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South Dakota Aquatic Nuisance Species Risk Assessment

Prepared by

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Acknowledgments

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Executive Summary

South Dakota's aquatic resources are highly valued because they provide habitat for a wide range of native species, recreational opportunities for residents and visitors, and ecosystem services, including water quality and biodiversity. Aquatic nuisance species threaten South Dakota's valued aquatic communities and associated habitats. Specifically, the State Comprehensive Wildlife Conservation Plan lists six native aquatic species that could be affected by aquatic nuisance species (lake chub *Couesius plumbeus*, mountain sucker *Catostomus platyrhynchus*, false map turtle *Graptemys pseudogeographica*, elktoe *Alasmidonta marginata*, rock pocketbook *Arcidens confragosus*, and creek heelsplitter *Lasmigona compressa*) (SDGFP 2006). The South Dakota Department of Game, Fish and Parks contracted with South Dakota State University to draft an aquatic nuisance species risk assessment that evaluated and prioritized the risks posed by aquatic nuisance species to South Dakota's aquatic environments. The ultimate aim of the risk assessment was to provide a foundation for development of a state aquatic nuisance species management plan. Specifically, the objectives of the risk assessment included: 1) identification of aquatic nuisance species risks relevant to South Dakota, 2) compilation of aquatic nuisance species biology, vectors, and pathways based on literature and communication with state and regional experts, and 3) qualitative expert ranking of aquatic nuisance species threats. The risk assessment process identified 61 aquatic nuisance species considered most relevant to South Dakota, 14 of which were identified as primary species of concern: brittle naiad (*Najas minor*), curly pondweed (*Potamogeton crispus*), didymosphenia (*Didymosphenia geminata*), Eurasian water-milfoil (*Myriophyllum spicatum*), New Zealand mudsnail (*Potamopyrgus antipodarum*), rusty crayfish (*Orconectes rusticus*), dreissenids (zebra and quagga mussels; *Dreissena* spp.), bighead carp (*Hypothalymichthys nobilis*), black carp (*Hypothalymichthys nigromaculatus*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypothalymichthys molitrix*), and viral hemorrhagic septicemia (VHS).

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Background

Risk assessment is a tool used to evaluate priorities and develop strategic plans to address issues across a variety of professional and scientific disciplines. The Federal, Aquatic Nuisance Species Task Force developed a Generic Nonindigenous Aquatic Organisms Risk Analysis Review Process in 1996 (RAM 1996) to estimate the risk associated with the introduction of nonindigenous aquatic organisms and strategically manage for that risk. They define risk assessment as a process to evaluate the risk associated with individual pathways and recently established nonindigenous organisms, whereas risk management is the practical operational approach to reducing both the probability of unintentional introductions and the risk associated with intentional introductions (RAM 1996). Aquatic nuisance species risk assessment should be reviewed and revised regularly because perceived threats are constantly changing along with associated assessment criteria.

Economic, ecological, and socio-political costs accompany species introductions. Invasive fishes and aquatic plants and invertebrates cost the United States at least 1 billion dollars each year in control measures and efforts to mitigate their effects (Pimentel et al. 2000). Introduced species have the potential to alter their newly-occupied habitats as well as affect the persistence of native organisms, especially threatened and endangered species. Risk assessment does not conclusively determine the timing or potential effect of each new threat, but assessment does provide managers with a relative ranking of perceived threats to most efficiently apply limited resources to prevention and mitigation. The assessment of risk posed by nonindigenous species is difficult because there is not a well-defined suite of characteristics that predict which species will become invasive. However, vegetative reproduction, propagule pressure, and invasion history are all factors positively related to successful invasions (Kolar and Lodge 2001). Vegetative reproduction is advantageous because a single fragment can invade a new habitat, and one individual can spread clonally within those new habitats. Propagule pressure is a measure of the rate at which colonists (seeds, fragments, or adults) arrive in a new habitat, and it is maximized when a large number of colonists arrive at one time (i.e., natural dispersal events; *r*-selected species) or when arrivals are very frequent (i.e., human mediated dispersal at popular destinations). Species that have a history of becoming invasive are more likely to invade other habitats. Rapid species phenotypic and/or genotypic change in response to the selection pressures of a novel environment also typically mark documented successful invasions (Palumbi 2001).

Fisheries and aquatic ecosystems are an abundant and highly-valued resource in South Dakota, but managing and enjoying South Dakota's aquatic resources increases the risks of transporting and introducing aquatic nuisance species (ANS). Quality sport fisheries in South Dakota attract tourists and provide recreational opportunities for residents and non-residents of the state (Berry et al. 2007). Missouri River reservoirs alone generate millions of dollars in revenue through camping, boating, and angling activities (Shearer 2007). South Dakota's waters are also valuable habitats for many threatened and endangered species. In particular, the State Comprehensive Wildlife Conservation Plan suggests that aquatic nuisance species could negatively affect aquatic species of greatest conservation need including: two fish (lake chub *Couesius plumbeus* and mountain sucker *Catostomus platyrhynchus*), one reptile (false map turtle *Graptemys*

pseudogeographica), and three freshwater mussels (elktoe *Alasmidonta marginata*, rock pocketbook *Arcidens confragosus*, and creek heelsplitter *Lasmigona compressa*) (SDGFP 2006).

Relatively few ANS currently occur in South Dakota, but a few notable exceptions exist. For example, Eurasian water-milfoil *Myriophyllum spicatum*, *Didymosphenia geminata*, brittle naiad *Najas minor*, zebra mussels *Dreissena polymorpha*, and Asian carps (e.g., *Hypophthalmichthys nobilis*) have all been collected in South Dakota waters and detailed coverage is provided in this risk assessment. Historically, the South Dakota Department of Game, Fish and Parks dealt with aquatic nuisance species, such as brittle naiad and *Didymosphenia*, on a case-by-case basis. Recently, the increased rate of introductions to South Dakota and heightened awareness of the threats posed by ANS prompted development of a statewide management plan informed by a risk assessment. Risk assessment is an integral preventative part of an overall risk management plan (Figure 1). The objective of this risk assessment is to supply the information required to identify potential threats and prioritize the most significant threats. This assessment qualitatively ranked threat level posed by aquatic nuisance species based on current species distributions, mobility, prevention capacity and the perceived severity of potential threats to critical South Dakota habitat and biota. The risk assessment required communication with state and regional experts and review of literature describing aquatic nuisance species' biology, ecology, pathways, and vectors, and it provides criteria for the design of South Dakota's aquatic nuisance species management plan. In cases where sufficient information was available, the risk assessment evaluated specific potential threats posed by ANS to state species of greatest conservation need.

Methods

The South Dakota Aquatic Nuisance Species Risk Assessment combined analyses of vectors, pathways, and species to qualitatively estimate likelihoods of ANS introduction, establishment, and invasiveness in South Dakota. Vector, pathway, and species analyses specifically focused on aquatic organisms and their associated habitats within the jurisdiction of the Division of Wildlife. Pathways are the routes between source and recipient regions, and vectors are the manners in which species are carried along pathways (Mack, 2004).

Vectors relevant to the Division's mission (i.e., mission-relevant vectors) were selected from the global list of transportation-related, living industry, and miscellaneous vectors compiled by the National Invasive Species Council (NISC 2007). Although ANS have the potential to move along any of the vectors listed by the NISC, only a subset of those vectors could realistically fall under the jurisdiction of and potentially be managed by the Division. Thus, through communications with representatives from the Division and selected members of the Research and Monitoring Subcommittee, vectors were identified that related to the management of fisheries and aquatic habitats. The Division recognizes that through their own routine management activities, including intentional

stocking, the potential exists for translocation of ANS. Thus, selected vectors explicitly exclude natural dispersal but include intentional stocking and planting.

Pathway analyses identified the most likely donor regions of ANS to South Dakota. Origins and destinations of boaters and anglers provided relative frequency data on movement along mission-relevant vectors. Data were obtained primarily from license sales and user surveys, specifically the 2006 South Dakota non-resident angler license and 100th Meridian Initiative databases. Ideally, estimates of propagule pressure for every potential ANS could be compared to indicate which species pose the greatest introduction and establishment threat. However, because such detailed information was lacking, pathway analyses were used as a surrogate for relative propagule pressure.

Species that historically moved within selected vectors and those that occur in relatively important donor regions (i.e., origins for many of the vectors and pathways to South Dakota), were analyzed for their potential to survive in South Dakota. This risk assessment provides biological descriptions from the literature and a panel of experts (Table 1), including available information on native range, current distribution, physicochemical tolerances, life history, trophic ecology, ecosystem effects, and invasion history.

Species that could: 1) be carried within a vector, 2) occur in a pathway, and 3) potentially survive in South Dakota, were ranked by a panel of experts and grouped into primary (i.e., watch list) and secondary species of concern according to the perceived threat. The panel (Table 1) of nearly 20 fish, fish health, plant, and invertebrate biologists convened during the annual meeting of the Dakota Chapter of the American Fisheries Society (February 19, 2008) in Sioux Falls, South Dakota. Species of primary concern were subjected to individual, qualitative organism risk assessments based on seven rating elements (RAM 1996). Panel experts qualitatively rated each species (high, medium, or low risk) and provided uncertainty estimates (very certain, reasonably certain, moderately certain, reasonably uncertain, or very uncertain) for establishment probability and consequences.

Results

Vector and pathway analyses

Vectors relevant to the mission of the Division of Wildlife of the South Dakota Department of Game, Fish and Parks included:

- bait (included collection, sale, fishing, and disposal),
- boat-barge-equipment (i.e., stowaways or hitchhikers in holds and surface-fouling organisms on boats and equipment),
- intentional stocking,
- intentional planting,
- aquaculture,
- aquarium animals,
- parasites,
- sportsmen-outdoor-home-garden shows,
- plant-animal importation for research,

- soil-sod-media, and
- aquatic plant trade.

Interstate pathways representing the greatest propagule pressure included: Minnesota-South Dakota (i.e., species originate in Minnesota and arrive in South Dakota), Iowa-South Dakota, Nebraska-South Dakota, North Dakota-South Dakota, and Colorado-South Dakota. In 2006, over 70% of non-resident angler licenses were sold to individuals in these five states (Figure 2). Non-resident angler license sales to individuals in nine other states accounted for less that 5% each of total sales, and sales in 45 other states and provinces accounted for less than 1% each of total non-resident license sales. These pathways were associated with at least two vectors: bait and boat-barge-equipment. These pathway data are corroborated by the 100th Meridian Initiative boater survey, which indicated that in 1999, 89% of non-resident boaters originated in Iowa (38%), Nebraska (31%), and Minnesota (20%; Figure 3). Remaining states were represented by 2% or less of the total non-resident boaters interviewed.

A review of the literature resulted in a list of 61 species that could be carried within at least one of the eleven vectors (i.e., vector identified in a documented introduction within or outside South Dakota), occurred in at least one of the five pathways, and could potentially survive in South Dakota. These species included 15 plants (includes 1 diatom), 14 invertebrates, and 31 vertebrates and associated vertebrate pathogens or parasites (Table 2). At least one-third (22) of these species were introduced or established in South Dakota. Intentional stocking was the vector associated with the greatest percentage (34.4%; Figure 4) of introductions, including 15 fishes (six already established in South Dakota) and five invertebrates (one already established in South Dakota; *Mysis relicta*). The boat-barge-equipment vector was cited in the movement of nearly 23% of the 61 species, including four fishes, seven invertebrates (one already collected in South Dakota; *Dreissena polymorpha*), and two plants (both of which are already established in South Dakota).

Watch list

Fourteen species were assigned watch list status (i.e., species of primary concern) by the expert panel. These species were perceived to pose the greatest risk to South Dakota fisheries and aquatic habitats. Two additional plant species pose serious threats to South Dakota but are already listed as noxious weeds by the South Dakota Weed Board: purple loosestrife (*Lythrum salicaria*) and salt cedar (*Tamarix* spp.). The watch list is divided into three categories: 1) plants and algae (four species), 2) invertebrates (four species), and 3) vertebrates and associated pathogens (six species). The plants and algae category includes brittle naiad, curly pondweed (*Potamogeton crispus*), didymosphenia (*Didymosphenia geminata*), and Eurasian water-milfoil (*Myriophyllum spicatum*). The invertebrates category includes New Zealand mudsnail (*Potamopyrgus antipodarum*), rusty crayfish (*Orconectes rusticus*), and dreissenids (zebra and quagga mussels; *Dreissena* spp.). The vertebrates and associated pathogens category includes bighead carp (*Hypothalymichthys nobilis*), black carp (*Hypothalymichthys nigromaculatus*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypothalymichthys molitrix*), and viral hemorrhagic septicemia (VHS). Each

