503.597 NAC 503.060
	Brown bullhead	*Ameiurus nebulosus*	Y[1] (early 1960s)	ISI	NRS 503.597 NAC 503.060
	Common carp	*Cyprinus carpio*	Y[1] (late 1900s)	ISI	CDFG NRS 503.597
	Fathead minnow	*Pimephales promelas*	U	RA	CDFG NRS 503.597
	Goldfish	*Carassius auratus auratus*	Y[1] (late 1980s)	ISI	NRS 503.597
	Green sunfish	*Lepomis cyanellus*	Y[1] (late 1980s)	ISI	NRS 503.597
	Largemouth bass	*Micropterus salmoides*	Y[1] (late 1980s)	ISI	NRS 503.597 NAC 503.060
	White crappie	*Pomoxis annularis*	N	ISI	NRS 503.597 NAC 503.060
Other Species	Asian clam	*Corbicula fluminea*	Y[1] (early 2000s)	RA	NRS 503.597
Type 4: Established but no operational control options					
Aquatic Plants	Rock snot	*Didymosphenia geminate*	Y	RA	NRS 503.597
Fishes	-	-	-	-	-
Other Species	Gill maggot	*Salmincola californiensis*	Y[1] (2006)	RA, RM	NRS 503.597
	Signal crayfish	*Pacifastacus leniusculus*	Y[2] (1895 & 1909)	ISI	NRS 503.597

Table 6 cont.

Group	Common name	Scientific name	In Tahoe Region (since)	Pathway	Applicable Pest Rating
Type 5: Unknown invasion potential					
Aquatic Plants	Water hyacinth	*Eichorrnia crassipes*	N	AT	CDFA “C” NRS 503.597
	Water lettuce	*Pistia stratiotes*	N	AT	CDFA “B” NRS 503.597
Fishes	-	-	-	-	-
Other Species	**-**	**-**	-	-	-
Type 6: Legal introduction					
Aquatic Plants	**-**	**-**	-	-	-
Fishes*	Brook trout	*Salvelinus fontinalis*	Y^2 (1870s)	MF	NAC 503.060 NRS 503.597
	Brown trout	*Salmo trutta*	Y^2 (1896)	MF	NAC 503.060 NRS 503.597
	Golden shiner	*Notemigonus crysoleucus*	Y^1 (early 1960s)	RA	NRS 503.597
	Golden trout	*Salmo aquabonita*	N (but introduced in 1918)	MF	NRS 503.597
	Kokanee salmon	*Oncorhynchus nerka*	Y^2 (1949)	MF	NRS 503.597
	Lake trout/Mackinaw	*Salvelinus namaycush*	Y^2 (1888)	MF	NAC 503.060 NRS 503.597
	Rainbow trout	*Oncorhynchus mykiss*	Y (1880s)	MF	NAC 503.060 NRS 503.597
Other Species	Mysid shrimp	*Mysis relicta*	Y^2 (1963-65)	ISI	NRS 503.597

Table 6 notes:

Sources of information for Table 6: LTAISCC, LTAISWG, applicable state or federal regulations, Vander Zanden et al. 2003; Anderson 2007; Kamerath 2008; Hackley et al. 2008; USGS 2008; NDOW; USFS-LTBMU

*Desirable non-native, coldwater game fish are actively managed in the Region through stocking programs or possession limits by NDOW (NAC 503.060) and CDFG. As of November 21, 2008, however, CDFG stocking programs are substantially reduced pending completion of an Environmental Impact Report (EIR) which is expected to be completed January 1, 2010. Waterbodies in the Region with halted stocking programs can be found at: http://www.dfg.ca.gov/news/stocking/.

Y = Yes; [1] = Detected; [2] = Intentionally Introduced

N = No

U = Unknown; no known surveys have been conduced and no documentation of the presence of this species has been located.

This does not constitute verification of presence or absence of this species

RM = Resource Management activities (i.e., fish stocking, vector control)

ISI = Intentionally Stocked Invasive

MF = Managed Fishery

RA = Recreational Activities

AT = Aquarium Trade

NDA = Nevada Department of Agriculture

“A” Weeds not found or limited in distribution throughout the state; actively excluded from the state and actively eradicated wherever found; actively eradicated from nursery stock dealer premises; control required by the state in all infestations

“B” Weeds established in scattered populations in some counties of the state; actively excluded where possible, actively eradicated from nursery stock dealer premises; control required by the state in areas where populations are not well established or previously unknown to occur

“C” Weeds currently established and generally widespread in many counties of the state; actively eradicated from nursery stock dealer premises; abatement at the discretion of the state quarantine officer

NAC = Nevada Administrative Code

NRS = Nevada Revised Statue

CDFA = California Department of Food and Agriculture Pest Ratings (Policy Letter #89-2; April 28, 1989)

“A” An organism of known economic importance subject to state (or commissioner when acting as a state agent) enforced action involving: eradication, quarantine, containment, rejection, or other holding action

“B” An organism of known economic importance subject to: eradication, containment, control or other holding action at the discretion of the individual county agricultural commissioner.

“C” An organism subject to no state enforced action outside of nurseries except to retard spread. At the discretion of the county agricultural commissioner.

“Q” An organism requiring a temporary “A” action pending determination of a permanent rating. It is suspected to be of economic importance, but its status is uncertain because of incomplete identification or inadequate information.

“D” Organisms determined to be of little or no economic importance

CDFG = California Department of Fish and Game, Restricted Species, California Code of Regulations Title 14 §671.5

US = U.S. Fish and Wildlife Service, Lacy Act CFR 16.11-16.15

4 Plan Development

The Plan was prepared by Tetra Tech, Inc. staff and greatly facilitated by numerous stakeholders, researchers, and agency staff, particularly the LTAISCC and the LTAISWG (Appendix A and Appendix D).

The Plan is based on the ANSTF's *Guidance for State and Interstate Aquatic Nuisance Species Management Plans*. The Implementation Table (Table 8) was developed by the LTAISCC and Tetra Tech, Inc. staff in a day long meeting on September 17, 2008 as a cooperative team effort. The timeline for plan development, stakeholder meetings, comments, and ANSTF presentation and approval is summarized in Figure 9.

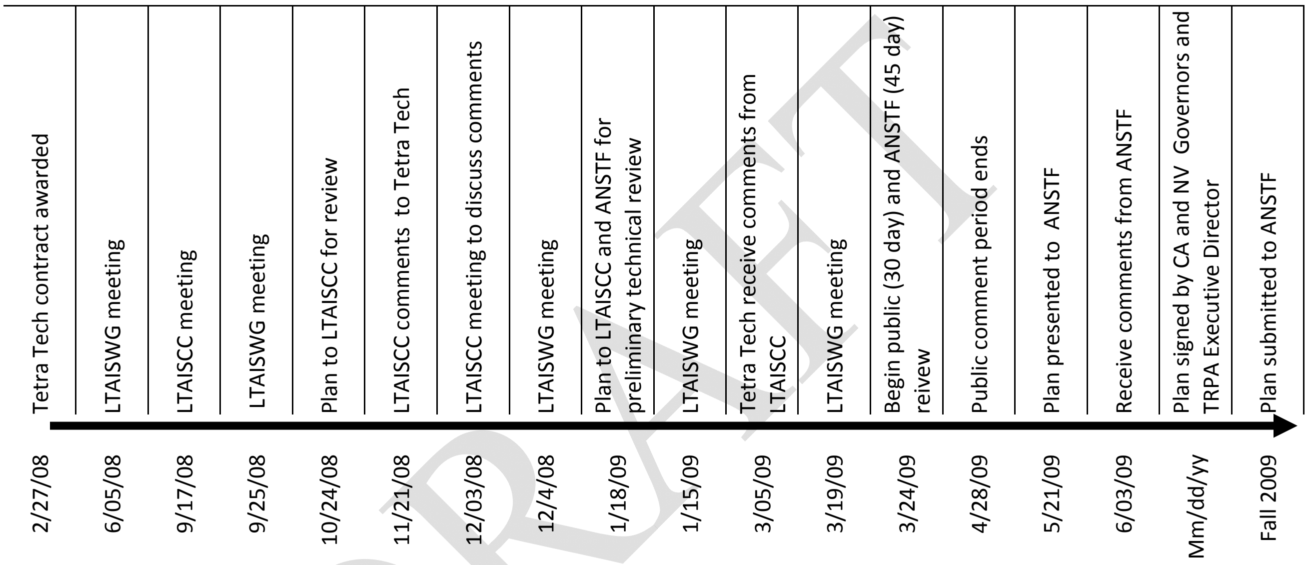

Figure 9. Lake Tahoe AIS Management Plan Development Timeline

Drafts of the Plan were submitted by Tetra Tech, Inc. to the LTAISCC on October 24, 2008 and on January 18, 2009 a second draft was submitted to the LTAISCC, the LTAISWG and to Ronald Smith, AIS Coordinator for USFWS - Region 8, for a cursory review. Comments were received from the CADPR, CDFG, California State Lands Commission (CSLC), LRWQCB, NDOW, NDSL, TRCD, TRPA, Tahoe Science Consortium (TSC), UCD – Tahoe Environmental Research Center (UCD – TERC), UNR, USDA-ARS, and the USFS – LTBMU. To facilitate Tetra Tech, Inc. in their response to comments, a LTAISCC review sub-committee was formed (identified in Appendix D) and met by conference call, email, and in person as needed. On March 24, 2009, a third draft of the Plan was posted to the TRPA website for a 30-day public comment period and simultaneously submitted to the ANSTF for a preliminary 45-day review. During the public comment period, additional comments were received by CADPR but no comments were received from the general public.

All comments and responses are presented in Appendix G and some common themes are summarized below:

- Does the geographic scope of the Plan cover the Lake Tahoe Basin or Lake Tahoe Region (as defined by TRPA Compact)?
- Clearly separate desirable non-native game fish from unwanted and invasive fish species. (e.g., largemouth bass)
- Define "invasive" species and distinguish invasive from non-native desirable or managed species, e.g. coldwater game fish
- Identify species *invasive* to the Lake Tahoe Region, their estimated dates of introduction, and assumed pathway for introduction, i.e., develop the ranking systems
- Rank or categorize non-native species to improve understanding of AIS issues
- Requested additional non-native species be added to Table 6, including bullfrog, spiny Waterflea, and smallmouth bass
- Explain why the life histories, invasive life strategies, and environmental requirements are identified for some species list in Table 6 but not all.
- Suggest adding information on collaboration/coordination with the WRP and the Quagga-Zebra Mussel Action Plan for Western U.S. Waters (known as "QZAP")

5 Management Plan Goals and Objectives

The goals of the Lake Tahoe AIS Management Plan are to:

I. Prevent new introductions of AIS to the Region

II. Limit the spread of existing AIS populations in the Region, by employing strategies that minimize threats to native species, and extirpate existing AIS populations when possible

III. Abate harmful ecological, economic, social and public health impacts resulting from AIS

The goal of no new AIS introductions will be accomplished by strengthening existing prevention measures including but not limited to staffed boat inspections at launches, billboards, signage, television commercials and, when available, boat sniffing dogs. These outreach and prevention measures must be adaptable and proactive to meet emerging issues. Adoption of early detection monitoring protocols is paramount to this effort and the ability to rapidly respond is also needed. Control and eradication efforts must be immediately ramped up to prevent in-lake spread of existing populations. The LTAISCC identified seven objectives (

Table 7) to meet the Plan's goals to limit AIS introductions, spread, and reduce their impacts.

Table 7. Lake Tahoe Region AIS Management Plan Objectives

Objective	Title	Brief Description
A	Management Plan Implementation and Updates	Determine implementing organization(s); determine review and revision protocols
B	Coordination and Collaboration	Continue to improve coordination efforts between and among various stakeholder groups
C	Prevention	Prevent the spread of existing AIS and the introduction of new AIS to the Tahoe Region
D	Early Detection, Rapid Response and Monitoring	Develop and maintain programs that: • Ensure the early detection of new AIS introductions • Monitor existing AIS populations • Establish and manage systems to rapidly respond to new AIS introductions
E	Long Term Control and Management	Establish and maintain funding sources to support activities that minimize impacts of AIS to native species and protect water quality and environmental health
F	Research and Information Transfer	Increase research on a) the baseline biology of AIS currently in or threatening introduction to Lake Tahoe, b) survivability thresholds for potential AIS, c) innovative detection technologies, d) alternative control strategies
G	Laws and Regulations	Coordinate existing regional, state, and federal laws and regulations related to AIS and provide guidance and education that direct content and needed policy

6 Current/Short- and Long-term Strategies and Actions

Prior to the development of this Plan, resource managers, researchers, and many community members recognized the need for organized AIS prevention, education, control, and research. Partnerships such as the LTAISWG and the LTAISCC have not only facilitated development of this Plan, but their early development demonstrates the momentum to protect waterbodies in the Lake Tahoe Region from further degradation from AIS.

This section identifies current/short-term (i.e., through fiscal year 2009) and long-term (i.e., fiscal year 2010 to 2015) strategies and actions. Additionally, the Implementation Table identifies the lead and cooperating entities, current funding, and where applicable, anticipated funding needed to implement actions over the five year period from 2010 to 2015 (Table 8).

6.1 Objective A: Management Plan Implementation and Updates

As an interstate management plan, strong oversight is necessary to ensure Plan objectives and action items continue to meet the goals of the Plan within the existing regulatory framework of both states and the Region. This requires identifying lead organizations to support Plan development, oversight, implementation and adaptive review.

Strategy A1: Oversight and Implementation

The following action items describe the process of Plan development and implementation and identifies the lead fiscal agent to facilitate financial transfer of funds, as needed, to support action items.

Actions

A1a. Development of the Lake Tahoe Region AIS Management Plan

Development of the Plan was directed and funded by the USACE and prepared by Tetra Tech, Inc. in cooperation with the LTAISCC. The Plan was developed according to the *ANSTF Guidelines for Preparing State and Interstate Aquatic Nuisance Species Management Plans*. The Plan was reviewed by the LTAISCC, members of the LTAISWG, a cursory review by CDFG, and three independent reviewers before the 45-day preliminary review by the ANSTF and simultaneous public comment period.

A1b. Lead Organization for Plan Oversight

Numerous regional, state, federal, and non-governmental organizations are involved in protecting and advocating for the environmental, recreational, and economic stability of Lake Tahoe. Implementation of the Plan will require committed oversight by an organization capable of regulation across the boundaries between the California and Nevada, federal and multiple local jurisdictions. The Tahoe Regional Planning Agency (TRPA) was created by California and Nevada as well as the U.S. Congress to have this regulatory power. It follows that TRPA is the one agency most suited for the oversight role.

A1c. Implementation of the Lake Tahoe Region AIS Management Plan

Implementation of the Plan will largely be conducted by the LTAISCC and LTAISWG. Both groups have representatives from regional, state, and federal agencies and non-profit groups from the Lake Tahoe Region.

A1d. Funding for Aquatic Nuisance Species (ANS) Coordinator

SNPLMA Round 8 and 9 funds currently support the USFWS ANS Coordinator for the Tahoe Region. Continued funding for this position is critical to for coordinating AIS prevention, management, and research efforts in the Region in collaboration with state (e.g., CDFG, NDOW, CDFA) and regional agencies (e.g., TRPA, WRP) and guidance at the national level (e.g., ANSTF).

A1e. Fiscal Agent for Plan

The TRPA has the ability to act as a fiscal agency for the implementation of the Plan. The TRPA cooperatively leads and successfully manages the Tahoe EIP, and has demonstrated the ability to be nimble when acting as a pass-through agency for funding proposes. For example, TRPA can pass funds from a State of California agency to a State of Nevada agency.

Strategy A2: Review Process

Timely review of the Plan is necessary to ensure strategies and specific action items continue to support the Plan's goals. New AIS threats and pathways of introduction should be evaluated for inclusion in updated Plan versions. Additionally, funding sources and levels should be considered to keep the Plan timely and ensure stakeholders have the support to implement the action items.

