Spiny Waterflea (*Bythotrephes longimanus*)
Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, February 2011
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Photo: J. Liebig, NOAA Great Lakes Environmental Research Laboratory

1 Native Range, and Status in the United States

Native Range

From CABI (2016):

"*B. longimanus* is native to the Baltic nations, Norway, northern Germany and the European Alps, covering Switzerland, Austria, Italy and southern Germany. It is also native to the British Isles and the Caucasus region, and is widespread in Russia."

Status in the United States

From Liebig et al. (2016):

"*Bythotrephes* is established in all of the Great Lakes and many inland lakes in the region. Densities are very low in Lake Ontario, low in southern Lake Michigan and offshore areas of Lake Superior, moderate to high in Lake Huron, and very high in the central basin of Lake Erie (Barbiero et al. 2001, Vanderploeg et al. 2002, Brown and Branstrator 2004)."

"*Bythotrephes* was first detected in December 1984 in Lake Huron (Bur et al. 1986), then Lake Ontario in September 1985 (Lange and Cap 1986), Lake Erie in October 1985 (Bur et al. 1986), Lake Michigan in September 1986 (Evans 1988), and Lake Superior in August 1987 (Cullis and Johnson 1988)."

"Collected from Long Lake approximately 5 miles SW of Traverse City, **Michigan** (P. Marangelo, unpublished data). Established in Greenwood Lake and Flour Lake, **Minnesota** (D. Branstrator, pers. comm.). Collected in Allegheny Reservoir, **New York** (R. Hoskin, pers. comm.)."

Means of Introductions in the United States

From Liebig et al. (2016):

"*Bythotrephes* was probably introduced from ship ballast water (Sprules et al. 1990, Berg et al. 2002) and possibly as resting eggs from mud (Evans 1988)."

From CABI (2016):

"The spread of the species in North American systems is thought to have arisen from contaminated fishing gear, which the species attaches to (Lui et al., 2010)."

Remarks

From Liebig et al. (2016):

"Formerly known as *Bythotrephes cederstroemii* (Berg and Garton 1994, Yan and Pawson 1998, Berg et al. 2002, Therriault et al. 2002)."

Similar information was located through searches regardless of whether the search used the accepted scientific name, *Bythotrephes longimanus*, or the synonym, *Bythotrephes cederstroemi* or *Bythotrephes cederstroemii*.

From GISD (2016):

"*B. longimanus* exhibits a high degree of morphological variability both throughout its range and seasonally within a locality. Until recently several different species were recognised, although these are now seen to be simply manifestations of the extreme polymorphism of *B. longimanus*. Currently, only the species *longimanus* is recognised in the genus *Bythotrephes* (Rivier, 1998). Initial reports of *Bythotrephes longimanus* in North America referred to the organism as *Bythotrephes cederstroemi*."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2016):

"Kingdom Animalia
Subkingdom Bilateria
Infrakingdom Protostomia
Superphylum Ecdysozoa
Phylum Arthropoda
Subphylum Crustacea
Class Branchiopoda
Subclass Phyllopoda
Order Diplostraca
Suborder Cladocera
Infraorder Onychopoda
Family Cercopagididae
Genus *Bythotrephes* Leydig, 1860
Species *Bythotrephes longimanus* Leydig, 1860 – spiny waterflea"

"Current Standing: valid"

Size, Weight, and Age Range

From CABI (2016):

"typically reaches a length of 10-15 mm at maturity"

"Kim and Yan (2013) reported a maximum lifespan for *B. longimanus* individuals of less than 22 days for low prey density environments. The median observed lifespan was of 12 days (Kim and Yan, 2013). *Bythotrephes longimanus* resting eggs can survive between 100 and 300 days, with an average potential survival time of 286 days (Andrew and Herzig, 1984)."