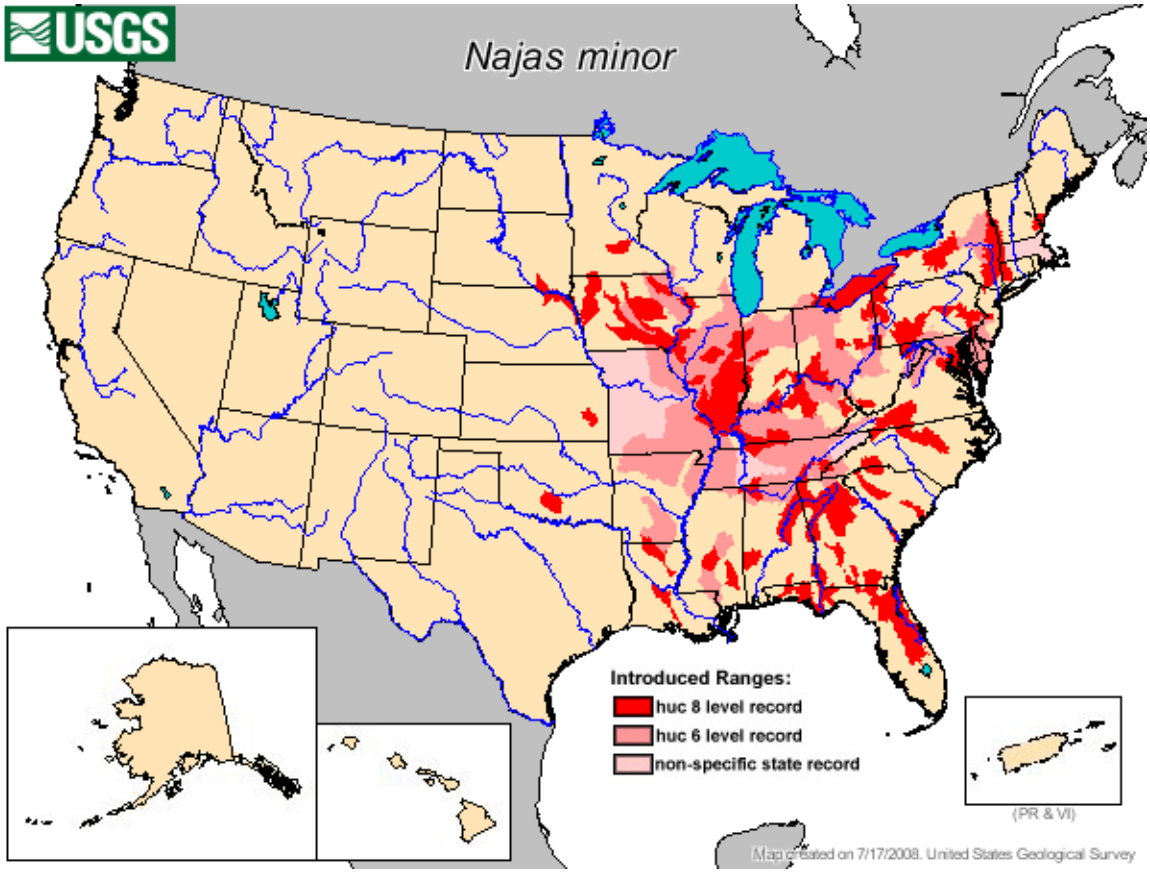
of these species was subjected to an individual qualitative risk assessment (expert panel rankings (high, medium, or low risk) were compiled and rationale was developed with support from the literature review), which is included with a biological description below.

Biological descriptions and risk assessment

Plants / algae

Brittle naiad (*Najas minor*)

Biology: Brittle naiad is an annual submersed aquatic macrophyte that primarily reproduces sexually by seeds. This species is native to Eurasia but was introduced to lentic and lotic habitats throughout the Midwest and northeastern United States. Although it typically assumes a short, bushy growth form and in some circumstances can provide food and habitat for fishes and aquatic invertebrates, it may grow up to 1 meter above the substrata and compete effectively with native aquatic macrophytes.



Risk: Expert panel rankings and rationale

1. Estimate the probability of brittle naiad being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
   a. rating = High
   b. uncertainty = Very certain

This species spreads along at least two vectors: intentional planting and boat-barge-equipment. It is currently established in South Dakota and present in other pathways, including Minnesota-South Dakota and Iowa-South Dakota (Sturtevant 2008a).

2. Estimate the probability of brittle naiad surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Brittle naiad already survived transit to and established in South Dakota.

3. Estimate the probability of brittle naiad successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

South Dakota Game, Fish and Parks identified an established population in McCook Lake in 2006, following a public complaint (St. Sauver personal communication).

4. Estimate the probability of brittle naiad to spread beyond the colonized area in South Dakota.
    a. rating = Medium
    b. uncertainty = Reasonably uncertain

South Dakota Game, Fish and Parks treated the McCook Lake brittle naiad population with herbicide on two occasions during 2007 (July 12th and August 2nd), which reduced propagule pressure and thus reduced the likelihood of human-mediated and natural spread beyond the colonized area. However, McCook Lake is an oxbow lake of the Missouri River so if connection occurs between the river and its floodplain, propagules of brittle naiad could disperse from McCook Lake throughout the Missouri River basin in South Dakota. Seeds of brittle naiad are small and boats, barges, or equipment could easily spread brittle naiad to new locations.

5. Estimate the economic impact if brittle naiad were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Reasonably uncertain

South Dakota Game, Fish and Parks spent $1162.34 ($581.17 per lake surface acre) to treat the brittle naiad in McCook Lake. Although treatment costs in other aquatic habitats in South Dakota might be similar, other economic effects of brittle naiad establishment are unknown (e.g., reduced lakeshore property value).

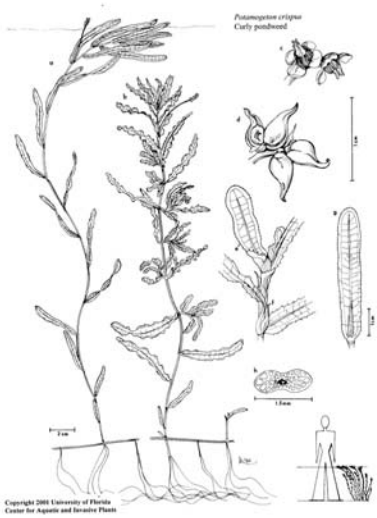
6. Estimate the environmental impact if the organism were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Reasonably uncertain

In McCook Lake, brittle naiad competed with native aquatic plants, forming a dense overstory canopy in some areas. It is uncertain what changes in the native plant and animal communities might ensue if brittle naiad were left untreated.

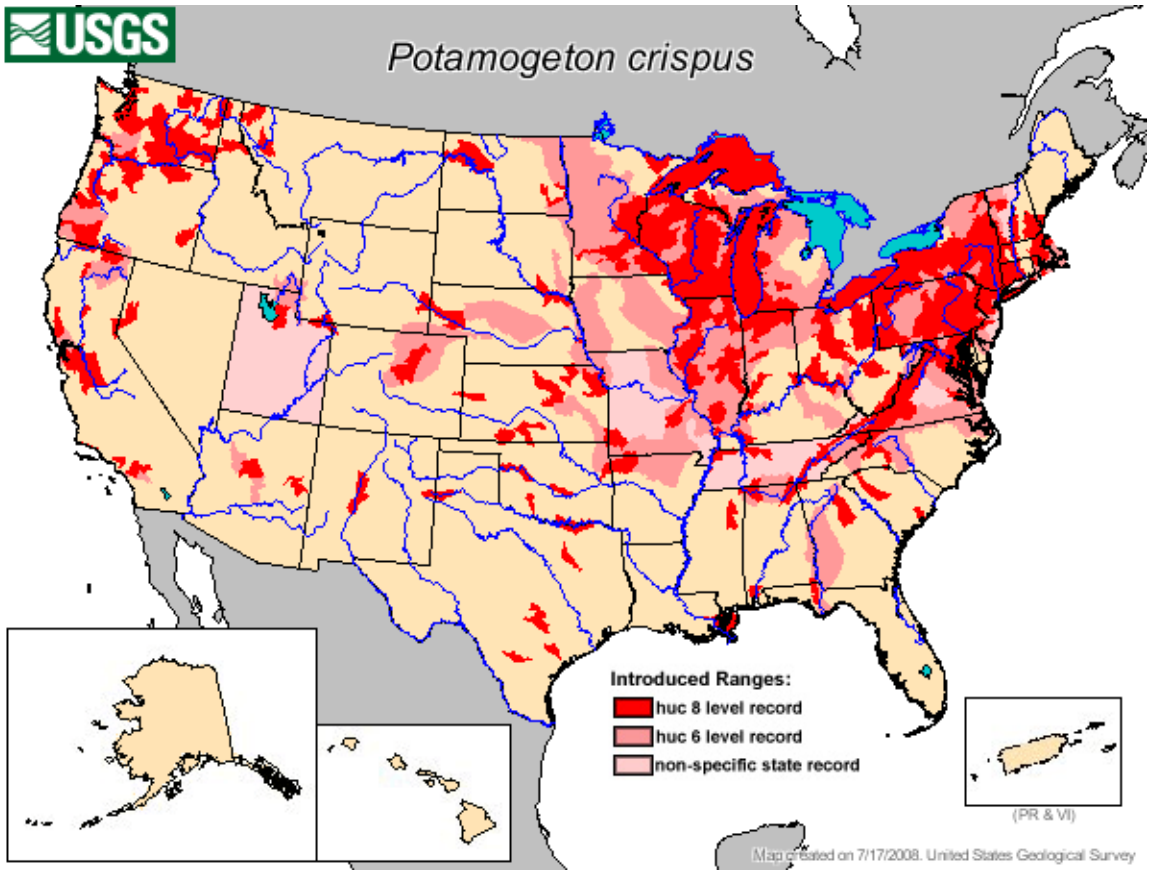
7. Estimate the impact from social and/or political influences if brittle naiad were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Resource users (e.g., boaters, swimmers, and lakeshore property owners) were immediately concerned with the dense growth of brittle naiad in McCook Lake, and requested that South Dakota Game, Fish and Parks take action to correct the problem.

Curly pondweed (*Potamogeton crispus*)



Biology: Curly pondweed or curly-leaf pondweed is a submerged aquatic perennial plant native to Eurasia and having leaves with crisped or wavy margins (Ode 2006). This species exhibits maximum growth, flowers, and produces vegetative propagules, called turions, in late spring (Sastroutomo 1981). These turions remain dormant until late summer, when they either initiate germination or continue dormancy for up to five years. Curly pondweed grows throughout the winter, even under snow-covered ice (Stuckey 1979). This species provides predation refugia for juvenile fish and smaller-bodied fishes, cover for ambush predators, habitat for aquatic invertebrates, and food for waterfowl (Ode 2006).



Risk: Expert panel rankings and rationale

1. Estimate the probability of curly pondweed being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).

a. rating = High
b. uncertainty = Very certain

This species spreads along at least two vectors: intentional planting and boat-barge-equipment. It is established in South Dakota but also occurs in all five of the most-traveled interstate pathways including Minnesota-South Dakota, Iowa-South Dakota, North Dakota-South Dakota, Nebraska-South Dakota, and Colorado-South Dakota (Stuckey 1979; Sturtevant 2008b).

2. Estimate the probability of curly pondweed surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Curly pondweed already survived transit to and established in South Dakota.

3. Estimate the probability of curly pondweed successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

By 1965, curly pondweed established populations in South Dakota and currently occurs in Burbank Lake, Clay County, Black Hills Lakes (including Sheridan and Canyon), Angostura Reservoir, and all reservoirs of the Missouri River in South Dakota with the exception of Lake Francis Case (Dave Ode and Gary Larson personal communication).

4. Estimate the probability of curly pondweed to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Curly pondweed already spread from its original colonization area to all but one reservoir of the Missouri River and lakes in the Black Hills region. The life history suggests that continued spread of vegetative propagules from established populations via human-mediated vectors and pathways is likely, especially during the summer months when turions are most abundant and the boat-barge-equipment vector is most active between water bodies.

5. Estimate the economic impact if curly pondweed were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively uncertain

Costs associated with mediating curly pondweed may be similar to those incurred for the mediation of brittle naiad. However, the current distribution of curly

pondweed is much more extensive than that of brittle naiad, suggesting that control efforts may be cost-prohibitive.

6. Estimate the environmental impact if curly pondweed were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively uncertain

Curly pondweed competes with native vegetation, but the outcome of the competitive interaction varies by context. In South Dakota, curly pondweed often initiates germination in advance of native aquatic macrophytes, and forms dense mats that dominate the aquatic macrophyte assemblage (Ode 2006). If the growth form becomes dense and mat-like, then native species and biogeochemical cycling may be affected; otherwise, the environmental effects of curly pondweed may be diffuse and undetectable.

7. Estimate the impact from social and/or political influences if curly pondweed were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively uncertain

Curly pondweed has the potential to outcompete native aquatic macrophytes and form dense mats, which could impede resource users. Similar to the case of brittle naiad in McCook Lake, curly pondweed infestations could trigger public complaints and requests for management and control. These influences are relatively uncertain and depend on the characteristics of the infestation and resource users' perception of the infestation.

Didymosphenia (*Didymosphenia geminata*)

Biology: Didymosphenia is a stalked diatom that occurs primarily in oligotrophic montane or northern-boreal streams. Excess growth of the monosaccharide stalks that anchor the photosynthetic cells to the substrata results in dense blooms that may outcompete other algal and plant species (light and nutrient limitation) and impede the feeding and mobility of aquatic invertebrates and fishes (Spaulding and Elwell 2007).

Risk: Expert panel rankings and rationale

1. Estimate the probability of didymosphenia being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

This species is native to North America and Europe, but is spreading from its historical range and became a nuisance in New Zealand. The primary vector implicated in its spread is boat-barge-equipment (Spaulding and Elwell 2007). It is established in South Dakota (Larson 2007), but details on its distribution in other relevant pathways are poorly understood.

2. Estimate the probability of didymosphenia surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Didymosphenia already survived transit to South Dakota.

3. Estimate the probability of didymosphenia successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Didymosphenia nuisance blooms were reported in Rapid Creek, South Dakota, beginning in May 2002 (Larson 2007).

4. Estimate the probability of didymosphenia to spread beyond the colonized area in South Dakota.

a. rating = Medium
b. uncertainty = Very certain

Although didymosphenia is easily transported along the boat-barge-equipment vector, its habitat requirements are fairly specific. Suitable habitat for this species in South Dakota is likely restricted to Black Hills streams. Furthermore, the development of nuisance blooms appear to be context-specific and the mechanism that triggers this growth form is not well-understood.

5. Estimate the economic impact if didymosphenia were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively uncertain

Costs associated with mediating didymosphenia nuisance blooms are not currently known. However, the apparent negative effect of the blooms on trout could influence revenue from angling-related tourism in the Black Hills of South Dakota.