Actions

A2a. LTAISCC Review Sub-committee

The LTAISCC was critical in development of the actions described in the Implementation Table, including identifying lead and supporting organizations. The LTAISCC is poised to evaluate Plan effectiveness and identify gaps that limit the Plan's acceptance and implementation by stakeholders from both Nevada and California. A sub-committee will be formed to address these issues. Members of the sub-committee will be:

- Familiar with AIS issues, regulations, and laws at the regional, state, and federal levels
- Familiar with other regional and state AIS plans
- Capable of recommending strategies to improve the effectiveness of the Plan
- Lead data assessment relative to progress on control and prevention and recommend adaptive management changes

A2b. LTAISCC Sub-committee Review

A year after Plan acceptance by the ANSTF, and annually thereafter, the Plan will be reviewed by the LTAISCC review sub-committee described above and presented to the LTAISCC. Key elements to address during this review are included in Section 8.

A2c. Plan Revision

A minimum of five years after Plan acceptance by the ANSTF, or if a Plan revision is deemed required based on A2d, the Review sub-committee shall follow revision procedures identified by the ANSTF. Current procedures may be found at: http://anstaskforce.gov.

A2d. Considerations for Plan Revision

During plan revision, first determine whether minor technical revisions, major technical revisions, or a complete plan overhaul is required (see *Developing and Revising State and Interstate Aquatic Nuisance Species (ANS) Management Plans* for further information on these levels and relevant required ANSTF approval).

Strategy A3: Funding

Sources of funds that support current AIS prevention, management and research activities in the Region come from a variety of sources ranging from federal and state programs to private donations (details in Appendix E). Federal funds currently authorized under Section 1204(b) of the NANPCA are limited to $4 million, split among other state AIS management plans. An additional $1.075 million is available from the USFWS for ANTSF-approved plans, however this is similarly split between state and interstate AIS plans. In 2009, the 31 approved plans received only $34,677. Increasing funding for state and interstate management plans to $30 million has been identified as a high priority in the Quagga-Zebra Mussel Action Plan for Western U.S. Waters (QZAP) (WRP 2009).

Actions

A3a. Establish LTAISCC Financial Sub-committee

A sub-committee of the LTAISCC shall be formed to:

- Interface with the LTAISWG to prioritize prevention, management, capital investments, and research needs
- Interface with the LTAISWG to determine funding sources for high priority needs
- Request NANPCA Section 1204 funds from the ANSTF for specific action items (as identified in the ANSTF-accepted Plan)
- Request funds for specific action items from non-Section 1204 funding sources

6.2 Objective B: Coordination & Collaboration

Numerous prevention, monitoring, education, and research projects are currently underway in the Region. This work is conducted by a variety of agencies, academics, and NGO's and in many cases the work is in collaboration with the LTAISWG. Actions included in this objective are aimed at improving and expanding existing AIS activities in the Region. Anticipated outcomes from these efforts will greatly improve funding partnerships, reduce or even eliminate redundant efforts, alert resource managers to emerging AIS problems, and facilitate bi-state collaboration.

Strategy B1: Regional, Bi-state, National and International

The following action items describe how regional, bi-state, national and international coordination and collaboration efforts may be improved to prevent and control AIS in the Region.

Actions

B1a. Nevada AIS Management Plan

Western states with ANSTF-approved AIS management plans include: California, Washington, Idaho, Montana, Oregon, and Utah (conditional). The CDFG completed the CAISMP in January 2008. Even though Nevada is currently without an ANSTF-approved AIS plan, NDOW currently has draft versions of the "Quagga Mussel Monitoring Program" as well as "Prevention and Disinfection Guidelines". The Arizona Invasive Species Advisory Council recently released *Arizona Invasive Species Management Plan 2008* in which the impacts and prevention of AIS are included. The Arizona Game and Fish Department is currently working to finalize an aquatic-specific invasive species plan. The absence an AIS plan from Nevada, an important recreational state where quagga mussels are found in Lakes Mead and Mojave, leaves the Tahoe Region particularly vulnerable to AIS introduction. The development and implementation of a Nevada AIS Management Plan is needed to:

- Prevent further spread of AIS between Nevada waterbodies and, by extension, prevent the introduction of devastating AIS to the Lake Tahoe Region
- Reinforce consistent AIS prevention messages
- Potentially increase enforcement, quarantine, and inspection authorization in Nevada
- Create and maintain a regional AIS buffer around the Tahoe Region to keep AIS out of surrounding watersheds

B1b. LTAISCC and LTAISWG

Continue monthly meetings of the LTAISCC and LTAISWG to identify and prioritize research needs, determine matching funds and share results between numerous agencies and organizations in the Tahoe Region.

B1c. Annual LTAISWG Reports

Continue synthesis and distribution of the annual LTAISWG summary of accomplishments and goals.

B1d. Foster Shorezone Partnerships

Foster partnership development among shore zone property owner/managers (e.g., Washoe Tribe, yacht club owners) to increase involvement in LTAISWG.

B1e. Link LTAISCC to State, National, and International AIS Groups

New AIS and introduction pathways are rapidly emerging due to increased internet trade, world-wide travel, and climate change. Similarly, innovative prevention and control methods are also increasing. To stay abreast of these emerging challenges and resources, stakeholders in the Region must be engaged with other state (particularly neighboring western states), national and even international AIS managers and researchers. Examples of organizations include (links provided in Appendix B):

- Aquatic Nuisance Species Task Force (ANSTF)
- California Department of Fish and Game (CDFG)
- California AIS Advisory Council (CAISAC)
- Invasive Species Specialist Group
- Sea Grant
- The 100th Meridian Initiative
- United States Geological Survey (USGS)
- Western Regional Panel (WRP)

6.3 Objective C: Prevention

Preventing the introduction of AIS to the Lake Tahoe Region (inter-region) and further spread of existing AIS within the Lake Tahoe Region (intra-region) requires adequate inspection and decontamination procedures coupled with effective and consistent education and outreach. Additionally, targeting prevention efforts to high risk introductory pathways will maximize limited resources.

Strategy C1: Inspection and Decontamination

The objective of decontamination is to completely eliminate all viable AIS life stages to prevent their introduction into waters of the Lake Tahoe Region. Such extreme action is needed as anything less will not be effective in preventing the introduction and further spread of AIS. Decontamination efforts should be extended to a variety of equipment, including watercraft, personalized watercraft, waders, construction equipment, et cetera from *all* AIS (i.e., snails, plants, mussels, and other less conspicuous organisms).

Actions

C1a. Vessel Inspection Plan (VIP)

Implement the VIP as according to TRPA Chapter 79.3 of the Code of Ordinances which provides for vessel decontamination and the closure of launch facilities when inspectors are not present. TRCD and TRPA staff have been certified by the 100th Meridian Initiative to provide inspection and decontamination trainings to contractors, launch facility staff and Washoe Tribe inspectors. The types of watercraft that are subject to inspection and possible decontamination include trailered boats and small watercraft such as canoes and kayaks entering Lake Tahoe. The most current version of the VIP can be found in Appendix E.

C1b. Fee-based System to Support VIP

Implement the TRPA Governing Board approved fee (effective June 1, 2009) to support the VIP adopted March of 2009. The fee will be assessed for each inspection of a motorized vessel. Vessels with an intact inspection seal that confirms that they last launched in Lake Tahoe are exempt from inspection and the fee. Reassess the fee on at least a yearly basis to determine if changes are needed, such as changes to the fee if other funds are found to offset costs.

C1c. Small Watercraft Screening

Implement the *Small Watercraft Screening Process for Aquatic Invasive Species* developed by the USFS-LTBMU (Appendix E). The purpose of this program is to reduce the likelihood of AIS introduction from non-motorized watercraft at campgrounds and other day-use facilities around Lake Tahoe.

C1d. Non-motorized Watercraft Inspection

Integrate inspection and decontamination protocols for all non-motorized watercraft, including the Small Watercraft Screeing procedures outlined by the USFS-LTBMU (Appendix E). As a first stop in this effort, the LTAISWG recently formed a non-motorized boat inspection and education sub-committee.

C1e. Evaluate Decontamination Methods

Conduct spot checks to ensure proper watercraft decontamination protocols are followed.

C1f. Ensure Decontamination of a Range of Equipment

Ensure there is full decontamination of equipment related to recreation, natural resource management, research, and construction activities.

C1g. Ensure Decontamination of a Range of AIS

Ensure inspection and decontamination procedures address all life stages of targeted, and non-targeted AIS. That is, train inspectors to look for a range of organisms (e.g., spiny waterflea) and not just mussels and plants.

C1h. Develop Professional AIS Inspector Program

Collaborate with the 100th Meridian Initiative to develop a program to certify professional watercraft inspectors. Such a program would provide a mechanism to communicate with certified inspectors across the U.S., thereby providing consistent updates on emerging AIS challenges, innovative outreach techniques, and maintain consistent inspection protocols.

C1i. National and International Contacts

Maintain regional, national and international contacts to stay apprise of alternative and current decontamination methods by appointing a LTAISWG member for this role.

Strategy C2: Pathways/Vectors

The physical means or agent by which AIS are transported to a new environment and eventually establishes is an AIS pathway or vector. These dispersal mechanisms can be natural or human connections that allow movement of species or their reproductive propagules from place to place.

Actions

C2a. Boaters

Continue to educate boaters about the risk of transporting AIS; not only to the Region, but out of the Region. Ensure watercraft inspectors are adequately trained to identify a range of organisms harbored on trailered watercraft (C1f and C2g).

C2b. Anglers

Continue to educate anglers to wash fishing equipment prior to its use in Region waterways.

C2c. Natural Resource Management

Continue to ensure that resource managers are aware of the potential to transport AIS (e.g., New Zealand mudsnails on waders and other sampling equipment) and that adequate decontamination measures are taken.

C2d. Wildfire Suppression Activities

Ensure that AIS are not transported between waterbodies by equipment used for wildfire suppression activities by following, where possible, the USFS-LTBMU's *Resource Guidelines for Wildfire Suppression*.

C2e. Construction Activities

Ensure that AIS are not transported between waterbodies by equipment used for construction activities (e.g., culvert placement, dock and pier maintenance).

C2f. Fish Stocking

Continue to provide adequate decontamination of equipment used to transport hatchery-raised fish for stocking.

C2g. AIS Identification

Train field biologists and boat inspectors to properly identify a range of AIS (and their life stages) including but not limited to dreissenid mussels, Asian clams, Eurasian watermilfoil, curlyleaf pondweed, and other potential invaders such as the spiny water flea.

Strategy C3: Education

Education is key to any effective management program and numerous efforts are currently underway in the Region, including providing clear and consistent messages to various users, including boaters and anglers. Maintaining a dialogue with resource managers in other regions of the U.S. and internationally will allow for information sharing and increase message recognition (e.g., *Stop Aquatic Hitchhikers!*).

Actions

C3a. LTAISWG Education/Outreach Plan

Continue to develop the Education/Outreach Plan including participation from aquatic nurseries and landscaping companies.

C3b. Stop Aquatic Hitchhikers! Campaign

Continue to utilize the USFWS *Stop Aquatic Hitchhikers!* message to improve national recognition.

C3c. Habitattitude National Public Awareness Campaign

Assess the appropriateness of using the USFWS/ANSTF Habitattitude National Public Awareness Campaign in the Region.

C3d. Press Releases

Increase the use of press releases during high travel season to warn travelers of boat inspections and potential decontamination procedures, particularly if they are traveling from high risk waterbodies during peak travel seasons.

C3e. Advertising and Publications

Continue the use billboards, magazine, radio, and cable television advertisements to warn travelers of boat inspections and potential decontamination procedures, particularly during peak travel seasons. Also, incorporate the use of direct mailings to residents in the Lake Tahoe Region.

C3f. National and International

Continue to maintain and encourage national and international contacts to stay apprise of effective education methods, i.e., Sea Grant Program and Stop Aquatic Hitchhikers campaign.

C3g. Aquascaping

Provide specific recommendations to vendors/suppliers and the general public for using suitable native plants and animals instead of non-native species in aquascaping projects.

C3h. AIS Hotlines

Continue to maintain regional (888-TAHO-ANS) and national (877-STOP-ANS) phone hotlines and to report sightings of AIS. Also continue to provide appropriate knowledgeable response.

6.4 OBJECTIVE D: MONITORING, DETECTION, AND RESPONSE

Following prevention, early detection, containment and control/eradication of new AIS introductions are the second most cost-effective measures to reduce the impacts from AIS. This is accomplished through rigorous monitoring followed by the ability to respond efficiently and aggressively. Response is facilitated by a collaborative effort between numerous agencies, NGO's, researchers, and other stakeholders.

Strategy D1: Potential AIS

Understanding the distribution and impacts of potential AIS (i.e., Species Management Types 1, 5) may be used as a benchmark for future management assessments and prioritization.

Actions

D1a. At-risk Waterbodies in Region

Identify waterbodies in the Region that could host specific AIS throughout all life stages. For example, if similar water quality conditions exist between Lake Tahoe and Fallen Leaf Lake, then efforts should be made to prevent the transport of aquatic weeds from Lake Tahoe to Fallen Leaf (note: a wash station is currently in operation at Fallen Leaf Lake).

D1b. Volunteer AIS Monitoring

Increase/recruit and train local volunteer monitors that routinely use Lake Tahoe and surrounding streams and lakes for recreation and aesthetic enjoyment. The likelihood that volunteers in close proximity to Lake Tahoe will routinely collect continuous information is greater based on ease of access and interest in promoting wise stewardship of area resources.

D1c. AIS-infested Waterbodies

Maintain a list of rivers and lakes outside of the Region with AIS. This list may be used to determine at-risk vessels so that inspectors can activate appropriate precautionary AIS prevention protocols. These records can be shared with inspectors in nearby watersheds and resource managers from AIS points-of-origin to coordinate an early-warning network for potential AIS transport.

D1d. At-risk In-lake Habitats

Establishment of AIS is not only dependent upon the frequency of introduction but the convergence of optimal physical and chemical factors (e.g., fine substrates, particulate organics, available calcium, et cetera.). Partitioning of optimal habitat can vary temporally and would enable critical life stages to survive and either complete a life cycle at the same location or enable migration to other locations that are more suitable for completion of remaining life stages (excluding invasive macrophyte species). Surveys of these optimal habitat zones should be conducted on a routine basis to identify new AIS infestations or areas where they could establish.

Strategy D2: Existing AIS

Understanding the distribution and impacts of existing AIS (i.e., Species Management Types 2, 3, 4) may be used as a benchmark for future management assessments and prioritization.

Actions

D2a. Invertebrate Monitoring Plan

Describe invertebrate monitoring protocols and current distributions. Review monitoring protocols as needed. Develop a site selection process that targets at-risk habitats from invasion of invertebrate AIS. Select protocols that measure appropriate habitat features that would be used by invertebrate AIS. Prepare a Quality Assurance Project Plan (QAPP) as part of a long-term monitoring program. Determine associations with other invasive species that provide habitat structure or physical features along the shoreline that would serve as suitable habitat for colonization.

D2b. Aquatic Plant Monitoring Plan

Continue to map the distribution of aquatic plants with annual surveys and identify likely locations of infestation within the Region. Determine associations with other invasive species that provide habitat structure or physical features along the shoreline (e.g., sediment types) that would serve as suitable habitat for colonization.

D2c. Warm Water Fish Monitoring Plan

Continue to identify habitats that currently support and are predicted to support all life stages of non-native warm water fish. Determine associations with other invasive species that provide habitat structure (e.g., Eurasian watermilfoil) or physical features along the shoreline that would serve as suitable habitat for colonization.

D2d. Bullfrog Monitoring Plan

Through partnerships, develop a plan to identify and survey at-risk habitat for bullfrog invasions in the Region. Determine associations with other invasive species that provide habitat structure (e.g., Eurasian watermilfoil) or physical features along the shoreline that would serve as suitable habitat for colonization.

