Tahoe Basin

Aquatic Invasive Species Risk Assessment Framework

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30 September 2023

Recommended citation: DeBruyckere, L.A., and R. Draheim. 2023. Tahoe Basin Aquatic Invasive Species Risk Assessment Framework. A report prepared for the Tahoe Regional Planning Agency. 136pp.

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The Purpose of AIS Risk Assessments

Characterized as frontline to and a cornerstone of an aquatic invasive species program (Hulme 2009; Mandrak and Cudmore 2015), aquatic invasive species (AIS) risk assessments contribute to numerous elements of prevention, monitoring, and response program activities. These include prioritizing resources for surveillance (Mahon et al. 2022), predicting establishment potential (Davidson et al. 2017), informing the development of effective legislation that lessens AIS introduction and spread (e.g., transportation, trade, and environmental policies) (Horan et al. 2002, Simberloff et al. 2005; Keller and Perrings 2011; Rickhus 2013; Mazzotti and Briggs-Gonzalez, n.d.), justifying initiatives that restrict trade, commerce, and consumer activities that contribute to AIS introduction and spread (Simberloff 2005; Roy et al. 2017; Davidson et al. 2017), evaluating the positive and negative effects of non-native species (Zhang et al. 2023), directing limited resources toward species most likely to cause harm (Reaser et al. 2020), classifying species for regulation (Ontario Ministry of Natural Resources and Forestry 2016), informing biosecurity strategies (Roy et al. 2019), compiling target lists (Srebaliene et al. 2019; Mahon et al. 2022), and informing sound management of aquatic systems, fishery resources and habitats, and aquaculture resources (Mandrak et al. 2011).

Using consistent, repeatable, reliable approaches to documenting AIS risk is critical to:

a) managing AIS at a variety of scales (e.g., internationally, nationally, regionally, and locally),

b) comparing levels of risk across species and pathways, and

c) comparing likelihood of introduction, establishment, and effects (Davidson et al. 2017; Zhang et al. 2023).

Natural resource-related risk assessment protocols and procedures have matured through time, originating in the 1970s with ecological risk assessments designed to address environmental degradation, evolving into assessments that identify stages of invasion as well as invasibility associated with specific pathways (Mazzotti and Briggs-Gonzalez, n.d.).

Types of Risk Assessments

There are three general types of risk assessments; each type of risk assessment can inform and prioritize future research by acknowledging gaps in information and uncertainties (Mandrak and Cudmore 2015):

1. **Qualitative frameworks** emphasize professional judgment to assign species to categories based on biological characteristics and climate information (Briggs-Gonzalez et al. 2016). Generally, numerical data are inadequate or unavailable and expertise is limited (Radu 2009). Issues of objectivity and consistency in professional opinions can affect qualitative assessment outcomes (Burgman et al. 1999), however, expert judgement can be structured to minimize bias

(Wittmann et al. 2014).

2. **Quantitative frameworks** incorporate case studies, verified and specific raw data, and models to predict the spread of species and associated effects. Quantitative risk incorporates numerical probabilities or descriptors (Hayes 1997; Keller et al. 2007; Davidson et al. 2017). Quantitative approaches are often favored despite their sensitivity to weighting schemes (e.g., Pheloung et al. 1999) and dependence on complete data sets, which rarely occur (Campbell 2009).

3. **Semi-qualitative frameworks** combine elements of both quantitative and qualitative risk assessments and are generally used to describe relative risk scale, e.g., low, medium, and high (Radu 2009). Accurate mathematical data is not required, and outcomes document the likelihood of producing threats and their impacts. Semi-quantitative risk assessments use quantitative data with either categorical descriptors or decision trees that incorporate arbitrary risk thresholds (Hayes 1997; Keller et al. 2007; Davidson et al. 2017). Using a semi-quantitative framework that incorporates numerous taxa and vectors considers the full invasion process from introduction to effect, and documents uncertainty (Davidson et al. 2017).

Risk Categories (sourced from US Fish and Wildlife Service, Ohio Department of Natural Resources, and Cal-IPC Inventory)

- **High risk**: Species that are considered high risk have a well-documented history of invasiveness in at least one location globally and a high or medium climate match to the location being assessed. AIS are considered high risk when scientifically credible evidence of adverse effects has been documented elsewhere with similar climate, habitat, water temperatures and biological characteristics, and if significant social and/or economic effects would occur. High risk species have several ecological impacts on physical processes, plant and animal communities, and vegetation structure, and their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most high-risk species are widely distributed ecologically.

- **Moderate risk**: These species have substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance. Ecological amplitude and distribution may range from limited to widespread (source: Cal-IPC Inventory).

- **Low risk**: Species that are considered low risk present a minimal risk of invasiveness because the climate where they are established is sufficiently different from the location being assessed and there is no evidence of invasiveness globally. AIS are considered low risk when no evidence of invasiveness is documented elsewhere, the risk of determining factors is not similar, low or minimal social and/or economic effects or benefits may occur, and there is uncertain risk (when information is insufficient to adequately determine risk, and additional information is required before a decision can be made). Low risk species can be invasive, but their ecological impacts are minor on a statewide level, or there is not enough information to characterize them as high risk. Their reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are generally limited, but these species may be locally persistent and problematic.

- **Uncertain risk:** Species that are considered uncertain risk need a more in-depth assessment to better define the species' risk to the location being assessed. This additional information will help inform decisions on where, when, and how the species may be used to minimize the risk of them becoming invasive.

Core Elements of Risk Assessments

Stohlgren and Schnase (2006) documented core elements of risk assessments, including identifying the problem, analyzing biological data (e.g., life history information, reproductive rates, dispersal size and rate, survival rates, and genetic information) associated with each species, characterizing risk for spread, documenting impacts and costs, and evaluating containment potential and costs.

The Ontario Ministry of Natural Resources and Forestry (2016) proposed risk assessment incorporate four primary categories: species' biological characteristics, harm the species has had on the natural environment (or is likely to have in the future), dispersal ability of the species, and social or economic impacts of the species. Ontario proposed a suite of risk assessment guiding principles, including focusing on species with potential or known impacts to the natural environment, using the best available information, using appropriate, peer-reviewed methods, considering the impacts of species establishment, focusing on provincial or regional impacts, using adaptive management, and aligning risk assessments and regulation of species with neighboring jurisdictions (Ontario Ministry of Natural Resources and Forestry 2016).

Roy et al. (2017) proposed that risk assessments be both consistent and maintain minimum standards that include:

1. Basic species description.
2. Likelihood of invasion.
3. Distribution, spread, and impacts.
4. Assessment of introduction pathways.
5. Assessment of impacts on biodiversity and ecosystems.
6. Assessment of impact on ecosystem services.
7. Assessment of socio-economic impacts.
8. Consideration of status (threatened or protected) of species or habitat under threat.
9. Assessment of effects of future climate change.
10. Completion possible even when there is a lack of information.
11. Documents information sources.
12. Provides a summary in a consistent and interpretable form.
13. Incorporates uncertainty; and
14. Includes quality assurance.

Lodge et al. (2016) used two components to assess the risk of aquatic species—how similar the climate is in the species' native environment compared to the recipient environment and its history of invasion in other locations.

Oregon's criteria for assessing risk includes species' natural range and habitat similarity to Oregon, invasive history, possibility of survival in Oregon, potential to prey upon native wildlife, potential to degrade the habitat of native wildlife, potential to pass disease or parasites to native wildlife, potential for competition of food, water, shelter, or space with native wildlife, potential to hybridize with native wildlife, distinguishability from other species, species categorization, and likelihood to be

commercially propagated (Oregon Division 56: Noncontrolled Classification - https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=238770).

Davidson et al. (2017) used an approach that considered species, vectors, and life history stages to reduce uncertainties associated with single species and single vector assessments, which inadequately document full invasion risk.

Chan et al. (2021) documented that species found to have higher establishment likelihood have a match in climate, prior invasion success, lower absolute fecundity, higher trophic level, and involvement in the aquarium trade.

Incorporating Uncertainty

There exists a variety of ways to incorporate uncertainty into risk assessment frameworks, including adding a qualitative approach (high, medium, low) to the assessment score (Baker et al. 2007, U.S. Army Corps of Engineers 2014), using "unknown" as an assessment category to avoid scoring a category for which adequate information does not exist, and producing a categorical description of unknown (high, medium, low) to mitigate the assessment score (Davidson et al. 2017).

Horizon Scanning

One tool in the risk assessment framework toolbox is the use of horizon scanning. Horizon scanning is the systematic examination of potential threats and opportunities (based on consensus methods). Horizon scanning is a tool used to develop initial priority lists of invasive species that have the potential to be introduced, become established and threaten economic, social, and natural resources (Roy et al. 2019). Horizon scanning supports decision making and helps identify, categorize, and prioritize potential invasive species across a variety of scales (e.g., regional to local) (Dobrzycka-Krahel and Medina-Villar 2023). The U.S. Fish and Wildlife Service initiated a series of regional horizon scans in the early 2020s to fresh water and brackish water species at risk of being introduced and establishing in geographic areas of the United States (USFWS 2023).

Figure 2. Geographic boundaries of Pacific Southwest horizon scan.

One of the regions for which a horizon scan was conducted was the Pacific Southwest, an area defined, for the purposes of the scan, as the entire states of California and Nevada, in addition to portions of Oregon that include the Klamath River basin. Advisors contributing to the horizon scan in this region identified high priority pathways, which included numerous criteria, the preferred one being the ability (or inability) to regulate or manage the pathway. The scan ultimately focused on recreational watercraft, hitchhiking in trade shipments of live organisms, and hydrologically connected reached of watersheds as the three primary pathways for analysis.

Scan advisors identified 17 countries and six states with medium or high climate similarity matches to the Pacific Southwest region, then species lists were generated based on climate match regions. Presence in the trade pathway, history of introduction elsewhere, and whether or not a species was already present in North America were primary attributes used to prioritize species for risk screening.

From an initial list of 44 species, the risk screening identified six high-risk (species has documented negative introduction effects and medium or high climate match to the Pacific Southwest region) fish, mollusk, and plant species for the Pacific Southwest. Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. nobilis*), Mexican primrose-willow (*Ludwigia octovalvis*), giant ramshorn snail (*Marisa cornuarietis*), and common river snail (*Viviparus viviparus*) had high climate matches to California, Nevada, and Oregon. False mussel (*Mytilopsis adamsi*) had a high climate match to California and a medium climate match to Nevada and Oregon.

Horizon scanning is an efficient tool to use to identify potential lists of species for which rigorous risk assessments can be completed using fine-tuned criteria specific to a region smaller in scope than the horizon scan. However, most horizon scans are limited in their outputs based on the pathways

identified for the scan and the limited scope of the scan itself. In the case of the Tahoe Basin, given the number of “uncertain” characterizations for overall risk for many of the species on the initial list of 44 species included in the USFWS Pacific Southwest horizon scan, thorough risk assessments should be completed for many of those species (Table 1), and all of the species on the list should be compared to other state and regional watch lists.

Table 1. Summary of risk screening results for 44 species in focal mollusk, fish, and plant families and genera with potential for future introduction into the Pacific Southwest via recreational watercraft, hitchhikers in live organism trade, and hydrological connection pathways. Excerpted from USFWS (2023). Species in bold are those determined to be high-risk to the Pacific Southwest. History of invasiveness categories represent the evidence for past introduction and harm caused by the species outside its native range ("High" if established and documented to cause harm, "Data Deficient" if established but harm is unknown, "No Known Nonnative Population" if no confirmed establishment outside native range). Climate match to the Pacific Southwest for each species is based on RAMP (Sanders et al. 2021) state-specific Climate 6 scores. Brackets around state abbreviations indicate that the climate match is not classified as medium or high under current climate conditions but is predicted to shift to medium or high under at least one future climate scenario. An asterisk indicates that future climate matching has not been conducted for this species to date. Full reports for each species are available at: https://fws.gov/library/categories/ecological-risk-screening.

Scientific Name	Common Name	History of Invasiveness[+]	Medium-High Climate Match	Certainty	Overall Risk for Pacific Southwest	Overall Risk for Contiguous U.S.
Asolene spixii	Spixi Snail, Zebra Apple snail	NKNP[+]	*	Low	U	U
Dreissena anatolica	--	Data Deficient	--	Low	U	U
Dreissena caputlacus	--	NKNP	CA, NV, OR	Low	U	U
Dreissena carinata	--	NKNP	CA, NV, OR	Low	U	U
Dreissena caspia	--	NKNP	CA, NV, OR	Low	U	U
Heterogen japonica	Japanese Mystery Snail	Data Deficient[+]	CA, OR, *	Medium	U	U
Heterogen lecythis	--	NKNP	--	Low	U	U
Heterogen malleata	Chinese Mystery Snail	NKNP	--	Low	U	U
Hypophthalmichthys molitrix	**Silver Carp**	**High**	**CA, NV, OR**	**Medium**	**High**	**High**
Hypophthalmichthys nobilis	**Bighead Carp**	**High**	**CA, NV, OR**	**Medium**	**High**	**High**
Ludwigia adscendens	Water Primrose	Data Deficient	CA	Low	U	U
Ludwigia affinis	--	Data Deficient	--, CA	Low	U	U
Ludwigia alternifolia	Seedbox	NKNP	CA, NV, OR	Low	U	U
Ludwigia erecta	Yerba de Jicotea	Data Deficient	CA, NV, OR	Low	U	U
Ludwigia helminthorrhiza	--	Data Deficient	CA	Low	U	U
Ludwigia hyssopifolia	Seedbox, Linear Leaf Water Primrose	Data Deficient	CA, NV, OR	Low	U	U
Ludwigia inclinata	--	NKNP	CA	Low	U	U
Ludwigia linifolia	Southeastern Primrose Willow	Data Deficient	--	Low	U	U
Ludwigia longifolia	Primrose Willow	Data Deficient	OR, CA	Low	U	U
Ludwigia octovalvis	**Mexican Primrose Willow**	**High**	**CA, NV, OR**	**Medium**	**High**	**High**
Ludwigia ovalis	Oval Ludwigia	NKNP	--	Low	U	U
Ludwigia perennis	Perennial Water Primrose	Data Deficient	CA, NV, OR	Low	U	U
Ludwigia prostrata	Creeping Water Primrose	High	--	Low	U	High

Scientific Name	Common Name	History of Invasiveness[+]	Medium-High Climate Match	Certainty	Overall Risk for Pacific Southwest	Overall Risk for Contiguous U.S.
Ludwigia sphaerocarpa	Globefruit Primrose-willow	NKNP	NV, OR	Low	U	U
Ludwigia suffruticosa	Shrubby Primrose Willow	NKNP	--, CA	Low	U	U
Marisa cornuarietis	**Giant Ramshorn Snail**	**High**	**CA, NV, OR**	**High**	**High**	**High**
Mylopharyngodon piceus	Black Carp	Data Deficient	--, *	Low	U	U
Mytilopsis adamsi	**False Mussel**	**High**	**CA**	**Medium**	**High**	**U**
Mytilopsis leucophaeta	Dark Falsemussel	High	--, *	High	U	High
Mytilopsis sallei	Santo Domingo Falsemussel	High	--, *	High	U	High
Pila globosa	Common Indian Apple Snail	NKNP	--	Low	U	U
Pila scutata	--	NKNP[+]	--, *	Low	U	U
Pomacea diffusa	Spike-topped Apple Snail	Data Deficient[+]	CA, *	Low	U	U
Pomacea haustrum	Titan Applesnail	Data Deficient[+]	--, *	Low	U	U
Pomacea paludosa	Florida Applesnail	Data Deficient[+]	--, *	Low	U	U
Pomacea urceus	Black Conch, Freshwater Conch	NKNP[+]	--,*	Low	U	U
Vallisneria australis	Ribbon Weed	Data Deficient	CA, NV, OR	Low	U	U
Vallisneria caluescens	--	NKNP	--	Low	U	U
Vallisneria nana	Tape Grass, Eelgrass	Data Deficient[+]	CA, NV *	Low	U	U
Vallisneria natans	Eelgrass	NKNP	--, *	Low	U	U
Vallisneria rubra	Rubra Giant Red	NKNP	--	Low	U	U
Vallisneria spiralis	Straight Vallisneria, Tape Grass	NKNP[+]	CA, NV, OR	Low	U	U
Vivaparus contectus	Lister's River Snail	NKNP	CA, NV, OR	Low	U	U
Viviparus vivaparus	**Common River Snail**	**High**	**CA, NV, OR**	**Medium**	**High**	**High**

[+]*The Ecological Risk Screening Summaries (ERSS) for these species were completed under a previous Standard Operating Procedures (SOP). The history of invasiveness classification listed in the ERSS uses different terms than currently used. "Uncertain" is equivalent to "No Known Nonnative Population" and "Not Documented" is equivalent to "Data Deficient."*

The number of species in the "Uncertain" category for the Pacific Southwest warrants more detailed risk assessments to determine their potential risk for the Tahoe Basin.

California, Oregon, Nevada, and Arizona Invasive Species Watch Lists

Another tool in the risk assessment framework for the Tahoe Basin is a continual review of state invasive species watch lists in states within and near the Tahoe Basin. Examples of these state lists include:

Cal-IPC Inventory has a search function that allows the user to search by Jepson regions, habitat types, and whether or not the species is characterized as being invasive or on the Watch List. As an example, filtering the list by Sierra Nevada and Sierra Nevada East, and habitat types that include freshwater systems, such as bogs, marshes, and riparian and bottomland habitats, results in a list of 26 high-ranked species. Detailed information (and corresponding scientific references), which can be used to populate a Tahoe basin-specific detailed risk assessment, can be found for each of the listed species.

California Department of Fish and Wildlife's Invasive Species Program identified aquatic invasive mammals, birds, reptiles, amphibians, fishes, and invertebrates that are currently established in California and not yet present (https://wildlife.ca.gov/Conservation/Invasives/Species).

The Oregon Invasive Species Council has created a searchable tool to compile available information for aggressive non-native species that pose a threat to Oregon's environment, economy, or public health. Species profiles include information about the species, species description, introduction pathways, and distributions. (https://www.oregoninvasivespeciescouncil.org/infohub).

Nevada Department of Agriculture has a Nevada Noxious Weed list (https://agri.nv.gov/Plant/Noxious_Weeds/Noxious_Weed_List/). Aquatic invasive species on this list could be compared with those of neighboring states, and similar to the Cal-IPC Inventory, detailed information about individual species can be located via hyperlinks for each species.

Tahoe Basin AIS

The Lake Tahoe Aquatic Plant Monitoring Program collects, analyzes, and compiles information on Lake Tahoe aquatic plants to inform control actions, which have been focused primarily on Eurasian watermilfoil (*Myriophyllum spicatum*), Curly-leaf pondweed (*Potamogeton crispus*), and Asian clams (*Corbicula fluminea*) to date. Plans are proposed to control target invasive fish in tributaries and shallow areas of Lake Tahoe using mechanical fish control methods (A Notice of Determination was completed in April 2020 and controls are scheduled to begin in 2025).