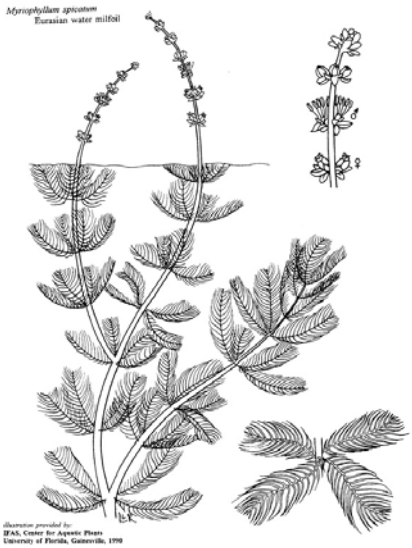
6. Estimate the environmental impact if didymosphenia were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Relatively uncertain

Didymosphenia competes with other algae and plants and may have negative effects on aquatic invertebrates and fishes, but the outcome of the competitive interaction and bottom-up effects on consumers varies by context. If the excess stalk growth results in a dense bloom, then organisms (abundance and diversity of invertebrates and fishes) and biogeochemical cycling (primary productivity and nutrient fluxes) may be noticeably affected (Spaulding and Elwell 2007). The mountain sucker is listed in the State Comprehensive Wildlife Conservation Plan as a species of greatest conservation need, and it may be affected by didymosphenia blooms because it feeds on plants and invertebrates in Black Hills streams (Churchill and Over 1938; Bailey and Allum 1962).

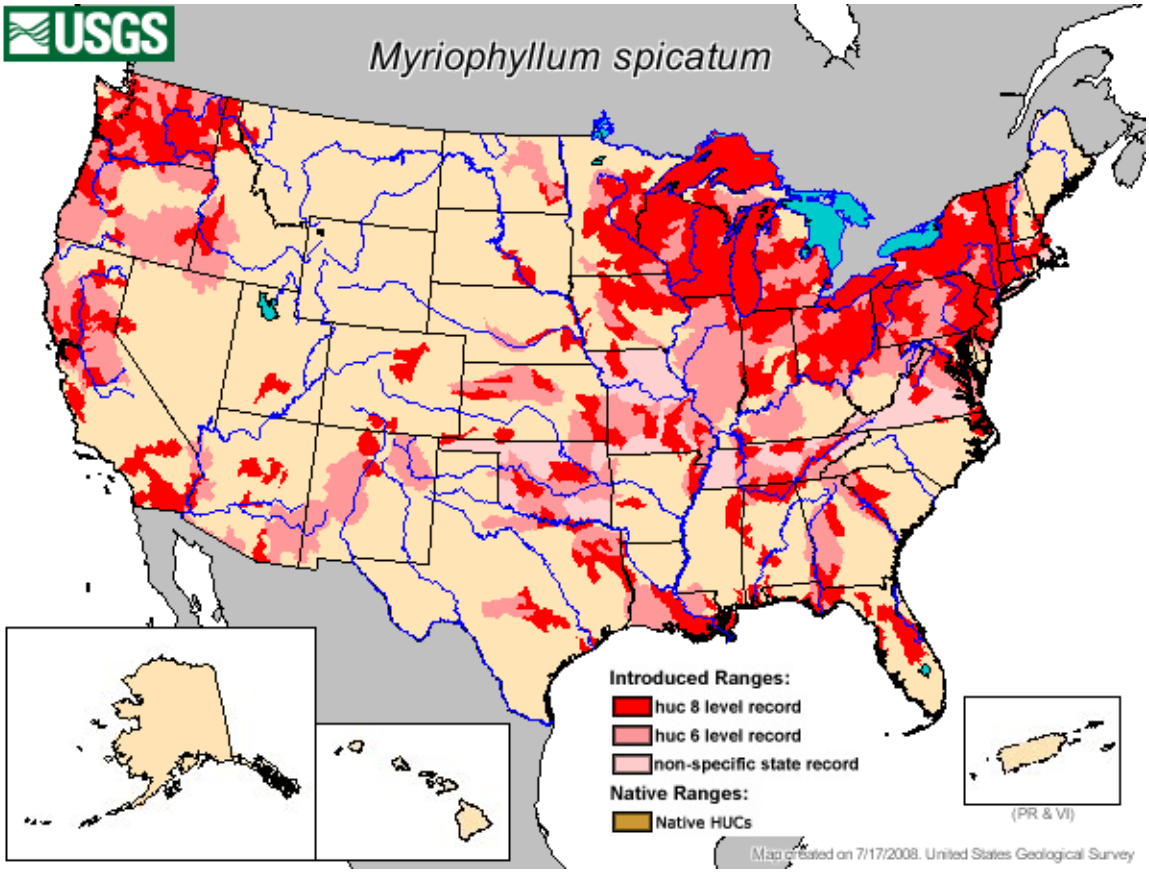
7. Estimate the impact from social and/or political influences if didymosphenia were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively uncertain

Didymosphenia blooms, which may superficially resemble fiberglass insulation or raw sewage pollution, generally elicit strong negative responses from resource users (Spaulding and Elwell 2007). The outcome of these responses is relatively uncertain and depends on the characteristics of the infestation and resource users' perception of the infestation.

Eurasian water-milfoil (*Myriophyllum spicatum*)



Biology: Eurasian water-milfoil is a submerged aquatic macrophyte that grows at 1 – 10 m water depths and tolerates a wide range of pH (5.4 – 11; Aiken et al. 1979). It is native to Europe, Asia, and northern Africa and exotic to the United States (Jacono 2008). This species reproduces primarily through fragmentation and breaks dormancy in early spring, sometimes outcompeting native vegetation by forming a dense canopy. In areas without vegetation, the introduction of Eurasian water-milfoil may increase habitat and refugia for aquatic invertebrates and fishes, but in areas where Eurasian water-milfoil extirpates native vegetation (e.g., *Potamogeton* spp.), reduced aquatic invertebrate diversity and abundance and increases in the relative abundance of small-bodied fishes may result (Keast 1984; Engel 1995).



Risk: Expert panel rankings and rationale

1. Estimate the probability of Eurasian water-milfoil being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

This species spreads along at least two vectors: intentional planting (Couch 1985) and boat-barge-equipment (Invasive Species Program 2008). Eurasian water-milfoil occurs in all five of the most-traveled interstate pathways including Minnesota-South Dakota, Iowa-South Dakota, Nebraska-South Dakota, North Dakota-South Dakota, and Colorado-South Dakota (Jacono 2008). In addition to human-mediated introductions, Eurasian water-milfoil is a perennial that may spread and establish from stolons and stem fragments (Aiken 1979; Madsen et al. 1988).

2. Estimate the probability of Eurasian water-milfoil surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Eurasian water-milfoil already survived transit to and established in South Dakota.

3. Estimate the probability of Eurasian water-milfoil successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

South Dakota Game, Fish and Parks identified an established, near-shore population of Eurasian water-milfoil in Lake Sharpe in 1999 (Dave Ode personal communication).

4. Estimate the probability of Eurasian water-milfoil to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

The population of Eurasian water-milfoil in Lake Sharpe is not as aggressive as others described in the literature, but its invasion history strongly indicates a potential nuisance to South Dakota, especially in lentic or slackwater habitats with elevated nutrient loading, intense plant management, and elevated motorboat traffic (Nichols 1994). The glacial lakes of northeastern South Dakota are more suitable for submerged plant growth and thus could be prone to establishment of nuisance populations (Dave Ode personal communication). Furthermore, Missouri River reservoirs, such as Lake Sharpe, are deep, man-made lentic habitats that lack well-developed, native plant communities typical of shallower

natural lakes. Eurasian water-milfoil would likely have more noticeable environmental effects in natural lakes than it currently has in large, deep reservoirs.

5. Estimate the economic impact if Eurasian water-milfoil were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Reasonably certain

Currently, South Dakota has not incurred any costs to mitigate the population in Lake Sharpe. However, more extensive and aggressive Eurasian water-milfoil populations in neighboring states (e.g., Minnesota) elicit research, monitoring and control expenditures, and it is not unreasonable to anticipate similar economic impacts in South Dakota. Effects of Eurasian water-milfoil on lakeshore property values are uncertain but likely to be negative.

6. Estimate the environmental impact if Eurasian water-milfoil were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

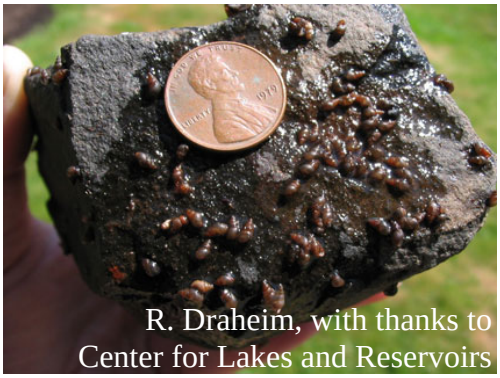
Effects of Eurasian water-milfoil documented in the literature primarily result from its canopy-forming, dense growth habit and include the following: reduced native plant and invertebrate diversity and abundance (Keast 1984; Smith and Barko 1990; Madsen 1994), reduced water quality, reduced food quality for waterfowl (Aiken 1979), increased survival of larval and juvenile fish, decreased feeding success of larger predatory fish (Lillie and Budd 1992; Engel 1995), and reduced fishing access as a result of mat thickness (Olson et al. 1998). Currently, the population in Lake Sharpe does not exhibit these characteristics or cause these effects, but if this species were spread to other more suitable waterbodies in South Dakota, these effects would likely be observed.

7. Estimate the impact from social and/or political influences if Eurasian water-milfoil were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

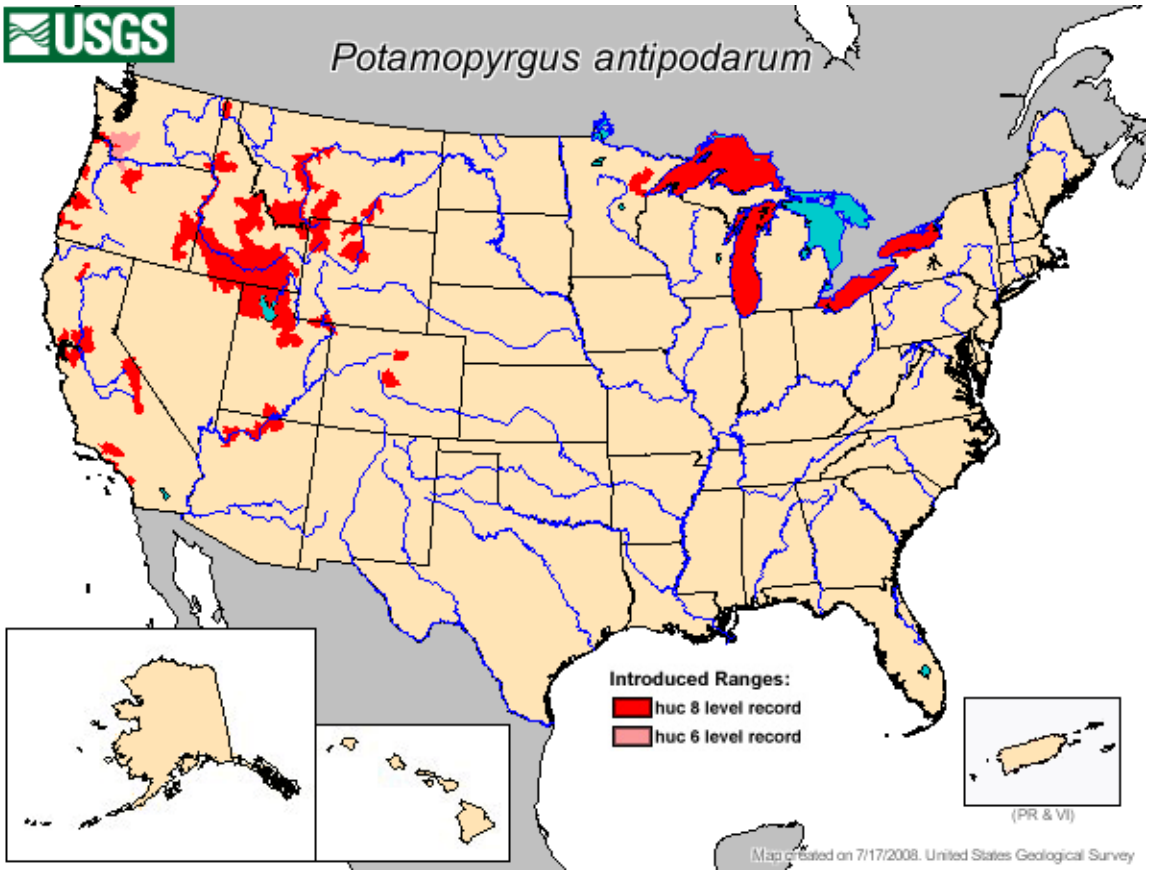
Similarly, social and/or political effects of Eurasian water-milfoil result from its canopy-forming, dense growth habit that impedes recreational (e.g., swimming and boating) and practical (e.g., water intake structures) water (Jacono 2008). As a result of the largely successful, national public outreach and education efforts, a newly established population of Eurasian water-milfoil might elicit a strong, negative response from user groups.

Invertebrates

New Zealand mudsnail (*Potamopyrgus antipodarum*)



Biology: New Zealand mudsnail is a small (adults typically 5 – 12 mm) gastropod species that grazes algae from the substrata of lentic and lotic habitats and can rapidly assume densities up to 750,000 m^{-2} through parthenogenesis (Hall et al. 2003; Richards 2004). This species competes with native aquatic invertebrates for food and may negatively affect trout feeding because of their impalatability and relative abundance compared with native aquatic invertebrates (Vinson in press).



Risk: Expert panel rankings and rationale

1. Estimate the probability of New Zealand mudsnail being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

As the name indicates, this species is native to freshwater lotic and lentic habitats of New Zealand and surrounding islands (Hall et al. 2003). The New Zealand mudsnail is exotic to the United States and spreads along the boat-barge-equipment and intentional stocking (i.e., translocation with fish) vectors (Benson and Kipp 2008). There are no documented occurrences of New Zealand mudsnail in South Dakota, but populations throughout North America consist entirely of parthenogenetic females (Hall et al. 2003), which increases the likelihood of successful establishment in new areas. Additionally, New Zealand mudsnail occurs in at least two pathways, including Minnesota-South Dakota and Colorado-South Dakota (Benson and Kipp 2008). Although the Montana-South Dakota pathway was not implicated in this risk assessment as a primary source of ANS, the New Zealand mudsnail is established in Montana and could continue its eastward range expansion into South Dakota.