Environment

From CABI (2014):

"*B. longimanus* can be found in all types of lentic water bodies (Grigorovich et al., 1998). Although it exhibits a high level of tolerance to changing and different habitats, it thrives in large, deep, temperate lakes, where it mostly inhabits the deeper, central areas of the water body and is seldom found at the shallower fringe (Grigorovich et al., 1998). It is usually found in oligotrophic environments, probably due to its reliance on sight for predation and the need for clear water (Brown et al., 2012; Jokela et al., 2013), but it is also known to withstand nutrient rich, eutrophic basins as well (Boudreau and Yan, 2003; Lui et al., 2010)."

"Species has been found in wide range of dissolved oxygen conditions with higher denstities in oxygenated waters (Grigorovich et al., 1998 and Branstrator et al., 2013)"

From Liebig et al. (2016):

"*Bythotrephes* is limited to regions where […] salinity values [range] between 0.04 and 8.0%, but it prefers […] salinity between 0.04 and 0.4% (Grigorovich et al. 1998)."

Climate/Range

From Liebig et al. (2016):

"*Bythotrephes* is limited to regions where water temperature ranges between 4 and 30°C […] but it prefers temperature between 10 and 24°C […] (Grigorovich et al. 1998). Temperature appears to play a major role in determining the abundance and location of *Bythotrephe*s in the Great Lakes, as it prefers cooler water and cannot tolerate very warm lake temperatures (Berg and Garton 1988, Garton et al. 1990, Brown and Branstrator 2004)."

Distribution Outside the United States

Native

From CABI (2016):

"*B. longimanus* is native to the Baltic nations, Norway, northern Germany and the European Alps, covering Switzerland, Austria, Italy and southern Germany. It is also native to the British Isles and the Caucasus region, and is widespread in Russia."

Introduced

From CABI (2016):

"*B. longimanus* is invasive in […] Broechen reservoir in Belgium and the Biesbosch reservoirs in the Netherlands."

CABI (2016) also reports the presence of *B. longimanus* in Lake Winnipeg, Manitoba, Canada (Mines et al. 2013) and Lake Ontario, Ontario, Canada (Barbiero and Tuchman 2004).

Means of Introduction Outside the United States

From Ketelaars and Gille (1994):

"There are several hypotheses to explain the first appearance of *B. longimanus* in reservoir Broechem. The first hypothesis postulates physical transport from the nearby Lake Volkerak-Zoom, which is in open connection with the Albert Canal […] A second hypothesis postulates an atmospheric route involving either the direct transport of resting eggs or the indirect transport of resting eggs by migrating waterfowl. […] The third hypothesis involves an invasion route via canals connecting the Rivers Rhine and Meuse (Canal de la Marne au Rhin and Canal de l'Est). […] Transport of mud with resting eggs, adhering to boots or for instance fishermen is another possible introduction vector (LEHMAN, 1987; EVANS, 1988). […] The fifth hypothesis is that animals or resting eggs were transported with bilge or bulk water in ships. […] It still remains unclear how *B. longimanus* reached The Netherlands and Belgium and where it originated from."

Short Description

From GISD (2016):

"The spiny water flea is a freshwater crustacean characterised by a well developed abdominal region (metasoma), a cauda continued into a long, thin caudal appendage, a head clearly delimited from the trunk and the ocular part of the head globular and filled with a large eye separated by a depression from the head shield."

Biology

From CABI (2016):

"*B. longimanus* can reproduce both asexually and sexually: pharthenogenetically [*sic*] during the summer and gametogenetically during the autumn (Straile and Hälbich, 2000; Vanderploeg et al., 2002). Populations predominantly made up of female specimens mainly reproduce in the spring and summer months (Branstrator et al., 2006). The generation time of offspring is short, ranging from 10 to 15 days, and several asexual generations of offspring are produced during one season (Miehls et al., 2012). The formation of the dorsal egg pouch marks the beginning of the parthenogenetic cycle. As the embryos develop they are nourished by the nutrient solution in the pouches and hatch as juveniles (Alwes and Scholtz, 2014). Due to the high generation turnover and parthenogenetic offspring production by predominantly female populations, *B. longimanus* population densities can rapidly increase (Brown, 2008)."