Strategy D3: Early Detection and Rapid Response (EDRR) Planning

The purpose of developing early detection and rapid response (EDRR) plans is to provide for a coordinated system to monitor, report, and effectively respond to newly discovered and localized invasive species (NISC 2008). Critical to the success of EDRR plans is the ability to share resources across jurisdictional boundaries, establishment of strategic partnerships, available funds and technical resources, and mutually agreed upon implementation plans. The NISC breaks EDRR into the following three components:

- Early Detection (ED): where targeted species surveys and localized monitoring efforts are used to construct distribution maps and other ecological/biological data to facilitate planning and response actions.
- Rapid Assessment (RA): where the appropriate response to the ED and an overall strategy is formulated; accounting for "transjurisdictional issues".
- Rapid Response (RR): where localized populations of invasive species are systematically eradicated or contained, including newly discovered as well as expanding populations of existing invasives.

The *Draft California AIS Rapid Response Plan* was developed to address general AIS issues in the state (CDFG 2008) and is based on the incident command system (ICS) where "participants are assigned specific roles in a well-defined hierarchical system that can be expanded or collapsed based on the size and complexity of the incident." ICS is now integrated into the National Incident Management System (NIMS) that

> "…provides a systematic, proactive approach to guide departments and agencies at all levels of government, nongovernmental organizations, and the private sector to work seamlessly to prevent, protect against, respond to, recover from, and mitigate the effects of incidents, regardless of cause, size, location, or complexity, in order to reduce the loss of life and property and harm to the environment."

The Columbia River Basin (CRB) Team of the 100th Meridian Initiative recently prepared a working draft of the *Columbia Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other* Dreissenid *Species* that similarly follows the management structure requirements of the NIMS (Columbia River Basin Team 2008). The Columbia River Basin Team identified ten response objectives to support their goal of delineating and controlling dreissenid mussel populations:

1. Make initial notifications
2. Activate appropriate organizational elements of the CRB Interagency Response Plan
3. Verify reported introduction
4. Define extent of colonization
5. Establish external communications system
6. Obtain and organize resources
7. Prevent further spread via quarantine and pathway management
8. Initiate available/relevant control actions
9. Institute long-term monitoring
10. Evaluate the Response Plan

Actions

D3a. Lake Tahoe Region AIS EDRR Plan

Develop a *Lake Tahoe Region AIS EDRR Plan* to address a broad range of potential AIS. The Plan may be modeled after the Draft *California Rapid Response Plan* (CDFG 2008) and the *Columbia Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other* Dreissenid *Species* but tailored to the unique jurisdictional authority of agencies in the Lake Tahoe Region. Adopt National Incident Command System as part of the EDRR framework.

D3b. Lake Tahoe Region Mussel EDRR Plan

Complete the *Lake Tahoe Region Mussel EDRR Plan* modeled after the Draft *California Rapid Response Plan* (CDFG 2008), the *Columbia Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other* Dreissenid *Species* (Columbia River Basin Team 2008), and the draft *Quagga-Zebra Mussel Action Plan* (WRP 2009), but tailored to the unique jurisdictional authority of agencies in the Lake Tahoe Region. Adopt National Incident Command System as part of the EDRR framework.

D3c. Rapid Response Drill

Trigger yearly rapid response drill for AIS using ICS protocols.

D3d. Plan Review

Review the *Lake Tahoe Region AIS EDRR Plan* and the *Lake Tahoe Mussel Rapid Response Plan* every two years by a LTAISCC sub-committee.

Strategy D4: Funding

Accessible and sufficient funding is critical to implementing EDRR elements, including those elements identified in under Strategy D3.

Actions

D4a. Establish Sustainable Funding Mechanisms

Establish monetary means to rapidly implement and sustain elements of the response plans named in D3a and D3b. Evaluate the use of boating fee/permits, fuel add-ons, and launch surcharges to provide financial support to AIS response efforts.

6.5 Objective E: Long-term Control/Eradication

Control of AIS implies that populations are present and small enough to curtail further increases while eradication means complete removal of all life stages of a species (see section 2 AIS Management Approach). Often the methods to control AIS are the same as those to eradicate an AIS, however, the methods are applied differently or used in a fully-integrated eradication regime. That is, the intensity of management may vary greatly from control to eradication. Methods to control or eradicate may overlap between groups of AIS while other methods are specific to a particular AIS.

Strategy E1: Aquatic Plant Control/Eradication

Each action should include an evaluation of effectiveness and ability to measure success in controlling and/or eradicating invasive aquatic plants. Options currently available to control or eradicate invasive aquatic plants in the Tahoe Region include physical and mechanical methods.

Actions

E1a. Tahoe Keys Aquatic Plant Management Plan

Develop and implement an aquatic plant management plan specific to the Tahoe Keys. Elements of the plan should include measures to

- Prevent spread of existing invasive aquatic plants populations beyond the Tahoe Keys
- Prevent the introduction of additional invasive plant species
- Determine long-term control or eradication goals for the Tahoe Keys using all available technologies (see Strategy G3: Provide for All Appropriate Treatment and Control Measures)

E1b. Benthic Barriers

Continue the use of benthic barriers to control unwanted aquatic vegetation in open areas where submersed wood and recreational activities would not impede efficacy.

E1c. Hand-pulling

Continue the use of hand-pulling, along with diver-operated suction if appropriate, in those areas where benthic barriers cannot be safely or effectively deployed.

E1d. Diver-operated Suction

Continue use of diver-operated suction to assist hand-pulling efforts as described in E1c.

E1e. Mechanical Harvesting

Where mechanical harvesting is used, continue to incorporate best management practices to ensure plant fragments are collected to prevent further spread.

E1f. Aquatic Herbicides

Continue efforts to provide for all available control technologies, including the use of aquatic herbicides to control Eurasian watermilfoil and curlyleaf pondweed (Strategy G3) by working closely with the LRWQCB. Establish protocols to isolate drift and reduce deleterious impacts to non-target organisms by incorporating best management practices.

E1g. Eradication Plan

For eradication projects, develop a plan that includes long-term monitoring, prevention, and rapid response to re-occurring infestations.

Strategy E2: Asian Clam Control/Eradication

Each action should include an evaluation of effectiveness and ability to measure success in controlling and/or eradicating Asian clams. Options currently available to control Asian clams in Lake Tahoe include physical and mechanical methods; however, these methods are under development and not yet operational lake-wide.

Actions

E2a. Pilot Asian clam control/eradication project

Continue to evaluate the logistics, effectiveness, and environmental impacts of using diver-operated suction and benthic barriers for Asian clam removal. More specifically, evaluate if re-suspended sediment in the water column can liberate sufficient organics to promote the growth of other AIS or algae.

E2b. Molluscicides

Provide for all available control technologies, including the use of molluscicides to control Asian clams (Strategy G3). Establish protocols to isolate drift and reduce deleterious impacts to non-target organisms by incorporating best management practices.

E2c. Eradication Plan

For eradication projects, develop a plan that includes long-term monitoring, prevention, and rapid response to re-occurring infestations.

E2d. Lakewide Asian clam Survey

Determine the distribution of Asian clams in Lake Tahoe using an autonomous underwater vehicle (AUV) called the "Gavia" (http://gavia.is/) which will be used to take high resolution photography of the lake bottom to look for surficial clam shells as an indicator of live Asian clam presence.

Strategy E3: Warm Water Fish Control/Eradication

Each action should include an evaluation of effectiveness and ability to measure success in controlling and/or eradicating warm water fish. Continued information about juvenile, subadult and adult life stages is essential for adapting various control/eradication strategies and methods. Control/eradication strategies and methods will need to be consistent with state and federal fisheries management objectives (i.e., threatened and endangered species recovery programs) and. For warm water fish control projects implemented on the Nevada side of Lake Tahoe, a scientific collection permit may be required as some warm water fish species are considered "game fish" according to NAC 503.060.

Actions

E3a. Tagging

Continue to monitor the movement of warm water invasive fish in Lake Tahoe and determine the spatial and temporal use of habitats to complete all life stages.

E3b. Tahoe Keys AIS Control and Demonstration

Determine how warm water fish respond to the removal of invasive aquatic plants in the Tahoe Keys. Conduct a dye study to determine residence time and water movement patterns in selected high priority sites in the Tahoe Keys for herbicide application.

E3c. Electro-fishing

Incorporate the use of electro-fishing to control invasive warm water fish from habitats identified through the tagging program (Action E3a).

E3d. Netting

Evaluate the use of nets to control invasive warm water fish from habitats identified through the tagging program (Action E3a).

E3e. Piscicides

Continue to provide for all available control technologies, including the use of piscicides (i.e., rotenone) to control warm water fishes (Strategy G3). Variance criteria for piscicide use are provide in the Basin Plan Establish protocols to isolate drift and for neutralization, and reduce deleterious impacts to non-target organisms by incorporating best management practices.

E3f. Eradication Plan

For eradication projects, develop a plan that includes long-term monitoring, prevention, and rapid response to re-occurring infestations.

Strategy E4: Bullfrog Control/Eradication

Each action should include an evaluation of effectiveness and ability to measure success in controlling and/or eradicating bullfrogs. Current efforts to control bullfrogs from the Region are limited and much work is needed to determine the most appropriate methods based on current population sizes and locations.

Actions

E4a. Evaluate Bullfrog Control/Eradication Methods

Evaluate the success of various methods to control/eradication bullfrogs.

E4b. Habitat Restoration to Support Native Amphibians

Implement restoration projects using data from D2d to restore habitat for native amphibians.

E4c. Eradication Plan

For eradication projects, develop a plan that includes long-term monitoring, prevention, and rapid response to re-occurring infestations.

6.6 Objective F: Research and Information Transfer

Research is critical to identifying environmental requirements and survivability thresholds of AIS and determining appropriate and innovative management techniques.

Strategy F1: Detection Technology

Continuing to identify and incorporate methods to detect various life stages of AIS is critical to improving rapid response and eradication. These technologies will improve the likelihood of identifying cryptic or microscopic life stages prior to a wide-spread infestation.

Actions

F1a. Innovative Technologies to Detect AIS

Continue to identify innovative technologies to detect AIS, i.e., PCR analysis, DNA testing, sonar/acoustic development for invertebrates and plants on a fine scale.

F1b. Alternative AIS Vectors

Continue to determine mechanisms for AIS introduction to the Region and continue to identify life stages more amenable to transport to and survival in the Region.

F1c. Prioritize AIS Management Efforts

Continue to prioritize AIS prevention, education, monitoring, control, and research efforts in order to implement strategies in an economical and effective manner. Determining the order for implementation of management actions will provide longer term effectiveness from re-occurrence.

Strategy F2: AIS Life Histories and Environmental Requirements

Successful prevention and control efforts are largely dependant upon understanding the life histories and environmental requirements of current or potential AIS. Conducting research or compiling information that facilitates this understanding is considered a high priority in the Region.

Actions

F2a. Calcium Sampling

Continue calcium sampling in Lake Tahoe and expand to other waterbodies in the Region to determine potential dreissenid mussel habitat.

F2b. Survivability

Continue to identify controlling and limiting factors for survival and proliferation for all life stages of existing and potential AIS, including plants, fishes, and invertebrates.

F2c. Risk Matrix

Develop a detailed substrate/energy matrix that identifies at-risk sites for expansion of existing and establishment of potential AIS.

Strategy F3: Research Needs

Research aimed at addressing species interactions, the ecological effects of control measures, potential sites for new invasions, and sources of funding are critical to preventing the spread and introduction of AIS to the Region. Future revisions of the Plan should carefully examine research needs based on adaptive management approaches.

Actions

F3a. Lake Tahoe AIS Research

Continue to foster research interest in the prevention, impacts and control of AIS in the Tahoe Region.

F3b. Yearly Workshop

Continue the LTAISWG yearly workshops to identify knowledge gaps and associated prevention, education, monitoring, control, and research needs as related to AIS in the Region.

F3c. Interactions of Native to Non-native and Native to Native Species

Continue to evaluate not only how native species are impacted by non-native species, but how native species can similarly impact other species. For example, when the growth of native species becoming noxious or problematic.

F3d. Evaluate Removal Disturbance

Continue to examine how removal efforts may result in disturbance processes and increase the likelihood of creating more invasions.

F3e. Species Facilitation of AIS Establishment

Continue to determine the extent to which existing AIS (e.g., Asian clams, aquatic weeds) facilitate the establishment of new AIS.

F4f. Global Climate Change and AIS Establishment

Evaluate the effects of global change on water quality and the the establishment success of new AIS.

F3g. Sites for Intra- and Inter-region Invasion

Determine vulnerable areas for within-lake invasion based on physical or chemical attributes (i.e., sediment type, protection from wave action, dissolved ions) and areas that serve as sources of invasive species for other parts of Lake Tahoe and other water bodies within the Region (e.g, Fallen Leaf Lake).

F3h. Research Funding

Continue to use the LTAISWG to prioritize research needs and identify and coordinate research funding.

Strategy F4: Information Transfer

The open exchange of information between regional, state, national, and even international resource managers is critical to staying apprise of AIS issues elsewhere. This is particularly important for the Tahoe Region because so many recreationalists visit Lake Tahoe from elsewhere.

Actions

F4a. Communication between Regional and State AIS

Improve communication about AIS activities in the Tahoe Region between the LTAISCC and state AIS activities (i.e., CAAIST and CDFG).

F4b. List of AIS Experts

Maintain list of AIS experts available to rapidly identify new AIS.

6.7 Objective G: Laws & Regulations

In the Lake Tahoe Region, laws and regulations limiting the possession, transportation, introduction, distribution, propagation, control, et cetera of AIS are overseen by numerous agencies at the regional (i.e., TRPA), state (e.g., CDFG, CDFA, NDOW, NDA), and federal (e.g., USDA) levels. The diverse legal landscape in the Lake Tahoe Region, has led to substantial gaps in AIS laws and regulations, particularly given the bi-state nature of the Region.

Strategy G1: AIS Lists

Maintain accurate lists of AIS to alert managers and watercraft inspectors to species either present or threatening introduction to the Lake Tahoe Region.

Actions

G1a. CDFA Weed Ratings

Partner with CDFA to increase the number of aquatic plants on the “A” list of noxious weeds (Table 6). Currently, neither curlyleaf pondweed nor Eurasian watermilfoil are included on the CDFA Noxious Weed List.

G1b. NDA Noxious Weed List

Partner with NDA to increase the number of aquatic plants on the "A" list of noxious weeds (Table 6). Currently, Eurasian watermilfoil is listed as an "A" category noxious weed according to the NDA; however, curlyleaf pondweed is not.

G1c. Tahoe-specific Prohibited AIS

Create a list of AIS prohibited from the Tahoe Region. Such a list would greatly benefit watercraft inspectors, resource managers, and law enforcement.

Strategy G2: Existing Laws and Regulations

Given the bi-state nature of the Tahoe Region, efforts should be made to ensure that existing AIS laws and regulations are consistent or at least not in conflict between the States of California and Nevada, the federal government, and this Plan.

Actions

G2a. Regional, State and Federal AIS Laws

Identify gaps and overlap in existing AIS laws, including but not limited to, quarantine, decontamination, possession, transport, and introduction. Determine the factors that limit enforcement capacity and how communication between policy makers and enforcement officers may be improved.

G2b. Amendments

Provide recommendations to policy makers to bolster existing laws and establish Region-wide consistency. For example, allow Nevada law enforcement to quarantine mussel-infested vessels similar to that allowed by California DFG Code §2301 (see Appendix A).

G2c. Coordinate CA and NV Law Enforcement

Facilitate the alignment of the TRPA and the States of California and Nevada's rules on AIS transport, possession, and introduction to establish Region-wide rules (summarized in Appendix A).

Strategy G3: Provide for All Appropriate Treatment and Control Measures

At present, the use of aquatic pesticides to control or eradicate AIS in the Lake Tahoe Region is essentially unavailable to resource managers (see LRWQCB in Appendix A). Discussions between the LTAISCC and the LRWQCB should continue in an effort to provide for all available and appropriate technologies to meet the management goals of this Plan.