2. Estimate the probability of New Zealand mudsnail surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

This species tolerates temperatures from 0 – 34˚C (Hylleberg 1987; Quinn 1994) and demonstrated survival in the boat-barge-equipment and intentional stocking (i.e., translocation with fish) vectors to colonize much of the western United States.

3. Estimate the probability of New Zealand mudsnail successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

New Zealand mudsnail is not freeze-tolerant, however this species has been very successful at colonizing aquatic habitats (freshwater lakes and streams as well as estuaries in Oregon) of the western United States. Furthermore, a clonal population of parthenogenetic females could successfully colonize a new habitat in South Dakota with the introduction of just one individual.

4. Estimate the probability of New Zealand mudsnail to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Relatively uncertain

Following its mid-1980s colonization of the Snake River in Idaho, this species spread to over 50 drainages by 2005 (Richards 2004). Once established in South Dakota, it is likely that the New Zealand mudsnail would spread throughout geothermal aquatic habitats (those that maintain above-freezing temperatures throughout the year) in western South Dakota, particularly in the Black Hills.

5. Estimate the economic impact if New Zealand mudsnail were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Relatively uncertain

It is difficult to predict the economic impact of this species. However, trout fishing in the Black Hills is a considerable source of tourism-related income for South Dakota, and the quality of the fishery might be influenced by the establishment of the New Zealand mudsnail (see rationale for criterion 6). Similar to the zebra mussel, the New Zealand mudsnail also has the potential to impair water intake structures by surface biofouling and clogging, which could result in considerable expense to responsible parties.

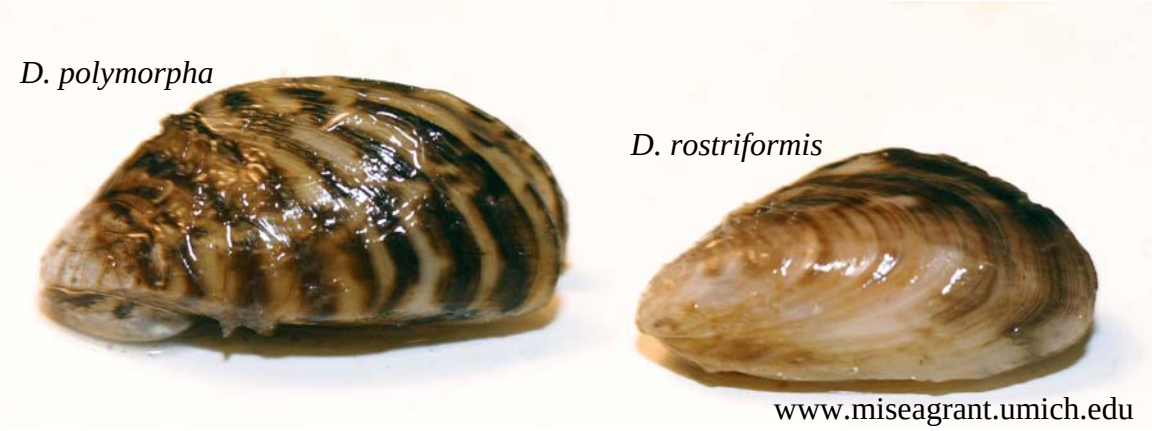
6. Estimate the environmental impact if New Zealand mudsnail were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively uncertain

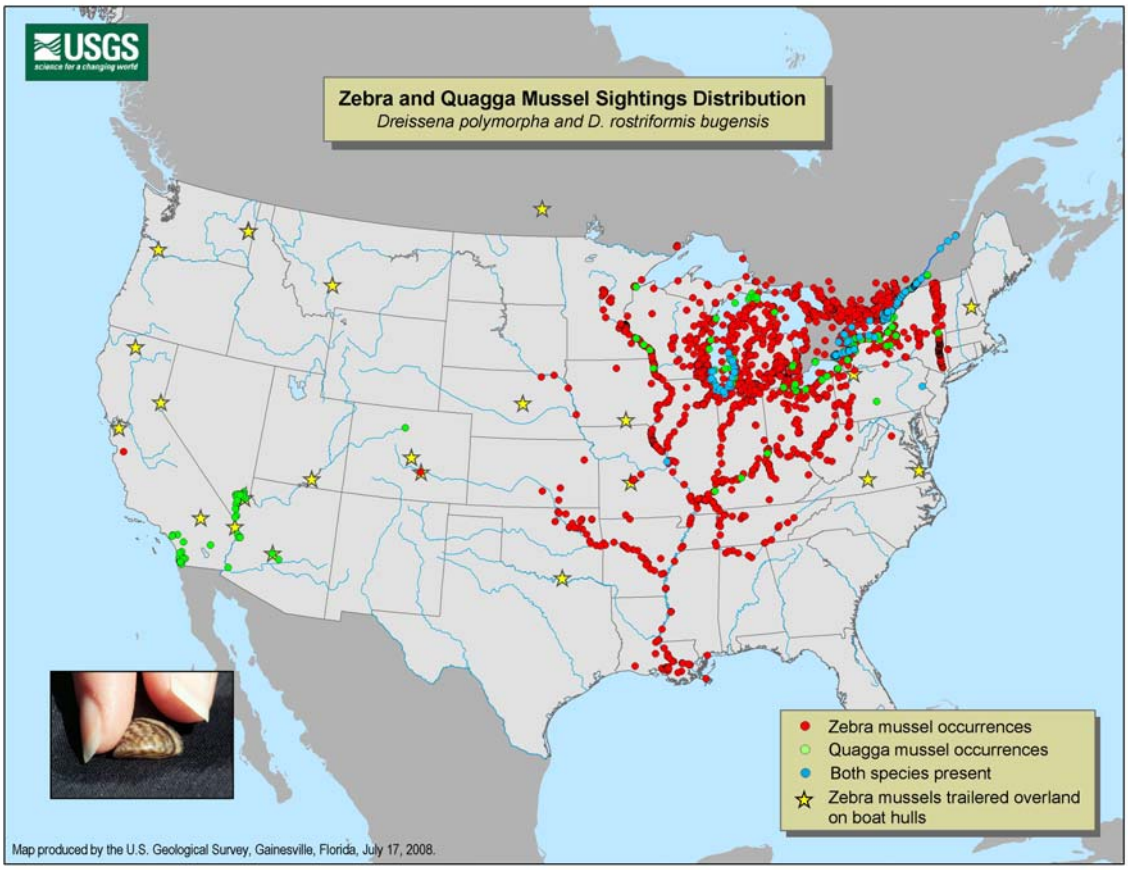
Environmental effects of New Zealand mudsnail may be direct and indirect. Direct effects of their grazing could include changes in primary producer assemblage structure and resultant ecosystem function. Indirect effects could include competition for food and space with native gastropods, bottom-up effects on secondary consumers, and trophic cascades. Salmonid diets are comprised largely of macroinvertebrates and the nutritional quality or edibility of those invertebrates contributes to overall salmonid condition and ultimately, the quality of the fishery (Cada 2004). Based on their dominance in other invaded habitats (e.g., 65 - 92% of macroinvertebrate production in three rivers in the Greater Yellowstone Area, WY (Hall 2006); densities between 300,000 m^{-2} in the Snake River, ID (Richards et al. 2001), competition may change native macroinvertebrate assemblage structure in recipient habitats in South Dakota. Rainbow trout is one of the targeted salmonid species in the Black Hills, and in recent experiments, rainbow trout exhibited decreased growth and poor condition as a result of feeding on New Zealand mudsnails (Vinson in press).

7. Estimate the impact from social and/or political influences if New Zealand mudsnail were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Relatively certain

Trout angler interest groups, including Trout Unlimited, and those businesses that benefit from angling-related tourism in western South Dakota could be affected by the establishment of New Zealand mudsnail in South Dakota. These groups might represent a vocal and powerful lobby if they perceived that their passion and/or livelihood were compromised by an aquatic nuisance species.

Dreissenids (*Dreissena polymorpha* and *Dreissena rostriformis*)





Biology: Two of the best-known aquatic nuisance species in the United States, zebra and quagga mussels, are sessile filter-feeders that reproduce sexually, disperse via larvae called veligers, and occupy a wide range of aquatic habitats. Their primary requirement for colonization is a hard substrate to which they can attach. Effects of dreissenids are generally negative (e.g., reduce the diversity and abundance of native mussels, clog water intake pipes, etc.), but these species sometimes convert hyper-eutrophic, turbid waters to clear, highly-valued fisheries for sight-oriented predators.

Risk: Expert panel rankings and rationale

1. Estimate the probability of dreissenids being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

These species are native to the Black, Caspian, and Asov Seas and exotic to the United States, where they spread along at least one vector: boat-barge-equipment (Benson and Raikow 2008; Benson et al. 2008). Additionally, dreissenids occur in all five of the most-traveled interstate pathways including Minnesota-South Dakota, Iowa-South Dakota, Nebraska-South Dakota, and Colorado-South Dakota (Benson and Raikow 2008; Benson et al. 2008).

2. Estimate the probability of dreissenids surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Zebra mussel veligers were collected in zooplankton tows below Fort Randall and Gavins Point dams in 2003 (Dennis Unkenholz personal communication), so their ability to survive transit to South Dakota has already been demonstrated.

3. Estimate the probability of dreissenids successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Veligers were confirmed on one occasion (see criterion 2 above), but no adults were collected since this introduction, which suggests that zebra mussels are not currently established in South Dakota (Berg and Klumb 2006). It is likely that with continued propagule pressure (i.e., veligers and adults are present in vectors and pathways) and suitability of aquatic habitats in South Dakota, dreissenids will eventually successfully colonize and maintain a population.

4. Estimate the probability of dreissenids to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Zebra mussels colonized Lakes St. Clair and Erie in 1988 (Ludyanskiy et al. 1993), quagga mussels colonized Lake Erie in 1991 (Mills et al. 1996), and currently, these species occur in at least 24 states (Benson and Raikow 2008; Benson et al. 2008). Given their rapid spread throughout the United States, it is likely that dreissenids would spread throughout South Dakota once established.

5. Estimate the economic impact if dreissenids were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Zebra mussel damage (i.e., clogging) to intake pipes, water filtration facilities, and power-generating plants was estimated to cost $100 million per year in the United States (Pimentel et al. 2000), and quagga mussels cause similar damage. South Dakota could be affected by costs for these types of damage, especially at the four Missouri River hydropower facilities, although estimated costs are not included here because of their purely speculative nature.

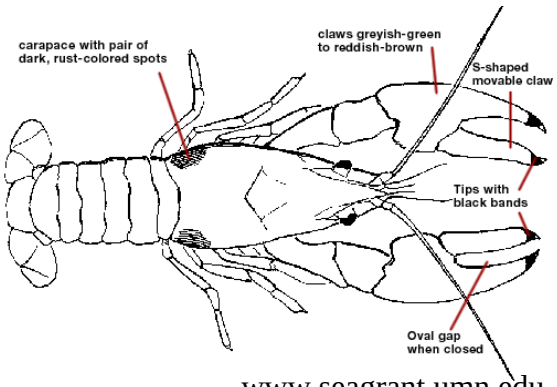
6. Estimate the environmental impact if dreissenids were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Dreissenids have both positive and negative environmental effects where introduced, but the negative effects largely outweigh the potential benefits. Once established in South Dakota, it is likely that dreissenids would achieve similarly high densities (e.g., up to 700,000 m^{-2}; Griffiths et al. 1991) to those observed in other locations outside their native range. At high densities, the environmental effects of dreissenids include: biofiltration and biotic sequestration of nutrients and toxins from the water column, bottom-up trophic effects (i.e., consume suspended algae and alter zooplankton, macroinvertebrate and fish assemblage structures), translocation of nutrients and toxins from the water column to the benthos, and competitive exclusion of native mussels (Ludyanskiy et al. 1993). Three mussels listed as aquatic species of greatest conservation need in the State Comprehensive Wildlife Conservation Plan (elktoe, rock pocketbook, and creek heelsplitter) would be particularly vulnerable to competition from dreissenids.