As of September 2023, the following aquatic invasive species have not been detected, and there is continuous surveillance occurring to detect numerous aquatic invasive species, including zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*)

Aquatic invasive species present in the Tahoe basin include:

- Aquatic plants
    - Eurasian watermilfoil (*Myriophyllum spicatum*)
    - Curlyleaf pondweed (*Potamogeton crispus*)

- Invertebrates

    - Asian clam (*Corbicula fluminea*)
    - Mysid shrimp (*Mysida spp.*)
    - Signal crayfish (*Pacifastacus leniusculus*)
    - New Zealand mud snails (*Potamopyrgus antipodarum*) were detected in Lake Tahoe in September of 2023

- Warmwater fish
    - Largemouth Bass (*Micropterus salmoides*)
    - Smallmouth Bass (*Micropterus dolomieu*)
    - Bluegill Sunfish (*Lepomis macrochirus*)
    - Black Crappie (*Pomoxis nigromaculatus*)
    - Bullhead Catfish (*Ameiurus melas*)

- Amphibians
    - American bullfrog (*Lithobates catesbeianus*)

For the purposes of this document, the Tahoe Basin is defined as, “The area which naturally drains into Lake Tahoe, including that Lake and the Truckee River upstream of the intersection between the Truckee River and the western boundary of Section 12, Township 15 North, Range 16 East, Mount Diablo Base and Meridian.” (Figure 2)

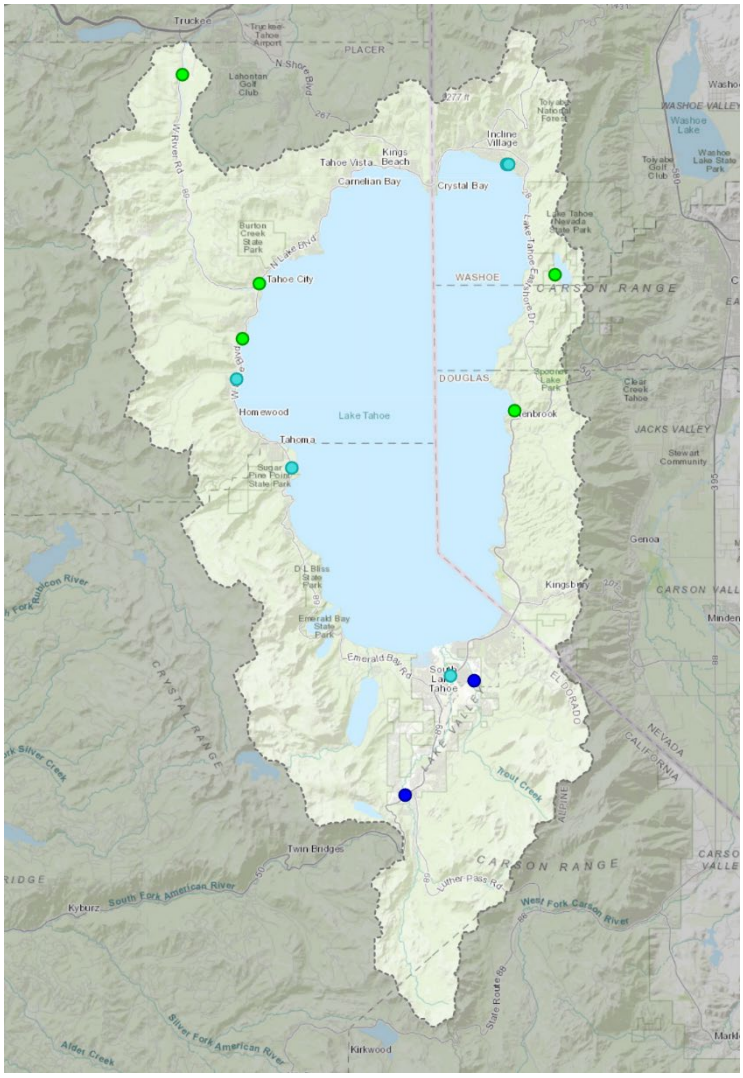


Figure 2. The Lake Tahoe Basin. Graphic credit: USGS Tahoe Hydro Mapper. https://webapps.usgs.gov/laketahoemap/

Recommendation for Risk Assessment Framework for the Tahoe Basin

The recommended approach for the Tahoe basin to assess risk of aquatic invasive species being introduced to and becoming established in the basin is to compile information at a variety of scales and from numerous sources to initially crosswalk existing horizon scans and state and regional watch lists and develop a prioritized list to conduct detailed risk assessments for individual species group by pathways of introduction.

Components of the risk assessment include potential for introduction, potential for establishment, potential environmental impact, potential socioeconomic impact, impact on culturally significant species, and a description of each species that includes information about taxonomy, invasion history, native, and introduced distribution range, and current geographic scope.

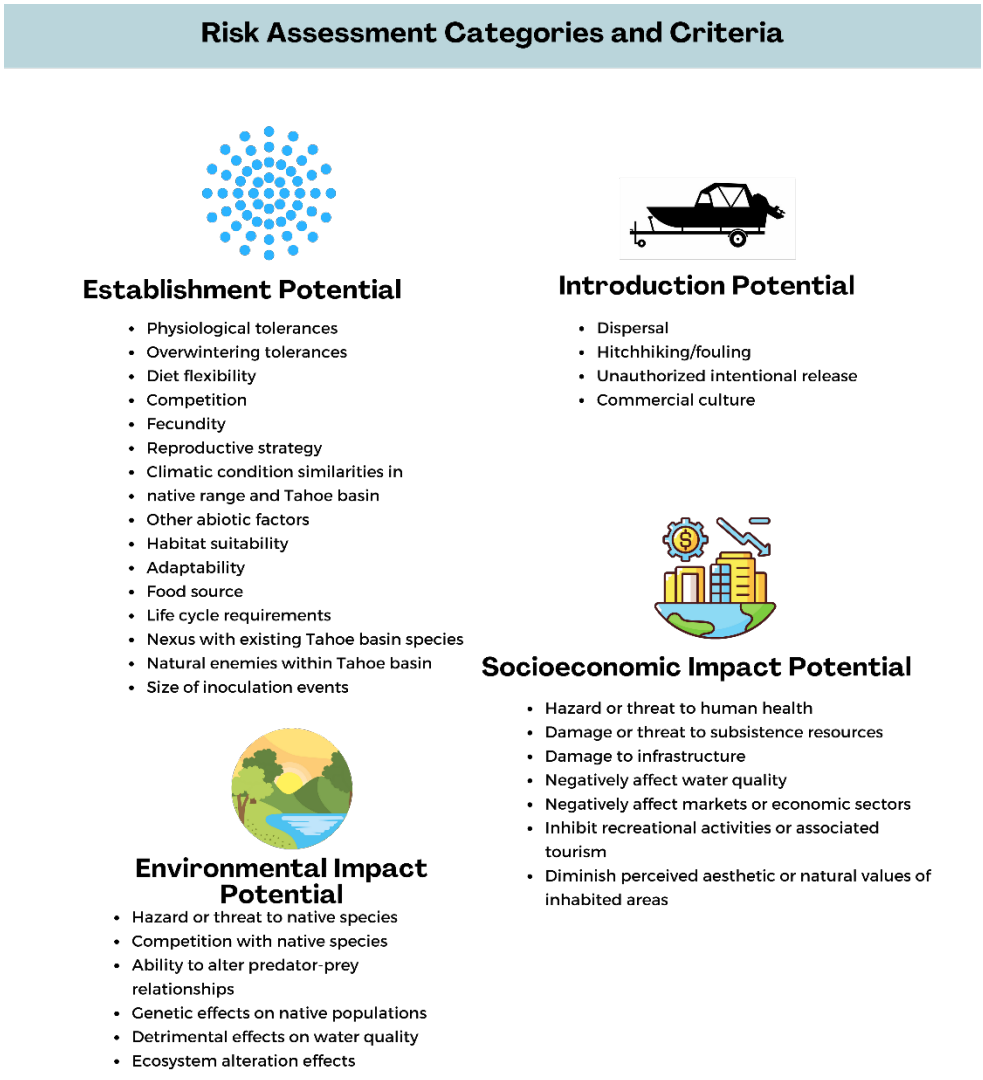
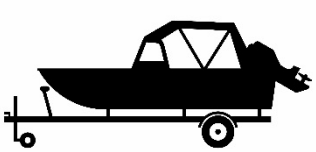


Figure 3. Risk assessment categories and criteria.



VECTOR POTENTIAL FOR INTRODUCTION

Five of the six vectors are initially scored for a species presence (100) or absence (0) in that vector. If present, a second "proximity" or "likelihood" question is answered based on expert advice. One criterion incorporates existing measures to prevent the introduction of the species.

Multiplication of the first score by the second score results in introduction potential score values. Dispersal and transport proximity thresholds of 100 miles and 50 miles are based on potential movement distances across taxa and barriers that might impede movement. Intentional release likelihood is based on access and popularity of the species, while recreational culture likelihood incorporates proximity, popularity, and regulation of the species. For each of these vectors, the multiplier score is equally divided among categories. Commercial culture has a similar division of likelihood categories based on regulation and proximity, with one additional low category for the lowest risk behavior.

The possible score values for each vector are binned into qualitative ranks, capturing the highest likelihood ("High") with a score of 80–100 (i.e., top categories of multiplied values: 80 and 100), intermediate likelihood ("Moderate") with a score of 40–79 (i.e., middle categories of multiplied values: 40, 50, and 75), lower likelihood ("Low") with a score of 1–39 (i.e. lowest categories of non-zero multiplied values: 4, 8, 10, 20, and 25), and lowest likelihood ("Unlikely") with a score of 0 (i.e., recognizing that there could still be a slight non-zero chance of introduction).

Confidence in the assessment rankings is deemed to be High if there are no unknowns, Moderate if there are unknowns for one-third or fewer of the vectors, Low if there are unknowns for more than one third of the vectors, and Very Low if there are unknowns for all but one vector.

DISPERSAL

1a. Does this species occur near waters (natural or artificial) connected to the Tahoe basin* (e.g., streams, ponds, canals, or wetlands)?

Yes, this species occurs near waters connected to the Tahoe basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Tahoe basin and/or is not mobile or able to be transported by wind or water upstream/downstream of Tahoe.	0
Unknown	U
TOTAL	

1b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 50 miles of the Tahoe basin, but dispersal to the basin is blocked; or this species occurs in waters within 100 miles of the Tahoe basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 miles of the Tahoe basin, but dispersal to the basin is blocked.	Score x 0.5
Unknown	U
TOTAL	

HITCHHIKING/FOULING

2a. Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Tahoe basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	0
Unknown	U
TOTAL	

2b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin.	Score x 1
This species occurs in waters within 100 miles of the Tahoe basin.	Score x 0.5
This species occurs in waters >100 miles from the Tahoe basin.	Score x 0.1
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a. Is this species sold at aquarium/pet/garden stores (''brick & mortar'' or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Tahoe basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0
Unknown	U
TOTAL	

3b. How easily is this species obtained within Tahoe basin states?

This species is widely popular, frequently sold, and/or easily obtained within the Tahoe basin states.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Tahoe basin states.	Score x 0.5
This species is not very popular or is not easily obtained within the Tahoe basin states.	Score x 0.1
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a. Is this species being stocked/planted to natural waters or outdoor water gardens around the Tahoe basin states?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Tahoe basin states.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Tahoe basin states.	0
Unknown	U
TOTAL	

4b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is authorized and/or is occurring directly in the Tahoe basin.	Score x 1
This activity is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin, and there are no widespread regulations against stocking/planting.	Score x 0.75
This activity is likely to occur in waters >50 miles from the Tahoe basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces).	Score x 0.5
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a. Is this species known to be commercially cultured in or transported through the Tahoe basin?

Yes, this species is being commercially cultured in or transported through the Tahoe basin.	100
No, this species in not commercially cultures in or transported through the Tahoe basin, however, it is commercially cultured elsewhere in the United States, which has led to unintentional escapes to natural water bodies.	50
No, this species is not commercially cultured in or transported through the Tahoe Basin.	0
Unknown	U
TOTAL	

5b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is unregulated or minimally regulated and is occurring directly in the Tahoe basin.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Tahoe basin, and/or this activity involves transport of live organisms on/across the Tahoe basin.	Score x 0.5
This activity is strictly regulated but occurs in Tahoe tributaries, connecting waters, or within 50 miles of the Tahoe basin, and/or this activity involves transport of live organisms within 50 miles of the Tahoe basin.	Score x 0.25
This activity occurs >50 miles from the Tahoe basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U
TOTAL	

6a. Are there any existing measures in the Tahoe basin to prevent the introduction of this species?

Yes, and they are likely to prevent introduction of the species. (There are no reported cases of this species adapting to or avoiding current measures. These measures are highly effective in preventing introduction.)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting to or avoiding current measures used to prevent introduction.)	-50% total points (at end)
Yes, but they are unlikely to prevent introduction of the species. (There are many reported cases of this species adapting to or avoiding current measures used to prevent introduction.)	-20% total points (at end)
No methods have been set to prevent its introduction.	0
Unknown	U
TOTAL	

VECTOR POTENTIAL FOR INTRODUCTION SCORECARD

Vector	Raw Points Scored	Proximity Multiplier	Total Points Scored	Probability of Introduction
Dispersal: Natural dispersal through waterbody connections or wind		x		
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		x		
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		x		
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Tahoe basin OR Accidental introduction to the Tahoe basin by escape from recreational culture (e.g., water gardens)		x		
Escape from commercial culture: Accidental introduction to Tahoe by escape from commercial culture (e.g., aquaculture)		x		

Adjustment of total score for response to 6a: _____

Potential pathway(s) of introduction:

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

POTENTIAL FOR ESTABLISHMENT

- High establishment potential = at least ¾ of the questions were scored as the maximum value "9"
- Moderate establishment potential if more than half of the questions were scored as "6" (or were evenly split with equivalent numbers of "3" and "9")
- Otherwise, Low establishment potential.

For each question, assign a value of 0 and 9, with 0 = least likely/fitting and 9 = most likely/fitting. Benchmark values for each question are provided as a guide, but the assessor may assign intermediate values based on best professional judgment. Record the tally of points (excluding deductions) and sequentially deduct percentage points (if any) from raw total. Use this score to determine establishment potential. Tally the total number of Unknown selections to determine overall confidence level.

1. How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
TOTAL	

2. How likely is it that any life stage of this species can overwinter in the Tahoe basin (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species can tolerate temperatures under 5°C and oxygen levels ≤0.5mg/L)	9
Somewhat likely (This species can tolerate some of these conditions or has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species can tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
TOTAL	

3. If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is a moderate dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
TOTAL	

4. How likely is this species to outcompete species in the Tahoe basin for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Tahoe basin)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Tahoe basin)	0
Unknown	U
TOTAL	

5. How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
TOTAL	

6. How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Tahoe basin (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Tahoe basin based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
TOTAL	

7. How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Tahoe basin?

Very similar (The climatic conditions are practically identical to those of the Tahoe basin)	9
Similar (Many of the climatic conditions are similar to those of the Tahoe basin)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	

8. How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., water temperature, salinity, pH) in the native and introduced ranges to those in the Tahoe basin?

Very similar (These factors are practically identical to those of the Tahoe basin)	9
Similar (Many of these factors are similar to those of the Tahoe basin)	6
Somewhat similar (Few of these factors are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	

9. How abundant are natural or anthropogenic habitats suitable for the survival, development, and reproduction of this species in the Tahoe basin (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
TOTAL	

10. How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Tahoe freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Tahoe basin a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Tahoe basin a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Tahoe basin a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Tahoe unsuitable)	0
Unknown	U
TOTAL	

11. How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Tahoe basin that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Tahoe that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
TOTAL	

12. Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Tahoe basin and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in parts of the Tahoe basin.	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Tahoe basin AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Tahoe basin but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Tahoe basin and is not likely to be introduced	-80% total points (at end)
Unknown	U
TOTAL	

13. How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Tahoe basin?

Likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin)	6
Somewhat unlikely (A non-indigenous species to the Tahoe that facilitates the development of this species—a major host, food item, pollinator—has already established in the Tahoe basin BUT it is still confined to a small area and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Tahoe basin that facilitates the development of this species has not been established in the Tahoe basin)	0
Unknown	U
TOTAL	

14. How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Tahoe and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Tahoe basin)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Tahoe basin.	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Tahoe basin)	-10% total points (at end)

Unlikely (Such a natural enemy is particularly rare or is not present in the Tahoe basin)	0
Unknown	U
TOTAL	

15. How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
TOTAL	

16. How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
TOTAL	

17. Are there any existing control measures that can be used in the Tahoe basin set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent the establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing its establishment and spread)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent its establishment and/or spread.	0
Unknown	U
TOTAL	

Establishment Potential Scorecard

<table>
<tr><th>Points</th><th>Probability for Establishment</th><th colspan="2">A. Total Points (pre-adjustment)</th><th></th></tr>
<tr><td rowspan="2">>100</td><td rowspan="2">High</td><td colspan="2">Adjustments</td><td></td></tr>
<tr><td>B. Critical species</td><td>A*(1- 0%)</td><td></td></tr>
<tr><td rowspan="2">51-99</td><td rowspan="2">Moderate</td><td>C. Natural enemy</td><td>B*(1- 0%)</td><td></td></tr>
<tr><td>Control measures</td><td>C*(1- 0%)</td><td></td></tr>
<tr><td>0-50</td><td>Low</td><td colspan="2">Potential for Establishment</td><td></td></tr>
<tr><td># of questions answered as ‘‘unable to determine’’</td><td>Confidence Level</td><td colspan="3"></td></tr>
<tr><td>0-1</td><td>High</td><td colspan="2" rowspan="2">Total # of questions unknown</td><td rowspan="2"></td></tr>
<tr><td>2-5</td><td>Moderate</td></tr>
<tr><td>6-9</td><td>Low</td><td colspan="2" rowspan="2">Confidence Level</td><td rowspan="2"></td></tr>
<tr><td>>9</td><td>Very low</td></tr>
</table>

POTENTIAL ENVIRONMENTAL IMPACT

- High impact potential if at least one question for an impact type is scored with the maximum value ("6") or all questions are scored with a lower value ("1").
- Moderate impact potential if no questions for an impact type are scored with the maximum value ("6"), but two to five questions are scored with a lower value ("1").
- Confidence in whether a species is likely to have a low impact or if impact potential cannot be adequately assessed is based on the combination of it scoring "Not significantly" for all but one or fewer impact types and its number of unknowns.
- If there is an impact score of "1" and one or more unknown impacts, or an impact score of "0" but two or more unknown impacts, the species is assessed overall as having "Unknown" impact potential. In that case, more research is needed to determine its potential impact. Otherwise, when most information is available and the species has a low impact score, it is deemed as having "Low" impact potential.

Complete all of the questions below. Both current and historical realized impacts from any non-native region should be considered. Add the total number of points and Unknown (U) selections for each section and use the scoring table to determine impact rank.

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

1. Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	

2. Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U
TOTAL	

3. Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end, or other significant alteration in the food web)	6

Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U
TOTAL	

4. Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U
TOTAL	

5. Does it negatively affect water quality (e.g., turbidity, altered nutrient, oxygen, chemical levels)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U
TOTAL	

6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered communities, physical or chemical changes to substrate, alters disturbance regimes)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U
TOTAL	

POTENTIAL FOR ENVIRONMENTAL IMPACT SCORECARD

Environmental Impact Total	
Total Unknowns (U)	

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	**Moderate**
0	0-1	**Low**
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

1. Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U
TOTAL	

2. Does the species pose some hazard or threat to culturally significant species important to Native American Tribes?

Yes, and it has impacted important culturally significant species, resulted in the reduction or extinction of one or more populations of culturally significant species, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations/ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	

3. Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U
TOTAL	

4. Does it negatively affect water quality (i.e., in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0
Unknown	U
TOTAL	

5. Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	

6. Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	

7. Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	

POTENTIAL FOR SOCIOECONOMIC IMPACT SCORECARD

Socio-Economic Impact Total	
Total Unknowns (U)	

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	**Moderate**
0	0-1	**Low**
1	0	
0	≥2	**Unknown**
1	≥1	

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Appendices

Appendix A. Bighead Carp (*Hypophthalmichthys nobilis*) risk assessment.