Actions

G3a. Acceptable Approaches to Treatment

Continue discussions with the LRWQCB to determine the most acceptable direction for providing all available AIS control methods, including the use of EPA-approved aquatic herbicides.

G3b. Environmental Documentation for Aquatic Pesticide Use

Determine the necessary environmental documentation to allow for the application of registered aquatic pesticides (herbicides, mulluscicides, fungicides, and insecticides) in the Tahoe Region. Particular emphasis shall be on the Basin Plan and 208 Plan (see Appendix A). To control invasive fish, resource managers can currently request a variance from the LRWQCB to allow application of the piscicide, rotenone.

G3c. Public Awareness

Provide outreach and education to agencies and policy makers about the need to utilize all available and appropriate technologies to control or eradicate selected AIS from the Tahoe Region. Outreach and education efforts may be accomplished, for example, through workshops (Action F4b) and signage.

7 Implementation Table

Descriptions of the objectives, strategies, and actions above provide background and justification of each action item. Action items in green indicate current efforts at the time of writing. The implementation table identifies additional important elements of each action item, including: the lead and cooperating entities, priority levels, current funding levels and, where known, anticipated funding needs over the period 2010 to 2015 (Table 8).

Table 8. Lake Tahoe Region AIS Management Plan Implementation Table

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
Objective A: Management Plan Implementation and Updates							
Strategy A1: Oversight and Implementation							
A1a	Development of Lake Tahoe Region AIS Management Plan	USACE, Tt	LTAISCC	High	$363	-	USACE
A1b	Lead Organization for Plan Oversight	TRPA	LTAISCC	High	-	$500 (1.0 FTE)	-
A1c	Implementation of the Lake Tahoe Region AIS Management Plan	TRPA	LTAISCC, LTAISWG	High	-	$	
A1d	Funding for ANS Coordinator	USFWS	LTAISCC, LTFAC	High	$200	$600	Multiple sources
A1e	Fiscal Agent for Plan	TRPA		High	-		-
Strategy A2: Review Process							
A2a	LTAISCC Review Sub-committee	LTAISCC		High	-	-	TRPA, USFWS, NDOW, CDFG, USDA-ARS, LRWQCB
A2b	LTAISCC Sub-committee Review	LTAISCC	TSC	Med	-	$4	
A2c	Plan Revision	LTAISCC	-	High	-	$50	
A2d	Considerations for Plan Revision	LTAISCC		High	-	-	-
Strategy A3: Funding							
A3a	Establish LTAISCC Financial Sub-committee	LTAISCC	TRPA	High	-	-	-
Objective B: Coordination and Collaboration							
Strategy B1: Regional, Bi-state, National and International							

Table 8 cont.

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
B1a	Nevada AIS Management Plan	NDOW	LTAISCC, multiple NV agencies	High	$250	$	-
B1b	LTAISCC and LTAISWG	TIE	LTFAC	High	-	-	-
B1c	Annual LTAISWG Reports	LTAISWG	-	Med	$1	$5	Multiple sources
B1d	Foster Shorezone Partnerships	TRCD	LTAISWG	High	$20	$100	Multiple sources
B1e	Link LTAISCC to State, National, and International AIS Groups (Host Conference)	LTAISCC	-	Med	-	$30	-
Objective C: Prevention							
Strategy C1: Inspection and Decontamination							
C1a	Vessel Inspection Plan	TRCD	CTC, USACE, TRPA, USFWS	High	$980	$700-$1M/year (includes private, local, federal shares)	USACE, TRF, IVGID, SNPLMA (Rd. 8)
C1b	Fee-based System to Support VIP	TRPA	LTASICC	High	$5	$125	TRPA
C1c	Small Watercraft Screening	USFS-LTBMU	LTAISWG	High	$	$	USFS-LTBMU
C1d	Non-motorized Watercraft Inspection	LTAISWG	-	High	-	Shared with Strategy E3	-
C1e	Evaluate Decontamination Methods	LTAISWG	-	High	-		-
C1f	Ensure Decontamination of a Range of Equipment	LTAISWG	-	High	-		-
C1g	Ensure Decontamination of a Range of AIS	TRPA			-		-

Table 8 cont.

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
C1h	Develop Professional AIS Inspector Program	LTAISCC	-	Low	-	$10	-
C1i	National and International Contacts	LTAISWG	USFWS	High	-	-	-
Strategy C2: Pathways/Vectors							
C2a	Boaters	LTAISWG	-	High	-		-
C2b	Anglers	LTAISWG	-	High	-		-
C2c	Natural Resource Management	LTAISWG	-	High	-		-
C2d	Wildfire Suppression Activities	USFS-LTBMU	LTAISCC	High	$	-	USFS-LTBMU
C2e	Construction Activities	LTAISWG	-	High	-	-	Funded through VIP
C2f	Fish Stocking	CDFG, NDOW	USFWS		-		-
C2g	AIS Identification	TRCD			-		-
Strategy C3: Education							
C3a	LTAISWG Education/Outreach Plan	TRCD, TRPA	CTC, USFWS	High	$25	-	USACE
C3b	Stop Aquatic Hitchhikers! Campaign	LTAISWG	-	High	$250 (Shared with remaining C3 actions)	$1M (Shared with remaining C3 actions)	Multiples sources
C3c	Habitattitude National Public Awareness Campaign	LTAISWG		Med	$250 (Shared with remaining C3 actions)	$1M (Shared with remaining C3 actions)	Multiples sources
C3d	Press Releases	LTAISWG	-	High	-	-	-

Table 8 cont.

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
C3e	Advertising and Publications	LTAISWG	-	High	$250 (Shared with remaining C3 actions)	$1M (Shared with remaining C3 actions)	Multiples sources
C3f	National and International Contacts	LTAISWG	-	Med	-	-	-
C3g	Aquascaping	TRCD	TRPA		$250 (Shared with remaining C3 actions)	$1M (Shared with remaining C3 actions)	Multiples sources
C3h	AIS Hotlines	TRCD, USFWS			$250 (Shared with remaining C3 actions)	$1M (Shared with remaining C3 actions)	Multiples sources
Objective D: Monitoring, Detection, and Response							
Strategy D1: Potential AIS							
D1a	At-risk Waterbodies in Region	LTAISWG	-	High	-	$150	-
D1b	Volunteer AIS Monitoring	TRCD	-	High	-		-
D1c	AIS-infested Waterbodies	TRPA (TIIMS)	Various agencies contribut e	High	-		-
D1d	At-risk In-lake Habitats	LTAISWG			-		-
Strategy D2: Existing AIS							
D2a	Invertebrate Monitoring Plan	TERC, TRPA	CTC	High	$3.5K	-	USACE

Table 8 cont.

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
D2b	Aquatic Plant Monitoring Plan	TRCD	CADSP, CSLC Remetrix, TRPA	High	$250K		USBOR
D2c	Warm Water Fish Monitoring Plan	USFS-LTBMU	CDFG, UNR, UCD		$		NDSL
D2d	Bullfrog Monitoring Plan	LTAISWG, USFS-LTBMU			-		-
Strategy D3: Early Detection and Rapid Response (EDRR) Planning							
D3a	Lake Tahoe Region AIS EDRR Plan	USFWS			-	$	-
D3b	Lake Tahoe Region Mussel EDRR Plan	USFWS	LTAISCC, LTAISWG, FTFAC	High	Agency supported	$25	USFWS
D3c	Rapid Response Drill	USFWS	Various agencies	High	-	$	-
D3d	Plan Review	LTAISCC	LTAISCC, LTAISWG	High	-	$	-
Strategy D4: Funding							
D4a	Evaluate Sustainable Funding Mechanisms	USFWS	LTAISCC	High	-		-
Objective E: Long-term Control/Eradication							
Strategy E1: Aquatic Plant Control/Eradication							
E1a	Tahoe Keys Aquatic Plant Management Plan	TRCD, USDA-ARS		High	-	$50	-

Table 8 cont.

	Objectives/Strategies/Actions	Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
E1b	Benthic barriers	TRCD	TDC, TRPA, CSLC		$250 (shared with E1c, E1d)		USBOR, CSL
E1c	Hand-pulling	LTAISWG			$250 (shared with E1b, E1d)		USBOR, CSL
E1d	Diver-operated suction	LTAISWG	TDC		$250 $250 (shared with E1b, E1c)		USBOR, CSL
E1e	Mechanical harvesting	TKPOA			$250	$1.3M	TKPOA
E1f	Aquatic herbicides	LTAISWG	-	High	-	See: Gaps and Challenges	-
E1g	Eradication Plan	TRCD, USDA-ARS			-		-
Strategy E2: Asian Clam Control/Eradication							
E2a	Pilot Asian clam control/eradication project	LTAISWG		High	$503 (shared with E2c)	-	USBOR, NDSL, LRWQCB, SNPLMA
E2b	Molluscicides	LTAISWG		High	-		-
E2c	Eradication Plan	LTAISWG			-	-	-
E2d	Lakewide Asian clam survey	LTAISWG		High	$125	-	LRWQCB, NSL
Strategy E3: Warm Water Fish Control/Eradication							

Table 8 cont.

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
E3a	Tagging	USFS-LTBMU, UNR			$40		NTLPF
E3b	Tahoe Keys AIS Control and Demonstration	USFS-LTBMU	USFWS	High	$464	-	SNPLMA (Rd. 8, 9, 10)
E3c	Electro-fishing	USFS-LTBMU, UNR, CDFG			-	$3.6 M (6 yrs.)	-
E3d	Netting	USFS-LTBMU, UNR			-	$1.8 M (6 yrs.)	-
E3e	Piscicides				-	$720 (3 yrs.)	-
E3f	Eradication Plan	USFS-LTBMU, UNR			-	$	-
Strategy E4: Bullfrog Control/Eradication							
E4a	Evaluate Bullfrog Control/Eradication Methods	LTAISWG, USFS-LTBMU			-	$	-
E4b	Habitat Restoration to Support Native Amphibians	LTAISWG, USFS-LTBMU			-	$	-
E4c	Eradication Plan	LTAISWG, USFS-LTBMU			-	$	-

Table 8 cont.

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
Objective F: Research and Information Transfer							
Strategy F1: Detection Technology							
F1a	Innovative Technologies to Detect AIS	LTAISWG	LTAISCC	High	-		
F1b	Alternative AIS Vectors	LTAISWG		High			
F1c	Prioritize AIS Management Efforts	LTAISWG	LTAISCC	High	Included in Plan	-	USACE
Strategy F2: AIS Life Histories and Environmental Requirements							
F2a	Calcium sampling	TERC, UNR, TRPA	CTC	High	$92K	-	USACE
F2b	Survivability	TERC, TRPA, UNR	CTC, TSC	High	$48K	-	USACE
F2c	Risk Matrix	LTAISCC			-	$	-
Strategy F3: Research Needs							
F3a	Lake Tahoe AIS Research	TSC	LTAISCC, LTAISWG	High	-		-
F3b	Yearly workshop	LTAISWG	Various agencies	High	$	$	
F3c	Interactions of Native to Non-native and Native to Native Species	LTAISCC	TSC	Med	-	$	-
F3d	Evaluate Removal Disturbance	LTAISWG	TRPA	High		$	
F3e	Species Facilitation of AIS Establishment	LTAISWG		High	$20	-	USACE
F3f	Global Climate Change and AIS Establishment	LTAISWG		Med	-	$	-
F3g	Sites for Intra- and Inter-region Invasion	LTAISWG		High	-	$	-

Table 8 cont.

Objectives/Strategies/Actions		Lead Entity	Coop. Entity	Priority	Current/ Short-term need $1K	FY10-15 Anticipated need $1K	Current Fund Source
F3h	Research Funding	LTAISWG		High	-	-	-
Strategy F4: Information Transfer							
F4a	Communication Between Regional and State AIS Activities	LTAISCC	USFWS	High	-	**$5**	-
F4b	List of AIS Experts	USDA-ARS	LTAISCC	Med	-	**$5**	-
Objective G: Laws and Regulations							
Strategy G1: AIS Lists							
G1a	CDFA Weed Ratings	TSC	LTAISCC	High	-		-
G1b	NDA Noxious Weed List	TRPA, USFWS	LTAISCC	High	-		-
G1c	Tahoe-specific Prohibited AIS	LTAISCC	TSC	High	-		-
Strategy G2: Existing Laws and Regulations							
G2a	Regional, State and Federal AIS Laws	LTFAC	LTAISCC	High	-		-
G2b	Amendments	LTAISCC	LTAISCC	High	-		
G2c	Coordinate CA and NV Law Enforcement	LTAISCC		High	-		-
Strategy G3: Provide for All Appropriate Treatment and Control Methods							
G3a	Acceptable Approaches to Treatment	LTAISCC		High	-		-
G3b	Environmental Documentation for Aquatic Pesticide Use	LRWQCB, USFS-LTBMU, TRPA	-	High	-	$325K	-
G3c	Public Awareness	LTAISWG	LTAISCC	High	$250 (Shared with remaining C3 actions)	$1M (Shared with remaining C3 actions)	-

8 Plan Review

Review of the Plan will be directed by the LTAISCC. The breadth of experience and representation on the LTAISCC allows for comprehensive guidance for subsequent Plan review. A subcommittee will be formed to provide an annual review and determine whether a formal revision is required to meet the emerging prevention, monitoring, control, education, and research needs in the Region. If needed, the subcommittee will revise the Plan every five years following the ANSTF's *Guidance for State and Interstate Aquatic Nuisance Species Management Plans*. Considerations for annual reviews and revision should include:

- An assessment of the effectiveness of management actions
- Increase or decrease in new introductions
- Effectiveness of eradication or control methods
- Success of education efforts
- Allocation of funds consistent with the objectives of the Plan
- An evaluation of vector pathways
- An evaluation of prevention measures
- Update species list, species management types, presence/absence, pathways of introduction, and applicable pest ratings in Table 6
- Evaluate necessary environmental documentation to allow for all control/eradication methods
- Evaluate gaps and challenges in regional, state, and federal regulations related to AIS introduction, spread, and control/eradication
- Evaluate early detection and rapid response protocols
- Ensure adaptive management approaches are used during Plan revision
- Evaluate known or potential effects from climate change on AIS
- Evaluate efforts to inspect and decontaminate all vectors (e.g., small watercraft, fishing equipment)

9 Research Considerations

The following research gaps have been identified and should be considered for future funding and Plan revisions. These gaps were determined from literature reviews of AIS currently in or threatening the Region and interactions with researchers and resource managers:

Environmental

- Are calcium levels in Lake Tahoe adequate to support all life stages of quagga/zebra mussels (this work in currently underway at UNR)?

- How do seasonal changes in calcium concentration affect mussel survivability (question being addressed by UNR)?
- Are concrete structures substantial sources of calcium to facilitate dreissenid mussel establishment?
- What are other substantial sources of calcium to Lake Tahoe that could support dreissenid mussel establishment?
- What are the spawning cycles of largemouth bass and other warm water fishes in Lake Tahoe?
- Are there unique microhabitats in the Region that would allow otherwise unpredictable invasions, e.g., geothermal springs?
- Is the algal assemblage in Lake Tahoe sufficient to support invertebrate growth and reproduction?
- Will physical habitat in the Lake Tahoe be limiting to quagga and zebra mussels?
- What causes the massive die-offs of signal crayfish along the west shore of Lake Tahoe?
- What are the impacts of signal crayfish on sedimentation and water clarity?
- Which waterbodies in the Tahoe Region are at risk for New Zealand mudsnail invasion?
- What other areas of Lake Tahoe physically resemble those currently inhabited by Asian clams? And, are chemical conditions limiting to survival of Asian clams in these areas?

Management

- Will management strategies for existing AIS alter Lake Tahoe water quality, food web structure, and benthic ecology?
- How can IPM be better incorporated into AIS control/eradication efforts?