7. Estimate the impact from social and/or political influences if dreissenids were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

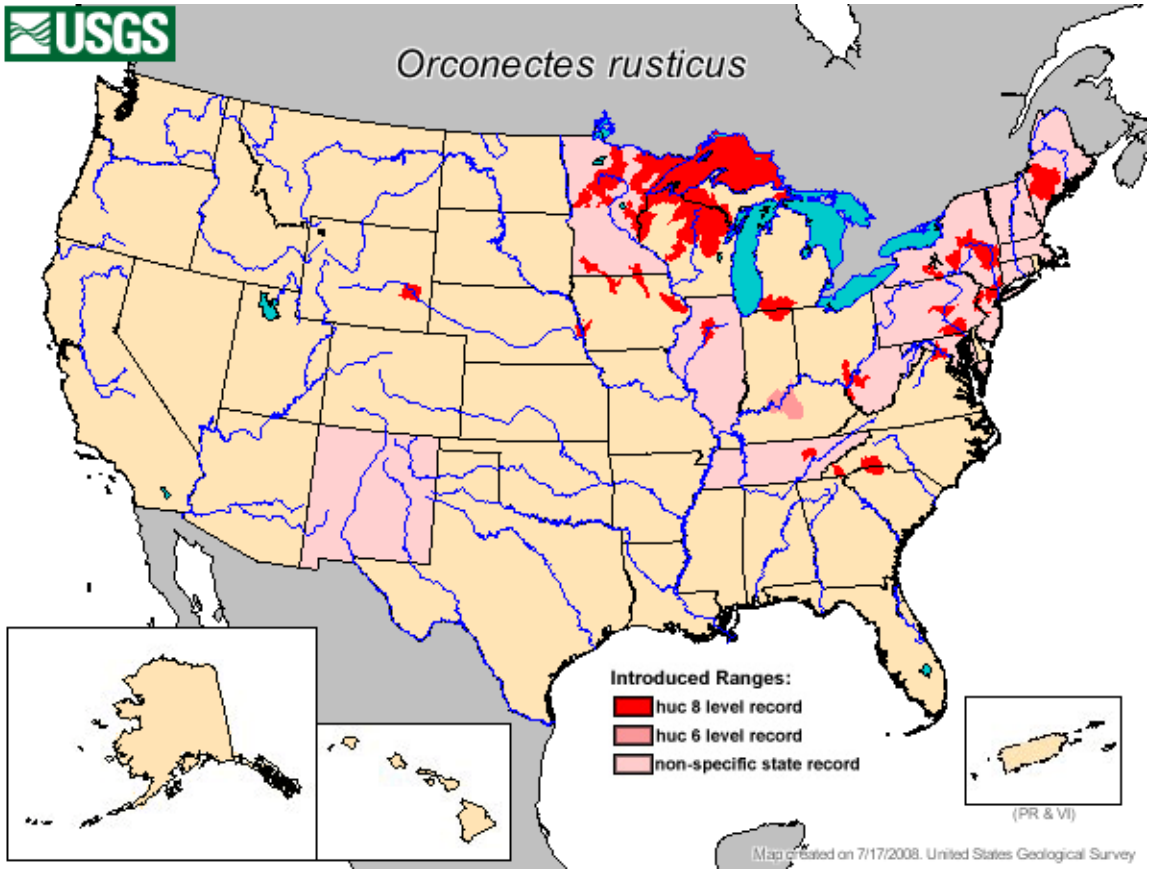
Similar to Eurasian water-milfoil (see above), social and/or political effects of dreissenids result from the high densities that they achieve outside their native range that impede recreational (e.g., sharp-edged mussel shells could pose an injury hazard to swimmers) and practical (e.g., water intake structures) water uses (Benson and Raikow 2008; Benson et al. 2008). As a result of the largely successful, national public outreach and education efforts, a newly established population of a dreissenid species might elicit a strong, negative response from user groups.

Rusty crayfish (*Orconectes rusticus*)



www.seagrant.umn.edu

Biology: Rusty crayfish is an herbivorous crustacean that reproduces sexually and is native to streams of the southeastern United States but is apparently spreading via the aquaculture and bait vectors to occupy new habitats. This species is generally larger and more aggressive, and may outcompete native crayfishes in South Dakota, resulting in changes to aquatic invertebrate communities and possibly influencing higher-order consumers.



Risk: Expert panel rankings and rationale

1. Estimate the probability of rusty crayfish being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

These species are native to the Ohio, Tennessee, and Cumberland River drainages of the United States, but they are assumed to have spread outside their native range to states including Minnesota (i.e., they occupy the Minnesota-South Dakota pathway) along at least one vector: bait (Hobbs and Jass 1988). General knowledge suggests that they may also spread along the plant-animal importation for research, aquaculture, and intentional stocking vectors.

2. Estimate the probability of rusty crayfish surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Rusty crayfish survived long-distance dispersal to neighboring states, including Minnesota, and it is likely that they are capable of surviving transit to South Dakota as well.

3. Estimate the probability of rusty crayfish successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Because they have successfully established in Minnesota (i.e., already present and established at a similar latitude), they will likely be successful at establishing in South Dakota once introduced. Furthermore, a population could become established from the introduction of just one female carrying viable sperm, which could result in 80 – 575 young (Hobbs and Jass 1988).

4. Estimate the probability of rusty crayfish to spread beyond the colonized area in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively certain

Once established in South Dakota, it is possible that rusty crayfish could spread naturally, albeit slowly, or be spread beyond the colonized area by anglers collecting and transporting their own bait (i.e., unable to distinguish between native crayfish and this aquatic nuisance species) and aquaculturists.

5. Estimate the economic impact if rusty crayfish were to establish (or is/was established) in South Dakota.
    a. rating = Low
    b. uncertainty = Very uncertain

The most likely economic effect of the establishment of rusty crayfish would be declining crayfish harvest, and potential collapse of the crayfish fishery. However, it is uncertain whether the collapse of the crayfish fishery in South Dakota would represent a noticeable fraction of the state's GDP. Another

potential economic effect is lost revenue as a result of a declining smallmouth bass fishery (see criterion 6 below).

6. Estimate the environmental impact if rusty crayfish were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Relatively certain

Several authors documented the decline of native crayfishes upon the establishment of rusty crayfish in states outside South Dakota (e.g., Lodge et al. 1986). Crayfish is an important component of smallmouth bass (*Micropterus dolomieu*) diets (Liao et al. 2002), and the smallmouth bass fishery could be negatively impacted by the establishment of rusty crayfish. Another environmental effect of rusty crayfish is their tendency to overgraze aquatic macrophytes, which leads to decreases in macrophyte abundance and diversity (Lodge and Lorman 1987) and may have indirect bottom-up effects on other trophic levels, including other invertebrates, reptiles (especially the false map turtle; Bandas and Higgins 2004), fish, and waterfowl. Although this has largely been documented as a detriment in northern, oligotrophic systems, the establishment of rusty crayfish in more productive, warmwater lakes of South Dakota has the potential, albeit uncertain, to stem excessive aquatic macrophyte growth.

7. Estimate the impact from social and/or political influences if rusty crayfish were to establish (or is/was established) in South Dakota.
    a. rating = Low
    b. uncertainty = Relatively certain

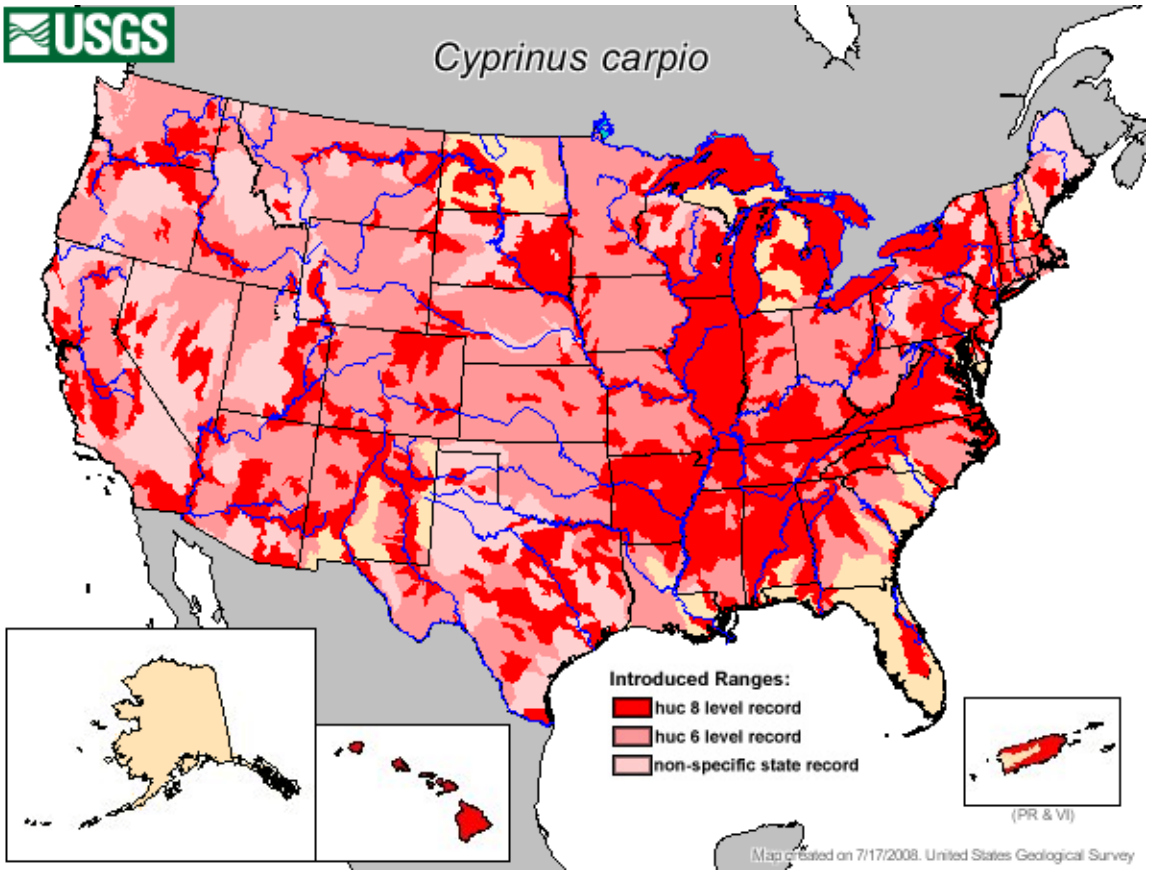
At this time, it is unlikely that the establishment of rusty crayfish would elicit measureable social or political effects in South Dakota.

Vertebrates and associated pathogens

Common carp (*Cyprinus carpio*)

Duane Raver, with thanks to USFWS

Biology: Common carp are prolific and widespread benthivorous fishes that reproduce sexually. South Dakota anglers do not consider common carp a desirable sport fish, but carp are harvested from South Dakota waters and sold at markets in larger metropolitan areas. In addition to their competition with native fishes, common carp disrupt benthic communities and may alter biogeochemical cycling.



Risk: Expert panel rankings and rationale

1. Estimate the probability of common carp being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

This species is native to Eurasia and exotic to the United States, but it was introduced to the United States and spread to South Dakota and other states along

at least two vectors: intentional stocking and bait (Blackwell 2007). It is currently established in South Dakota as well as present in all five of the other most-traveled pathways, including Minnesota-South Dakota, and Iowa-South Dakota, Nebraska-South Dakota, North Dakota-South Dakota, and Colorado-South Dakota (Nico et al. 2008b).

2. Estimate the probability of common carp surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Common carp already survived transit to and established in South Dakota.

3. Estimate the probability of common carp successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Common carp likely colonized South Dakota in 1885 and have since maintained populations throughout the state (Blackwell 2007).

4. Estimate the probability of common carp to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Common carp occur statewide in South Dakota. Once established in South Dakota, common carp likely spread beyond the colonized area by anglers collecting and transporting their own bait (Blackwell 2007).

5. Estimate the economic impact if common carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very uncertain

The primary economic effect of common carp in South Dakota was the establishment of a commercial fishery, which harvests thousands of pounds from South Dakota lakes each winter for export to larger metropolitan markets (Blackwell 2007).

6. Estimate the environmental impact if common carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Several authors documented decreased diversity and abundance of aquatic macrophytes coupled with increased turbidity following establishment of common

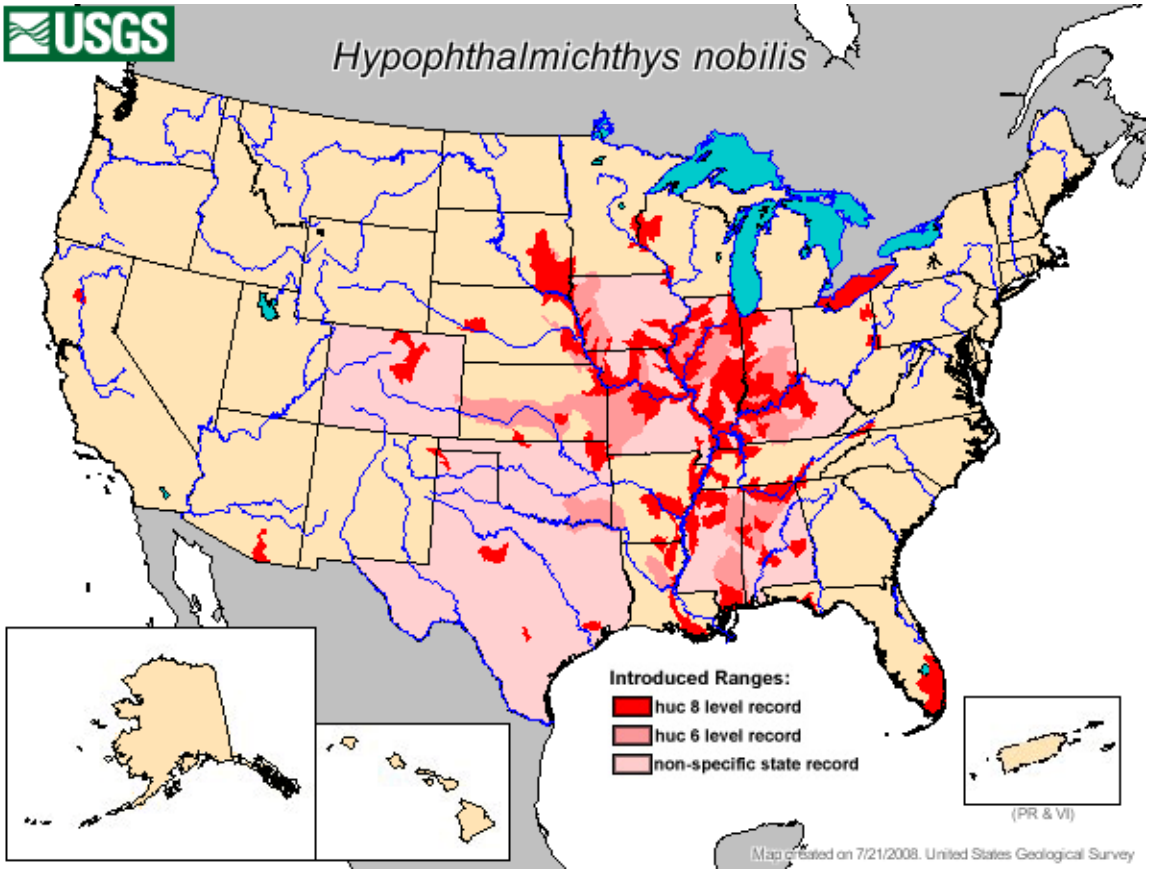
carp (e.g., Laird and Page 1996). Additionally, common carp may compete with ecologically similar species (i.e., catostomids) and have indirect negative effects on sight-oriented predators, benthic feeders and nesters, and fishes and birds relying on aquatic macrophytes for food and habitat (Fuller et al. 1999).