"The parthenogenetic cycle is interrupted in the autumn by a period of sexual reproduction (Branstrator et al., 2006; Miehls et al., 2012). The sexual reproduction period serves to produce gametogenetic eggs, also known as diapausing or resting eggs; these dormant eggs serve as *B. longimanus*' overwintering strategy (Vanderploeg et al., 2002; Branstrator et al., 2006; Brown, 2008). During the gastrula stage the sexually fertilized diapausing eggs develop in the female's brood pouch; once they are released they settle down to the sediment and remain dormant until the right environmental conditions prompt them to hatch (Brown, 2008)."

"The sex of individuals is assigned non-genetically and influenced by environmental stress factors. When females sense a shift in environmental conditions in the autumn (temperature drop/food scarcity), they produce more male offspring which can then facilitate the production of gametogenetic resting eggs (Caceres and Lehman, 2010). This explains the shift from asexual to sexual reproduction during the end of the growing season."

"The caudal spine, which makes up most of *B. longimanus*' body, is meant to protect it from predation by small (<100 mm) gape-limited fish (Branstrator, 2005; Branstrator et al., 2006). The species also exhibits patterns of diel vertical migration to deeper waters as well as the ability to produce resting eggs in order to survive the pressures of predation (Ketelaars et al., 1995; Grigorovich et al., 1998; Caceres and Lehman, 2010). Diel vertical migration to deeper waters reduces exposure to predatory fish."

"*B. longimanus* exhibits diel vertical migration (DVM) patterns, remaining in the deeper parts of lakes during daytime hours and migrating to upper sections at night (Ketelaars et al., 1995). The

DVM patterns exhibited by *B. longimanus* populations mirrored the observed migration trends and population densities, with depth, of *Daphnia*, the prey of *B. longimanus* (Ketelaars et al., 1995). Ketelaars et al. (1995) concluded that these trends support the hypothesis that *B. longimanus*' migration is related to its active pursuit of prey."

"Grigorovich et al. (1998) reported that the DVM exhibited by *B. longimanus* is season-dependent. During winter, active specimens are not present in the plankton fraction, whereas in the spring the population is mainly found at the epilimnion, the top-most layer. During the summer months, in well mixed, unstratified basins, *B. longiamanus* [*sic*] can be found at all depths."

"*B. longimanus* is a predatory zooplankton (Therriault et al., 2002) that feeds primarily on other cladoceran species, such as *Daphniidae* and *Bosminidae* (ranging in size from 300 to 700 µm) (Ketelaars and Gille, 1994). *B. longimanus* offspring begin to feed a few hours after spawning (Ketelaars et al., 1995). Adult *B. longimanus* specimens mainly consume small, slow, soft shelled prey. In the spring they feed mainly on rotifers and copepods, whereas in the summer they revert to a diet mostly made up of cladocerans (Grigorovich et al., 1998)."

"*B. longimanus* catches its prey using its large front legs and holds it with its shorter legs while the prey is consumed (Caceres and Lehman, 2010). It grinds its prey before eating it, when it is then sucked into the gut as liquid food (Ketelaars et al., 1995)."

Human Uses

No information reported for this species.

Diseases

No information reported for this species.

Threat to Humans

From CABI (2016):

"*B. longimanus* can ruin fishing gear when they are attached to fishing lines and accidentally reeled in (Brown, 2008; USGS NAS, 2015). Spiny waterfleas collect in 'jelly-lake masses' on fishing gear (Lui et al., 2010)."

3 Impacts of Introductions

From Walsh et al. (2016):

"*Bythotrephes* was detected in the well-studied eutrophic Lake Mendota in the fall of 2009 at some of the highest densities on record (>150 m^{-3}; mean open water density). The invasion was of immediate concern, because a preferred prey of *Bythotrephes*, *Daphnia pulicaria*, has been the focal point of Lake Mendota's food web management, supporting the lake's fishery [Johnson and Kitchell 1996] and maintaining clear water through grazing algae [Lathrop et al. 2002]. Lake Mendota is located within an agricultural watershed and receives large amounts of P from farm runoff, reducing water quality by stimulating algal growth [Lathrop and Carpenter 2014]. This ecosystem service provided by *D. pulicaria* has delivered huge economic benefits, providing recreational value to citizens who have been estimated to be willing to pay US$140 million (present-day value) for 1 m of water clarity (1.6- to 2.6-m change in summer clarity) [Lathrop et al. 1998; Stumborg et al. 2001]."