Interaction with Other Existing AIS

- Can nearshore habitats currently infested with AIS (e.g., Eurasian watermilfoil, Asian clams) facilitate the establishment of other AIS (e.g., quagga/zebra mussels, New Zealand mudsnails, and hydrilla)?
- How does competition with other invasive species (bivalves and macrophytes) affect ability to colonize or to maintain established colonies of Asian clams?
- What is the energetic contribution of signal crayfish to predatory warm water fishes such as largemouth bass?
- Will Asian clam removal facilitate recolonization by Asian clams or other invasive species (e.g., aquatic weeds, dreissenid mussels)?

- Are there potential predators of the New Zealand mudsnail currently in Lake Tahoe?
- How do established colonies of New Zealand mudsnails affect potential colonization for other invasive species?

Surveys

- Survey tributaries to Lake Tahoe and other waterbodies in the Region for AIS such as New Zealand mudsnails, Asian clams, and non-native submersed aquatic plants.
- What is the level of *Batrachochytrium dendrobatidis* (Bd) infection in native amphibian populations and their habitats?

Vector Pathways

- Examine new vector pathways for existing species of concern.
- What are the primary pathways of AIS introduction to Lake Tahoe in addition to motorized watercraft?
- What are the likely pathways of New Zealand mudsnail introduction to Lake Tahoe?

Climate Change

- What is the response of warm-water fishes and bullfrog in Lake Tahoe to regional/local climate change (UCD 2008)?
- Will physicochemical factors resulting from climate change enhance potential for successful colonization of new AIS?

10 Literature Cited

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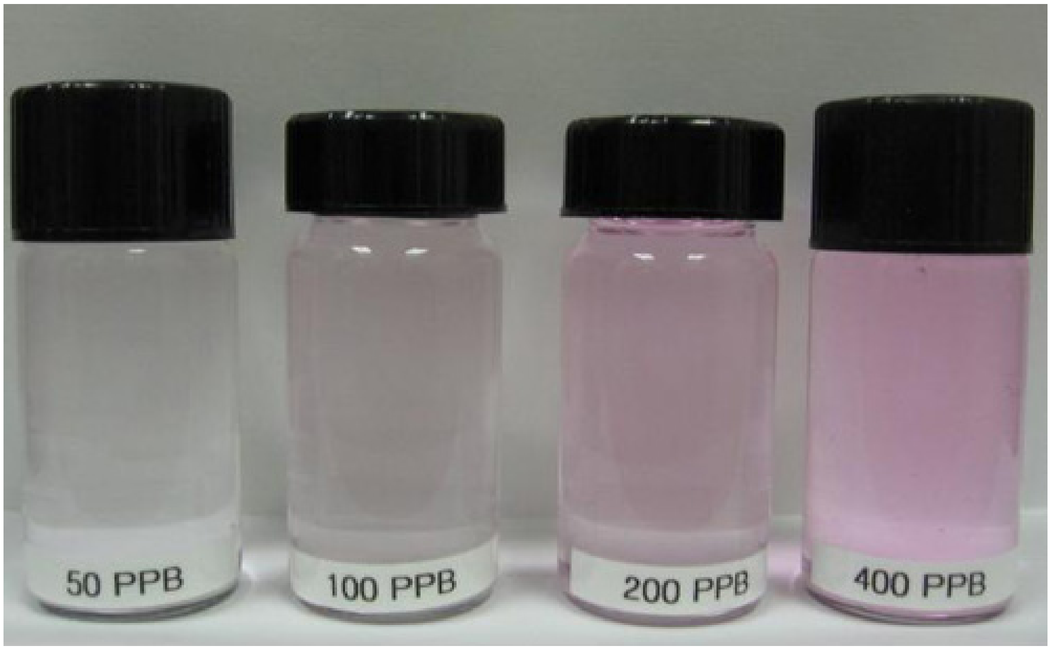
Enclosure 2

Enclosure 2: Photograph showing different concentrations of Rhodamine WT



Request To Lahontan Regional Water Quality Control Board

Use of Rhodamine WT (fluorescent dye) as a Surrogate to Determine Dissipation and Movement of Potential Aquatic Herbicides for Control of Eurasian Watermilfoil and Curlyleaf Pondweed in Tahoe Keys Marina:

Phase I of Research on Management of Invasive Aquatic Weeds in Lake Tahoe

Submitted by Lars Anderson, Ph.D.
USDA- ARS Exotic and Invasive Weed Research
Davis, CA

Submitted December 10, 2009

(NOTE: This Proposal is seeking approval for use of Rhodamine WT dye only- it is NOT a request for funding.)

Background

In the late 1960s and early 1970s the Tahoe Keys marina sites were constructed along the south shore of Lake Tahoe. The keys lie in a historic wetland complex at what was a wetland/lake interface between the Upper Truckee River and Taylor Creek marshes. Historically, wetlands along Lake Tahoe's south shore were important habitats for native plants and animal species, including Lahontan redside shiner (*Richardsonius egregius*), speckled dace (*Rhinichthys osculus*) and Sierra Nevada yellow-legged frog (*Rana sierrae*). Though records are sparse, photographic evidence, and recent surveys suggest that native aquatic plants were also present in the historic marsh, including coontail (*Ceratophyllum demersum*), sago pondweed (*Stuckenia pectinata*) and Richardsons pondweed (*Potamogeton richardsonii*). The presence of the native *Myriophyllum* (*M. quitense, commonly known as Andean milfoil*) was not documented until surveys in the mid- 1990s.

After construction of the Keys in 1975 the presence of "milfoil" plants at Taylor Creek was noted. There is no way to be certain what species of *Myriophyllum* this was since no voucher specimens were made, nor were there any photographic records. Studies conducted in the mid-1990s and early 2000s by the USDA – Agricultural Research Service (ARS) confirmed both the presence of invasive *Myriophyllum spicatum* (Eurasian watermilfoil) and that spread of this species was occurring to other parts of Lake Tahoe. In 2003 the non-native invasive aquatic plant curlyleaf pondweed (*Potamogeton crispus*) was discovered in both of the Tahoe Keys channels. Subsequent whole-lake surveys in 2006 and localized monitoring in 2008 have confirmed the rapid spread of *P. crispus* along the South Shore from the Keys channels to Lakside Marina, and within the West Tahoe Keys basin and the East "turning/sailing basin". Figures 1-5 summarize results of aquatic plant surveys in 2009 and clearly shows that the flora consists of two non-native plants (Eurasian watermilfoil and Curlyleaf pondweed) as well as a mixed population of some native plants. It should also be pointed out the current practices (harvesting) include removal of some native species (e.g. *Elodea canadensis* and *Potamogeton richardsonii*), and mainly coontail (*Ceratophyllum demersum*).

In the late 1970s and early 1980s a variety of non-native fish species were discovered in the Tahoe Keys. The species were of warm-water habitat origins (southeastern United States) and thought to be tied to illegal introductions by anglers eager to catch these fish. Invasions of non-native aquatic plants and warm-water fishes have disrupted ecological interactions, decreased localized distribution of native species and resulted in high costs to control aquatic weeds.

In 2007 the Lake Tahoe Aquatic Invasive Species Working Group (LTAISWG) was formed as an interagency mechanism to coordinate and implement AIS prevention and control measures. Prior to formation of LTAISWG the US Forest Service, Lake Basin Management Unit (LTBMU) funded a research project (University of Nevada, Reno) that investigated distribution and relative abundance of currently established largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) and determine potential impacts of non-native fish on native fishes. It was recognized through this study effort that contemporary investigations into aquatic weed persistence in the keys was ongoing. Scientists soon developed preliminary habitat relationship linkages between aquatic weed and warm-water fish populations. In early 2008 the Tahoe Keys AIS Subcommittee initiated a planning effort to further investigate these linkages in the Tahoe Keys in order to better refine measures of control and/or eradication for aquatic weeds and warm-water fishes.

This request, therefore, the use of Rhodamine WT is part of a phased approach toward management of invasive aquatic weeds in Lake Tahoe. This fist phase is to develop water-movement information with the Keys and certain near-shore sites, and subsequently apply this information to refine protocols for a second-phase that will examine the efficacy and dissipation characteristics of EPA and CalEPA/DPR approved aquatic herbicide including: Triclopyr, Endothal, Fluridone as candidates for potential use in controlling invasive aquatic weeds in Lake Tahoe.

Need for Evaluation of Control Methods

At present, only *non-herbicide-based* aquatic weed management approaches have been attempted in a few small infestations (e.g. hand removal and small bottom barrier materials in Emerald Bay, Lakeside Marina). Although some success has been achieved, their long-term efficacy at Tahoe has yet to be determined. In addition, these are much smaller and less dense infestations of Eurasian watermilfoil than those larger infestation occurring within the Tahoe Keys system, as well as some infestations along the near-shore areas (e.g. Logan Shoals, Ski Run, Lower Truckee River outlet, and Fleur du loc marina area).

The current practice in the Keys for reducing aquatic weed impacts relies exclusively on barge-mounted, plant cutters and harvesting operations during peak growth periods. This harvesting activity, generally spanning June to October, provides some open channels for boats, but also generates many thousands of viable plant fragments that can freely disperse within the Keys and out the channels to the lake proper. Since there are now two exotic invasive aquatic plants in the Keys- Eurasian watermilfoil and Curlyleaf pondweed- the continued harvesting actions no doubt contribute to the further spread of these plants both within the Keys and to Lake Tahoe proper. The harvesting operation can also stimulate growth of plants by opening more areas for light to reach the bottom where plants are left intact.

Equally important, the continued threat from potential introductions of quagga and zebra mussels suggests that more understanding is needed about localized water movement in the Keys and how this may affect veliger (microscopic larvae) movement and any future rapid response actions. Although there have been some studies on movement of water in/out of the Keys, this pertains more to mass water movement, not to localized areas (e.g. specific “arms” or “fingers” and boat slip areas). The Keys marinas consist of a variety of bathymetic configurations including short “dead-end” areas, “main channels” connectors and areas immediately adjacent to the narrow channels that open to the lake proper. These types of configuration are subject to different exposures to wind and to spring run off conditions as well as different thermally driven movements. The exotic invasive weeds infest all these areas.

Rhodamine WT Dye Approach

The purpose of this study is to use a well-known surrogate (indicator) dye, Rhodamine WT to determine the movement of water in specific sites, and to gain site- specific information on the potential dissipation and movement of aquatic herbicides, without having to introduce pesticides into Lake Tahoe, or the Tahoe Keys Marina sites. I have provided background references (Table 1) (published papers and reports) in three topical areas for convenient referral: (1) Toxicity Information; (2) General Tracer Use; and (3) Specific Uses as Aquatic Herbicide Surrogates.

Toxicity and fate of Rhodamine WT

Since the use of various fluorescent dyes as tracers began in the 1950’s, a range of compounds have been used for tracer studies (Smart and Laidlow 1977, Field 2005). These dyes are have been used in the range of a few parts per million (ppm) down to 5 to 10 parts per billion (ppb). One of the first reports on the toxicity of dyes is a report by Smart (1984), who found Rhodamine WT was the least toxic compared to others such as Rhodamine B, Fluroescein (= Rose Bengal dye), Eosine, and Pyranine. He suggested using levels below 100 ppb.

The environmental concerns and risks were reported by Field et al. (1995). Other studies are also referenced (Steinheimer and Johnson. 1986; Jensen and Kristennsen 1989; Abdidi et al. 1986). More recent reviews of the potential environmental toxicity of Rhoadmine WT (Field 2005) have consistently affirmed this evaluation for typical uses in the ppb range. The only report suggesting Rhodamine WT should not be used was by Behrens et al. (1995), and this appears to be based on levels of 10 ppm. However, as pointed out by Field (2005), there seems to be no available database or referenced, published work by which Behrens et al. came to this conclusion. They refer to a "genotoxicity" effect, apparently using a bacterial assay at these high concentrations, but provide no details on protocols or access to them. Their Table 1 also shows *no toxicity* at this level for "fish" or "Daphiniae" in tests.

Therefore, the most recent toxicity data appears to be Field et al. 1995 (see their Table VI) and Field 2005 (see Field's Tables 1,2). Note that the LC50 values (20 to 320 **ppm**) are all two-three orders of magnitude **above** the typical field use concentrations (5 to 10 **ppb**), including the concentrations proposed here.

Because Rhodamine WT (and other dyes) absorb light and fluoresce, photolysis appears to drive some of the breakdown. Tai and Rathbun (1988) conducted extensive studies on the effect of light on breakdown of Rhodamine WT reported ranges of half-life from ca. 30 days to 89 days at 30 deg. N. latitude sunlight conditions, at various water depths. They found a general trend toward greater half-lives associated with more northern latitudes and that spring-summer half-lives (ca. 15 days) were about half those found for fall-winter conditions (ca. 22 to 30 days). They also found that humic substances accelerated loss, but that pH had negligible effects on half-life.

Another example is a study by Suijlen and Buyse (1994) in which they examined the photolytic degradation of fluorescence in Rhodamine WT under artificial and natural light. Whereas prior reports (Behrens and Teichmann 1982) stated ca. 54 day half-life, Suijlen and Buyes found it to be ca. 170 days using artificial light. They repeated this experiment in natural waters under sunlight and found that the half-life was still ca. 150 days.

Most recently, Schladow and Clark (2008), while studying water movement from an abandoned mercury mine (near Clear Lake, CA) also found that degradation of Rhodamine WT in "dark" bottles was negligible; whereas dye in clear bottles declined exponentially (see their Fig. 6 in Appendix 1).

In fact, due to the typical clarity of Lake Tahoe waters, one might expect Rhodamine WT to exhibit less persistence than it would in more turbid waters such as the Sacramento-San Joaquin Delta. However, given the ranges of half-lives reported, even a modest 20 to 30 day half-live would easily provide adequate time for use as a surrogate for herbicides since most have half-lives of a few days to a 2 weeks (e.g. triclopyr and endothal). Fluridone has the longest half-life of the candidate herbicides (ca. 45 to 120 days; therefore early dissipation can be estimated using Rhodamine WT but long-term monitoring (water sampling and immunoassays) (ca. 2 to 4 months) is typically employed to determine residues in most lake systems.

(Note that as part of the proposed protocol, an assessment of Rhodamine WT half-live in Tahoe water under field conditions will be made under surface-light and bottom-light

conditions using both in situ bottles and open vessels under natural irradiance similar to surface and bottom waters (i.e. 0.5 m depth and ca. 3 m depths). Furthermore, each application will include sets (n=3) of clear bottles containing actual "Tahoe Keys" (or appropriate near shore water sites) for mid-depth conditions. Any decline in fluorescence will be used to account for photolytic degradation (not movement or dilution).

In conclusion, the keen interest in using safe, acceptably stable dyes for a host of environmental "tracer" needs prompted US Environmental Protection Agency (EPA) to weigh in on the use of Rhodamine WT in 1988 and stated (see attached documentations) that Rhodamine WT is safe for potable water when used as a tracer at 10 ppb. *This request is to use Rhodamine WT as nominal (mixed) level of between 5 and 10 ppb.*

General Tracer Uses (water movement, nutrient migration/diffusion, sediment interactions).

A search of available databases (e. g Agricola, BIOSIS, Google, Google Scholar) revealed that Rhodamine WT has been used frequently since the 1970's and is still being used for a variety of tracer studies. It appears that other fluorescent dyes (e.g. fluorescein) have gradually fallen off in use, and that Rhodamine WT has become the preferred choice for most studies. (To be sure, other tracer chemicals have been used, such as LiCl, NaCl, bromides, when conditions are suitable and analysis is available.) But the preponderance of citations for water-tracer studies are those in which Rhodamine WT has been used, which is not surprising since it has been approved for use by the US EPA for over 20 years.