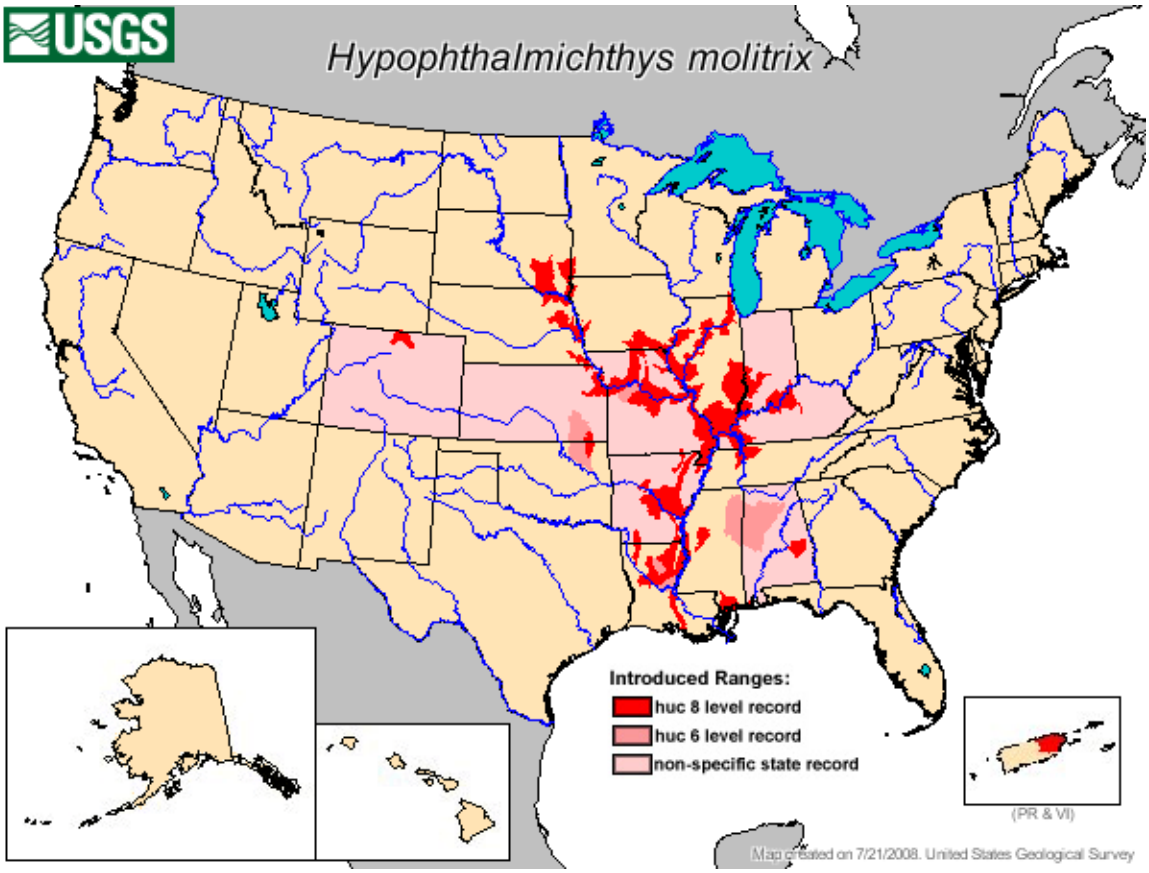
7. Estimate the impact from social and/or political influences if common carp were to establish (or is/was established) in South Dakota.
    a. rating = Low
    b. uncertainty = Relatively certain

Common carp established over 100 years ago, and although most South Dakotans, especially fishermen, consider them rough fish, their social and/or political effects are negligible. Many people have forgotten that they are exotic species (Shearer 2007).

Silver / bighead carp (*Hypophthalmichthys molitrix and Hypophthalmichthys nobilis*)

Biology: Silver and bighead carp are considered jointly here because of they readily hybridize and have similar biology and ecological functions. These species reproduce sexually, are prolific and widespread in the Mississippi River and its tributaries, and as they extend their ranges in the Missouri River basin, concern is growing over their potential to alter plankton community dynamics and negatively affect other planktivores, especially paddlefish (*Polyodon spathula*). Similar to common carp, anglers consider silver and bighead carp rough fish, and these species potentially injure boaters by jumping out of the water in response to passing boats. However, archery fishing for these species does occur. Silver carp are listed as an injurious species by the U. S. Fish and Wildlife Service under the provisions of the Lacey Act (USFWS 2007a).





Risk: Expert panel rankings and rationale

1. Estimate the probability of silver / bighead carp being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

These species are native to eastern Asia and exotic to the United States, but they were introduced to the United States and spread to South Dakota and other states along at least two vectors: intentional stocking (Freeze and Henderson 1982; Fuller et al. 1999) and bait (Shearer 2007). Silver and bighead carp are currently established in South Dakota as well as present in three other pathways including Iowa-South Dakota, Nebraska-South Dakota, and Colorado-South Dakota (Nico 2008), whereas bighead carp are additionally present in the Minnesota-South Dakota pathway (Nico and Fuller 2008).

2. Estimate the probability of silver / bighead carp surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Silver / bighead carp already survived transit to and established in South Dakota.

3. Estimate the probability of silver / bighead carp successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Moderately certain

Silver / bighead carp likely colonized and have since maintained a population in South Dakota by migrating upstream through the mainstem of the Missouri River (Nico 2008; Nico and Fuller 2008).

4. Estimate the probability of silver / bighead carp to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Relatively certain

Given their success at escape from captivity, upstream migration, and colonization throughout the Mississippi and Missouri Rivers it is likely that both species will eventually become widespread in South Dakota. Both silver carp (primarily phytoplanktivores) and bighead carp (primarily zooplanktivores) would find suitable habitat and ample food to maintain populations throughout the warmwater streams and rivers and the shallow, eutrophic wetlands, lakes, and reservoirs of South Dakota.

5. Estimate the economic impact if silver / bighead carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Moderately uncertain

Although it is difficult to predict the economic effect of these fishes in South Dakota, the potential for lost revenue from angling-related tourism exists. The primary environmental effects of these species (see criterion 6 below) implies that they will compete with native planktivores, some of which are highly valued sport fisheries (e.g., paddlefish *Polyodon spathula*; Fuller et al. 1999).

6. Estimate the environmental impact if silver / bighead carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Both species are efficient planktivores with the potential to compete with native filter-feeding planktivores (fishes and mussels; Laird and Page 1996). It is possible that sustained pressure on the plankton community could eventually lead to plankton community collapse and effects on higher-order consumers through a trophic cascade. The three mussel species (elktoe *Alasmidonta marginata*, rock pocketbook *Arcidens confragosus*, and creek heelsplitter *Lasmigona compressa*) listed as species of greatest conservation need in South Dakota's State

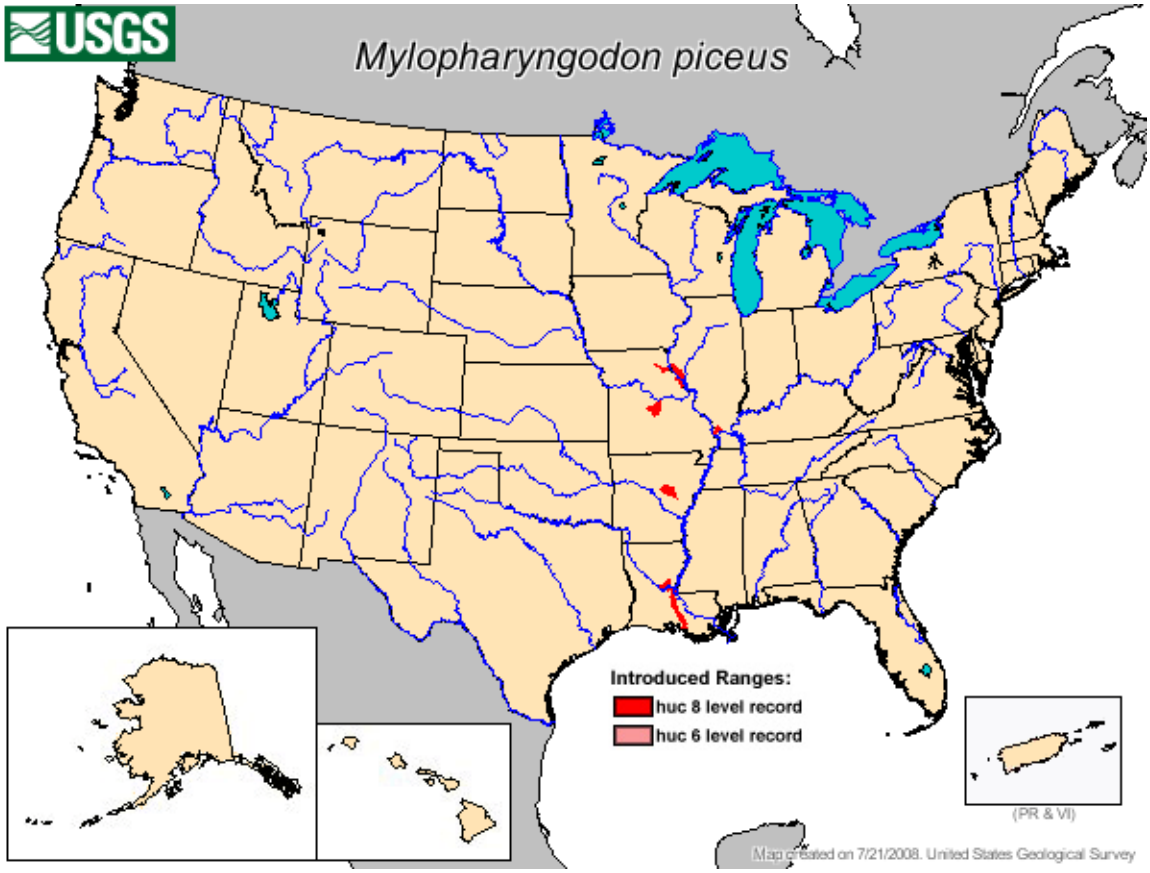
Comprehensive Wildlife Conservation Plan (SDGFP 1996) are particularly threatened by competition from filter-feeding fishes.

7. Estimate the impact from social and/or political influences if silver / bighead carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Moderately certain

Silver carp are notoriously known for their propensity to jump out of the water when disturbed and injure a passing boater (Shearer 2007). Upon widespread establishment in South Dakota, anticipate a strongly negative social and political response.

Black carp (*Mylopharyngodon piceus*)

Biology: Black carp is a molluscivore that was introduced (most recently of all the Asian carps) to the United States as a biocontrol agent to stem parasitic fish diseases in aquaculture facilities by consuming molluscan hosts. After their escape from aquaculture they were listed as an injurious species by the U. S. Fish and Wildlife Service under the provisions of the Lacey Act (USFWS 2007b). Black carp closely resemble grass carp, are widely tolerant of lentic and lotic freshwater habitats, and reproduce sexually.



Risk: Expert panel rankings and rationale

1. Estimate the probability of black carp being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
   a. rating = Medium
   b. uncertainty = Moderately certain

These species are native to eastern Asia and exotic to the United States, but they were introduced to the United States with intentionally stocked grass carp in the 1970s (Nico and Williams 1996). Black carp have not been collected in South Dakota or in any of the five primary pathways, but because they are similar in

appearance to grass carp and because they are listed by the U.S. Fish and Wildlfie Service as an injurious species under the Lacey Act, South Dakota's risk assessment research and monitoring oversight committee chose to include them in South Dakota's primary species watch list.

2. Estimate the probability of black carp surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Black carp escaped aquaculture ponds in Missouri in April of 1994 and so could survive transit via natural dispersal, intentional (albeit illegal) stocking, or unintentional capture and transfer as bait.

3. Estimate the probability of black carp successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Moderately certain

Grass carp with very similar requirements to those of black carp have successfully colonized and maintained populations throughout South Dakota, and thus, it is likely that black carp would also successfully establish in South Dakota.

4. Estimate the probability of black carp to spread beyond the colonized area in South Dakota.
    a. rating = Medium
    b. uncertainty = Moderately certain

Given their success at escape from captivity, upstream migration, and colonization throughout the Mississippi and Missouri Rivers it is possible that black carp could eventually become widespread in South Dakota.

5. Estimate the economic impact if black carp were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Moderately uncertain

Although it is difficult to predict the economic effect of these fishes in South Dakota, the potential for lost revenue from angling or waterfowl hunting exists. The primary environmental effects of these species (see criterion 6 below) implies that they have the potential to affect desirable sport fisheries and waterfowl populations by reducing the diversity and abundance of native mussels on which fishes and waterfowl feed (Nico and Williams 1996).