Appendix B. New Zealand Mudsnail (*Potamopyrgus antipodarum*) risk assessment.

Appendix C. Hydrilla (*Hydrilla verticillata*) risk assessment.

Appendix D. Quagga mussel (*Dreissena rostriformis bugensis*) risk assessment.

Appendix E. Alligator weed (*Alternanthera philoxeroides*) risk assessment.

Appendix F. Brazilian waterweed (*Egeria densa*) risk assessment.

Appendix A. Bighead Carp (*Hypophthalmichthys nobilis*) risk assessment.

SPECIES: *Hypophthalmichthys nobilis* (Richardson, 1845, *Leuciscus nobilis* Richardson, 1945))
COMMON NAMES: Bighead carp

DESCRIPTION: *(summarized from Nico et al. 2023)* Bighead Carp is listed as injurious by the USFWS. The filter-feeding fish is a large, narrow fish with eyes that project downward. Coloration of the body is dark gray, fading to white toward the underside, and with dark blotches on the sides. Its head has no scales, a large mouth with no teeth, and a protruding lower jaw. Its eyes are located far forward and low on its head. It is very similar to the silver carp and can be distinguished by the dark coloration on its sides. Bighead Carp can be identified by a smooth keel between the anal and pelvic fins that does not extend anterior of the base of the pelvic fins. Bighead Carp lack a true stomach, which requires them to feed almost continuously (Henderson 1976).

INITIATION: *(summarized from Nico et al. 2023)* Bighead Carp were imported into the United States in 1973 by a private fish farmer in Arkansas to improve water quality and increase fish production in culture ponds. The species was detected in the Ohio and Mississippi rivers in the early 1980s, likely a result of aquaculture facilities escapes (Jennings 1988). In April 1994, several thousand Bighead Carp, along with a few Black Carp, *Mylopharyngodon piceus*, escaped into the Osage River, Missouri. Fish that escaped into the Missouri River have increased and spread, since 1990, into the lower Kansas River of Kansas, and elsewhere (Cross and Collins 1995). The species was illegally stocked along with Grass Carp (*Ctenopharyngodon idella*) in one or a few ponds in California by a commercial aquaculturist (Dill and Cordone 1997).

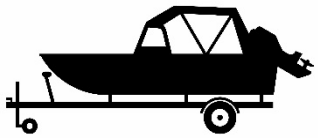
FOREIGN DISTRIBUTION: The native range of Bighead Carp is southern and central China (Li and Fang 1990, Robins et al. 1991).

U.S. DISTRIBUTION AND STATUS: Bighead Carp have been documented in 28 U.S. states (Nico et al. 2023). They were detected in 1992 in two locations in California, but both populations failed (Nico et al. 2023). For a full description of nonindigenous occurrences, visit the Great Lakes Aquatic Nonindigenous Species Information System.

RISK ASSESSMENT SUMMARY:

- Potential for introduction
    - From escape from commercial culture facilities – LOW
- Potential for establishment – MODERATE (with high confidence)
- Potential environmental impact – HIGH (with high confidence)
- Potential socio-economic impact – HIGH (with high confidence)

VECTOR POTENTIAL FOR INTRODUCTION



Five of the six vectors are initially scored for a species presence (100) or absence (0) in that vector. If present, a second "proximity" or "likelihood" question is answered based on expert advice. One criterion incorporates existing measures to prevent the introduction of the species.

Multiplication of the first score by the second score results in introduction potential score values. Dispersal and transport proximity thresholds of 100 miles and 50 miles are based on potential movement distances across taxa and barriers that might impede movement. Intentional release likelihood is based on access and popularity of the species, while recreational culture likelihood incorporates proximity, popularity, and regulation of the species. For each of these vectors, the multiplier score is equally divided among categories. Commercial culture has a similar division of likelihood categories based on regulation and proximity, with one additional low category for the lowest risk behavior.

The possible score values for each vector are binned into qualitative ranks, capturing the highest likelihood ("High") with a score of 80-100 (i.e., top categories of multiplied values: 80 and 100), intermediate likelihood ("Moderate") with a score of 40-79 (i.e., middle categories of multiplied values: 40, 50, and 75), lower likelihood ("Low") with a score of 1-39 (i.e. lowest categories of non-zero multiplied values: 4, 8, 10, 20, and 25), and lowest likelihood ("Unlikely") with a score of 0 (i.e., recognizing that there could still be a slight non-zero chance of introduction).

Confidence in the assessment rankings is deemed to be High if there are no unknowns, Moderate if there are unknowns for one-third or fewer of the vectors, Low if there are unknowns for more than one third of the vectors, and Very Low if there are unknowns for all but one vector.

DISPERSAL

1a. Does this species occur near waters (natural or artificial) connected to the Tahoe basin* (e.g., streams, ponds, canals, or wetlands)?

Yes, this species occurs near waters connected to the Tahoe basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Tahoe basin and/or is not mobile or able to be transported by wind or water upstream/downstream of Tahoe.	0
Unknown	U
TOTAL	**0**

USGS NAS: *Hypophthalmichthys nobilis* map:
https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=551
Note that the only records of bighead carp from California date back to 1992 and are classified as a failed introduction. (Nico, et al. 2023)

1b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 50 miles of the Tahoe basin, but dispersal to the basin is blocked; or this species occurs in waters within 100 miles of the Tahoe basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 miles of the Tahoe basin, but dispersal to the basin is blocked.	Score x 0.5
Unknown	U
TOTAL	

HITCHHIKING/FOULING

2a. Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Tahoe basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	0
Unknown	U
TOTAL	**0**

No records of this species being transported as a fouling species or hitchhiking were found during the literature review.

2b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin.	Score x 1
This species occurs in waters within 100 miles of the Tahoe basin.	Score x 0.5
This species occurs in waters >100 miles from the Tahoe basin.	Score x 0.1
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a. Is this species sold at aquarium/pet/garden stores (''brick & mortar'' or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Tahoe basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0
Unknown	U
TOTAL	**0**

In the United States, Bighead Carp (as well as Silver Carp, Largescale Silver Carp, and Black Carp) are federally listed as injurious species under the Lacey Act (18 U.S.C. 42; 50 CFR 16), making it illegal to import or to transport live specimens, including viable eggs or hybrids of the species, across state lines, except by permit for zoological, educational, medical, or scientific purposes. Although commercial harvest and sale of live Bighead Carp is prohibited, the harvest, transport, and improper disposal of wild-caught baitfish by anglers cannot be eliminated as potential introduction pathway as juvenile Bighead and Silver Carp species can be difficult to distinguish from some species of native baitfish common in the Midwest (e.g., Gizzard Shad (*Dorosoma cepedianum*)) (Minnesota DNR 2013).

3b. How easily is this species obtained within Tahoe basin states?

This species is widely popular, frequently sold, and/or easily obtained within the Tahoe basin states.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Tahoe basin states.	Score x 0.5
This species is not very popular or is not easily obtained within the Tahoe basin states.	Score x 0.1
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a. Is this species being stocked/planted to natural waters or outdoor water gardens around the Tahoe basin states?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Tahoe basin states	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Tahoe basin states.	0
Unknown	U
TOTAL	**0**

4b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is authorized and/or is occurring directly in the Tahoe basin.	Score x 1
This activity is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin, and there are no widespread regulations against stocking/planting.	Score x 0.75
This activity is likely to occur in waters >50 miles from the Tahoe basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces).	Score x 0.5
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a. Is this species known to be commercially cultured in or transported through the Tahoe basin?

Yes, this species is being commercially cultured in or transported through the Tahoe basin.	100
No, this species is not commercially cultured in or transported through the Tahoe basin, however, it is commercially cultured elsewhere in the United States, which has led to unintentional escapes to natural water bodies.*	50
No, this species is not commercially cultured in or transported through the Tahoe Basin.	0
Unknown	U
TOTAL	**50**

*Although not commercially cultured per se, it is unknown if the stocking of blackhead carp in fish culture ponds for water quality management purposes (as per their original importation) is a common occurrence.

5b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is unregulated or minimally regulated and is occurring directly in the Tahoe basin.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Tahoe basin, and/or this activity involves transport of live organisms on/across the Tahoe basin.	Score x 0.5
This activity is strictly regulated but occurs in Tahoe tributaries, connecting waters, or within 50 miles of the Tahoe basin, and/or this activity involves transport of live organisms within 50 miles of the Tahoe basin.	Score x 0.25
This activity occurs >50 miles from the Tahoe basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U
TOTAL	**5**

6a. Are there any existing measures in the Tahoe basin to prevent the introduction of this species?

Yes, and they are likely to prevent introduction of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing introduction.)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-50% total points (at end)
Yes, but they are unlikely to prevent introduction of the species. (There are many reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-20% total points (at end)
No methods have been set to prevent its introduction.	0
Unknown	U
TOTAL	

Both the listing of Bighead Carp as prohibited species under the provisions of the Lacey Act, as well as the prohibition on the use of live bait harvested outside of Lake Tahoe and the tributaries of the Tahoe Basin, are likely to limit if not eliminate most opportunities for unintentional or uninformed release. However, these prohibitions may not deter intentional release of Bighead Carp.

VECTOR POTENTIAL FOR INTRODUCTION SCORECARD

Vector	Raw Points Scored	Proximity Multiplier	Total Points Scored	Probability of Introduction
Dispersal: Natural dispersal through waterbody connections or wind	0	X	0	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	0	X	0	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	0	X	0	Unlikely*
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Tahoe basin OR Accidental introduction to the Tahoe basin by escape from recreational culture (e.g., water gardens)	0	Total X 0.5	0	Unlikely
Escape from commercial culture: Accidental introduction to Tahoe by escape from commercial culture (e.g., aquaculture)	50	X 0.1	5	Low
Total Unknowns (U) 0	**Confidence Level**		High	

*This species scores Unlikely for “unauthorized intentional release,” however, it does have a history of spread to other water bodies in other states via unintentional release as escapes from fish farms/aquaculture facilities (Nico, et al. 2023).

Potential pathway(s) of introduction: Release from aquaria, watercraft/trailer vector

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

POTENTIAL FOR ESTABLISHMENT

- High establishment potential = at least ¾ of the questions were scored as the maximum value "9"
- Moderate establishment potential if more than half of the questions were scored as "6" (or were evenly split with equivalent numbers of "3" and "9")
- Otherwise, Low establishment potential.

For each question, assign a value of 0 and 9, with 0 = least likely/fitting and 9 = most likely/fitting. Benchmark values for each question are provided as a guide, but the assessor may assign intermediate values based on best professional judgment. Record the tally of points (excluding deductions) and sequentially deduct percentage points (if any) from raw total. Use this score to determine establishment potential. Tally the total number of Unknown selections to determine overall confidence level.

1. How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0- saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
TOTAL	**6**

The mean annual air temperature ranges from -4 °C in the Manchurian Plain Region to 24 °C in the South (Hseih 1973). Air temperature extremes are -30 °C to 16 °C during the coolest month (January), and between 20 °C and 30 °C during the warmest month (July) (Jennings 1988).

2. How likely is it that any life stage of this species can overwinter in the Tahoe basin (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species can tolerate temperatures under 5°C and oxygen levels ≤0.5mg/L)	9
Somewhat likely (This species can tolerate some of these conditions or has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species can tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
TOTAL	**9**

From GLANSIS: Overwinter mortality may influence the northern limits of their native range but has not been modeled specifically for this species in North America. Ecological niche modeling predicted this species could survive well north of the Great Lakes basin (Herborg et al. 2007), therefore, overwinter mortality will likely not be a limiting factor in most years (Cudmore et al. 2012). In colder climates, individuals grow at slower rates and mature later in life (Cudmore et al. 2012) compared to populations in warmer conditions (Jennings 1988).

3. If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is a moderate dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3

This species is an autotroph.	0
Unknown	U
TOTAL	**3**

Cudmore et al. (2012) documented the most common effect of bigheaded carp feeding is a strong decline in crustacean zooplankton populations, even though bigheaded carps are not thought to be primarily crustacean consumers. Kolar et al. (2007) described the methods by which bigheaded carps can have this effect. Bigheaded carps also cause substantial changes in phytoplankton composition. This likely occurs from the removal of larger phytoplankton, which can often lead to an increase in picophytoplankton and smaller nanophytoplankton.

4. How likely is this species to outcompete species in the Tahoe basin for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Tahoe basin)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Tahoe basin)	0
Unknown	U
TOTAL	**6**

Bighead Carp are powerful filter-feeders, have a wide food spectrum, grow fast, and reproduce quickly (Xie and Chen 2001), which makes this species a strong competitor. Its diet overlaps with that of planktivorous species (fish and invertebrates) and to some extent with that of the young of virtually all native fishes. Bighead Carp are thought to deplete plankton stocks for native larval fishes and mussels (Laird and Page 1996).

5. How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
TOTAL	**9**

In North America, fecundity ranged from 4,792-1.6 million eggs (Kipp et al. 2011). In its native range, Silver Carp has a fecundity ranging from 299,000-5.4 million eggs (Kolar et al. 2007). In North America, it has ranged from 26,650- 3.7 million eggs (Kipp et al. 2011).

6. How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Tahoe basin (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Tahoe basin based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid	6

establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
TOTAL	**6**

Bighead carp are a highly fecund species, however, but this may be balanced by the Kolar et al. (2007) documentation that the limiting factor for invasive carp establishment in most regions of United States would be access to spawning habitat in flowing rivers.

7. How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Tahoe basin?

Very similar (The climatic conditions are practically identical to those of the Tahoe basin)	9
Similar (Many of the climatic conditions are similar to those of the Tahoe basin)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

The mean annual air temperature ranges from -4 °C in the Manchurian Plain Region to 24 °C in the South (Hseih 1973). Air temperature extremes are -30 °C to 16 °C during the coolest month (January), and between 20 °C and 30 °C during the warmest month (July) (Jennings 1988).

8. How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Tahoe basin?

Very similar (These factors are practically identical to those of the Tahoe basin)	9
Similar (Many of these factors are similar to those of the Tahoe basin)	6
Somewhat similar (Few of these factors are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

9. How abundant are natural or anthropogenic habitats suitable for the survival, development, and reproduction of this species in the Tahoe basin (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
TOTAL	**3**

Kolar et al. (2007) documented that the limiting factor for establishment in most regions of United States would be access to spawning habitat in a river.

10. How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Tahoe freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Tahoe basin a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Tahoe basin a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Tahoe basin a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Tahoe unsuitable)	0
Unknown	U
TOTAL	**6**

Bighead Carp are likely to grow faster and mature earlier under warmer climate conditions (Jennings 1988).

11. How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Tahoe basin that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Tahoe that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
TOTAL	**6**

12. Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Tahoe basin and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in parts of the Tahoe basin.	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Tahoe basin AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Tahoe basin but is likely to be introduced	0

Yes, but the critical species (or one that may provide a similar function) is not present in the Tahoe basin and is not likely to be introduced	-80% total points (at end)
Unknown	U
TOTAL	**9**

13. How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Tahoe basin?

Likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin)	6
Somewhat unlikely (A non-indigenous species to the Tahoe that facilitates the development of this species—a major host, food item, pollinator—has already established in the Tahoe basin BUT it is still confined to a small area and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Tahoe basin that facilitates the development of this species has not been established in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

14. How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Tahoe and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Tahoe basin)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Tahoe basin.	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Tahoe basin)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

15. How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
TOTAL	**9**

First imported into North America in 1973, Bighead Carp has since escaped cultivation and spread to more than 18 different states and province due to both human activities and natural means (Nico et al. 2023).

16. How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
TOTAL	**9**

First imported into North America in 1973, Bighead Carp has since escaped cultivation and spread to more than 18 different states and provinces due to both human activities and natural means (Nico et al. 2023).

17. Are there any existing control measures in the Tahoe basin set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent the establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing its establishment and spread)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent its establishment and/or spread.	0
Unknown	U
TOTAL	**0**

ESTABLISHMENT POTENTIAL SCORECARD

Points	**Probability for Establishment**	**A. Total Points (pre-adjustment)**		93
>100	High	Adjustments		
		B. Critical species	A*(1- 0%)	
51-99	Moderate	C. Natural enemy	B*(1- 0%)	
		Control measures	C*(1- 0%)	
0-50	Low	Potential for Establishment		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

POTENTIAL ENVIRONMENTAL IMPACT

- High impact potential if at least one question for an impact type is scored with the maximum value ("6") or all questions are scored with a lower value ("1").
- Moderate impact potential if no questions for an impact type are scored with the maximum value ("6"), but two to five questions are scored with a lower value ("1").
- Confidence in whether a species is likely to have a low impact or if impact potential cannot be adequately assessed is based on the combination of it scoring "Not significantly" for all but one or fewer impact types and its number of unknowns.
- If there is an impact score of "1" and one or more unknown impacts, or an impact score of "0" but two or more unknown impacts, the species is assessed overall as having "Unknown" impact potential. In that case, more research is needed to determine its potential impact. Otherwise, when most information is available and the species has a low impact score, it is deemed as having "Low" impact potential.

Complete all of the questions below. Both current and historical realized impacts from any non-native region should be considered. Add the total number of points and Unknown (U) selections for each section and use the scoring table to determine impact rank. NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

1. Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**6**

The Bighead Carp hosts two pathogens that have the potential to affect native fish species. The gill-damaging *Lernaea cyprinacea*, known as anchorworm, was found in channel catfish being cultured with Bighead Carp (Goodwin 1999). This parasite is also known to affect salmonids and eels. Anchorworm occurs worldwide, is known from 40 cyprinid species, and completes its life history on a single host (Hoole et al. 2001). Bighead carp also hosts *Bothriocephalus acheilognathi*, the invasive carp tapeworm. Although adverse effects are minimal on Bighead Carp (Kolar et al. 2005), the invasive carp tapeworm is known to have infected native fishes of concern in five states: Arizona, Colorado, Nevada, New Mexico, and Utah. As the introduced range of Bighead and Silver Carp species grows in U.S. waters, numerous native fishes, particularly, but not limited to, cyprinids, percids, and centrarchids, will likely become hosts of the invasive carp tapeworm (Kolar et al. 2005).

2. Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U
TOTAL	**6**

Within its native China, this species is considered invasive and is associated with declines in native planktivorous fishes when translocated outside their natural range (Li and Xie 2002). Xie and Chen (2001) found that stocking of Bighead Carp into the plateau lakes of China had disastrous effects on endemic fishes, particularly filter-feeding, endemic Barbless Carp (*Cyprinus pellegrini*). The catch of Barbless Carp, that once represented 50% of yield of total fishes caught, declined to 20% in the 1960s, to 10% in the early 1970s, and plummeted to <1% in the 1980s. Reducing zooplankton through consumption and competing with zooplankton for phytoplankton is likely the cause for a reduction in recruitment of juvenile sport fish in reaches where silver carp are established in the Upper Mississippi River System (Chick et al. 2020).

Lake Tahoe, which was once characterized by a relatively simple community assemblage, has experienced significant shifts in food-web dynamics and resource availability due to introduced species. The intentional introduction of mysid shrimp in the 1960s resulted in a significant shift in the zooplankton community and a corresponding decrease in water clarity in Lake Tahoe (Chandra et al. 2011). The population crash of the mysid population in 2022 led to the resurgence of native cladocerans and an increase in water clarity (Schladow 2023). It is uncertain what the introduction of a planktivore, such as Bighead Carp, known to decrease zooplankton populations, would have on Tahoe basin ecosystems.

3. Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U
TOTAL	**1**

The establishment of invasive Bighead and Silver Carp species is correlated with an alteration of the zooplankton community that potentially benefits carp. Increases in rotifer abundances directly benefit Bighead and Silver Carp because their capacities to filter very small particles far exceed those of many native fishes, and rotifers are a dominant prey item in their diets (Sampson et al. 2009, Williamson and Garvey 2005). Bighead Carp have considerable effects on zooplankton communities, primarily by decreasing the size availability within the zooplankton community (Radke and Kahl 2002; Kim et al. 2003), possibly removing a species from the size category that would be consumed effectively by other planktivores. It seems likely that carp could have the potential to alter the food web in ways that could negatively affect fishes that feed on large crustacean zooplankton (Kolar et al. 2005).

4. Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U
TOTAL	**6**

(From Lu et al. 2020): Population divergence of Bighead Carp or Silver Carp has occurred within their native rivers, whereas, within the Mississippi River Basin (MRB), an introduced region, genetic differentiation is likely taking place in Silver Carp. Interspecific hybridization between Silver and Bighead Carp species is rare within their native regions; however, extensive hybridization is observed in the MRB, likely a result of a more homogenous environment that lacks reproductive isolation barriers for the restriction of gene flow between species. Introduced Bighead Carp have overpopulated the MRB and are considered two invasive species, which strongly suggests fishing efforts are essential for fishery resource exploitation and management.

5. Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Although introduced to the United States in the 1970s to help improve water quality in aquaculture retention ponds and other fish culture enclosures, there is limited evidence that Bighead Carp are effective at improving water clarity (Nico et al. 2023). In addition, the unique contributions of the zooplankton community in Lake Tahoe to water clarity could be altered by Bighead Carp establishment.

6. Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate, alters disturbance regimes)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U
TOTAL	**6**

Alteration of the size structure and overall reduction of the zooplankton community through consumption and competition with zooplankton for phytoplankton by bighead carp is likely the cause for a reduction in the recruitment of juvenile sport fish in the Upper Mississippi River System (Chick et al. 2020).

POTENTIAL FOR ENVIRONMENTAL IMPACT SCORECARD

Environmental Impact Total	31
Total Unknowns (U)	0

Scoring		
Score	# U	**Impact**
>24	Any	**High**
15-24	Any	**Moderate**
0-15	0-1	**Low**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

1. Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U
TOTAL	**0**

2. Does the species pose some hazard or threat to culturally significant species important to Native American Tribes?

Yes, and it has impacted important culturally significant species, resulted in the reduction or extinction of one or more populations of culturally significant species, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations/ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*) are the only native trout in Lake Tahoe and are of considerable importance to the Northern Paiute Tribe and Washoe Tribe of Nevada and California.

3. Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U
TOTAL	**0**

4. Does it negatively affect water quality (i.e., in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0
Unknown	U
TOTAL	**0**

5. Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors*	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1

Not significantly	0
Unknown	U
TOTAL	**6**

*The negative impacts to commercial fisheries experienced in the Mississippi River Basin may have little to no relevance to Lake Tahoe.

6. Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

7. Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

POTENTIAL FOR SOCIOECONOMIC IMPACT SCORECARD

Socio-Economic Impact Total	**24**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>24	Any	**High**
15-24	Any	**Moderate**
0-15	0-1	**Low**

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Appendix B. New Zealand mudsnails (*Potamopyrgus antipodarum*) risk assessment.

SPECIES: *Potamopyrgus antipodaruml* (J.E. Gray, 1853)
COMMON NAMES: New Zealand mudsnail

DESCRIPTION: *(excerpted from Therriault et al. 2010):* The New Zealand mudsnail is a small freshwater gastropod in the family Hydrobiidae with a relatively elongate shell with five to seven whorls and an operculum that can be closed to prevent desiccation if removed from the water or digestion if ingested by fishes or waterfowl. Maximum size is generally 5 mm in North American populations, but it has been reported to 12 mm in its native range. All introduced populations in North America are comprised of asexually reproducing female clones with eggs that mature and hatch in a brood pouch and the young crawl away. Females mature in three months in native populations and produce 20–120 young per brood with up to six generations possible in a single year. In invaded areas, peak densities of 50,000 to 800,000 snails m^2 have been found but in the Great Lakes, densities are considerably lower (10 to 5000 m^2). New Zealand mudsnails occupy primarily freshwater habitats including lakes, ponds, springs and streams. This species is a general grazer found on numerous substrates, including mud, aquatic macrophytes, clay, concrete, fine cobble and fine sand. Preferred food includes periphyton, macrophytes and detritus, although it will readily graze on green algae or diatoms. It is preyed upon by fishes and waterfowl. The species has broad environmental tolerances.

INITIATION: New Zealand mudsnails are considered highly invasive and can be transported to new areas by people, animals, and equipment.

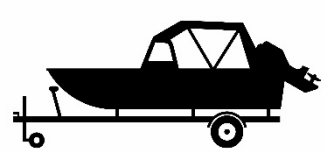
FOREIGN DISTRIBUTION: *P. antipodarum* is native to New Zealand and adjacent islands (Ponder 1988) and has been introduced to Europe, Iraq, Turkey, Japan, the Americas and Australia.

U.S. DISTRIBUTION AND STATUS: In the U.S., they have been found in all western states. In California, they are found in many lakes and river systems, including, but not limited to, the Owens, Klamath, Russian, Lower American, Stanislaus, Merced, San Joaquin, and Sacramento rivers, and many of their tributaries. In February 2016, New Zealand mudsnails were discovered in the lower Yuba and lower Feather rivers. In September 2023, they were detected in Lake Tahoe.

RISK ASSESSMENT SUMMARY:

- Potential for introduction (with high confidence):
  - From hitchhiking (e.g., watercraft) – HIGH
- Potential for establishment – HIGH (with high confidence).
- Potential environmental impact – LOW (with high confidence)
- Potential socio-economic impact – LOW (with high confidence)

VECTOR POTENTIAL FOR INTRODUCTION



Five of the six vectors are initially scored for a species presence (100) or absence (0) in that vector. If present, a second "proximity" or "likelihood" question is answered based on expert advice. One criterion incorporates existing measures to prevent the introduction of the species.

Multiplication of the first score by the second score results in introduction potential score values. Dispersal and transport proximity thresholds of 100 miles and 50 miles are based on potential movement distances across taxa and barriers that might impede movement. Intentional release likelihood is based on access and popularity of the species, while recreational culture likelihood incorporates proximity, popularity, and regulation of the species. For each of these vectors, the multiplier score is equally divided among categories. Commercial culture has a similar division of likelihood categories based on regulation and proximity, with one additional low category for the lowest risk behavior.

The possible score values for each vector are binned into qualitative ranks, capturing the highest likelihood ("High") with a score of 80-100 (i.e., top categories of multiplied values: 80 and 100), intermediate likelihood ("Moderate") with a score of 40-79 (i.e., middle categories of multiplied values: 40, 50, and 75), lower likelihood ("Low") with a score of 1-39 (i.e. lowest categories of non-zero multiplied values: 4, 8, 10, 20, and 25), and lowest likelihood ("Unlikely") with a score of 0 (i.e., recognizing that there could still be a slight non-zero chance of introduction).

Confidence in the assessment rankings is deemed to be High if there are no unknowns, Moderate if there are unknowns for one-third or fewer of the vectors, Low if there are unknowns for more than one third of the vectors, and Very Low if there are unknowns for all but one vector.

DISPERSAL

1a. Does this species occur near waters (natural or artificial) connected to the Tahoe basin* (e.g., streams, ponds, canals, or wetlands)?

Yes, this species occurs near waters connected to the Tahoe basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Tahoe basin and/or is not mobile or able to be transported by wind or water upstream/downstream of Tahoe.	0
Unknown	U
TOTAL	**100**

USGS NAS *Potamopyrgus antipodarum* map:
https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=1008
The New Zealand mudsnail (NZMS) is present in the Tahoe basin (Benson, et al. 2023)

1b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 50 miles of the Tahoe basin, but dispersal to the basin is blocked; or this species occurs in waters within 100 miles of the Tahoe basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 miles of the Tahoe basin, but dispersal to the basin is blocked.	Score x 0.5
Unknown	U

See map above. NZMS were reported from the Truckee River and the South Fork of the American River in 2021 (Benson et al. 2023).

HITCHHIKING/FOULING

2a. Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Tahoe basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	0
Unknown	U
TOTAL	**100**

NZMS were likely introduced to the western United States in the water of a shipment of live fish imported from Australia and has since been spread widely throughout the West, moving between streams and lakes by hitchhiking on fishing and boating equipment (Benson et al. 2023).

2b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin.	Score x 1
This species occurs in waters within 100 miles of the Tahoe basin.	Score x 0.5
This species occurs in waters >100 miles from the Tahoe basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a.Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Tahoe basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0
Unknown	U
TOTAL	**0**

3b. How easily is this species obtained within Tahoe basin states?

This species is widely popular, frequently sold, and/or easily obtained within the Tahoe basin states.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Tahoe basin states.	Score x 0.5
This species is not very popular or is not easily obtained within the Tahoe basin states.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a. Is this species being stocked/planted to natural waters or outdoor water gardens around the Tahoe basin states?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Tahoe basin states.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Tahoe basin states.*	0
Unknown	U
TOTAL	**0**

There is some risk associated with incidental introduction of NZMS with intentional fish stocking from infested hatcheries/transport tanks.

4b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is authorized and/or is occurring directly in the Tahoe basin.	Score x 1
This activity is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin, and there are no widespread regulations against stocking/planting.	Score x 0.75
This activity is likely to occur in waters >50 miles from the Tahoe basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces).	Score x 0.5
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a. Is this species known to be commercially cultured in or transported through the Tahoe basin?

Yes, this species is being commercially cultured in or transported through the Tahoe basin.	100
No, this species in not commercially cultures in or transported through the Tahoe basin, however, it is commercially cultured elsewhere in the United States, which has led to unintentional escapes to natural water bodies.	50
No, this species is not commercially cultured in or transported through the Tahoe Basin.	0
Unknown	U
TOTAL	**0**

5b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is unregulated or minimally regulated and is occurring directly in the Tahoe basin.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Tahoe basin, and/or this activity involves transport of live organisms on/across the Tahoe basin.	Score x 0.5
This activity is strictly regulated but occurs in Tahoe tributaries, connecting waters, or within 50 miles of the Tahoe basin, and/or this activity involves transport of live organisms within 50 miles of the Tahoe basin.	Score x 0.25
This activity occurs >50 miles from the Tahoe basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

6a. Are there any existing measures in the Tahoe basin to prevent the introduction of this species?

Yes, and they are likely to prevent introduction of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing introduction.)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-50% total points (at end)
Yes, but they are unlikely to prevent introduction of the species. (There are many reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-20% total points (at end)
No methods have been set to prevent its introduction.	0
Unknown	U
TOTAL	

The Lake Tahoe Watercraft Inspection Program substantially reduces the risk of aquatic invasive species introductions such as NZMS through boater education, mandatory inspections and decontamination services, and early detection and monitoring programs.

VECTOR POTENTIAL FOR INTRODUCTION SCORECARD

Vector	Raw Points Scored	Proximity Multiplier	Total Points Scored	Probability of Introduction
Dispersal: Natural dispersal through waterbody connections or wind	100	X 1	100	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	100	X 1	100	High
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	0	X	0	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Tahoe basin OR Accidental introduction to the Tahoe basin by escape from recreational culture (e.g., water gardens)	0	X	0	Unlikely
Escape from commercial culture: Accidental introduction to Tahoe by escape from commercial culture (e.g., aquaculture)	0	X	0	Unlikely
Total Unknowns (U) 0	**Confidence Level**		High	

Potential pathway(s) of introduction: Release from aquaria, watercraft/trailer vector

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

POTENTIAL FOR ESTABLISHMENT

- High establishment potential = at least ¾ of the questions were scored as the maximum value "9"
- Moderate establishment potential if more than half of the questions were scored as "6" (or were evenly split with equivalent numbers of "3" and "9")
- Otherwise, Low establishment potential.

For each question, assign a value of 0 and 9, with 0 = least likely/fitting and 9 = most likely/fitting. Benchmark values for each question are provided as a guide, but the assessor may assign intermediate values based on best professional judgment. Record the tally of points (excluding deductions) and sequentially deduct percentage points (if any) from raw total. Use this score to determine establishment potential. Tally the total number of Unknown selections to determine overall confidence level.

1. How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0- saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
TOTAL	**9**

The New Zealand mudsnail has been known to thrive in a wide range of fresh water and brackish habitats including lakes, rivers, streams, estuaries, and reservoirs (Benson et al. 2023). The species can tolerate a wide range of salinities, with maximum tolerances reaching 26 percent (Zaranko et al. 1997). In North America, the New Zealand mudsnail is found in freshwater streams, creeks, lakes, and estuaries in very high densities (Alonso and Castro-Diez 2008).

2. How likely is it that any life stage of this species can overwinter in the Tahoe basin (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species can tolerate temperatures under 5°C and oxygen levels ≤0.5mg/L)	9
Somewhat likely (This species can tolerate some of these conditions or has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species can tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
TOTAL	**6**

The broad range of environmental conditions tolerated by NZMS (Geist et al. 2022), combined with their mobility, makes it highly likely that NZMS could successfully overwinter even when optimal conditions for establishment are not available. NZMS can tolerate water temperatures from 0–34°C (Benson et al. 2023). However, waters with low conductivity, specifically those deficient in calcium ions, may negatively impact NZMS growth and reproduction (Geist, et al. 2022).

3. If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is a moderate dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
TOTAL	**9**

(excerpted from Therriault et al. 2010): This species is a general grazer found on numerous substrates, including mud, aquatic macrophytes, clay, concrete, fine cobble, and fine sand. Preferred food includes periphyton, macrophytes and detritus, although it will readily graze on green algae or diatoms.

4. How likely is this species to outcompete species in the Tahoe basin for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Tahoe basin)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Tahoe basin)	0
Unknown	U
TOTAL	**6**

Experimental and field observations in Wyoming, Idaho, and Montana springs and streams provide some evidence for competition with native snails, summarized by Alonso and Castro-Diez (2012). In field experiments, tiles with high densities of New Zealand Mudsnails had reduced settlement of native invertebrates (insects and mollusks, Kerans et al. 2005). In the Owens River, California, a population boom of *P. antipodarum* was accompanied by a crash of native grazers, which recovered when the snail abundance sharply declined, strongly indicative of competition (Moore et al. 2012). However, in the Columbia River estuary, a competition experiment using *P. antipodarum* and the native isopod *Gnorimosphaeroma insulare* found that snail density had no effect on isopod feeding, but isopod density reduced snail feeding (Brenneis et al. 2011).

5. How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
TOTAL	**9**

NZMS can reach densities of more than 400,000 snails per m^2 in the United States (Hall et al. 2006, Kerans et al. 2005) and are capable of between 1 and 6 generations per year depending on conditions with reproduction happening primarily in spring and summer. A single adult female can produce an average of 230–240 clonal offspring annually (CABI 2013).

6. How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Tahoe basin (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Tahoe basin based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
TOTAL	**9**

NZMS are parthenogenic brooders and are often observed releasing brooded clones under stressful conditions (Geist, et al. 2022).

7. How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Tahoe basin?

Very similar (The climatic conditions are practically identical to those of the Tahoe basin)	9
Similar (Many of the climatic conditions are similar to those of the Tahoe basin)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**9**

From Geist, et al. (2022): Across their invaded range, they have been found in high-elevation temperate streams (e.g., Hall et al. 2006), lakes and their tributaries (e.g., Zaranko et al. 1997; Levri et al. 2007), drainage ditches (e.g., Ge´rard et al. 2003), reservoirs (e.g., Lewin and Smolin´ski 2006; Lewin 2012), and estuaries and coastal waterways (e.g., Davidson et al. 2008; Brenneis et al. 2010). The variety of aquatic environments they occupy both within and outside of their native range demonstrates their tolerance and the utility of having generalist traits for invading a broad range of habitats and environmental conditions.

8. How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Tahoe basin?

Very similar (These factors are practically identical to those of the Tahoe basin)	9
Similar (Many of these factors are similar to those of the Tahoe basin)	6
Somewhat similar (Few of these factors are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

The concentration of calcium in Lake Tahoe had been thought to be a deterrent to the establishment of invasive mollusks, however, the establishment of Corbicula clams (*Corbicula fluminea*) in the ultra-oligotrophic and low calcium waters of Lake Tahoe indicates that the concentration of calcium in benthic areas, in particular sediment pore-water, may be enough to facilitate establishment of calcium-limited species (Caldwell and Chandra 2012).

9. How abundant are natural or anthropogenic habitats suitable for the survival, development, and reproduction of this species in the Tahoe basin (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
TOTAL	**9**

From Geist, et al. (2022): The invasion success of NZMS stems from opportunistic traits, and although their tolerance of broad ranges of environmental conditions facilitates spread, optimal conditions for successful NZMS establishment are evident: stable hydrology, slow water velocity, high specific conductivity, and moderate salinity.

10. How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Tahoe freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Tahoe basin a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Tahoe basin a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Tahoe basin a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Tahoe unsuitable)	0
Unknown	U
TOTAL	**9**

See answers to 7–9.

11. How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Tahoe basin that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Tahoe that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
TOTAL	**9**

As a general grazer, NZMS can utilize a variety of food sources including periphyton, macrophytes and detritus in addition to grazing on green algae or diatoms (Therriault et al. 2010).

12. Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Tahoe basin and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Tahoe basin.	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Tahoe basin AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Tahoe basin but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Tahoe basin and is not likely to be introduced	-80% total points (at end)
Unknown	U
TOTAL	**9**

No critical species is required.

13. How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Tahoe basin?

Likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin)	6
Somewhat unlikely (A non-indigenous species to the Tahoe that facilitates the development of this species—a major host, food item, pollinator—has already established in the Tahoe basin BUT it is still confined to a small area and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Tahoe basin that facilitates the development of this species has not been established in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

14. How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Tahoe and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Tahoe basin)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Tahoe basin.	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Tahoe basin)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Tahoe basin)	0

Unknown	U
TOTAL	**0**

Although predation on NZMS occurs in invaded habitats, the amount of NZMS consumption varies greatly, and it is unclear if predation is deliberate or incidental and if variation is attributable to snail density, food preference, etc. (Geist et al. 2022). Nonetheless, predation has not been shown to prevent of slow the establishment of NZMS.

15. How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
TOTAL	**9**

Although waterfowl have been implicated as a potential NZMS vector, the preponderance of overlapping NZMS populations with popular recreational locations, such as boat ramps and blue-ribbon trout streams, suggests that angling and other recreational water-related activities are a significant introduction pathway (Geist et al. 2022, Benson 2023).

6. How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
TOTAL	**9**

First reported in western North America in 1987, within 15 years, NZMS had been discovered in nearly all the western U.S. states. NZMS populations have now been confirmed in 22 states (Benson 2023).

17. Are there any existing control measures in the Tahoe basin set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent the establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing its establishment and spread)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent its establishment and/or spread.	0
Unknown	U
TOTAL	**0**

Although the Lake Tahoe Region Aquatic Invasive Species Management Plan (TRPA 2104) includes guidance on rapid response to prevent or control the establishment of species such as NZMS, the concentrations of chemicals used to kill NZMS in hatcheries and other closed systems are hazardous or lethal to co-occurring fish species and unlikely to be approved for open-water application (CABI 2013, Geist et al. 2022).