This approach has been widely used specifically to determine likely patterns of dilution, diffusion and movement (i.e. residence time), rates of river flow, migration of sub-surface waters (and potential for movement of pollutants), diurnal and seasonal movements of near-shore water and water/sediment dynamics in a range of aquatic sites (Ditmars 1975' see also Table 1 for "General Use categories). Specific examples include recent work at Clear Lake (Rueda et al. 2008), the Pend Oreille River (Wa). Also recently, ***and quite locally in the Tahoe Basin, the Truckee River*** flows were investigated by injection of Rhodamine WT (Crompton 2008). Other examples are provided in Table 1 (list of references by category).

Specific Aquatic Herbicide Surrogate Uses:

The use of Rhodamine WT as a surrogate for herbicides used in water has several advantages: (1) It has been approved for use by the US EPA; (2) levels typically are 1 to 10 ppb (parts per billion); (3) it can be detected in real-time using a field fluorometer; (4) minimum detection levels are around 5 to 10 parts per trillion; and (5) it can be applied to the top, middle or bottom of the water column to mimic applications of aquatic herbicides.

The utility of Rhodamine WT for this purpose is evident in the number of papers and reports related to aquatic herbicide usage. This dye has been shown to provide reasonable estimates of herbicide dissipation (Fox and Haller 1993). That study showed the similarity between the dissipations of the aquatic herbicide diquat and Rhodamine WT. Rhoadamine WT was also used to determine residence time and movement of triclopyr herbicide in weed-infested areas of the Pend 0reille River (WA) (Turner et al. 1994). Getsinger et al. (1994) and Turner et al. (1994) used Rhodamine WT to determine application rates and locations expressly to optimize control of Eurasian watermilfoi with tricopyr, one of the candidate herbicides selected for Phase II of this work. Similarly, Fox et al. (2006) used Rhodamine WT to assess herbicide residence time in tidal canals in Florida as part of a control program using endothal. They found that the dissipation of the dye correlated well with the dissipation of the active ingredient, endothal. Note that endothal is also in the list of candidates for use in controlling Eurasian watermifoil and Curlyleaf pondweed at Lake Tahoe as part of Phase II.

Our ARS laboratory has also used Rhodamine WT as part of our research program to develop management strategies in the Sacramento-San Joaquin Delta. Anderson (1999) reported on the “half-life” and “wash-out” time for Rhodamine in selected sloughs in the Sacramento-San Joaquin Delta, a system highly influenced by tides and seasonal flows (runoff). A similar study was just conducted in March 2009 in White Slough, 14 Mile slough and Disappointment Slough. (Boating and Waterways 2009). (Anderson, pers. commun. 2009; Ca. Dept. of Boating and Waterways 2009-their report is in review).

The proposed use here follows accepted practices (e.g. Alberta Canada 1999; Turner Designs websites), which include use of final, dispersed concentrations from 1 to 5 ppb (parts per billion), and use of field fluorimetry to provide adequate, real-time monitoring of dye levels. ARS staff has had many years’ experience using this approach and has the equipment required to conduct the proposed study. We have requested the 5-10 ppb final dispersed concentration to allow for flexibility while still keeping within the US EPA approved level of 10 ppb. It should be noted that most uses result in instantaneous, initial, concentrations usually range from 3 to 5 X the final dispersed levels, which quickly mix to targeted levels w/in a few hours. (From published studies in river systems, it’s clear that this initial level may be higher so that downstream dilution will still result in detectable levels. This is because the 10 ppb level may be rapidly achieved within a short distance in high-volume flow systems.)

The results of this proposed study will provide an understanding of how soluble materials behave in the proposed target sites and also provide information on how small “pelagic” particles such as larvae of veligers may be dispersed within the Keys and offshore areas. This data will facilitate evaluations (risks, benefits) of using EPA-approved aquatic herbicides, and will add to the overall understanding of risk due to movement of invasive plants and animals in the near-shore environment.

Study Objectives:

- **Determine the retention time and movement of the water-soluble fluorescent dye Rhodamine WT as an indicator of herbicide movement and dissipation.**

- **Compare retention time and movement of Rhodamine WT in several typical aquatic weed infested locations including: Tahoe Keys marina, Ski Run, Lakeside Marina and adjacent near-shore, Meeks Bay, and weed-infested site adjacent to the Truckee dam.**

- **Use data from this dye study to develop proposed aquatic herbicide evaluation protocols and monitoring protocols (e.g. location and timing of pre- and post-herbicide application water sampling).**

- **Use data from this dye study to help understand potential dispersal patterns for plant propagules (stem fragments, turions) and invasive clam larvae.**

Hypotheses:

- **Movement of soluble dye will approximate the physical dissipation and movement of aquatic herbicides fluridone, endothal and triclopyr.**
- **Results will be useful in both optimizing applications methods and in placement and timing of monitoring stations for sampling.**
- **Water movement and dye dissipation and movement will be different in early summer (June) from dissipation and movement in early fall (later August-early September) due to change in water input an outflows that are driven by prevailing wind, due to changes in temperature in the water column.**
- **Dissipation will be more rapid in "unconfined" near-shore sites such as Ski Run, Olympic Circ. Drive (Ca. shore) and Emerald Bay compared to highly protected marinas.**
-

Methods:

1. Site Selection:

a. **Using previous plant surveys (2006, 2008) and spring 2009, specific coves ("fingers") within the east and West Keys basins will be identified for pre-management evaluation. Sites will be chosen to represent typical plant species and typical fish habitat and range of small and large coves. Three (3) sites will be chosen within the West Basin of the Tahoe Keys that represent typical areas (i.e. small "coves" and one large open-water area. One site in the East Basin ("sailing lagoon") will be included. (See Figures 4, 5). The specific "coves" will be chosen following another site-visit in April-May, 2010.**

b. Three-four sites "off-shore" in Lake Tahoe proper will be selected at: Ski Run, Lakeside Marina (and adjacent areas just north of the marina, Emerald Bay, a site on the California side, and a site at Truckee Dam (late summer only).
c. All sites and dye applications will be documented via GPS.
d. Final site selection will be made at least 30 days before use of the dye and a notice will be provide to the Lahontan Regional Water Quality Board 30 days prior to application(s).
e. Sites will range in size (area) from 1.0 to 3.0 acres; typical depths range from 4 ft to 15 ft.

2. Timing: Applications will be made (except Truckee Dam) in Mid-late- June and in late August-early September 2010, and if necessary, repeated in 2011.

3. Applications: Rhodamine WT Dye will be injected ca. 2 to 4 feet below the surface, or near the bottom to simulate actual application methods. Dye will be pre-mixed (tank mixed) or mixed in-line, and distributed via boom system typically used for aquatic herbicide applications. All applications will targeted to range from 1 to 10 ppb (parts per billion) and will be applied based on estimates of total water volume within each site. Since this study is aimed at determining movement, no containment curtains will be used.

>Estimated total treated water volumes (per season) (based on maximum size/depth ranges):

Tahoe Keys: 180 acre-ft =(four, 3-acre site at 15 ft deep)=2.4 lbs Rhodamine WT

<u>Tahoe Keys: 90 acre-ft (*most likely use*)= 1.2 lb. Rhoadmine WT.</u>

Off-shore sites: (*Based on approximate size/depths*)

Ski Run:	**120 acre-ft**
Emerald Bay:	**36 acre-ft**
Dam:	**5 acre ft**
Olympic Circ. Site	**1 acre ft**

<u>Total: 162 acre-ft = 2.2 lbs Rhodamine WT</u>

-

4. Monitoring: Concentrations of Rhodamine WT will be determined using field fluorometers (Turner Designs field Flurometer Model 10) which employ a constant flow-through systems and digital readout. Instruments will be standardized and calibrated according to manufacturers recommendations and protocols. Dye concentrations will be determined at the top, middle (mid-depth) and lower 30 cm of the site

5. Reporting: Results will be reported to TRPA and Lahontan Regional Water Quality Control Board within 45 days after completion of all applications. Reports will include both summaries (graphs, tables) and the fluorescence output recorded from the fluorometers. A detailed summary report will be produced and provided

to TRPA, Lahontan Regional Water Quality Control Board, LTAISWG, LTAISCC and other cooperators at the end of this study.

References: (See Table 1)
Appendix 1. Copies of all references
>also see this Site: http://smig.usgs.gov/SMIG/rhodamine_reader.html

Table 1.

Category	Reference (by subject category)
General	Alberta Environment. 1999. Tracer Study Guidelines. Water Quality Branch, Standards and Approvals division, Alberta Environment, Alberta, Canada. 9 p.
General	Bencala K. E., Rathbun R. E., Jackman A. P., Kennedy V. C., Zellweger G. W., and Avanzino R. J. (1983) Rhodamine WT dye losses in a mountain stream environment. Water Resources Bulletin 19(6): 943-950.
General	Crompton E. J. (2008) Traveltime data for the Truckee River between Tahoe City, California, and Vista, Nevada, 2006 and 2007. USGS Open File Report: pp. 1-12.
General	Cushing C. E., Minshall G. W., and Newbold J. D. (1993) Transport dynamics of fine particulate organic matter in two Idaho streams. Limnology and Oceanography 38(6):1101-1115.
General	Dierberg F. E., Juston J. J., DeBusk T. A., Pietro K., and Gu B. (2005) Relationship between hydraulic efficiency and phosphorus removal in a submerged aquatic vegetation-dominated treatment wetland. Ecological Engineering 25:9-23.
General	Ditmars, J. D. 1975. Mixing and Transport. J. Water Poll. Cont. Fed. 47: 1769-1783.
General	Fox A. M. and Getsinger K. D. (1991) Factors that influence water exchange in spring-fed tidal canals. Estuaries 14(4):404-413.
General	James W. F. and Barko J. W. (1991) Estimation of phosphorus exchange between littoral and pelagic zones during nighttime convective circulation. Limnology and Oceanography 36(1):179-187.
General	Koltun G. G., Ostheimer C. J., and Griffin M. S. (2006) Velocity, bathymetry, and transverse mixing characteristics of the Ohio River upstream from Cincinnati, Ohio, October 2004—March 2006. USGS Open File Report 2006: pp1-31.
General	Kratzer C. R. and Biagtan R. N. (2007) Determination of traveltimes in the lower San Joaquin River Basin, California, from dye-tracer studies during 1994-1995.USGS Open File Report pp 1-20.
General	Kung K. J. S., Steenhuis T. S., Kladivko E. J., Gish T. J., Bubenzer G., and Helling C. S. (2000) Impact of preferential flow on the transport of adsorbing and non-adsorbing tracers. Soil Science Society of America Journal 64:1290-1296.
General	Lawrence G. A., Ashley K. I., Yonemitsu N., and J. R. (1995) Natural dispersion in a small lake. Limnology and Oceanography 40(8):1519-1526.
General	Lipp C. W., Gillis P. A., Spradling R. D., Tsai K., and Melton L. A. Measurement of reactive mixing of liquids with combined PICV and reactive PLIF methodology. pp 1-12.
General	Mines C. H., Ghadouani A., and Ivey G. N. (2009) Dying to find the source –the quantitative use of rhodamine WT as a proxy for soluble point source pollutants in closed pipe surface drainage networks. Hydrology and Earth System Science Discussions 6:4535-4562.
General	Precht E. and Huettel M. (2003) Advective pore-water exchange driven by surface gravity waves and its ecological implications. Limnology and Oceanography 48(4) 1674-1684.
General	Rathbun R. E. and Tai D. Y. (1981) Technique for determining the volatilization coefficients of priority pollutants in streams. Water Research 15(2):243-250.
General	Redford D. Cruise Ship Plume Tracking Survey (2001). EPA Oceans and Coastal Protection Division. pp 1-177.
General	Rueda, F. J. , S. G. Schladow, and J. F. Clark. 2008. Mechanisms of contaminant transport in a multi-basin lake. Ecological Applications 18 (Supplement): A72-A87.
General	Schladow S. G. and Clark J. F. (2008) Use of tracers to quantify subsurface flow through a mining pit. Ecological Application 18(8):A55-A71.
General	Schneider V. R. (1986) Programs and Plans—Dyes for water tracers. USGS Technical Memorandum No. 86.08 pp 1-2.
General	Smart C. C., Zabo L., Alexander Jr. E. C., and Worthington S. R. H. (1998) Some advances in fluorometric techniques for water tracing. Environmental Monitoring and Assessment 53:305-320.
Herbicide	**Anderson, L.W.J. 1999. Egeria invades the Sacramento-San Joaquin**

	Delta. Aquat. Nuis. Species Digest 3:37-40.
Herbicide	Fox A. M. and Haller W. T. (1992) Improving herbicide efficacy in spring-fed tidal canals by timing and application methods. Journal of Aquatic Plant Management 30:58-62.
Herbicide	Fox A. M. Haller W. T. (1990) Use of rhodamine WT dye to predict herbicide dissipation in moving water. European Weed Research Society pp. 105-110.
Herbicide	Fox A. M., Haller W. T., and Getsinger K. D. (1992) Correlation of bensulfuron methyl and dye concentrations in water following concurrent application. Journal of Aquatic Plant Management JAPMDB 30(2):73-74.
Herbicide	Fox A. M., Haller W. T., and Getsinger K. D. (2006) Correlation of endothal and fluorescent dye concentrations following concurrent application to tidal canals. Pesticide Science 37(1):99-106).
Herbicide	Fox A. M., Haller W. T., Getsinger K. D., and Petty D. G. (2002) Dissipation of triclopyr herbicide applied in Lake Minnetonka, MN concurrently with rhodamine WT dye. Pest Management Science 58(7):677-686.
Herbicide	**Fox, a. and W. T. Haller. 1993. Correlation of endothal and fluorescent dye concentrations following concurrent application to tidal canals. Pestic. Sci. 37:99-106.**
Herbicide	Getsinger K. D., Turner E. G., Madsen J. D., and Netherland M. D. (1997) Restoring native vegetation in a Eurasian water milfoil-dominated plant community using the herbicide triclopyr. Regulated Rivers: Research & Management 13:357-375.
Herbicide	Netherland M. D. and Getsinger K. D. (1995) Potential control of hydrilla and Eurasian watermilfoil under various fluridone half-life scenarios. Journal of Aquatic Plant Management 33:36-42.
Herbicide	Sabatini D. A. and Austin T.A. (1991) Characteristics of rhodamine WT and fluorescein as adsorbing ground-water tracers. Ground Water 29(3)341-349.
Herbicide	Turner E. G., Getsinger K. D., and Netherland M. D. (1994) Correlation of triclopyr and rhodamine WT dye dissipation in the Pend Oreille River. Journal of Aquatic Plant Management 32:39-41.
Toxicity	Abdidi, S.L., V. K. Dawson and R. C. Huber. 1986. Potential for nitrosamine formation in seven fishery chemicals The Progressive Fish-Culturist, 48, 301, 1986.
Toxicity	Behrens H., Beims U., Dieter H., Dietze G., Eikmann T., Grummt T., Hanisch H., Henseling H., Käß W., Kerndorff H., Leibundgut C., Müller-Wegener U., Rönnefahrt I., Scharenberg B., Schleyer R., Schloz W., and Tilkes F. (2001) Toxicological and ecotoxicological assessment of water tracers. Hydrogeology Journal 9:321-325.
Toxicity	Bencaia K. E. and Zellweger G. W. (1988) Review of experimental additions of rhodamine WT dye into reactive aquatic environments. Preprints of Papers Presented at National Meeting, Division of Water, Air and Waste Chemistry, American Chemical Society, (USA) 29:2.
Toxicity	Crimaldi J. P. (1997) The effect of photobleaching and velocity fluctuations on single-point LIF measurements. Experiments in Fluids 23:325-330.
Toxicity	Deaner D. G. (1973) Effect of chlorine on fluorescent dyes. Water Pollution Control Federation 45(3):507-514.
Toxicity	Dierberg F. E. and DeBusk T. A. (2005) An evaluation of two tracers in surface-flow wetlands: rhodamine-WT and lithium. Wetlands 25(1):8-25.
Toxicity	Field M. S. (2005) Assessing aquatic ecotoxicological risks associated with fluorescent dyes used for water-tracing studies. Environmental & Engineering Geoscience 9(4):295-308.
Toxicity	Field M. S., Wilhelm R. G., Quinlan J. F., and Aley T. J. (1995) An assessment of the potential adverse properties of fluorescent tracer dyes used for groundwater tracing. Environmental Monitoring and Assessment 38:75-96.
Toxicity	Finkner S. C. and Gilley J. E. (1986) Sediment and dye concentration effects on fluorescence. Applied Engineering in Agriculture 2(2):104-107.
Toxicity	Jensen, M. and K.K. Kristennsen. 1989. Effects of Rhodamine water tracer on *Escherichia Coli* densities. Water Research, **23**, 257, 1989.
Toxicity	Lin A. Y., Debroux, J. F., Cunningham J. A., and Reinhard M. (2003) Comparison of rhodamine WT and bromide in the determination of hydraulic characteristics of constructed

	wetlands. Ecological Engineering 20:75-88.
Toxicity	Perler A. H. (1988) Flurometric Facts. EPA Bulletin No. 104 Fluorescent Tracer dyes: pp 1-2.
Toxicity	Smart P. L. and Laidlaw I. M. S. (1977) An evaluation of some fluorescent dyes for water tracing. Water Resources Research 13(1):15-33.
Toxicity	Smart P.L. 1984 A review of the toxicity of tweleve fluroescent dyes used for water tracing. NSS Bulletin 46: 21-33.
Toxicity	Steinheimer, T.R. and S.M. Johnson. 1986. Investigation of the possible formation of diethylnitrosamine resulting from the use of Rhodamine WT dye as a tracer in river waters. USGS WSP 2290, 37, 1986.
Toxicity	Suijlen J. M. and Buyse J. J. (1994) Potentials of photolytic rhodamine WT as a large-scale water tracer assessed in a long-term experiment in the Loosdrecht lakes 39(6):1411-1423.
Toxicity	Tai D. Y. and Rathbun R. E. (1988) Photolysis of rhodamine-WT dye. Chemosphere 17(3):559-573.
Toxicity	Turner E. G., Netherland M. D., and Getsinger K. D. (1991) Submersed plants and algae as factors in the loss of rhodamine WT dye. Journal of Aquatic Plant Management 29:113-115.