6. Estimate the environmental impact if black carp were to establish (or is/was established) in South Dakota.
    a. rating = High

b. uncertainty = Very certain

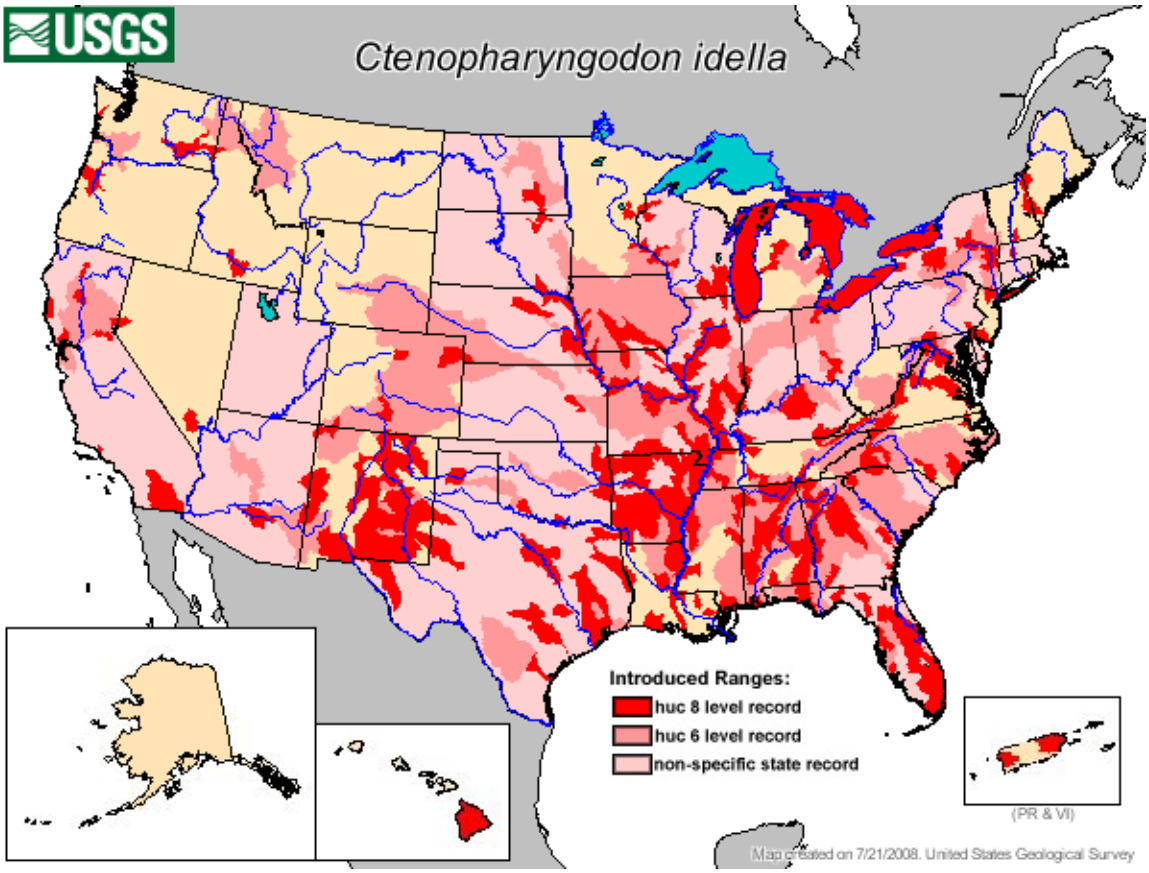
The primary environmental effects of black carp include: reduced diversity and abundance of native mussels, competition with native fishes, competition with waterfowl that consume mussels, and introduction of parasites (Nico and Williams 1996). The three mussel species (elktoe, rock pocketbook, and creek heelsplitter) listed as species of greatest conservation need in South Dakota's State Comprehensive Wildlife Conservation Plan are particularly threatened by predation by black carp (SDGFP 1996).

7. Estimate the impact from social and/or political influences if black carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Moderately certain

Because black carp are federally listed as injurious, each new state occurrence is likely to elicit a strongly negative social and political response.

Grass carp (*Ctenopharyngodon idella*)

Biology: Grass carp are used for biocontrol of aquatic plants across a wide array of habitat types; to minimize the threat of natural reproduction and establishment of undesirable populations, South Dakota requires that only sterile triploid grass carp can be stocked. Grass carp decrease aquatic plant biomass but can increase algal biomass, nitrite-nitrogen, nitrate-nitrogen, total phosphorus, and abundances of phytoplankton, zooplankton and benthic fauna (Kirkagac and Demir 2004). Grass carp were stocked extensively in the United States since 1963 (Mitchell and Kelly 2006), but this species is native to China, highly fecund, and is capable of long-distance migration and dispersal (Fuller et al. 1999). Thus, propagule pressure from grass carp may be strong.



Risk: Expert panel rankings and rationale

1. Estimate the probability of grass carp being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
   a. rating = High
   b. uncertainty = Very certain

These species are native to eastern Asia and exotic to the United States, but they were introduced to the United States and spread to South Dakota and other states along at least two vectors: intentional stocking and escape from aquaculture (Fuller et al. 1999). Grass carp are currently established in South Dakota as well as present in all five other pathways including Minnesota-South Dakota, Iowa-South Dakota, Nebraska-South Dakota, North Dakota-South Dakota, and Colorado-South Dakota (Nico et al. 2008a).

2. Estimate the probability of grass carp surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Grass carp already survived transit to and are established in South Dakota.

3. Estimate the probability of grass carp successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively certain

Although many states prohibit the intentional release of diploid grass carp into open drainages, grass carp have colonized and have maintained a population in South Dakota since at least 1980 (Fuller et al. 1999). Nebraska, Iowa, eastern Colorado (in addition to Hawaii, Kansas, Missouri, Oklahoma, Arkansas, Mississippi, and Alabama) are three states that currently allow the legal stocking of diploid grass carp (Mitchell and Kelly 2006) and grass carp have been collected in the Missouri River downstream of Gavins Point Dam (Stukel et al. 2006).

4. Estimate the probability of grass carp to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Given their success at escape from captivity, upstream migration, and colonization throughout the Mississippi and Missouri Rivers it is likely that grass carp will eventually become widespread in South Dakota. Grass carp, as the name implies, are primarily herbivorous grazers that would find suitable habitat and ample food to maintain populations throughout the warmwater streams and rivers and the shallow, eutrophic wetlands, lakes, and reservoirs of South Dakota.

5. Estimate the economic impact if grass carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very uncertain

Although it is difficult to predict the economic effect of these fishes in South Dakota, the potential for lost revenue from angling-related tourism exists. The primary environmental effects of these species (see criterion 6 below) suggests their potential to manipulate a clear-water, macrophyte-dominated fishery into a highly eutrophic, turbid phytoplankton-dominated fishery, with negative implications for sight-oriented predators (Fuller et al. 1999).

6. Estimate the environmental impact if grass carp were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Grass carp are efficient grazers that decrease the abundance of aquatic macrophytes, compete with native crayfishes, and may negatively affect fishes (e.g., reduced habitat and food availability). In South Dakota lakes, the identity of the top fish predator (i.e., largemouth bass *Micropterus salmoides* vs. northern pike *Esox lucius*) may influence the effectiveness of grass carp at macrophyte removal. Bauer and Willis (1990) found that grass carp eliminated macrophytes in a northern latitude water body with largemouth bass but did not control macrophytes in a similar lake with northern pike, and they suggested grass carp depredation as an explanation. They also host parasites and diseases with unknown transmissibility to native fishes (Fuller et al. 1999).

7. Estimate the impact from social and/or political influences if grass carp were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Moderately certain

When introduced for biocontrol, grass carp are initially perceived as a positive addition to waterbodies with dense growth of aquatic macrophytes. However, in other habitats, grass carp may be responsible for the initiation of major shifts in the trophic status and quality of a fishery. Thus, it is likely that there would be some social and political effects following new introductions, but the responses could be positive or negative.

Viral Hemorrhagic Septicemia (VHS)

Biology: VHS is an acute to chronic viscerotropic disease of rabdoviral etiology that could infect, spread, and eventually result in die-offs of several valuable fish species in South Dakota (Cordes 2006). South Dakota's Fish Health Management Plan and Risk Assessment Protocols lists VHS as "Emergency Prohibitive", which are pathogens not known to be present in South Dakota, have the potential to cause severe mortality, and cannot be controlled (Cordes 2006).

Risk: Expert panel rankings and rationale

1. Estimate the probability of VHS being on, with, or in one of the vectors and pathways to South Dakota and state which vector(s) and pathway(s).
    a. rating = High
    b. uncertainty = Very certain

The North American isolate of VHS was first detected in 1988 from salmonids and Pacific cod occupying Puget Sound and the Gulf of Alaska, and in 2005, a new substrain was implicated in several Great Lakes die-offs, including muskellunge (*Esox musquinongy*), freshwater drum (*Aplodinotus grunniens*), yellow perch (*Perca flavescens*), and gizzard shad (*Dorosoma cepedianum*). Although the transmission vector is not well-understood (i.e., fish, fish gametes, and equipment are all in question), the virus is present in at least one pathway: Minnesota-South Dakota (Cordes 2006) and has recently been found in the Ohio River.

2. Estimate the probability of VHS surviving in transit to South Dakota.
    a. rating = High
    b. uncertainty = Very certain

VHS survived transit into the Great Lakes and could likely survive transit to South Dakota in contaminated shipment of fish or fish gametes.

3. Estimate the probability of VHS successfully colonizing and maintaining a population where introduced in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Fishes that were infected in the Great Lakes (e.g., yellow perch and salmonids; see criterion 1 above) are also abundantly present in South Dakota waters and could serve as suitable hosts for VHS to establish successfully.

4. Estimate the probability of VHS to spread beyond the colonized area in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Movement of fish stocks, fish gametes, and equipment used in transfer could spread the virus from one waterbody to another in South Dakota, potentially infecting another susceptible population of fish.

5. Estimate the economic impact if VHS were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Although it is difficult to predict the total economic effect of these fishes in South Dakota, the potential expenses of viral screening and clean-up of fish die-offs, and the potential lost revenue from angling-related tourism are possibilities. The primary environmental effect of the virus (see criterion 6 below) is a die-off of fishes with substantial angling-related value in South Dakota (e.g., yellow perch and salmonids).

6. Estimate the environmental impact if VHS were to establish (or is/was established) in South Dakota.
    a. rating = Medium
    b. uncertainty = Relatively certain

VHS infections could result in die-offs of several valuable fish species in South Dakota (Cordes 2006). Fish die-offs could potentially disrupt trophic status of a waterbody (i.e., through removal of top predators) and alter biogeochemical cycling (i.e., decomposition of large quantities of fish carcasses).

7. Estimate the impact from social and/or political influences if VHS were to establish (or is/was established) in South Dakota.
    a. rating = High
    b. uncertainty = Very certain

Although humans have not been infected from eating VHS-infected fish, the physical symptoms of infected fishes would be readily observable by South Dakota anglers. Because outbreaks of VHS in the Great Lakes were well-publicized, social and political reactions to establishment in South Dakota would likely be strongly negative.

Conclusions and Management Recommendations

The risk assessment met the overall objective of supplying the information required to identify potential threats and prioritizing the most significant threats. Specifically, the risk assessment identified over sixty species that pose relevant threats to South Dakota's aquatic resources, incorporated a literature review and communications with state and regional experts, and ranked threats posed by ANS. Current ANS distributions in South Dakota are restricted to one or a few water bodies, but the potential for localized populations to spread and the potential for new species introductions from outside South Dakota are high. It is also possible, indeed likely, that some additional ANS occur undetected in South Dakota, and it is evident that considerable gaps still exist in our knowledge of these species, especially quantitative predictions of their potential distributions, interactions with native species, and economic, environmental, and socio-political effects in South Dakota.

Three general areas of aquatic nuisance species research are warranted to address these deficiencies. First, a coordinated long-term monitoring program, in combination with a rapid response and management plan for affected waters, is needed to detect and prevent the spread of aquatic nuisance species within South Dakota. Second, the relative vulnerability of aquatic habitats in South Dakota at multiple spatial scales could be assessed using a two-pronged approach: experimental research to evaluate the mechanisms of successful establishment and GIS-based ecological niche modeling. Third, paired comparisons of affected and unaffected waters in addition to mesocosm and laboratory studies could be designed to evaluate the effects of aquatic nuisance species on valuable South Dakota fisheries. Aquatic nuisance species pose real and considerable threats to South Dakota fisheries and aquatic habitats, but timely planning, research, and education could effectively stem future introductions and spread, and save valuable resources.

Based on this assessment of risk, we recommend a re-evaluation of current rules and regulations and potential implementation of new rules and protocols to prevent the intentional and unintentional introduction and spread of ANS in South Dakota. Specifically, revisiting stocking decisions, gear handling procedures, and bait regulations may provide the greatest risk reductions in terms of ANS. Managers must thoroughly evaluate stocking decisions for the potential to intentionally or unintentionally translocate ANS. Intentional stocking and planting were the two vectors most-commonly associated with introducing and spreading aquatic nuisance species. More than one-third of the ANS were likely introduced intentionally. This suggests that the benefits of well-intentioned stocking programs need to be carefully weighed against the potential drawbacks of ANS.

Boats, barges, or equipment were the second most common vector cited for introducing ANS to new areas. Nearly 25% of ANS identified in this risk assessment were transported by this vector. Although these introductions are unintentional, they can be prevented by developing and strictly following protocols to clean and inspect equipment before re-deployment. We recommend that managers use the organism information contained in this risk assessment to adopt HACCP (Hazard Analysis and Critical Control Point; for more information see www.seagrant.umn.edu/ais/haccp) plans to prevent the unintentional introduction and spread of ANS. We further recommend that

investing in education and outreach to educate resource users in proper inspection and cleaning techniques for their equipment will reduce the rate of ANS introductions and spread.

Bait was the third most commonly cited vector in the introduction and spread of ANS. From collection and sale to angling and disposal, there are several opportunities for ANS to reach new habitats. We recommend more restrictive rules and regulations regarding import/export, harvest, and reporting requirements for the bait industry in South Dakota. In addition, we recommend inspections of bait industry facilities, equipment, sales points, and angler equipment (e.g., public ramp inspections of boats, trailers, and other equipment) to reduce unintentional or intentional ANS movement along this vector and provide educational materials.

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TABLE 1.—Panel of experts consulted and/or assembled to qualitatively assess risk posed by aquatic nuisance species in South Dakota.

Name	Title	Affiliation	E-mail	Phone
Doug Backlund	Database Manager / Biologist	GFP	doug.backlund@state.sd.us	605-773-4345
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Rob Klumb	Fish Biologist	USFWS	robert_klumb@fws.gov	605-224-8693
Norm Kopecky	Concerned citizen	USPS - retired	nkopecky@iw.net	
Gary Larson	Professor	SDSU	gary.larson@sdstate.edu	605-688-4552
Nathan Morey	Biologist	SDDOT	nathan.morey@state.sd.us	
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Todd St. Sauver	Regional Fisheries Manager	GFP	todd.st.sauver@state.sd.us	605-362-2726
Greg Wanner	Fish Biologist	USFWS	greg_wanner@fws.gov	605-224-8693
David Willis	Department Head	SDSU	david.willis@sdstate.edu	605-688-6121
Stephen Wilson	Resource Management/GIS specialist	Missouri National Recreational River, NPS	stephen_k_wilson@nps.gov	402-667-5524

TABLE 2.—Summary of ANS taxa identified for South Dakota ANS Risk Assessment. An expert panel and a literature review gave priority to watch list taxa (n=14), which represent species that pose the most substantial economic, environmental, and socio-political threats to South Dakota. Probable vector by which the species was or will be introduced include intentional planting or stocking (I), boat-barge-equipment (BBE), bait (B), aquaculture (AE), plant trade (PT), aquarium (AM), and parasite (PE).