"Since the detection of *Bythotrephes* in 2009, average water clarity in Lake Mendota has declined by 0.9 m […] alongside a 60% reduction in *D. pulicaria* biomass […]. In addition, there was a decrease in total phosphorus (TP) […], despite no clear change in P loading […], and an overall increase in total grazing zooplankton biomass […] (17% overall and 56% increase in non-*D. pulicaria* grazers). These findings show a cascading impact of *Bythotrephes* that has not been previously documented in other lakes [Strecker and Arnott 2008] and that is unusually large for an invertebrate predator [Terborgh and Estes 2010]."

"External P load reduction of 71% is needed to offset the decline in *D. pulicaria* (i.e., obtain pre-2009 water clarity under post-2009 *D. pulicaria* biomass) […]. Recent estimates of the cost of P diversion from Lake Mendota indicate that a P load reduction of 71% will cost between US$86.5 million and US$163 million (US$430–US$810 per household in Dane County) [Strand Associates Inc. 2013]. This conservative estimate is drawn from a detailed, itemized, and expert-elicited review investigating this very question in Lake Mendota. Investing in a 71% reduction would return the lake to preinvasion clarity, and any additional improvements to water clarity would have to be made on top of this investment."

From Liebig et al. (2014):

"It has caused major changes in the zooplankton community structure; invasion history; reproduce rapidly; competes directly with small fish and can have impact on zooplankton community (USEPA 2008)."

"The first noticeable impact of *Bythotrephes* was on fisherman. The tail spines of *Bythotrephes* hook on fishing lines, fouling fishing gear. *Bythotrephes* consumes small zooplankton such as small cladocerans, copepods, and rotifers, competing directly with planktivorous larval fish for food (Berg and Garton 1988, Evans 1988, Vanderploeg et al. 1993). *Bythotrephes* has been implicated as a factor in the decline of alewife (*Alosa pseudoharengus*) in Lakes Ontario, Erie, Huron, and Michigan (Evans 1988). *Bythotrephes* also competes with, and possibly preys on, *Leptodora kindtii* and may be a causal factor in the decline of *Leptodora* (Branstrator 1995). *Bythotrephes* and *Leptodora* abundances are often negatively correlated (Garton et al. 1990, Branstrator 1995). There is speculation that *Bythotrephes* may control the abundance of *Cercopagis pengoi* though competition and predation (Vanderploeg et al. 2002). *Bythotrephes* is a food source for fish including yellow perch, white perch, walleye, white bass, alewife, bloater chub, chinook salmon, emerald shiner, spottail shiner, rainbow smelt, lake herring, lake whitefish and deepwater sculpin (Bur et al. 1986, Makarewicz and Jones 1990, Branstrator and Lehman 1996)."

From GISD (2016):

“Boudreau and Yan (2003) found that, It is apparent that current summer zooplankton communities of Canadian Shield lakes with *B. longimanus* differ substantially from non-invaded lakes.”

“The crustacean zooplankton community of Harp Lake, Ontario, Canada, has changed appreciably since the invasion by the spiny water flea, *Bythotrephes.* Crustacean species richness has declined, large-bodied ClaDOCera [*sic*] have replaced small-bodied ones, and there has been a downward trend in the total abundance of zooplankton because copepod abundance has remained stable while ClaDOCeran [*sic*] abundance has declined (Yan *et al* 2001). Dumitr[u] *et al* (2001) observes that a number of small-bodied zooplankton declined dramatically, following the 1993 invasion of Harp Lake by the spiny water flea, when compared to pre-invasion densities, and some larger species increased.”