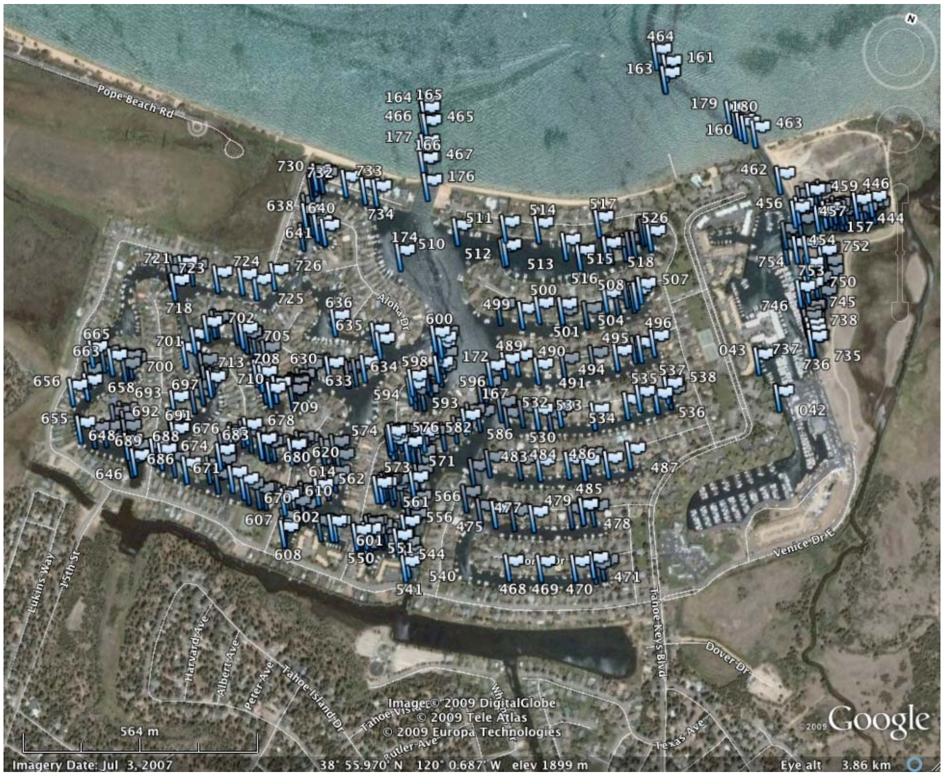


Figure 1. Survey points (physical samples) taken to determine aquatic plant species distribution in the Tahoe Keys (USDA-ARS 2009).

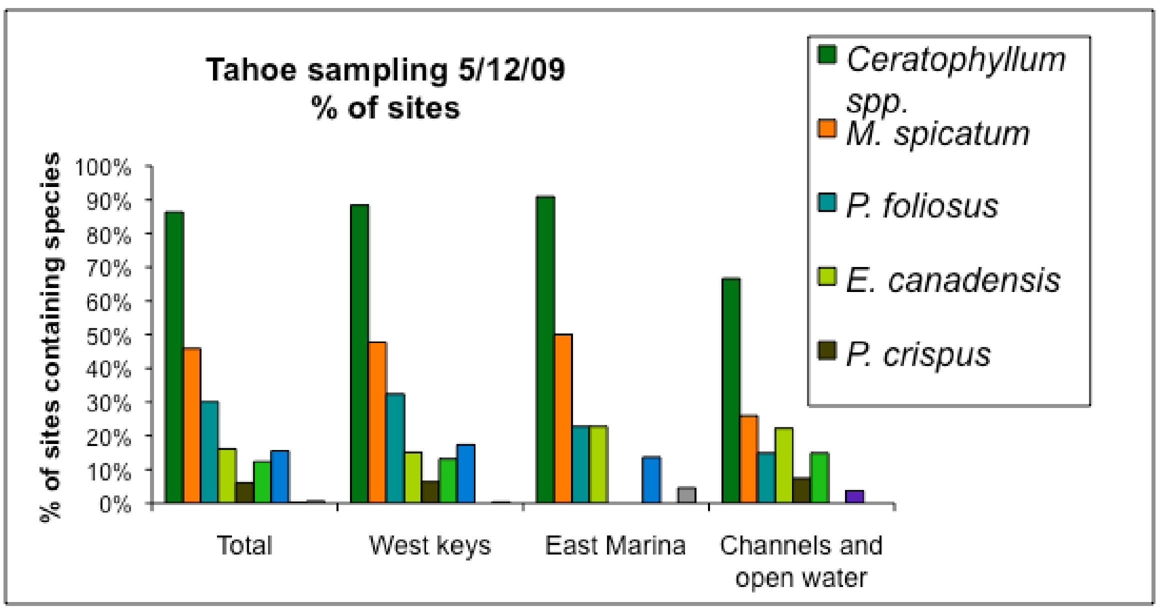


Figure 2. Relative abundance (presence) of main aquatic plants in the Tahoe Keys area (2009 survey by USDA- ARS).

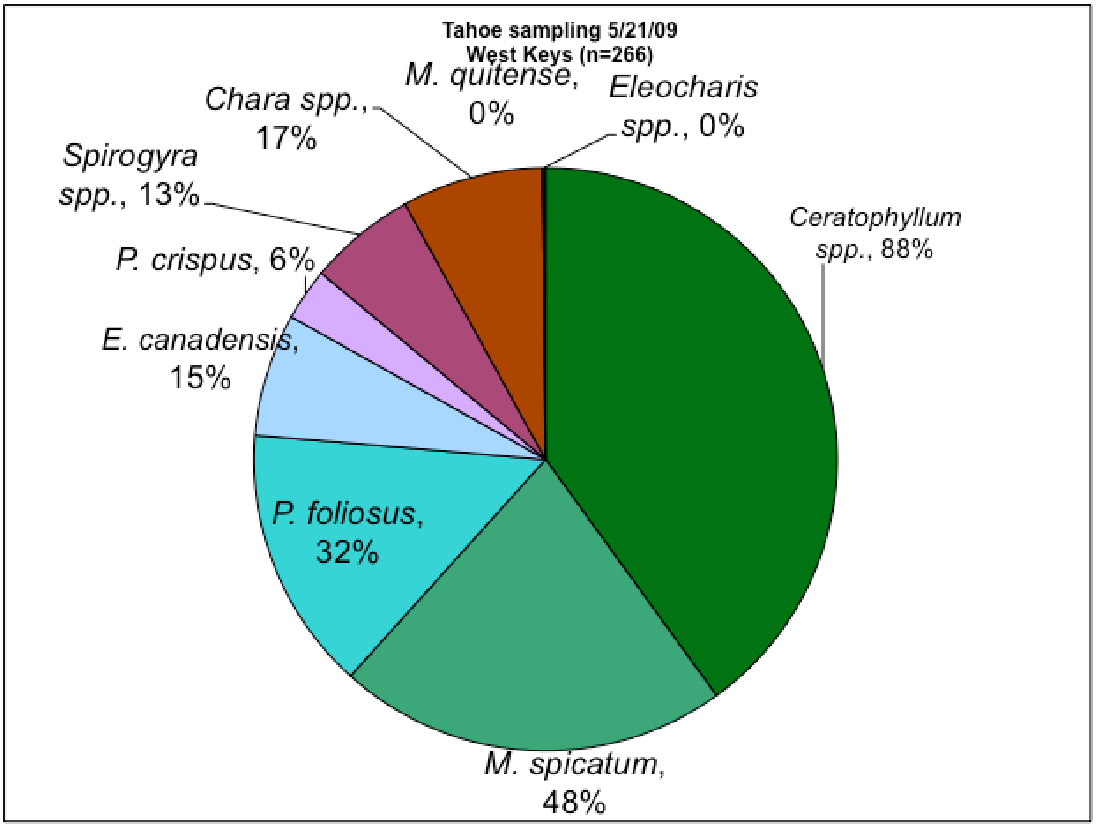


Figure 3. Relative distribution (presence) of aquatic plants in the Tahoe Keys West Basin (2009).

Figure 4. Areas infested with invasive aquatic plants in the West Basin of the Tahoe Keys. Note: Figure 3 (below) shows the distribution of aquatic plants within the numbered "fingers" (dock areas).

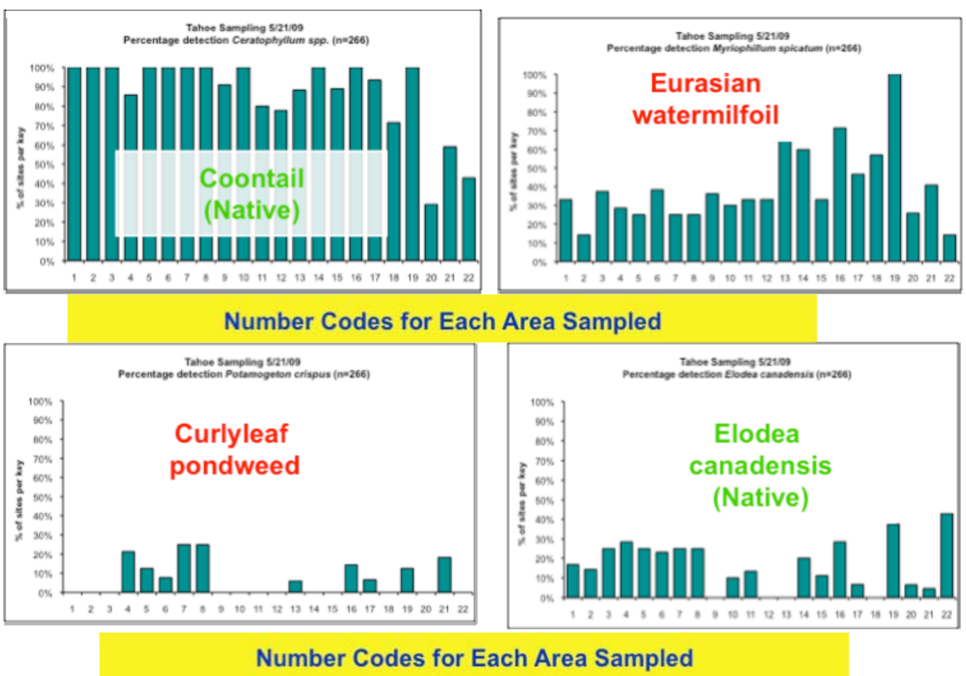


Figure 5. Relative abundance of major aquatic plants in the Tahoe Keys. Number refer to "finger" numbers shown in Fig. 3

California Regional Water Quality Control Board
Lahontan Region

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REQUEST FOR ADDITIONAL INFORMATION FOR PROPOSED DYE TRACER STUDY IN LAKE TAHOE, EL DORADO COUNTY

Thank you for responding to our request for a Report of Waste Discharge within the timeframe requested. On December 10, 2009, you submitted a Report of Waste Discharge and supplemental information to the Lahontan Regional Water Quality Control Board (Water Board) proposing the use of Rhodamine WT (RWT), a fluorescent dye, in certain parts of Lake Tahoe. You proposed to use RWT as a surrogate to determine dissipation and movement of aquatic pesticides to treat aquatic invasive weeds.

Water Board staff reviewed the proposal, including the information you submitted, and find that additional information is needed to complete your Report of Waste Discharge. The Water Board needs information about the composition and fate of RWT and about aspects of the project design, implementation, and monitoring plan. If you are unable to furnish any information requested, please include written justification for the absence.

ADDITIONAL INFORMATION REQUESTED

1. Breakdown products, accumulation, and nitrogen bioavailability: The chemical structure of RWT includes nitrogen. Given the proposed use both in the Tahoe Keys and the open lake, the breakdown constituents of the dye, potential for accumulation in bottom sediments, and the nitrogen bioavailability and quantity of the residuals are needed to determine possible water quality and toxicity impacts.

2. Justification for final target concentrations: The US EPA advisory memo (dated August 2, 1988) on rhodamine dyes directs that "the actual concentration [of dye] used should not exceed the amount required for reasonably certain detection of the dye as required to accomplish the intended purpose of the study."

According to your proposal (page 5), minimum detection levels of RWT are around 5 to 10 parts per trillion. Further, the Turner Designs field fluorometer can detect RWT at 0.01 parts per billion. The final, dispersed target concentrations requested for this study are 5 to 10 parts per billion, much higher than stated detection limits. The only justification for requested target level of RWT is to "allow flexibility". Please provide justification for the requested target levels of 5 to 10 parts per billion, which appear in excess of the amount required for reasonably certain detection of the dye.

3. Initial application concentrations: On page 6 of your proposal, it is stated that "most uses" [of RWT] result in initial concentrations 3 to 5 times the final dispersed levels, and that those initial concentrations are reduced to target levels in a few hours. Please specify maximum anticipated concentrations at initial application based on dosage rate, percent solution or mass of RWT, and anticipated initial dispersion. Discuss how maximum initial concentrations around water intakes will not exceed 10 μg/L.

4. RWT concentrations near drinking water intakes: The US EPA advisory memo directs that concentrations should not exceed 10 micrograms/liter (μg/L) when RWT is used around drinking water intakes. This limit is at the upper range of final target levels requested for this project. During RWT application, initial concentrations will likely be many times higher. Several water suppliers in the Lake Tahoe Basin pump drinking water directly from the lake in your project area; for example, intakes are located near proposed dye applications at Lakeside Marina, Logan Shoals, Rock Cribs, and Off Olympic Circle. Please provide information on how you will conduct your project to ensure that applications near water intakes will not exceed 10 μg/L, and how you will coordinate with all water suppliers to ensure that drinking water is not impacted by RWT applications. The recommended maximum concentration of RWT in drinking water is 0.1 μg/L.