Common name	Scientific name	Status in SD	Probable vector
Watch list			
brittle naiad	*Najas minor*	established	I, BBE
curly pondweed	*Potamogeton crispus*	established	I, BBE
didymosphenia	*Didymosphenia geminata*	established	BBE
Eurasian water-milfoil	*Myriophyllum spicatum*	established	I
New Zealand mudsnail	*Potamopyrgus antipodarum*	not present	I, BBE
rusty crayfish	*Orconectes rusticus*	not present	B
dreissenids			
zebra mussel	*Dreissena polymorpha*	collected	BBE
quagga mussel	*Dreissena rostriformis bugensis*	not present	BBE
bighead and silver carps			
bighead carp	*Hypothalmichthys nobilis*	established	AE
silver carp	*Hypothalmichthys molitrix*	established	AE
black carp	*Mylopharyngodon piceus*	not present	I, B
common carp	*Cyprinus carpio*	established	I, B
grass carp	*Ctenopharyngodon idella*	established	I
viral hemorrhagic septicemia	-	not present	I, BBE
Secondary species of concern			
black alder	*Alnus glutinosa*	not present	I
Brazilian waterweed	*Egeria densa*	not present	
bur reed	*Sparganium glomeratum (Laestad.) L. Neum.*	not present	
European water clover	*Marsilea quadrifolia*	not present	I
flowering rush	*Butomus umbellatus*	established	I, PT
purple loosestrife	*Lythrum salicaria*	established	I, PT
salt cedar	*Tamarix spp.*	established	I, PT
water foxtail	*Alopecurus arundinaceus*	established	
yard dock	*Rumex longifolius DC.*	not present	
yellow floating-heart	*Nymphoides peltata*	not present	AM
yellow iris	*Iris pseudacorus*	established	PT
asian clam	*Corbicula fluminea*	collected	B, AE
big-ear radix	*Radix auricularia*	not present	PT, AM
calanoid copepod	*Megacyclops viridis*	not present	BBE
Chinese mystery snail	*Cipangopaludina chinensis malleata*	not present	AM
European stream valvata	*Valvata piscinalis*	not present	BBE
freshwater jellyfish	*Craspedacusta sowerbyi*	not present	I, PT
Japanese mystery snail	*Cipangopaludina (Bellamya) japonica*	not present	I
opossum shrimp	*Mysis relicta*	established	I
snail	*Melanoides tuberculata*	established	
spiny water flea	*Bythotrephes longimanus*	not present	BBE
water flea	*Daphnia lumholtzi*	not present	I, BBE

water flea	*Eubosmina coregoni*	not present	BBE
alewife	*Alosa pseudoharengus*	not present	I
bowfin	*Amia calva*	not present	I
brook silverside	*Labidesthes sicculus*	not present	
bullhead minnow	*Pimephales vigilax*	established	I, B
cisco	*Coregonus artedi*	established	I
digenean fluke	*Ichthyocotylurus*	not present	PE
digenean fluke, trematode	*Neascus brevicaudatus*	not present	PE
goldfish	*Carassius auratus*	established	AM
lake chubsucker	*Erimyzon sucetta*	not present	I
monogenetic fluke	*Dactylogyrus amphibothrium*	not present	PE
monogenetic fluke	*Dactylogyrus hemiamphibothrium*	not present	PE
myxosporidian	*Sphaeromyxa sevastopoli*	not present	
nutria	*Myocastor coypus*	not present	I
redside shiner	*Richardsonius balteatus*	not present	B
round goby	*Apollonia melanostomus*	not present	BBE
rudd	*Scardinius erythropthalmus*	established	B
ruffe	*Gymnocephalus cernuus*	not present	BBE
sacramento perch	*Archoplites interruptus*	established	I
salmonid whirling disease	*Myxobolus cerebralis*	not present	I
tench	*Tinca tinca*	not present	I
three-spined stickleback	*Gasterosteus aculeatus*	not present	I, BBE, B
tubenose goby	*Proterorhinus semilunaris*	not present	BBE
western and eastern mosquitofish	*Gambusia affinis and Gambusia holbrooki*	not present	I
white catfish	*Ameirus catus*	not present	I
zander	*Sander lucioperca*	established	I

FIGURE 1.—Organizational chart relating South Dakota's aquatic nuisance species risk assessment to the overall risk management plan.

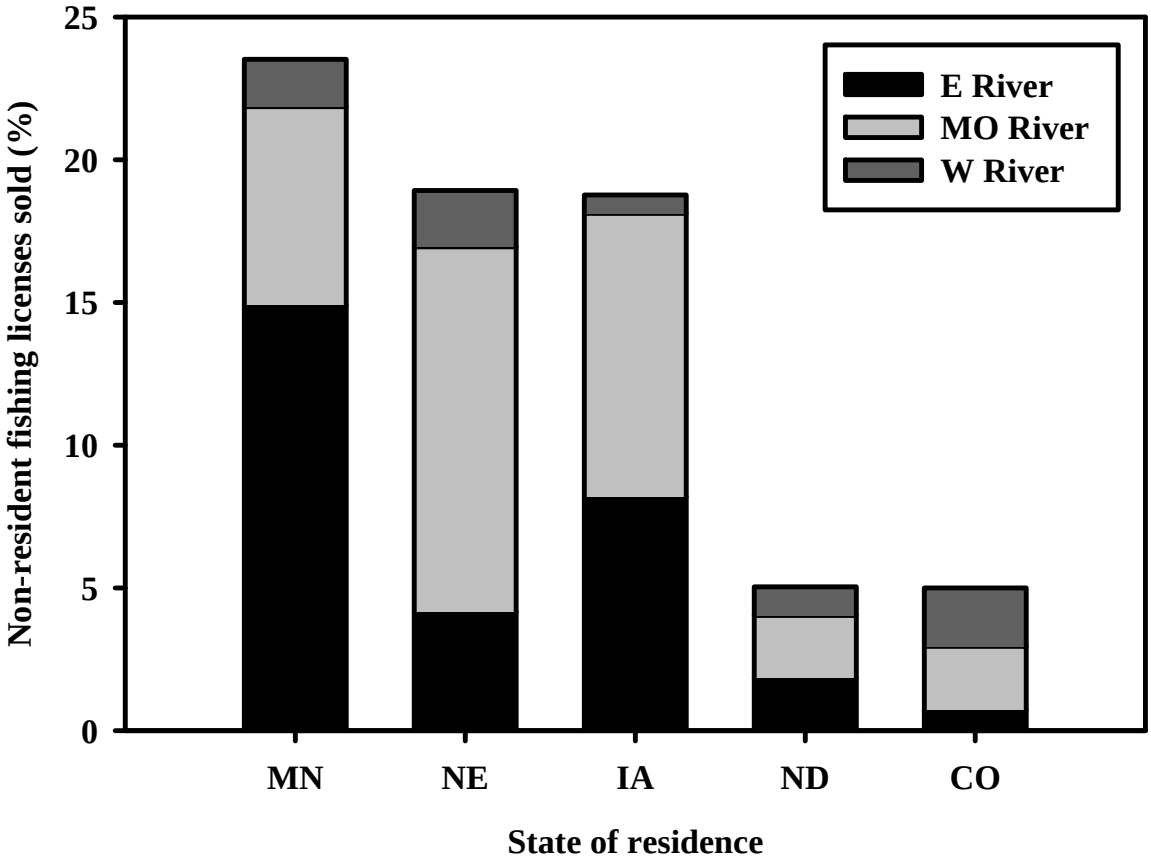

FIGURE 2.— Percent of South Dakota non-resident fishing licenses sold in 2006 by angler state of residence and by point of sale. Point of sale refers to the county in which the license was purchased. Those counties that border the Missouri River were categorized "MO River," whereas counties to the east and west of the Missouri River, excluding those bordering the Missouri River, were categorized "E River" and "W River," respectively.

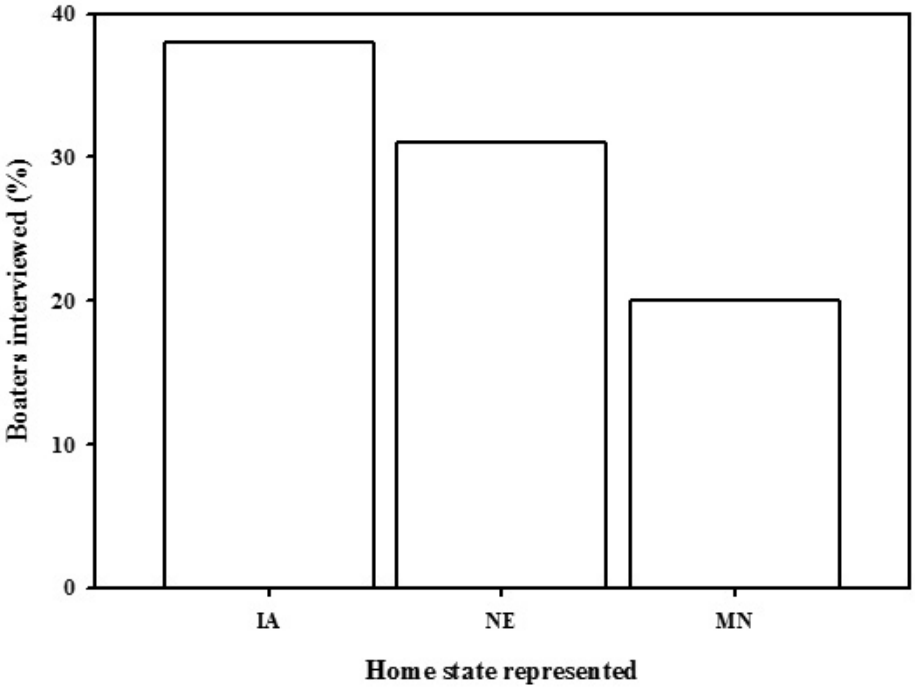

FIGURE 3.—Percent of out-of-state boaters by home state interviewed in South Dakota in 1999 for the 100th Meridian Initiative boater survey.

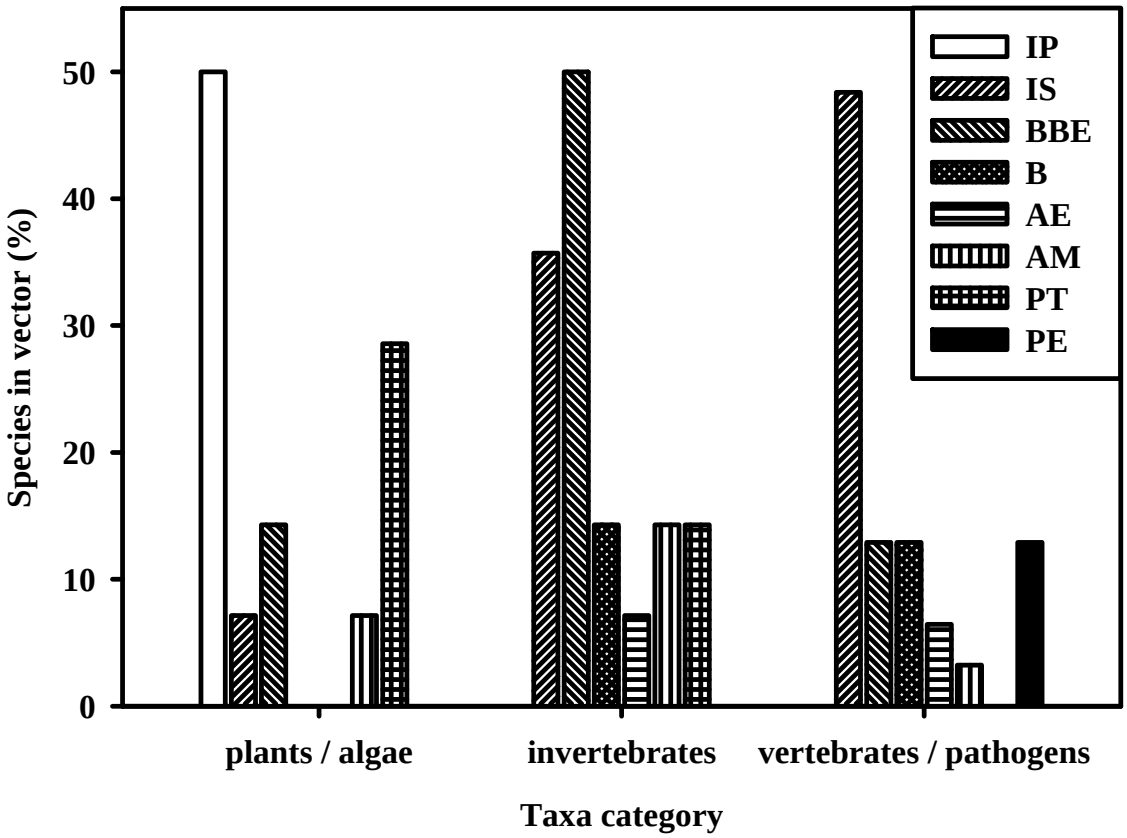

FIGURE 4.— Probable vector of introduction as a percentage of the number of aquatic nuisance species within one of three taxa categories (plants / algae, invertebrates, and vertebrates / pathogens). Introduction vectors include intentional planting (IP), intentional stocking (IS), boat-barge-equipment (BBE), bait (B), aquaculture (AE), aquarium (AM), plant trade (PT), and parasite (PE).