ESTABLISHMENT POTENTIAL SCORECARD

<table>
<tr><td>Points</td><td>Probability for Establishment</td><td colspan="2">A. Total Points (pre-adjustment)</td><td>117</td></tr>
<tr><td rowspan="2">>100</td><td rowspan="2">High</td><td colspan="2">Adjustments</td><td></td></tr>
<tr><td>B. Critical species</td><td>A*(1- 0%)</td><td></td></tr>
<tr><td rowspan="2">51-99</td><td rowspan="2">Moderate</td><td>C. Natural enemy</td><td>B*(1- 0%)</td><td></td></tr>
<tr><td>Control measures</td><td>C*(1- 0%)</td><td></td></tr>
<tr><td>0-50</td><td>Low</td><td colspan="2">Potential for Establishment</td><td>High</td></tr>
<tr><td># of questions answered as “unable to determine”</td><td>Confidence Level</td><td colspan="3"></td></tr>
<tr><td>0-1</td><td>High</td><td colspan="2" rowspan="2">Total # of questions unknown</td><td rowspan="2">0</td></tr>
<tr><td>2-5</td><td>Moderate</td></tr>
<tr><td>6-9</td><td>Low</td><td colspan="2" rowspan="2">Confidence Level</td><td rowspan="2">High</td></tr>
<tr><td>>9</td><td>Very low</td></tr>
</table>

POTENTIAL ENVIRONMENTAL IMPACT

- High impact potential if at least one question for an impact type is scored with the maximum value ("6") or all questions are scored with a lower value ("1").
- Moderate impact potential if no questions for an impact type are scored with the maximum value ("6"), but two to five questions are scored with a lower value ("1").
- Confidence in whether a species is likely to have a low impact or if impact potential cannot be adequately assessed is based on the combination of it scoring "Not significantly" for all but one or fewer impact types and its number of unknowns.
- If there is an impact score of "1" and one or more unknown impacts, or an impact score of "0" but two or more unknown impacts, the species is assessed overall as having "Unknown" impact potential. In that case, more research is needed to determine its potential impact. Otherwise, when most information is available and the species has a low impact score, it is deemed as having "Low" impact potential.

Complete all of the questions below. Both current and historical realized impacts from any non-native region should be considered. Add the total number of points and Unknown (U) selections for each section and use the scoring table to determine impact rank.

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

1. Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**0**

2. Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U
TOTAL	**1**

NZMS can outcompete native mollusks for space and food sources because of their large, overwhelming densities post-invasion, thus reducing the growth of native species (CABI 2013). However, these rapid density increases may not necessarily predict long term population levels or dynamics over time (Geist et al. 2022).

3. Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6

Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U
TOTAL	**1**

Experimental and field observations in Wyoming, Idaho, and Montana springs and streams provide some evidence for competition with native snails, summarized by Alonso and Castro-Diez (2012). In field experiments, tiles with high densities of New Zealand Mudsnails had reduced settlement of native invertebrates (insects and mollusks, Kerans et al. 2005). In the Owens River, California, a population boom of *P. antipodarum* was accompanied by a crash of native grazers, which recovered when the snail abundance sharply declined, strongly indicative of competition (Moore et al. 2012). However, in the Columbia River estuary, a competition experiment using *P. antipodarum* and the native isopod *Gnorimosphaeroma insulare* found that snail density had no effect on isopod feeding, but isopod density reduced snail feeding (Brenneis et al. 2011).

4. Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U
TOTAL	**0**

5. Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U
TOTAL	**1**

In instances of high density, NZMS populations and their subsequent grazing efficiency have led to record high secondary production levels and altered nutrient cycling, in particular elevated nitrogen levels (Geist, et al. 2022).

6. Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate, alters disturbance regimes)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1

Not significantly	0
Unknown	U
TOTAL	**1**

From Geist et al. (2022): In its invaded range, NZMS significantly reduced algal standing stock and periphyton biomass relative to controls (Riley et al. 2008; Kolosovich et al. 2012; Krist and Charles 2012). Moreover, NZMS grazing can alter diatom assemblages more than that of native grazers and can reduce the abundance of medium-to-large diatoms, filamentous cyanobacteria, and green algae while increasing tough, filamentous chlorophytes.

POTENTIAL FOR ENVIRONMENTAL IMPACT SCORECARD

Environmental Impact Total	**4**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>24	Any	**High**
15-24	Any	**Moderate**
0-15	0-1	**Low**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

1. Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U
TOTAL	**0**

2. Does the species pose some hazard or threat to culturally significant species important to Native American Tribes?

Yes, and it has impacted important culturally significant species, resulted in the reduction or extinction of one or more populations of culturally significant species, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations/ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**U**

It is unknown if NZMS nutrient regime effects could rise to level of impacts on Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*), the only native trout in Lake Tahoe and of considerable importance to the Northern Paiute Tribe and Washoe Tribe of Nevada and California.

3. Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U
TOTAL	**1**

Reports of NZMS impacting infrastructure seem to be limited to costs incurred by eradication efforts at hatcheries, but as a species that can occur in high densities, biofouling of water intake facilities is a possibility, although preventative measures may be taken (Benson 2023).

4. Does it negatively affect water quality (i.e., in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0
Unknown	U
TOTAL	**0**

5. Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**1**

Economic impacts have likely been observed at facilities such as infested fish hatcheries (stocking areas limited to those with established NZMS populations).

6. Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**1**

In the early years of the NZMS invasion of the western United States, sites with established NZMS populations may have experienced a decrease in angling tourism, however, NZMS are common in many states, thus it is less likely that the presence of NZMS is a deterrent to tourism. Costs incurred may be attributable to prevention efforts.

7. Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**1**

Although many new NZMS populations receive media attention, subsequent negative economic, cultural, or ecological consequences have not been documented.

POTENTIAL FOR SOCIOECONOMIC IMPACT SCORECARD

Socio-Economic Impact Total	**4**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>24	Any	**High**
15-24	Any	**Moderate**
0-15	0-1	**Low**

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Appendix C. Hydrilla (*Hydrilla verticillata*) risk assessment.

PLANT SPECIES: *Hydrilla verticillata* (L.f.) Royle (Hydrocharitaceae) (NPGS 2020).
COMMON NAMES: Hydrilla, Florida-elodea, water-thyme (NPGS 2020).

BOTANICAL DESCRIPTION: *Hydrilla verticillata* is a shallowly rooted aquatic herb that lives in freshwater habitats from a few inches to 20 feet deep and tolerates a range of environmental conditions. The leaves grow in whorls at about 2-inch intervals along the slender stems and have saw-toothed margins (Ramey 2001). It produces seed in its native range (Lal and Gopal 1993), but in the United States, it reproduces only through detached buds called turions and by fragmentation. Both monoecious and dioecious varieties are present in the United States (Ramey 2001).

INITIATION: *Hydrilla verticillata* is a Federal Noxious Weed and a U.S. invasive plant. We developed this assessment to review and summarize the traits that have made this species a significant invader.

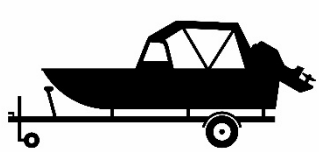
FOREIGN DISTRIBUTION: *Hydrilla verticillata* is native to Asia, Australia, tropical Africa, central to southeastern Europe, and the islands of Madagascar, Reunion, Mauritius, Great Britain, and Ireland (BSBI 2020; NPGS 2020). It is naturalized throughout South America and in Mexico, New Zealand, New Caledonia, Fiji, and the Canary Islands (NPGS 2020). It has been cultivated as an aquarium plant (Ramey 2001).

U.S. DISTRIBUTION AND STATUS: *Hydrilla verticillata* is naturalized through the United States as far north as Connecticut, on both the Atlantic and Pacific coasts (Ramey 2001), and in Puerto Rico (Jacono et al, 2020). It is more common in the eastern part of the country (Mullin et al. 2000). The monoecious biotype is most common north of South Carolina, and the dioecious biotype is most common in the southern states (Ramey 2001) and California (Yeo and McHenry 1977). There is no evidence of it being cultivated or offered for sale in the United States (Amazon 2020; Buce Plant 2020; Plant Information Online 2020), it was most likely introduced to Florida in the 1950s as an aquarium plant (Ramey 2001). It is a Federal Noxious Weed (7 CFR § 360, 2010). California and Washington initiated eradication programs (Lake County 2020; Mullin et al. 2000), and the species has been eradicated from Washington (Shearer 2014).

RISK ASSESSMENT SUMMARY:

- Potential for introduction (with high confidence):
  - From hitchhiking (e.g., watercraft) – MODERATE
  - Unauthorized intentional release as an organism in trade or recreational culture – LOW
- Potential for establishment – HIGH (with high confidence).
- Potential environmental impact – HIGH (with high confidence)
- Potential socio-economic impact – HIGH (with high confidence)

VECTOR POTENTIAL FOR INTRODUCTION



Five of the six vectors are initially scored for a species presence (100) or absence (0) in that vector. If present, a second "proximity" or "likelihood" question is answered based on expert advice. One criterion incorporates existing measures to prevent the introduction of the species.

Multiplication of the first score by the second score results in introduction potential score values. Dispersal and transport proximity thresholds of 100 miles and 50 miles are based on potential movement distances across taxa and barriers that might impede movement. Intentional release likelihood is based on access and popularity of the species, while recreational culture likelihood incorporates proximity, popularity, and regulation of the species. For each of these vectors, the multiplier score is equally divided among categories. Commercial culture has a similar division of likelihood categories based on regulation and proximity, with one additional low category for the lowest risk behavior.

The possible score values for each vector are binned into qualitative ranks, capturing the highest likelihood ("High") with a score of 80-100 (i.e., top categories of multiplied values: 80 and 100), intermediate likelihood ("Moderate") with a score of 40-79 (i.e., middle categories of multiplied values: 40, 50, and 75), lower likelihood ("Low") with a score of 1-39 (i.e. lowest categories of non-zero multiplied values: 4, 8, 10, 20, and 25), and lowest likelihood ("Unlikely") with a score of 0 (i.e., recognizing that there could still be a slight non-zero chance of introduction).

Confidence in the assessment rankings is deemed to be High if there are no unknowns, Moderate if there are unknowns for one-third or fewer of the vectors, Low if there are unknowns for more than one third of the vectors, and Very Low if there are unknowns for all but one vector.

DISPERSAL

1a. Does this species occur near waters (natural or artificial) connected to the Tahoe basin* (e.g., streams, ponds, canals, or wetlands)?

Yes, this species occurs near waters connected to the Tahoe basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Tahoe basin and/or is not mobile or able to be transported by wind or water upstream/downstream of Tahoe.	0
Unknown	U
TOTAL	**0**

Map of hydrilla distribution (USGS NAS) https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=6

1b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 50 miles of the Tahoe basin, but dispersal to the basin is blocked; or this species occurs in waters within 100 miles of the Tahoe basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 miles of the Tahoe basin, but dispersal to the basin is blocked.	Score x 0.5
Unknown	U

HITCHHIKING/FOULING

2a. Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Tahoe basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	0
Unknown	U
TOTAL	**100**

Hydrilla may be transported by recreational gear and watercraft as both plant fragments (often caught up in an anchor line or propeller or live well) or tubers that can be picked up and transported in benthic sediment (Jacono et al. 2020).

2b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin.	Score x 1
This species occurs in waters within 100 miles of the Tahoe basin.	Score x 0.5
This species occurs in waters >100 miles from the Tahoe basin.	Score x 0.1
Unknown	U

See map in 1a. This is likely conservative as Clear Lake (~200 mi away) is the closest, most recent location with a population of hydrilla (currently eradication efforts are underway at Clear Lake).

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a. Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Tahoe basin?

Yes, this species is available for purchase.	0
No, this species this species is rarely/never sold.	25
Unknown	U
TOTAL	**25**

This species, likely introduced as an aquarium species in the 1950s, is now listed by the USDA as a noxious weed making cultivation, sale, and possession of the species illegal. This however has not eliminated the risk of its being purchased or traded online either illegally or mis-identified as common waterweed (*Elodea* spp.), or collected in the wild for use in aquariums and water gardens (CCE 2022, Center for Aquatic and Invasive Plants 2023).

3b. How easily is this species obtained within Tahoe basin states?

This species is widely popular, frequently sold, and/or easily obtained within the Tahoe basin states.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Tahoe basin states.	Score x 0.5
This species is not very popular or is not easily obtained within the Tahoe basin states.	Score x 0.1
Unknown	U

Because this species is likely only intentionally obtained through limited, illegal online sales or wild collection it is difficult to quantify how easily it can be obtained.

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a. Is this species being stocked/planted to natural waters or outdoor water gardens around the Tahoe basin?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Tahoe basin.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Tahoe basin but...*	20
Unknown	U
TOTAL	**20**

In addition to being a USDA listed noxious weed, hydrilla is an A listed weed in both California and Nevada. However, it has been stocked in water gardens and ponds in the past and may have been a contaminant in shipments of other aquatic plants (Jacono et al. 2020), thus it was given a score of 20 (arbitrary, but a value greater than 0).

4b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is authorized and/or is occurring directly in the Tahoe basin.	Score x 1
This activity is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin, and there are no widespread regulations against stocking/planting.	Score x 0.75
This activity is likely to occur in waters >50 miles from the Tahoe basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces).	Score x 0.5
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a. Is this species known to be commercially cultured in or transported through the Tahoe basin?

Yes, this species is being commercially cultured in or transported through the Tahoe basin.	100
No, this species in not commercially cultures in or transported through the Tahoe basin, however, it is commercially cultured elsewhere in the United States, which has led to unintentional escapes to natural water bodies.	50
No, this species is not commercially cultured in or transported through the Tahoe Basin.	0
Unknown	U
TOTAL	**0**

See noxious weed status above.

5b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is unregulated or minimally regulated and is occurring directly in the Tahoe basin.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Tahoe basin, and/or this activity involves transport of live organisms on/across the Tahoe basin.	Score x 0.5
This activity is strictly regulated but occurs in Tahoe tributaries, connecting waters, or within 50 miles of the Tahoe basin, and/or this activity involves transport of live organisms within 50 miles of the Tahoe basin.	Score x 0.25
This activity occurs >50 miles from the Tahoe basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

6. Are there any existing measures in the Tahoe basin to prevent the introduction of this species?

Yes, and they are likely to prevent introduction of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing introduction.)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-50% total points (at end)
Yes, but they are unlikely to prevent introduction of the species. (There are many reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-20% total points (at end)
No methods have been set to prevent its introduction.	0
Unknown	U
TOTAL	

The Lake Tahoe Watercraft Inspection Program substantially reduces the risk of aquatic invasive species introductions such as hydrilla through boater education, mandatory inspections and decontamination services, and early detection and monitoring programs. Federal prohibitions against cultivation, sale and possession greatly decrease the risk of introduction through organisms in trade.

VECTOR POTENTIAL FOR INTRODUCTION SCORECARD

Vector	Raw Points Scored	Proximity Multiplier	Total Points Scored	Probability of Introduction
Dispersal: Natural dispersal through waterbody connections or wind	0	X	0	Low
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	100	X 0.5	50	Moderate
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	50	X 0.5	25	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Tahoe basin OR Accidental introduction to the Tahoe basin by escape from recreational culture (e.g., water gardens)	0	X	20	Low
Escape from commercial culture: Accidental introduction to Tahoe by escape from commercial culture (e.g., aquaculture)	0	X	0	Unlikely
Total Unknowns (U) 1	**Confidence Level**		Moderate	

Potential pathway(s) of introduction: Release from aquaria, watercraft/trailer vector

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

POTENTIAL FOR ESTABLISHMENT

- High establishment potential = at least ¾ of the questions were scored as the maximum value "9"
- Moderate establishment potential if more than half of the questions were scored as "6" (or were evenly split with equivalent numbers of "3" and "9")
- Otherwise, Low establishment potential.

For each question, assign a value of 0 and 9, with 0 = least likely/fitting and 9 = most likely/fitting. Benchmark values for each question are provided as a guide, but the assessor may assign intermediate values based on best professional judgment. Record the tally of points (excluding deductions) and sequentially deduct percentage points (if any) from raw total. Use this score to determine establishment potential. Tally the total number of Unknown selections to determine overall confidence level.

1. How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0- saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
TOTAL	**6**

APHIS PPQ estimates that 52–94 percent of the United States is suitable for establishment of hydrilla (PPQ 2020).

2. How likely is it that any life stage of this species can overwinter in the Tahoe basin (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species can tolerate temperatures under 5°C and oxygen levels ≤0.5mg/L)	9
Somewhat likely (This species can tolerate some of these conditions or has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species can tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
TOTAL	**9**

Both biotypes of hydrilla are known to overwinter as a tubers in the sediment (Jacono et al. 2020).

3. If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is a moderate dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
TOTAL	**0**

4. How likely is this species to outcompete species in the Tahoe basin for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Tahoe basin)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Tahoe basin)	0
Unknown	U
TOTAL	**9**

Hydrilla is known to form large, dense, monotypic mats capable of outshading and excluding competitors through crowding (Jacono et al. 2020).

5. How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
TOTAL	**9**

Hydrilla grows aggressively. Each stem on a hydrilla plant can grow up to 1–4 inches per day with ideal conditions. Early in the growing season, this submersed plant grows horizontally along the bottom. Side shoots and new turions develop along the stem at the nodes. With increasing water temperatures, the stems become elongated and grow up to the water surface where the stems again branch and new horizontal growth forms thick vegetative mats. These dense monocultures shade other aquatic plants, displacing beneficial and diverse native plant assemblages (Center for Aquatic and Invasive Plants 2023).

6. How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Tahoe basin (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Tahoe basin based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
TOTAL	**9**

Hydrilla reproduces by both vegetative and sexual methods. Vegetative reproduction strategies include reproduction by both stem fragmentation, e.g., hydrilla breaks apart very easily and small pieces of stem,

no more than one inch long, can produce entire new plants (CFDA 2023) as well as by the production of turions at stem nodes (Jacono et al. 2020).

7. How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Tahoe basin?

Very similar (The climatic conditions are practically identical to those of the Tahoe basin)	9
Similar (Many of the climatic conditions are similar to those of the Tahoe basin)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

The presence of other, similar aquatic plant species (both native and introduced) indicates that the climactic conditions are likely highly favorable (Tahoe Resource Conservation District 2013).

8. How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., water temperature, salinity, pH) in the native and introduced ranges to those in the Tahoe basin?

Very similar (These factors are practically identical to those of the Tahoe basin)	9
Similar (Many of these factors are similar to those of the Tahoe basin)	6
Somewhat similar (Few of these factors are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

The presence of other, similar aquatic plant species (both native and introduced) indicates that the climactic conditions are likely favorable.

9. How abundant are natural or anthropogenic habitats suitable for the survival, development, and reproduction of this species in the Tahoe basin (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
TOTAL	**9**

The presence of other, similar aquatic plant species (both native and introduced) indicates that the climactic conditions are likely favorable.

10. How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Tahoe freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Tahoe basin a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Tahoe basin a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Tahoe basin a better environment for establishment and spread of this species)	3

Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Tahoe unsuitable)	0
Unknown	U
TOTAL	**9**

Although hydrilla can successfully overwinter in sediment, this perennial invader is likely to demonstrate greater growth rates and volume with warmer water temperatures and a shorter duration of ice cover. Hydrilla is predominantly a freshwater species but can tolerate salinities up to 7ppt (CABI 2020).

11. How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Tahoe basin that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Tahoe that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
TOTAL	**9**

Given the existing challenges eradicating and controlling other invasive aquatic plants in Lake Tahoe it seems likely that all the essential conditions for aquatic weed health are present and available for hydrilla.

12. Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Tahoe basin and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Tahoe basin.	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Tahoe basin AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Tahoe basin but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Tahoe basin and is not likely to be introduced	-80% total points (at end)
Unknown	U
TOTAL	**9**

No, there is no critical species required by hydrilla.

13. How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Tahoe basin?

Likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin)	6
Somewhat unlikely (A non-indigenous species to the Tahoe that facilitates the development of this species—a major host, food item, pollinator—has already established in the Tahoe basin BUT it is still confined to a small area and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Tahoe basin that facilitates the development of this species has not been established in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

No such species that might aid in the establishment of hydrilla are known.

14. How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Tahoe and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Tahoe basin)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Tahoe basin.	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Tahoe basin)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

Herbivory of hydrilla is not known to be a significant contributor to the control of this species with exceptions made for Grass Carp (*Ctenopharyngodon idella*) (a nonspecific herbivore and an invasive species of concern in many locations) and a limited number of biocontrol options, such as weevils (CABI 2020).

15. How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
TOTAL	**9**

Hydrilla has been spread extensively throughout the globe by human activities (CABI 2020)

16. How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
TOTAL	**9**

17. Are there any existing control measures in the Tahoe basin set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent the establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing its establishment and spread)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent its establishment and/or spread.	0
Unknown	U
TOTAL	

The California Department of Food and Agriculture has an active hydrilla eradication program that has completed hydrilla eradications in 15 counties (CDFA 2023).

ESTABLISHMENT POTENTIAL SCORECARD

Points	**Probability for Establishment**	**A. Total Points (pre-adjustment)**		111
>100	High	Adjustments		
		B. Critical species	A*(1- 0%)	
51-99	Moderate	C. Natural enemy	B*(1- 0%)	
		Control measures	C*(1- 0%)	
0-50	Low	Potential for Establishment		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

POTENTIAL ENVIRONMENTAL IMPACT

- High impact potential if at least one question for an impact type is scored with the maximum value ("6") or all questions are scored with a lower value ("1").
- Moderate impact potential if no questions for an impact type are scored with the maximum value ("6"), but two to five questions are scored with a lower value ("1").
- Confidence in whether a species is likely to have a low impact or if impact potential cannot be adequately assessed is based on the combination of it scoring "Not significantly" for all but one or fewer impact types and its number of unknowns.
- If there is an impact score of "1" and one or more unknown impacts, or an impact score of "0" but two or more unknown impacts, the species is assessed overall as having "Unknown" impact potential. In that case, more research is needed to determine its potential impact. Otherwise, when most information is available and the species has a low impact score, it is deemed as having "Low" impact potential.

Complete all of the questions below. Both current and historical realized impacts from any non-native region should be considered. Add the total number of points and Unknown (U) selections for each section and use the scoring table to determine impact rank.

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

1. Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**0**

Hydrilla is a threat to native species but not for the above reasons.

2. Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U
TOTAL	**6**

Dense monocultures of hydrilla are known to shade out other aquatic plants and displace or eliminate beneficial and diverse native plant assemblages (Center for Aquatic and Invasive Plants 2023).

3. Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U
TOTAL	**6**

Colle and Shireman (1980) found reduced weight and size in sportfish when hydrilla occupied the majority of the water column, suggesting that foraging efficiency was reduced as open water and natural vegetation gradients were lost. Changes in water chemistry due to hydrilla may also be implicated in zooplankton and phytoplankton declines (Schmitz and Osborne 1984; Schmitz et al. 1993).

4. Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U
TOTAL	**6**

It shades and outcompetes native plants, as its dense mats block sunlight to submerged vegetation (Hofstra and Clayton 2014; Langeland 1996). Several species of fish grow smaller in waters infested with *H. verticillata* (Colle and Shireman, 1980), and infested waters also have smaller populations of gastropods (Colon-Gaud et al. 2004).

5. Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Hydrilla has been shown to alter the physical and chemical characteristics of lakes. Stratification of the water column (Schmitz et al. 1993; Rizzo et al. 1996), decreased oxygen levels (Pesacreta 1988), and fish kills (Rizzo et al. 1996) have been documented in waters with hydrilla.

6. Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate, alters disturbance regimes)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U
TOTAL	**6**

According to CABI (2020): Hydrilla infestations have been shown to alter the physical and chemical characteristics of lakes by affecting stratification of the water column, decreasing oxygen levels and impeding the flow of water (Jacono et al. 2020). Dense mats can shade out and outcompete native macrophyte assemblages (CDFA 2023).

POTENTIAL FOR ENVIRONMENTAL IMPACT SCORECARD

Environmental Impact Total	**30**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	**Moderate**
0	0-1	**Low**
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

1. Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U
TOTAL	**1**

Hydrilla facilitates the growth of the toxic cyanobacterium, allowing for food chain accumulation of the toxin (Dodd et al. 2016). In addition, dense mats of hydrilla can pose a drowning risk for swimmers.

2. Does the species pose some hazard or threat to culturally significant species important to Native American Tribes?

Yes, and it has impacted important culturally significant species, resulted in the reduction or extinction of one or more populations of culturally significant species, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations/ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*) are the only native trout in Lake Tahoe and are of considerable importance to the Northern Paiute Tribe and Washoe Tribe of Nevada and California.

3. Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U
TOTAL	**6**

The plant clogs canals, pumping stations, and irrigation channels and affects hydroelectric power generation (Ramey 2001; Sousa 2011). During the 1970s, it affected 500 miles of irrigation channels in California (Mullin et al. 2000).

4. Does it negatively affect water quality (i.e., in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0
Unknown	U
TOTAL	**6**

5. Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

CABI (2020) reports negative impacts to fisheries, and aquaculture from hydrilla.

6. Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

Recreational activities and their associated tourism, including as fishing, boating, swimming and sightseeing may all be negatively impacted by infestations of hydrilla (CABI 2020, Center for Aquatic and Invasive Plants 2023).

7. Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

The negative social impacts of dense monocultures of hydrilla include a decrease in both the aesthetic and recreational value of waterbodies (CABI 2020).

POTENTIAL FOR SOCIOECONOMIC IMPACT SCORECARD

Socio-Economic Impact Total	**37**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>24	Any	**High**
15-24	Any	**Moderate**
0-15	0-1	**Low**

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Appendix D. Quagga mussel (*Dreissena rostriformis bugensis*) risk assessment.

SPECIES: *Dreissena rostriformis bugensis* (Andrusov, 1897)
COMMON NAMES: Quagga mussel

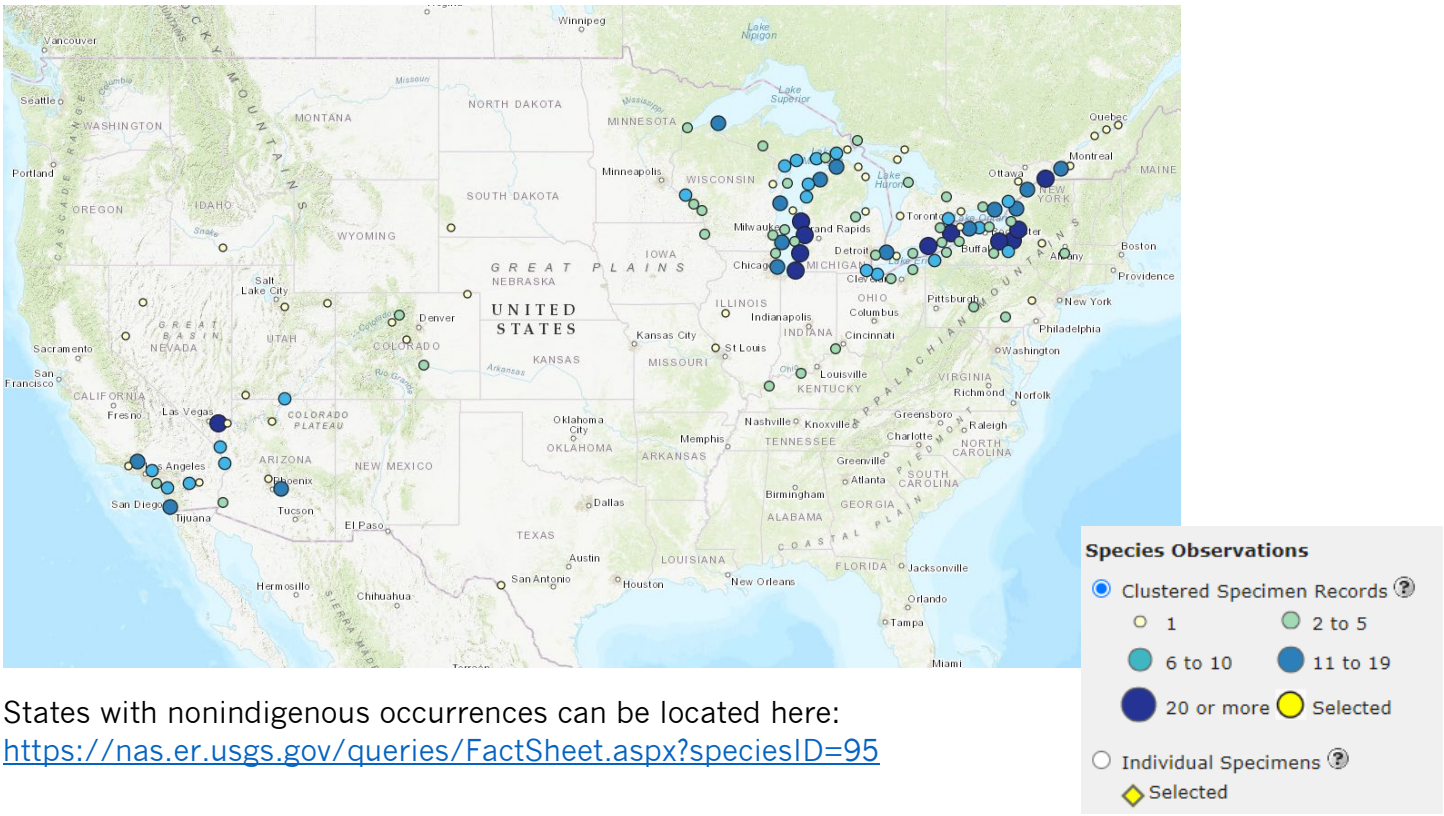
DESCRIPTION: *(summarized from Therriault et al. 2013)* the quagga mussel (*Dreissena rostriformis bugensis*) has a convex ventral surface. It displays asymmetry in valve shape and can be distinguished by the byssal groove that is located more ventrally and posteriorly than observed in the zebra mussel (*Dreissena polymorpha*). The color (black, cream or white) and band patterns of specimens are highly variable; some have no bands (Marsden et al. 1996). Where bands are visible, they are concentric and tend to fade in color towards the hinge (Benson et al. 2012b).

Quagga mussels can live and spawn in cooler, more oligotrophic conditions (Roe and MacIsaac 1997; Baldwin et al. 2002). The ability of quagga mussels to use a broad range of substrates has been proposed to be a potential fitness advantage compared to zebra mussels and relative to habitat colonization (Peyer et al., 2011). Due to their euryhalinity, quagga mussels can be found in both freshwater and brackish water (Orlova et al. 2005) and can occupy both profundal and littoral zones of lakes and rivers (Mills et al. 1996, Baldwin et al. 2002, Stoeckmann 2003). Quagga mussel salinity tolerance ranges from 0–6 ppt: 0·4 ppt is supportive of embryonic development and 6 ppt is an upper lethal limit (Rosenberg and Ludyanskiy 1994, Spidle et al., 1995, Orlova et al. 2005). In Lakes Erie and Ontario, quagga mussels have been found at depths of up to 60 m and in other Great Lakes up to 130 m (Mills et al. 1993, Mills et al. 1996, Claxton and Mackie 1998). At very shallow depths within the littoral zone of the Great Lakes dreissenids may be exposed to fatal winter conditions (primarily due to high winds, ice scour) especially if attached to mud substrates (Dermott et al. 2003). Quagga mussels do not regularly attach to submerged aquatic vegetation (Diggins et al., 2004), instead preferentially colonizing cobble and gravel (Dermott et al. 2004) or sedimentary surfaces (Mills et al. 1993). The different preferences for attachment on submerged plants (e.g., macrophytes), which can become entangled on recreational boats and boat trailers, may offer one explanation why zebra mussel dispersal across the United States has occurred much more rapidly than dispersal of quagga mussels (Benson et al. 2012a; Benson et al, 2012b). The most widely used environmental criteria to assess the potential for establishment and reproduction of this species is calcium. Thresholds for several environmental variables (e.g., temperature, pH, dissolved oxygen, calcium) are suggested to limit quagga mussel populations (Mackie and Claudi 2010).

INITIATION: *(summarized from Therriault et al. 2013)* Quagga mussels were introduced to the Laurentian Great Lakes of North America via ballast water (Hebert et al., 1989, Pathy and Mackie 1993, Therriault et al. 2004). The most studied potential vectors of secondary introduction/spread is recreational boating (attached to watercraft/trailers or entrained in livewell/bilge/lines) (Johnson and Padilla 1996, Orlova et al. 2004, Pollux et al. 2010). Dreissenid mussels also can spread via natural dispersal (e.g., drift, attachment to wildlife) or other human-mediated activities (e.g., intra-basin ballast water discharge, canal creation, waterway operations, scientific expeditions) (Johnson and Carlton 1996, Stoeckel et al.1997, Jantz and Neumann 1998, Schneider et al. 2003, Orlova et al. 2005, Ricciardi 2006). Natural dispersal is especially important for drainages where there is a large lake or reservoir that can act as a source of propagules for downstream locations (Therriault et al. 2004).

FOREIGN DISTRIBUTION: Quagga mussels are native to the Ponto-Caspian Region of Eastern Europe. The Quagga Mussel is native to the Dnieper and Bug Limans of the Black Sea basin (Van der Velde et al. 2010, Therriault and Orlova 2010).

U.S. DISTRIBUTION AND STATUS:

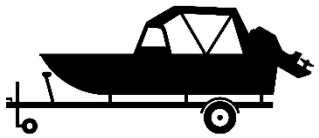


States with nonindigenous occurrences can be located here: https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=95

RISK ASSESSMENT SUMMARY:

- Potential for introduction
  - Hitchhiking/fouling – MODERATE
- Potential for establishment – HIGH (with high confidence)
- Potential environmental impact – HIGH (with high confidence)
- Potential socio-economic impact – HIGH (with high confidence)

VECTOR POTENTIAL FOR INTRODUCTION



Five of the six vectors are initially scored for a species presence (100) or absence (0) in that vector. If present, a second "proximity" or "likelihood" question is answered based on expert advice. One criterion incorporates existing measures to prevent the introduction of the species.

Multiplication of the first score by the second score results in introduction potential score values. Dispersal and transport proximity thresholds of 100 miles and 50 miles are based on potential movement distances across taxa and barriers that might impede movement. Intentional release likelihood is based on access and popularity of the species, while recreational culture likelihood incorporates proximity, popularity, and regulation of the species. For each of these vectors, the multiplier score is equally divided among categories. Commercial culture has a similar division of likelihood categories based on regulation and proximity, with one additional low category for the lowest risk behavior.

The possible score values for each vector are binned into qualitative ranks, capturing the highest likelihood ("High") with a score of 80-100 (i.e., top categories of multiplied values: 80 and 100), intermediate likelihood ("Moderate") with a score of 40-79 (i.e., middle categories of multiplied values: 40, 50, and 75), lower likelihood ("Low") with a score of 1-39 (i.e. lowest categories of non-zero multiplied values: 4, 8, 10, 20, and 25), and lowest likelihood ("Unlikely") with a score of 0 (i.e., recognizing that there could still be a slight non-zero chance of introduction).

Confidence in the assessment rankings is deemed to be High if there are no unknowns, Moderate if there are unknowns for one-third or fewer of the vectors, Low if there are unknowns for more than one third of the vectors, and Very Low if there are unknowns for all but one vector.

DISPERSAL

1a. Does this species occur near waters (natural or artificial) connected to the Tahoe basin* (e.g., streams, ponds, canals, or wetlands)?

Yes, this species occurs near waters connected to the Tahoe basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Tahoe basin and/or is not mobile or able to be transported by wind or water upstream/downstream of Tahoe.	0
Unknown	U
TOTAL	**0**

See distribution map above.

1b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 50 miles of the Tahoe basin, but dispersal to the basin is blocked; or this species occurs in waters within 100 miles of the Tahoe basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 miles of the Tahoe basin, but dispersal to the basin is blocked.	Score x 0.5
Unknown	U
TOTAL	

HITCHHIKING/FOULING

2a. Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Tahoe basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	0
Unknown	U
TOTAL	**100**

Quagga mussels, like other dreissenids, use byssal threads to attach to hard surfaces and can be transported out of water for long distances.

2b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin.	Score x 1
This species occurs in waters within 100 miles of the Tahoe basin.	Score x 0.5
This species occurs in waters >100 miles from the Tahoe basin.	Score x 0.1
Unknown	U
TOTAL	

Quagga mussels are established in Lahontan Reservoir (Lahontan State Recreation Area), Nevada, which is about 70 miles from the Tahoe basin.

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a. Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Tahoe basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0
Unknown	U
TOTAL	**0**

3b. How easily is this species obtained within Tahoe basin states?

This species is widely popular, frequently sold, and/or easily obtained within the Tahoe basin states.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Tahoe basin states.	Score x 0.5
This species is not very popular or is not easily obtained within the Tahoe basin states.	Score x 0.1
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a. Is this species being stocked/planted to natural waters or outdoor water gardens around the Tahoe basin states?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Tahoe basin states	100

No, this species cannot be stocked/planted or there is not enough interest to do so in the Tahoe basin states.	0
Unknown	U
TOTAL	**0**

The quagga mussel is a federally listed prohibited species under the Lacey Act and as such cannot be possessed, sold or transported.

4b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is authorized and/or is occurring directly in the Tahoe basin.	Score x 1
This activity is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin, and there are no widespread regulations against stocking/planting.	Score x 0.75
This activity is likely to occur in waters >50 miles from the Tahoe basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces).	Score x 0.5
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a. Is this species known to be commercially cultured in or transported through the Tahoe basin?

Yes, this species is being commercially cultured in or transported through the Tahoe basin.	100
No, this species in not commercially cultures in or transported through the Tahoe basin, however, it is commercially cultured elsewhere in the United States, which has led to unintentional escapes to natural water bodies.	50
No, this species is not commercially cultured in or transported through the Tahoe Basin.	0
Unknown	U
TOTAL	**0**

5b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is unregulated or minimally regulated and is occurring directly in the Tahoe basin.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Tahoe basin, and/or this activity involves transport of live organisms on/across the Tahoe basin.	Score x 0.5
This activity is strictly regulated but occurs in Tahoe tributaries, connecting waters, or within 50 miles of the Tahoe basin, and/or this activity involves transport of live organisms within 50 miles of the Tahoe basin.	Score x 0.25
This activity occurs >50 miles from the Tahoe basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U
TOTAL	

6a. Are there any existing measures in the Tahoe basin to prevent the introduction of this species?

Yes, and they are likely to prevent introduction of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing introduction.)	-90% total points (at end)
Yes, and they are moderately likely to prevent introduction of the species. (There are few reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-50% total points (at end)

Yes, but they are unlikely to prevent introduction of the species. (There are many reported cases of this species adapting or avoiding current measures used to prevent introduction.)	-20% total points (at end)
No methods have been set to prevent its introduction.	0
Unknown	U
TOTAL	

The Lake Tahoe Watercraft Inspection Program substantially reduces the risk of aquatic invasive species introductions such as dreissenid mussels through boater education, mandatory inspections and decontamination services, and early detection and monitoring programs.