5. Monitoring plan: Your proposal (page 8) states "concentrations of RWT will be determined using field fluorometers. Dye concentrations will be determined at the top, middle, and lower 30 cm of the site." Please provide a more detailed monitoring plan, including:

- Pre-application turbidity measurements
- Photo monitoring at application and detection locations, including time of photos
- RWT concentration at time intervals to determine breakdown and dilution
- Monitoring of RWT concentrations where applications are near drinking water intakes.

AUTHORITY

California Water Code (CWC) section 13260(a) requires that any person discharging or proposing to discharge waste that could affect the quality of the State waters must file a Report of Waste Discharge (RoWD) with the appropriate Regional Water Quality

Control Board, with any supporting information required by the Regional Board. The information needed for a complete RoWD is specified herein.

As a Discharger, you should understand that pursuant to CWC section 13264, no discharge may occur until the Regional Board issues either Waste Discharge Requirements (WDRs) or a waiver of WDRs, or (subject to conditions specified in section 13264(2)) until 140 days have elapsed from submittal of a complete RoWD if the Regional Board has not acted within that period.

We look forward to assisting you in this matter. If you wish to discuss this matter further, please contact either me at (530) 542-5466, or Douglas F. Smith, Chief, TMDL/Basin Planning Unit, at (530) 542-5453.

Daniel Sussman
Environmental Scientist

DSS/ALH/clhT: Rhodamine WT Incomplete RoWD.doc
File under: New File: Tahoe Keys Dye and Herbicide; Pending: El Dorado County

California Regional Water Quality Control Board
Lahontan Region

Linda S. Adams
Secretary for Environmental Protection

2501 Lake Tahoe Boulevard, South Lake Tahoe, California 96150
(530) 542-5400 • Fax (530) 544-2271
www.waterboards.ca.gov/lahontan

Arnold Schwarzenegger
Governor

February 10, 2010

Lars W.J. Anderson, PhD
USDA-ARS Exotic and Invasive Weed Research
One Shields Ave. Mail Stop #4
Davis, CA 95616

SECOND REQUEST FOR ADDITIONAL INFORMATION FOR PROPOSED DYE TRACER STUDY IN LAKE TAHOE, EL DORADO COUNTY

Thank you for your prompt response to our request for additional information. On December 10, 2009, you submitted a Report of Waste Discharge and supplemental information to the Lahontan Regional Water Quality Control Board (Water Board) proposing the use of Rhodamine WT (RWT), a fluorescent dye, in certain parts of Lake Tahoe. You proposed to use RWT as a surrogate to determine dissipation and movement of aquatic pesticides to treat aquatic invasive weeds.

On January 12, 2010 you submitted a response to our request for additional information (Response Letter). Water Board staff reviewed the additional information and find that several of the items addressed in your response require more detail.

ADDITIONAL INFORMATION REQUESTED

1. **Initial application concentrations:** Response 3 in your Response Letter indicates that it "is common to find 3 to 5 times the concentrations at and near the point of injection." Page 8 of your proposal details estimated mass of RWT to be applied in the Tahoe Keys and the combined mass of RWT to be applied in the off-shore sites. Estimates of water volumes to be treated are also provided on page 8 of your proposal. Neither the proposal nor the Response Letter detail how much RWT will be applied at each of the off-shore sites and at each of the four Tahoe Keys sites. Additionally, neither of the documents details the injection concentration of RWT (the concentration of the RWT in the solution prior to application). Provide the mass of RWT to be injected at each of the eight proposed sites, the corresponding volume of water at each site, the volume of any buffer zone, and the concentration of RWT in the pre-mixed solution. What application apparatus will be used to make confirm the injection concentrations and ensure they are not outside the range described? Describe measures to be taken to prevent the dye from concentrating in constricted basins and eddies, especially in the Tahoe Keys application areas.

A concentration of 3 to 5 times the target concentration is higher than the maximum recommended concentration near a water intake is 10 µg/L. Explain how you will prevent your maximum initial concentrations around water intakes from exceeding 10 µg/L.

2. **Concentrations Near Drinking Water Intakes:** Your response to this issue fails to take into consideration the water purveyors. Water purveyors have guidelines independent of Lahontan's objectives and often subject to direction from the Department of Public Health. In addition to discussing water intake issues with Lahontan, TRPA, and homeowners, it is imperative that you discuss this issue with the water purveyors that operate the intake systems. Please describe your plans to address this issue with the water purveyors that operate water intakes in your project area, and the public that receives water from their intakes.

3. **Monitoring Plan:** In your Response Letter you stated that our recommendations will be included the final monitoring plan and that the plan will include emergency spill procedures. Please provide the monitoring plan for your project.

AUTHORITY

California Water Code (CWC) section 13260(a) requires that any person discharging or proposing to discharge waste that could affect the quality of the State waters must file a Report of Waste Discharge (RoWD) with the appropriate Regional Water Quality Control Board, with any supporting information required by the Regional Board. The information needed for a complete RoWD is specified herein.

As a Discharger, you should understand that pursuant to CWC section 13264, no discharge may occur until the Regional Board issues either Waste Discharge Requirements (WDRs) or a waiver of WDRs, or (subject to conditions specified in section 13264(2)) until 140 days have elapsed from submittal of a complete RoWD if the Regional Board has not acted within that period.

We look forward to assisting you in this matter. If you wish to discuss this matter further, please contact either me at (530) 542-5466, or Douglas F. Smith, Chief, TMDL/Basin Planning Unit, at (530) 542-5453.

Daniel Sussman
Environmental Scientist

DSS/adw/t:/RWT_incompleteROWD2.doc
File Under: Tahoe Keys Dye and Herbicide; Pending: El Dorado County

January 12, 2009

Subject: Rhodamine WT (RWT) Proposal/ Tahoe Keys/Lake Tahoe

To: Dan Sussman
California Regional Water Quality Control Board, Lahotan Region
2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150

Dear. Mr. Sussman:
I received your letter of January 5 on January 12, 2009. Thank you for responding to my proposal to use Rhodamine WT dye as a surrogate to characterize movement and dissipation of aquatic herbicides in the Tahoe Keys and selected near-shore areas in Lake Tahoe proper. In response to your questions, please note the following.

1. Breakdown products, accumulation and nitrogen bioavailability.
The previous papers and summary I provided reflects what I have been able to find regarding breakdown of RWT. An additional search conducted January 13, 2010 provided some more information, primarily regarding sorption behavior of RWT.

a. Vasudevan et al. 2001: Points out that there are two isomers (para- and meta-) with regard to the carboxylate/ N- bound in the nitrile ring in RWT with slightly different fluorescence spectra. This paper was primarily concerned with using RWT as a groundwater tracer. However, the bottom line is their conclusion that this is a good dye for tracer studies. For our purposes, we are mainly interested in where that RWT goes and how fast it is moved and diluted from the target sites.
b. Aley, T. 2002: This is an excellent "primer" on uses of various tracer dyes, though it is primarily aimed at "groundwater" studies. ***I suggest noting the following tables***:
4. (Detection limits and "human" visual thresholds)- Note that an experienced person in the dark can detect 50 ppb and 125 ppb in the field whereas the "public" notices 1,200 ppb in the field. My experience is that 50-100 can be detected visually in the filed if one is looking for it.
5. (Sorptive properties of dyes)- Note that WRT is generally less likely to be bound up than other dyes, a characteristic that is desirable for detection of water movement over time. This table also shows that organic materials can bind it (thus these can be used as "containment and sorbents for spills").
6. and 8.(Interferences from various potential water constituents/conditions)- Again RWT has favorable characteristics.
7. (Sunlight effects)-These are probably underestimates considering the high light levels and water clarity at Lake Tahoe. This was also addressed in prior information I submitted regarding photolysis.

Regarding N- bioavailability: The molecular weight of RWT is 566.5 DA (or 566 g/mol), which includes two N-atoms. (see attached pdf #1)

Of that total mol. wt, the two N = 4.2% total. Therefore, at 10 ppb (10 g/l), *N is theoretically present at 0.42µg/l* in the final concentration proposed, but this would be available for biological uptake only if the nitrogen in all the RWT molecules were cleaved and made available as nitrate or nitrite, or ammonia. I have found no references that address or mention the "addition of N" as a concern when using RWT as a tracer in any of the papers retrieved by all the searchers that I conducted. Since Lahontan Regional Water Quality Control Board no doubt has access to water quality data from the keys and near-shore areas, I suggest that this be examined relative to the N concentration that would be introduced as part of the RWT. It is probably very unlikely that any measurable effects from the RWT-borne N would be observed with the ambient (background) levels of various forms of N that already persist in the Keys and near-shore areas. Furthermore, since only a small proportion of the Tahoe Keys total volume is proposed for dye application, over time, the initial theoretical 0.42µg/l would be greatly diluted through diffusion and water movements.

2. Final Target concentration. Since the objective of this study is to determine residence time in the Keys and near-shore areas, the standard concentration of 5-10 µg/l was chosen to provide detectable levels for several days or more so that slow flows can be characterized. It is possible that lower levels can be used, but until we are able to characterize movements, the standard concentrations allow the most flexibility in assessing movements. Secondly, although detection limits are quite low, applying initially at or near the detection does not provide enough statistical power to accurately define concentrations. This is because the movements and dissipation characteristics are unknown and because at very low concentrations, interferences can lead to high variability in readings. Thus, a 1-5 pbb initial concentration might be used once the typical movement and dissipation pattern is found, but the 5-10 ppb levels provide better (repeatable) fluorescence values when movement are unknown. If the rate(s) of movement and dissipation is slow enough, then the protocol can be adjusted to target the 5 ppb level.

3. Initial application concentrations. The practical injection of dye (or herbicides) from a small, but concentrated sources to achieve a "final", nominal concentration, will always result in initially high concentrations at point of injection(s) until the material is mixed in the water column. The objective of this study is to "mimic" the herbicide injection and thus provide a close surrogate to the actually use of herbicides. It is common to find 3 to 5x concentrations at and near the point of injection. Since RWT is highly water soluble, and since multiple nozzles are used, mixing usually requires a few hours, but this of course depends on depth, currents, and presence of a thermocline. It is impractical to attain an "instantaneous" final concentration since this would require very rapid flushing of the injection sites -i.e. recirculation of the entire volume in the presence of the dye before

"releasing" to the site. Therefore, one expects transient excursions above the 5 to 10 ppb target level, but these higher levels usually do not persist for more that a few hours.

4. Concentrations near drinking water intakes. Intakes will be identified and sites will be selected away from intakes where possible and/or intake systems will be turned off until concentrations dissipate below 10 ppb. In areas where intakes cannot be turned off, nominal target concentrations will be set at **2 ppb**. Water-intake issues will be discussed with Lahontan Water Board, TRPA and homeowners at least 45 days before proposed dye applications. Unless there is written agreement with affected homeowners or other "water users" whose intakes are in the area to be exposed to RWT, applications will not be made. For any site containing drinking water intakes, tap-water samples will be taken and fluorescence levels determined *immediately before applications and upon use of the lake water after applications are made*. If fluorescence levels exceed 0.1 ppb, then monitoring will be continued daily until levels are found below 0.1 ppm.

5. Monitoring plan. The recommendations in your January 5, 2010 letter will be included in the final monitoring plan as they are part of the normal and standard monitoring procedures to determine water movement and dissipation of RWT. The plan will include procedures for emergency spills and contact information for principals conducting the study. The expanded protocol will be sent under separate cover next week.

Additional References Cites (provided as pdfs via email attachments).

1. Structure, mol. Wt and calculations to determine "N" load in RWT.
2. Aley, T. 2002. Groundwater Tracing Handbook. The Ozark Underground Laboratory; Protem, MO. 35p.
3. Vasudevan, D., R. L. Fimmen and A. B. Franacisco. 2001. Tracer-grad rhodamine WT: Structure of constituent isomers and their sorption behavior. Environ. Sci. Technol. 35: 4089-4096.
4. Sabatini, D. A. and T. AL Austin. 1991. Characteristics of rhodamine WT and fluorescein as adsorbing ground-water tracers. Ground Water 29: 341-349.
5. Shiau, Bor-Jier, D. A. Sabatini and J. H. Harwell. 1993. Influence of rhodamine WT properties on sorption and transport in subsurface media. Ground Water 31: 913-920.
6. Keystone Aniline Corp. 2001. MSDS for Rhodamine WT. 6 p.

Sincerely,

Lars W.J. Anderson, Ph.D.

Subject: Dye study/Reply to questions
To: Doug Smith
Lahontan Regional Water Quality Control Board

Dear Doug:

Regarding question and clarifications per Dan Sussman's Feb 10, 2010 letter, please consider the following:

1. Regarding initial concentrations during injections of Rhodamine WT: In order to achieve the nominal concentration of 5 to 10 ppb (parts per billion) in the water column (depths from 4 to 10 ft.), the dye is applied using multiple nozzles at the end of flexible hoses affixed to boom. The total used in a site (e.g. .5 surface acres) is based on total water volume in the site (e.g. it would be 5 ac.ft. if the depth were 10 feet). The injection hoses are deployed near the bottom (ca. 2 -3 ft. from the bottom) and the dye concentration as it exits the nozzles are initially high until it diffuses throughout the treated site- usually a matter of a few hours depending upon actual water depth and mixing through water movement. It is not possible, nor efficient to achieve an "instant" target concentration as this would require pumping in several thousands of gallons of "pre-mixed" water. Equally important, typical applications of actual liquid herbicides are also made this way. Since the dye study is in part to serve as a surrogate, the methods should be similar.
2. Regarding drinking water intakes: The locations of the intakes will be identified, flagged and applications will not be made within 300 ft. of any intake. I understand that these locations are known and can be easily flagged. Secondly, pre- and post application monitoring will be conducted hourly at the intake sites located within 500 ft. of any application site. Similarly, for "near shore" sites, any known intakes will be avoided and no application will be made within 500 ft. of any known intake. The greater buffer for the "near shore" sites is to accommodate possible greater movement of water compared to the Keys sites. Similarly, samples will be made hourly near the bottom at any known intakes sites for 4 hours, and 24 hrs. post-application.
3. Dye Application/Monitoring Plan: The exact locations of the dye applications will be provided to the LRWQB 10 working days before target application date. The following monitoring scheduled will be used (i.e. in-situ fluorescence).
    a. Pre-application for baseline: Six stations representing three shallow and three deep areas within each site will be established with GPS coordinates (and buoys where needed) at which fluorescence will be determined 1 ft deep (from the surface), ½ depth, and 2ft. from the bottom. Thus 18 fixed samples will be made before applications.
    b. Post-applications: After application is complete, sampling will commence at the same stations/depths used for pre-application baseline monitoring at 1-hour intervals. In addition, beginning 2 hr.

post applications, continuous mid-depth sampling will be made along continuous, parallel arcs-tracks from the outer edge of the treated site at 10 ft spacing between arcs up to 50 ft. if only baseline levels are found, or continuing until dye is reduced to 2x baseline (zero) levels are found. This is the method by which the dye is “tracked’. GPS-referenced notations will be recorded during all monitoring so that resulting dye levels can be displayed as a GIS layer.

c. To minimize likelihood of accidental spillage, only the amount of dye to be used in a single site will be carried aboard, within double containers, contained within a sealed cooler that will float.
d. To minimize any potential contamination of “monitoring” vessels/equipment, a separate vessel will be used for the dye applications.
e. All application equipment will be calibrated for proper flow rate(s) and integrity of connections, pumps, and hoses before each application. This is done by pumping clear water through the systems and adjusting pumping rate to achieve known output volume over a known time, generally 15 to 30 min. period depending on size of the site.
f. Per normal operations of USDA-ARS vessels, all crew will have Coast Guard approved pfds (life jackets) that automatically inflate upon immersion.
g. Per normal safety precautions, application crew will wear proper body protection and gloves and eye protection. Clear potable water will keep about for quick wash-off in case of spillage on clothing or hands.

h. Within 48 hr. of completion of each application and monitoring operation, a written notification will be submitted to the Lahontan Water Quality Control Board summarizing total dye injected, location of site and data summary showing dye dissipation.