VECTOR POTENTIAL FOR INTRODUCTION SCORECARD

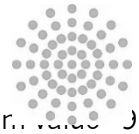
Vector	Raw Points Scored	Proximity Multiplier	Total Points Scored	Probability of Introduction
Dispersal: Natural dispersal through waterbody connections or wind	0	X	0	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	100	X 0.5	50	Moderate
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	0	X	0	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Tahoe basin OR Accidental introduction to the Tahoe basin by escape from recreational culture (e.g., water gardens)	0	X	0	Unlikely
Escape from commercial culture: Accidental introduction to Tahoe by escape from commercial culture (e.g., aquaculture)	0	X	0	Unlikely
Total Unknowns (U) 0	**Confidence Level**		High	

50-5=45

Potential pathway(s) of introduction: Watercraft/trailer vector

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate - 45
1-39	Low
0	Unlikely
# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

POTENTIAL FOR ESTABLISHMENT



- High establishment potential = at least ¾ of the questions were scored as the maximum value "9"
- Moderate establishment potential if more than half of the questions were scored as "6" (or were evenly split with equivalent numbers of "3" and "9")
- Otherwise, Low establishment potential.

For each question, assign a value of 0 and 9, with 0 = least likely/fitting and 9 = most likely/fitting. Benchmark values for each question are provided as a guide, but the assessor may assign intermediate values based on best professional judgment. Record the tally of points (excluding deductions) and sequentially deduct percentage points (if any) from raw total. Use this score to determine establishment potential. Tally the total number of Unknown selections to determine overall confidence level.

1. How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0- saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
TOTAL	**6**

Chandra et al. (2009) documented quagga mussels had an 87% survival with positive growth rate when mussels from Lake Mead in Nevada and Arizona were exposed to waters from the Tahoe Keys marina of Lake Tahoe for a 51-day period. Although Lake Tahoe had previously been categorized as low risk because of low dissolved calcium concentrations, this study demonstrated survivability and growth under Lake Tahoe conditions. Davis et al. (2015) documented quagga mussels have a higher risk of establishments in low calcium lakes if habitats within the lake have slightly elevated calcium. At least eight Coloradan limnetic ecosystems (some hydrologically connected) where dreissenids have been detected exhibit varying calcium concentrations ranging from 3.5-75 mg·L–1. Five of the eight locations that have been invaded by quagga mussels (Willow Creek Reservoirs, Lake Granby, Shadow Mountain Reservoir, Grand Lake and Blue Mesa Reservoir) have similar calcium concentrations and water quality characteristics to the oligotrophic water bodies in the Tahoe basin (Chandra et al. 2009).

2. How likely is it that any life stage of this species can overwinter in the Tahoe basin (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species can tolerate temperatures under 5°C and oxygen levels ≤0.5mg/L)	9
Somewhat likely (This species can tolerate some of these conditions or has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species can tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
TOTAL	**6**

Juvenile and adult dreissenid mussels have a broad temperature tolerance ranging from -2°C to 32°C (Karateyev et al. 1998). Low growth rates occur from 0 to 8°C or 28 to 30°C, with maximal growth rates occurring between 18 to 20°C (Claudi and Mackie 1994). De Ventura et al. (2016) documented dreissenid populations undergo rapid and convergent adaptation to local conditions after invasion, in particular to low oxygen, and that this factor should be considered when predicting spread.

3. If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is a moderate dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
TOTAL	**6**

Quagga mussels are filter feeders, consuming phytoplankton from the water column.

4. How likely is this species to outcompete species in the Tahoe basin for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Tahoe basin)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Tahoe basin)	0
Unknown	U
TOTAL	**9**

According to *Benson (2023*) quagga mussels are prodigious water filterers, removing substantial amounts of phytoplankton and suspended particulate from the water. Quagga mussels decrease the food source for zooplankton and alter the food web.

5. How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
TOTAL	**9**

The fecundity of quagga mussels is assumed to be similar to zebra mussels (Keller et al. 2007). Estimates range from 275,000-300,000 eggs per female per season (Lvova 1977, 1980) to 1,000,000 per female per season (Sprung 1991). Borcherding (1991) documented dreissenids are prolific, reproducing multiple times each season, with >1,000,000 eggs per female zebra mussel.

6. How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Tahoe basin (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Tahoe basin based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	6

Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
TOTAL	**6**

7. How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Tahoe basin?

Very similar (The climatic conditions are practically identical to those of the Tahoe basin)	9
Similar (Many of the climatic conditions are similar to those of the Tahoe basin)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

8. How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Tahoe basin?

Very similar (These factors are practically identical to those of the Tahoe basin)	9
Similar (Many of these factors are similar to those of the Tahoe basin)	6
Somewhat similar (Few of these factors are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

9. How abundant are natural or anthropogenic habitats suitable for the survival, development, and reproduction of this species in the Tahoe basin (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
TOTAL	**6**

10. How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Tahoe freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Tahoe basin a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Tahoe basin a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Tahoe basin a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Tahoe unsuitable)	0

Unknown	U
TOTAL	**9**

11. How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Tahoe basin that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Tahoe that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
TOTAL	**6**

12. Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Tahoe basin and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in parts of the Tahoe basin.	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Tahoe basin AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Tahoe basin but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Tahoe basin and is not likely to be introduced	-80% total points (at end)
Unknown	U
TOTAL	**9**

13. How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Tahoe basin?

Likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin)	6
Somewhat unlikely (A non-indigenous species to the Tahoe that facilitates the development of this species—a major host, food item, pollinator—has already established in the Tahoe basin BUT it is still confined to a small area and the likelihood of encounter with this species assessed is hard to predict)	3

Unlikely (A non-indigenous species to the Tahoe basin that facilitates the development of this species has not been established in the Tahoe basin)	0
Unknown	U
TOTAL	**U**

14. How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Tahoe and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Tahoe basin)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Tahoe basin.	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Tahoe basin)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

15. How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
TOTAL	**9**

16. How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
TOTAL	**9**

17. Are there any existing control measures in the Tahoe basin set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent the establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing its establishment and spread)	-90% total points (at end)

Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent its establishment and/or spread.	0
Unknown	U
TOTAL	**0**

ESTABLISHMENT POTENTIAL SCORECARD

Points	**Probability for Establishment**	**A. Total Points (pre-adjustment)**		102
>100	High	Adjustments		
		B. Critical species	A*(1- 0%)	
51-99	Moderate	C. Natural enemy	B*(1- 0%)	
		Control measures	C*(1- 0%)	54
0-50	Low	Potential for Establishment		Moderate
# of questions answered as ‘‘unable to determine’’	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

POTENTIAL ENVIRONMENTAL IMPACT

- High impact potential if at least one question for an impact type is scored with the maximum value ("6") or all questions are scored with a lower value ("1").
- Moderate impact potential if no questions for an impact type are scored with the maximum value ("6"), but two to five questions are scored with a lower value ("1").
- Confidence in whether a species is likely to have a low impact or if impact potential cannot be adequately assessed is based on the combination of it scoring "Not significantly" for all but one or fewer impact types and its number of unknowns.
- If there is an impact score of "1" and one or more unknown impacts, or an impact score of "0" but two or more unknown impacts, the species is assessed overall as having "Unknown" impact potential. In that case, more research is needed to determine its potential impact. Otherwise, when most information is available and the species has a low impact score, it is deemed as having "Low" impact potential.

Complete all of the questions below. Both current and historical realized impacts from any non-native region should be considered. Add the total number of points and Unknown (U) selections for each section and use the scoring table to determine impact rank.

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

1. Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Establishment of dreissenids in the lower Laurential Great Lakes was associated with a 90% decline in unionid mussel abundance within 10 years and concomitant losses of mussel diversity (COSEWIC 2007).

2. Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U
TOTAL	**6**

Establishment of dreissenids in the lower Laurential Great Lakes was associated with a 90% decline in unionid mussel abundance within 10 years and concomitant losses of mussel diversity (COSEWIC 2007). Numerous endangered mussel species have been affected by the introduction and establishment of dreissenids in the Great Lakes (e.g. Rainbow mussel (*Villosa iris*), Wavy-rayed Lampmussel (*Lampsilis Fasciola*) (COSEWIC 2007).

3. Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U
TOTAL	**6**

See documentation from two categories above.

4. Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U
TOTAL	**6**

5. Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Impacts associated with the filtration of water include increases in water transparency, decreases in mean chlorophyll *a* concentrations, and accumulation of pseudofeces (Claxton et al. 1998). Water clarity increases light penetration causing a proliferation of aquatic plants that can change species dominance and alter the entire ecosystem. The pseudofeces that is produced from filtering the water accumulates and creates a foul environment. As the waste particles decompose, oxygen is consumed, and the pH becomes very acidic and toxic byproducts are produced. In addition, quagga mussels accumulate organic pollutants within their tissues to levels more than 300,000 times greater than concentrations in the environment. These pollutants are found in their pseudofeces, which can be passed up the food chain, therefore increasing wildlife exposure to organic pollutants (Snyder et al. 1997). Macksasitorn et al. (2015) found that mussel tissue polychlorinated biphenyl (PCB) concentration was positively related to sediment PCB levels, suggesting that quagga (and zebra) mussels might provide an entry point for PCBs into near-shore benthic trophic webs.

6. Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate, alters disturbance regimes)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U
TOTAL	**6**

See section above.

POTENTIAL FOR ENVIRONMENTAL IMPACT SCORECARD

Environmental Impact Total	36
Total Unknowns (U)	0

Scoring		
Score	# U	**Impact**
>24	Any	**High**
15-24	Any	**Moderate**
0-15	0-1	**Low**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

1. Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U
TOTAL	**6**

The pseudofeces that is produced from filtering the water accumulates and creates a foul environment (Claxton et al. 1998). As the waste particles decompose, oxygen is consumed, and the pH becomes very acidic and toxic byproducts are produced. In addition, quagga mussels accumulate organic pollutants within their tissues to levels more than 300,000 times greater than concentrations in the environment. These pollutants are found in their pseudofeces, which can be passed up the food chain, therefore increasing wildlife exposure to organic pollutants (Snyder et al. 1997). Macksasitorn et al. (2015) found that mussel tissue polychlorinated biphenyl (PCB) concentration was positively related to sediment PCB levels, suggesting that quagga (and zebra) mussels might provide an entry point for PCBs into near-shore benthic trophic webs.

2. Does the species pose some hazard or threat to culturally significant species important to Native American Tribes?

Yes, and it has impacted important culturally significant species, resulted in the reduction or extinction of one or more populations of culturally significant species, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations/ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*) are the only native trout in Lake Tahoe and are of considerable importance to the Northern Paiute Tribe and Washoe Tribe of Nevada and California.

3. Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U
TOTAL	**6**

Dreissenid mussels grow on a variety of infrastructure systems, including water intake pipes for drinking water, irrigation, power plants, locks, and dams and canal systems, greatly impacting operation and maintenance costs (ISAC 2016). Continual attachment can increase corrosion rates of steel and concrete (USGS 2016), leaving equipment and infrastructure vulnerable to failure. Additionally, the mussels grow

on navigational buoys, docks, and hulls of boats and ships—increasing drag, affecting steering, and clogging engine intakes—all of which can lead to overheating and engine malfunctions (ISAC 2016).

4. Does it negatively affect water quality (i.e., in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	3
Not significantly	0
Unknown	U
TOTAL	**3**

Quagga and zebra mussels filter particles from the water, resulting in improved water clarity (Karatayev et al. 1997, 2002), and corresponding increases in benthification (Mills et al. 2003). Scientists refer to this as "turning ecosystems upside down" because of the transfer of energy to littoral areas with concurrent increases in benthic biomass (Mayer et al. 2014; Rumzie et al. 2021). Water systems infested with dreissenids must be treated to improve the taste of the water and allow for water to be delivered through pipes and screens (see section below).

5. Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

Invasive mussels pose serious threats to water resources hydropower infrastructure and operations (Rumzie et al. 2021). Invasive mussels can affect all facility components exposed to raw water; mussels can clog pipelines and water intakes and disrupt operations at hydroelectric power plants, municipal water supply facilities, and conveyance systems used in irrigation, resulting in water lines incapable of supplying a consistent and reliable source of water (Vissichelli 2018). Smell, bacteria, and decay are other key issues associated with a mussel infestation; management response is continual cleaning, treatment, mitigation filters, and other actions. A 2021 study of costs associated with invasive mussel impacts and management at 13 hydropower facilities in Canada and the United States (Rumzie et al. 2021) documented costs associated with established invasive mussels in both preventative control measures and increased maintenance.

- Preventative control capital costs (one-time costs) ranged from $100,000 to $200,000 per facility
- Preventative control annual costs ranged from $4,000 to $141,700 per facility
- Increased maintenance reoccurring costs ranged from $22,000 to $505,000 per facility
- Increased maintenance annual costs ranged from $26,000 to $112,000 per facility
- Annual monitoring costs ranged from $1,970 to $47,245 per facility
- Unplanned outages cost per occurrence ranged from $44,000 to $80,000 per facility
- Unplanned outages total cost was $849,000

Examples of preventative and maintenance costs include treating with chlorine, cleaning generator coolers 3-4 times per year to remove mussel debris, and increased labor costs to maintain all hydropower equipment.

The cost to remove mussels and manage drinking water intakes at Hoover, Davis, and Parker Dams, three facilities with invasive mussel infestations on the Colorado River, was more than $6,026,100 in 2016. Mussel-related costs at Hoover, Davis, and Parker Dams through 2016 totaled $6,025,100, and expected costs from 2017 to 2026 totaled $10,372,108 (Boyd 2016). The State of Washington estimated direct impacts to dams from invasive mussels is $42.9 million (Community Attributes 2017). The cost for the management response is passed to the consumer (Vissichelli 2018).

6. Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

The shells from dead dreissenid mussels can wash ashore, smothering beaches and potentially injuring swimmers and other water recreationalists from cuts sustained from the shells' sharp edges (Nelson 2019). The California Department of Fish and Wildlife (2020) produced Guidance for Developing a Dreissenid Mussel Prevention Program in 2020. Included in the document is an acknowledgement that fishing tournaments are a common human-mediated pathway of dreissenid mussel introduction, and that "conditions on fishing tournaments" are a potential management action to prevent a dreissenid mussel introduction. The State of Montana calculated estimated per day expenditures for resident anglers multiplied by the number of days of fishing, total angler expenditures for 2013 amounted to approximately $193 million (Swanson 2016). percent and 10 percent reduction in fishing. To date there are no studies estimating the impact of invasive mussels on tourism (Nelson 2019). The State of Montana used a scenario-based approach for recreational fishing to estimate the economic damages – 2 percent, 5 percent, and 10 percent reductions in visitation as a result of dreissenid establishment. Tourism spending was assumed to be proportional to visitation. They documented a 2-10% range of percent reductions in visitation and the corresponding reduction in spending. If visitation is reduced by two percent, the most conservative scenario, the amount of money spent by nonresident visitors would decrease by $17.8 million, a half of a percent reduction in total tourist spending in 2017. At the 10 percent reduction in visitation, tourism spending would decrease by $89 million or 2.6 percent of total tourist spending in 2017. Dreissenid mussels grow on a variety of infrastructure systems, including water intake pipes for drinking water, irrigation, power plants, locks, and dams and canal systems, greatly impacting operation and maintenance costs (ISAC 2016). Continual attachment can increase corrosion rates of steel and concrete (USGS 2016), leaving equipment and infrastructure vulnerable to failure. Additionally, the mussels grow on navigational buoys, docks, and hulls of boats and ships—increasing drag, affecting steering, and clogging engine intakes—all of which can lead to overheating and engine malfunctions (ISAC 2016).

7. Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

The shells from dead dreissenid mussels can wash ashore, smothering beaches and potentially injuring swimmers and other recreationalists from cuts sustained from the shells' sharp edges (Nelson 2019).

POTENTIAL FOR SOCIOECONOMIC IMPACT SCORECARD

Socio-Economic Impact Total	**39**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>24	Any	**High**
15-24	Any	**Moderate**
0-15	0-1	**Low**

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Appendix E. Brazilian waterweed (*Egeria densa*) risk assessment.

SPECIES: *Egeria densa* (Planch.) Vict.
COMMON NAMES: Leafy elodea, dense waterweed, Brazilian elodea, Egeria, anacharis

DESCRIPTION: Egeria densa is an emergent plant species with stems that may grow up to 15 ft. long. Stems are 1-3 mm in diameter, and leaves are whorled. The species may be rooted, or found free-floating in mats. (eFloras 2015, Anderson and Hoshovsky 2015). For a full botanical description, see CABI (2015).

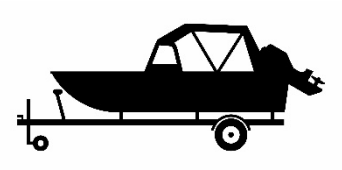
FOREIGN DISTRIBUTION: *Egeria densa* is native to South America, specifically Brazil, Uruguay, Paraguay, northern Argentina, and Chile (Kowata et. al 2014, Cook and Urmi-König 1984, Catling and Wojtas 1985). It is naturalized in North America (Canada and Mexico), the British Isles, New Zealand, Australia, southern Africa (South Africa and Ghana), the Caribbean islands (Cuba, Guadeloupe, Martinique, and Jamaica), Central America (Costa Rica, El Salvador, and Nicaragua) and eastern Europe (Italy, Switzerland, France, Germany, Portugal, the Czech Republic, the Netherlands, and Spain), as well as Russia, Japan, and Colombia (Kadono 2004, GBIF 2015).

U.S. DISTRIBUTION AND STATUS: *Egeria densa* was first detected outside of its native range in the United States, in 1893 in Millneck, Long Island, New York (Yarrow et. al 2009; Cook and Urmi-König 1984). Populations have been detected in 42 U.S. states. View the USGS NAS map for species observations: https://nas.er.usgs.gov/viewer/omap.aspx?speciesID=1107. Egeria occurs in cool to warm freshwater ponds, lakes, reservoirs, and slowly flowing streams and sloughs. It can root up to seven meters below the water surface (Parsons 1992). In California, egeria occurs at less than 7,000 feet elevation in the Sierra Nevada, Central Valley, central coast San Francisco Bay, and San Jacinto Mountains (Hickman 1993). In 2018, Egeria densa was observed in Emerald Bay State Park on the west side of the Tahoe Basin (38.95185, -120.10655).

RISK ASSESSMENT SUMMARY:

- Potential for introduction
  - Hitchhiking/fouling – MODERATE
  - Intentional release - HIGH
- Potential for establishment – MODERATE (with high confidence)
- Potential environmental impact – HIGH (with high confidence)
- Potential socio-economic impact – HIGH (with high confidence)

Lake Tahoe Basin Aquatic Invasive Species Risk Assessment Form



VECTOR POTENTIAL FOR INTRODUCTION

Five of the six vectors are initially scored for a species presence (100) or absence (0) in that vector. If present, a second "proximity" or "likelihood" question is answered based on expert advice. One criterion incorporates existing measures to prevent the introduction of the species.

Multiplication of the first score by the second score results in introduction potential score values. Dispersal and transport proximity thresholds of 100 miles and 50 miles are based on potential movement distances across taxa and barriers that might impede movement. Intentional release likelihood is based on access and popularity of the species, while recreational culture likelihood incorporates proximity, popularity, and regulation of the species. For each of these vectors, the multiplier score is equally divided among categories. Commercial culture has a similar division of likelihood categories based on regulation and proximity, with one additional low category for the lowest risk behavior.

The possible score values for each vector are binned into qualitative ranks, capturing the highest likelihood ("High") with a score of 80–100 (i.e., top categories of multiplied values: 80 and 100), intermediate likelihood ("Moderate") with a score of 40–79 (i.e., middle categories of multiplied values: 40, 50, and 75), lower likelihood ("Low") with a score of 1–39 (i.e. lowest categories of non-zero multiplied values: 4, 8, 10, 20, and 25), and lowest likelihood ("Unlikely") with a score of 0 (i.e., recognizing that there could still be a slight non-zero chance of introduction).

Confidence in the assessment rankings is deemed to be High if there are no unknowns, Moderate if there are unknowns for one-third or fewer of the vectors, Low if there are unknowns for more than one third of the vectors, and Very Low if there are unknowns for all but one vector.

DISPERSAL

1a. Does this species occur near waters (natural or artificial) connected to the Tahoe basin* (e.g., streams, ponds, canals, or wetlands)?

Yes, this species occurs near waters connected to the Tahoe basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Tahoe basin and/or is not mobile or able to be transported by wind or water upstream/downstream of Tahoe.	0
Unknown	U
TOTAL	**0**

1b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 50 miles of the Tahoe basin, but dispersal to the basin is blocked; or this species occurs in waters within 100 miles of the Tahoe basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 miles of the Tahoe basin, but dispersal to the basin is blocked.	Score x 0.5
Unknown	U
TOTAL	

HITCHHIKING/FOULING

2a. Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Tahoe basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Tahoe basin.	0
Unknown	U
TOTAL	**100**

Migratory water birds play an important role in the dispersal of aquatic alien species, through both epizoochory and endozoochory, thus enabling transport across considerable distances (Reynolds et al. 2015, Green 2016, Coughlan et al. 2017).

2b. What is the proximity of this species to the Tahoe basin?

This species occurs in waters within 50 miles of the Tahoe basin.	Score x 1
This species occurs in waters within 100 miles of the Tahoe basin.	Score x 0.5
This species occurs in waters >100 miles from the Tahoe basin.	Score x 0.1
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a. Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Tahoe basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0
Unknown	U
TOTAL	**100**

3b. How easily is this species obtained within Tahoe basin states?

This species is widely popular, frequently sold, and/or easily obtained within the Tahoe basin states.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Tahoe basin states.	Score x 0.5
This species is not very popular or is not easily obtained within the Tahoe basin states.	Score x 0.1
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a. Is this species being stocked/planted to natural waters or outdoor water gardens around the Tahoe basin states?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Tahoe basin states.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Tahoe basin states.	0

Unknown	U
TOTAL	**0**

4b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is authorized and/or is occurring directly in the Tahoe basin.	Score x 1
This activity is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin, and there are no widespread regulations against stocking/planting.	Score x 0.75
This activity is likely to occur in waters >50 miles from the Tahoe basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces).	Score x 0.5
Unknown	U
TOTAL	

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a. Is this species known to be commercially cultured in or transported through the Tahoe basin?

Yes, this species is being commercially cultured in or transported through the Tahoe basin.	100
No, this species in not commercially cultures in or transported through the Tahoe basin, however, it is commercially cultured elsewhere in the United States, which has led to unintentional escapes to natural water bodies.	50
No, this species is not commercially cultured in or transported through the Tahoe Basin.	0
Unknown	U
TOTAL	**0**

5b. What is the nature and proximity of this activity to the Tahoe basin?

This activity is unregulated or minimally regulated and is occurring directly in the Tahoe basin.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Tahoe tributaries or connecting waters, or within 50 miles of the Tahoe basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Tahoe basin, and/or this activity involves transport of live organisms on/across the Tahoe basin.	Score x 0.5
This activity is strictly regulated but occurs in Tahoe tributaries, connecting waters, or within 50 miles of the Tahoe basin, and/or this activity involves transport of live organisms within 50 miles of the Tahoe basin.	Score x 0.25
This activity occurs >50 miles from the Tahoe basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U
TOTAL	

6a. Are there any existing measures in the Tahoe basin to prevent the introduction of this species?

Yes, and they are likely to prevent introduction of the species. (There are no reported cases of this species adapting to or avoiding current measures. These measures are highly effective in preventing introduction.)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting to or avoiding current measures used to prevent introduction.)	-50% total points (at end)
Yes, but they are unlikely to prevent introduction of the species. (There are many reported cases of this species adapting to or avoiding current measures used to prevent introduction.)	-20% total points (at end)
No methods have been set to prevent its introduction.	0

Unknown	U
TOTAL	

VECTOR POTENTIAL FOR INTRODUCTION SCORECARD

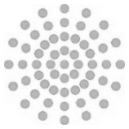
Vector	Raw Points Scored	Proximity Multiplier	Total Points Scored	Probability of Introduction
Dispersal: Natural dispersal through waterbody connections or wind	0	x	0	**Unlikely**
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	100	X 0.5	50	**Moderate**
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	100	X 1	100	**High**
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Tahoe basin OR Accidental introduction to the Tahoe basin by escape from recreational culture (e.g., water gardens)	0	x	0	**Unlikely**
Escape from commercial culture: Accidental introduction to Tahoe by escape from commercial culture (e.g., aquaculture)	0	x	0	**Unlikely**

Adjustment of total score for response to 6a: ___150-20%= **120**_____

Potential pathway(s) of introduction:

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

POTENTIAL FOR ESTABLISHMENT



- High establishment potential = at least ¾ of the questions were scored as the maximum value "9"
- Moderate establishment potential if more than half of the questions were scored as "6" (or were evenly split with equivalent numbers of "3" and "9")
- Otherwise, Low establishment potential.

For each question, assign a value of 0 and 9, with 0 = least likely/fitting and 9 = most likely/fitting. Benchmark values for each question are provided as a guide, but the assessor may assign intermediate values based on best professional judgment. Record the tally of points (excluding deductions) and sequentially deduct percentage points (if any) from raw total. Use this score to determine establishment potential. Tally the total number of Unknown selections to determine overall confidence level.

1. How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
TOTAL	**6**

(from USGS NAS) Egeria densa has broad physiological tolerances. It can tolerate low light conditions (Lara et al. 2002). Although a tropical plant, it is able to adapt to seasonal changes and overwinter (Parsons and Cuthbertson 2001, Rixon et al. 2005, Yarrow et al. 2009). It can tolerate low levels of CO_2 (Casati et al. 2000), nitrogen, phosphorus, and nutrients (Yarrow et al. 2009). This species can survive in waters with salinities up to 8 ppt (Hauenstein and Ramirez 1986). Increased salinization may negatively impact this species' establishment if salinities exceed 8 ppt (Hauenstein and Ramirez 1986). This species is known to have a relatively fast growth rate (Yarrow et al. 2009). This species can survive in freshwater habitats of varying temperatures, light levels, and CO_2 levels. It is likely that *Egeria densa* will benefit from the effects of climate change, including warmer temperatures and shorter duration of ice cover (Morgan et al. 2023). Morgan et al. (2018) documented *Egeria densa* can inhabit waters with a wide range of temperatures, low CO_2 levels, and low light levels. The plant can overwinter as seeds, dormant shoots, or semi-dormant shoots until temperatures rise above 15°C (Parsons and Cuthbertson 2001). *Egeria densa* exhibits the C4 pathway and utilizes HCO_3-; it is able to photosynthesize in waters with low CO_2 levels (Casati et al. 2000). *Egeria densa* can tolerate high phosphorous levels, but is susceptible to iron deficiency (Parsons and Cuthbertson 2001). This species has a low light requirement and can thrive in turbid environments (Parsons and Cuthbertson 2001). Optimal light intensity is about 100 lux. *Egeria densa* cannot tolerate high light intensities or high levels of ultra-violet and blue light, as it experiences chlorophyll damage to light levels of 1250 lux. *Egeria densa* cannot tolerate high UV-B radiation, as it can damage the enzymes involved in photosynthesis and can reduce photosynthetic capacity (Casati et al. 2002).

2. How likely is it that any life stage of this species can overwinter in the Tahoe basin (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species can tolerate temperatures under 5°C and oxygen levels ≤0.5mg/L)	9
Somewhat likely (This species can tolerate some of these conditions or has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species can tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
TOTAL	**9**

3. If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is a moderate dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
TOTAL	**0**

4. How likely is this species to outcompete species in the Tahoe basin for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Tahoe basin)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Tahoe basin)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Tahoe basin)	0
Unknown	U
TOTAL	**9**

This species can reduce the abundance and diversity of native plant seeds in lake bottoms due to increased sediment accumulation under its weed beds (Hoshovsky and Anderson 2001). *E. densa* can out-compete and displace native vegetation, such as *Elodea canadensis,* in the northwest USA (CABI 2019). *Egeria densa* can outcompete native species. In Duck Lake, Washington, *E. densa* displaced native stonewart, elodea, and pondweed in a period of 3 years (Washington State Department of Ecology 2013). In Hawkesbury-Negean River, Australia, *E. densa* outcompeted native vallisneria (*Vallisneria americana*) for light (Roberts et al. 1999).

5. How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0

Unknown	U
TOTAL	**9**

This species has a high fecundity, and the principal means of reproduction is vegetative, by fragmentation of stems (CABI 2018). It is a highly invasive species solely through vegetative propagation (CABI 2018).

6. How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Tahoe basin (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Tahoe basin based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Tahoe basin based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
TOTAL	**9**

7. How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Tahoe basin?

Very similar (The climatic conditions are practically identical to those of the Tahoe basin)	9
Similar (Many of the climatic conditions are similar to those of the Tahoe basin)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

8. How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., water temperature, salinity, pH) in the native and introduced ranges to those in the Tahoe basin?

Very similar (These factors are practically identical to those of the Tahoe basin)	9
Similar (Many of these factors are similar to those of the Tahoe basin)	6
Somewhat similar (Few of these factors are similar to those of the Tahoe basin)	3
Not similar	0
Unknown	U
TOTAL	**6**

9. How abundant are natural or anthropogenic habitats suitable for the survival, development, and reproduction of this species in the Tahoe basin (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0

Unknown	U
TOTAL	**9**

High phenotypic plasticity enables relatively fast adaptation to a wide range of habitats in introduced areas (Riis et al. 2010) and augments their invasive potential. E. densa is frequently dominant and appears to perform best in clear water conditions (Bini et al. 1999; Carrillo et al. 2006).

10. How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Tahoe freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Tahoe basin a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Tahoe basin a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Tahoe basin a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Tahoe unsuitable)	0
Unknown	U
TOTAL	**9**

The climate match for *Egeria densa* is high across most of the contiguous United States (USFWS 2018). There are small pockets of medium and low match in the Great Plains, southern Texas, and along the Canadian border in the Midwest. Established populations of *E. densa* already occur in many states. The Climate 6 score (Sanders et al. 2014; 16 climate variables; Euclidean distance) for the contiguous United States was 0.962, high. All states have individually high climate scores.

11. How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Tahoe basin that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Tahoe that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Tahoe that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
TOTAL	**9**

12. Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Tahoe basin and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9

Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in parts of the Tahoe basin.	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Tahoe basin AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Tahoe basin but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Tahoe basin and is not likely to be introduced	-80% total points (at end)
Unknown	U
TOTAL	**9**

13. How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Tahoe basin?

Likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Tahoe basin that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Tahoe basin)	6
Somewhat unlikely (A non-indigenous species to the Tahoe that facilitates the development of this species—a major host, food item, pollinator—has already established in the Tahoe basin BUT it is still confined to a small area and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Tahoe basin that facilitates the development of this species has not been established in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

14. How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Tahoe and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Tahoe basin)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Tahoe basin.	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Tahoe basin)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Tahoe basin)	0
Unknown	U
TOTAL	**0**

15. How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
TOTAL	**9**

16. How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
TOTAL	**9**

17. Are there any existing control measures that can be used in the Tahoe basin set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent the establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing its establishment and spread)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent its establishment and/or spread.	0
Unknown	U
TOTAL	

Establishment Potential Scorecard

<table>
<tr><th>Points</th><th>Probability for Establishment</th><th colspan="2">A. Total Points (pre-adjustment)</th><th>108</th></tr>
<tr><td rowspan="2">>100</td><td rowspan="2">High</td><td colspan="2">Adjustments</td><td></td></tr>
<tr><td>A. Critical species</td><td>A*(1- 0%)</td><td></td></tr>
<tr><td rowspan="2">51-99</td><td rowspan="2">Moderate</td><td>B. Natural enemy</td><td>B*(1- 0%)</td><td></td></tr>
<tr><td>C. Control measures</td><td>C*(1- 0%)</td><td>-20%= 86</td></tr>
<tr><td>0-50</td><td>Low</td><td colspan="2">Potential for Establishment</td><td>Moderate</td></tr>
<tr><td># of questions answered as ‘‘unable to determine’’</td><td>Confidence Level</td><td colspan="3"></td></tr>
<tr><td>0-1</td><td>High</td><td colspan="2" rowspan="2">Total # of questions unknown</td><td rowspan="2"></td></tr>
<tr><td>2-5</td><td>Moderate</td></tr>
<tr><td>6-9</td><td>Low</td><td colspan="2" rowspan="2">Confidence Level</td><td rowspan="2">High</td></tr>
<tr><td>>9</td><td>Very low</td></tr>
</table>

POTENTIAL ENVIRONMENTAL IMPACT

- High impact potential if at least one question for an impact type is scored with the maximum value ("6") or all questions are scored with a lower value ("1").
- Moderate impact potential if no questions for an impact type are scored with the maximum value ("6"), but two to five questions are scored with a lower value ("1").
- Confidence in whether a species is likely to have a low impact or if impact potential cannot be adequately assessed is based on the combination of it scoring "Not significantly" for all but one or fewer impact types and its number of unknowns.
- If there is an impact score of "1" and one or more unknown impacts, or an impact score of "0" but two or more unknown impacts, the species is assessed overall as having "Unknown" impact potential. In that case, more research is needed to determine its potential impact. Otherwise, when most information is available and the species has a low impact score, it is deemed as having "Low" impact potential.

Complete all of the questions below. Both current and historical realized impacts from any non-native region should be considered. Add the total number of points and Unknown (U) selections for each section and use the scoring table to determine impact rank.

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

1. Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**0**

2. Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U
TOTAL	**6**

E. densa can out-compete and displace native vegetation, such as *Elodea canadensis,* in the northwest USA (CABI 2019). In Duck Lake, Washington, *E. densa* displaced native stonewart, elodea, and pondweed in a period of 3 years (Washington State Department of Ecology 2013). In Hawkesbury-Negean River, Australia, *E. densa* outcompeted native vallisneria (*Vallisneria americana*) for light (Roberts et al. 1999). *E. densa* reduces nutrient availability for phytoplankton (Feijoo et al.

2002, Mazzeo et al. 2003). The dense canopies of *E. densa* favor mono-specific stands that can lower biodiversity through competition and exclusion (Roberts et al. 1999). Under favorable conditions, E. densa can grow rapidly, covering water surfaces and blocking light to lower levels of the waterbody, which can cause a decline in populations of native plant species and thereby reduce populations of fish and other aquatic wildlife (Westerdahl & Getsinger 1988).

3. Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end, or other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U
TOTAL	**1**

Although the USGS NAS website states that Egeria is not known to influence predator-prey relationships, King County Noxious Weed Program (2014) in the State of Washington documents that Egeria can reduce biodiversity, change predator/prey relationships, and adversely impact the food web.

4. Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U
TOTAL	**0**

5. Does it negatively affect water quality (e.g., turbidity, altered nutrient, oxygen, chemical levels)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Potential invasion of *E. densa* poses a serious threat to aquatic ecosystems by affecting water-flow, sedimentation, water quality and hydrochemistry, light penetration and native species (Yarrow et al. 2009). *E. dens*a promotes eutrophication because it has very little fibrous material and starts to decompose when temperatures exceed 30 °C and/or water level decreases allowing high light penetration. When this occurs, the plant releases high levels of phosphorus into the water (Cook & Urmi-Konig 1984).

6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered communities, physical or chemical changes to substrate, alters disturbance regimes)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U
TOTAL	**6**

E. densa alters hydrology – plants release oxygen during the day; however, plants respire (take up oxygen) at night and cause the lowest oxygen levels to occur in the early morning. Fish kills can occur if plant density is high enough and dissolved oxygen levels become depleted overnight due to plant respiration (UF|IFAS 2023). *E. densa* depletes available nitrogen, phosphorous, and oxygen, taking nutrients up through its leaves and stems in the water column, as well as through its shoots in the sediment (Suzuki et al. 2015, Cook & Urmi-König 1984; Weragoda et al. 2009, Chagas et al. 2008, Yarrow et. al 2009).

POTENTIAL FOR ENVIRONMENTAL IMPACT SCORECARD

Environmental Impact Total	**19**
Total Unknowns (U)	

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	**Moderate**
0	0-1	**Low**
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

1. Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U
TOTAL	**1**

Egeria densa may pose a risk to human safety. It may have caused the drowning of at least one person due to entanglement in the long stems (GLANSIS 2015).

2. Does the species pose some hazard or threat to culturally significant species important to Native American Tribes?

Yes, and it has impacted important culturally significant species, resulted in the reduction or extinction of one or more populations of culturally significant species, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations/ecosystems)	1
Not significantly	0
Unknown	U
TOTAL	**6**

Dense beds of E. densa can alter the distribution and abundance of native macrophyte and invertebrate assemblages, block the migration of fish and support different fish assemblages (Growns et al. 2003).

3. Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U
TOTAL	**6**

In southeast Brazil, *E. densa* causes significant losses to hydro-electric companies. Interruptions of electricity generation and damage to grids and equipment are common in reservoirs belonging to hydro-electric companies in São Paulo (Barreto et al. 2000). It can also interfere with river traffic as well as recreational activities such as boating, swimming and fishing (Parsons & Cuthbertson 2001).

4. Does it negatively affect water quality (i.e., in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0
Unknown	U
TOTAL	**6**

E. densa clogs reservoirs, preventing fishing, boating, swimming, and reducing potable water quality (Mori et. al 2012, Kadono 2004, U.S. Army Corps of Engineers 1976).

5. Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

E. densa has restricted navigation and boating, clogged irrigation and water supply systems and slowed river flow. The dense growth of *E. densa* can interfere with irrigation projects, hydroelectric dams, and urban water supply (Hoshovsky and Anderson 2001, Parsons and Cuthbertson 2001). In New Zealand, there was an infestation of *E. densa* in the Wikato River that clogged the water intake pipes resulting in the shut-down of an electrical plant (Washington State Department of Ecology 2013). In Brazil , *E. densa* (as well as *E. najas, Ceratophyllum demersum,* and *Eichhornia crassipes*) have severely infested hydropower reservoirs. It was estimated that 48,000 cubic meters of aquatic weeds were removed from water intake structures in Jupia Reservoir (Marcondes et al. 2000).

6. Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

Egeria densa can inhibit recreational activities as a nuisance for navigation, fishing, swimming, and water skiing (Washington State Department of Ecology 2013). The removal of *E. densa* is costly; Washington local and state governments spend thousands of dollars each year to control the species.

7. Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U
TOTAL	**6**

E. densa decreases the aesthetic and ecological values of ecosystems (Washington State Department of Ecology Water Quality Program 2010).

POTENTIAL FOR SOCIOECONOMIC IMPACT SCORECARD

Socio-Economic Impact Total	**37**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	**Moderate**
0	0-1	**Low**
1	0	
0	≥2	**Unknown**
1	≥1	

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