“In the Great Lakes, *Bythotrephes longimanus* has caused major changes in the zooplankton community structure. The spiny water flea had almost immediate effects on zooplankton assemblage upon its introduction into the Great Lakes collapsing some *Daphnia* populations (Sikes, 2002). *Bythotrephes longimanus* also has increased competition with small fish and native predatory zooplankton like *Leptodora kindtii*. Fish species that formerly preyed upon *Daphnia sp*. and *B. longimanus*' competitors have been forced to shift their diets, many to the invader (Sikes, 2002).”

From Kerfoot et al. (2016):

“*Bythotrephes* alters the seasonal biomass pattern by severely depressing microcrustaceans during summer and early fall, when the predator is most abundant. Cladoceran and cyclopoid copepods suffer the most serious population declines, although the resistant cladoceran *Holopedium* is favored in spatial comparisons. Microcrustacean biomass is reduced 40–60 % and secondary production declines by about 67 %. The microcrustacean community shifts towards calanoid copepods. The decline in secondary production is due both to summer biomass loss and to the longer generation times of calanoid copepods (slower turnover). The *Bythotrephes* ‘‘top-down’’ perturbation appears to hold across small, intermediate, and large-sized lakes (i.e. appears scale-independent), and is pronounced when *Bythotrephes* densities reach 20–40 individuals L^{-1}. Induction tests with small cladocerans (*Bosmina*) suggest that certain native prey populations do not sense the exotic predator and are ‘‘blindsided’’.”

4 Global Distribution

Figure 1. Map of known global distribution of *Bythotrephes longimanus*. Map from GBIF (2017). Location in South Africa (not pictured) was not included in climate matching because it was incorrectly located.

5 Distribution within the United States

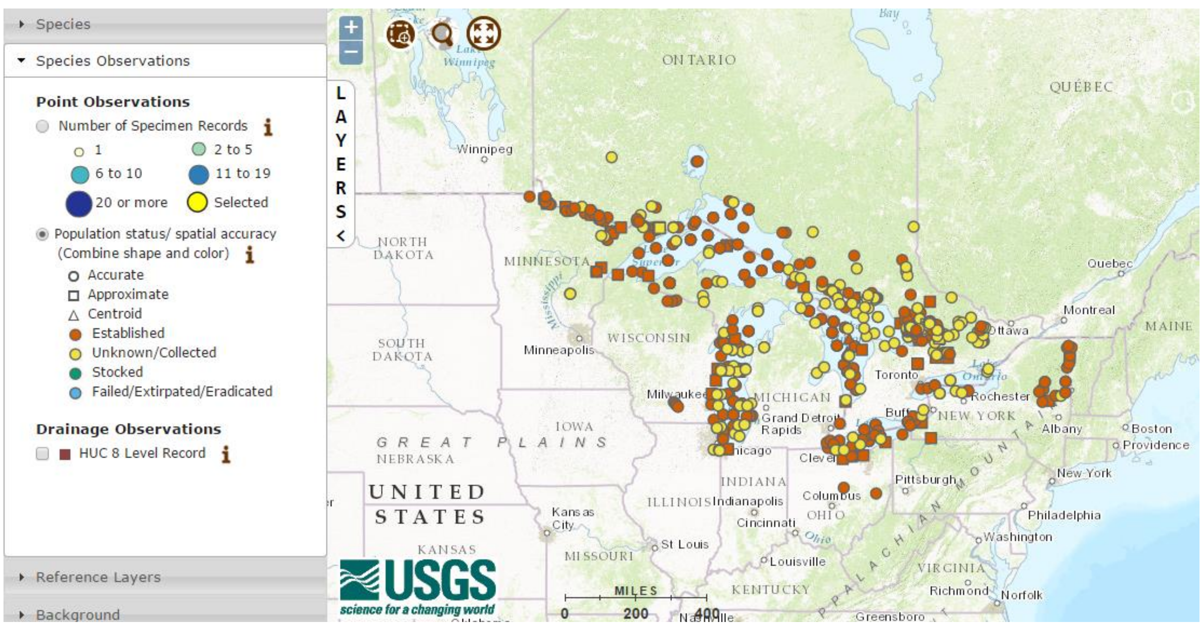

Figure 2. Distribution of *Bythotrephes longimanus* in the United States. Map from Liebig et al. (2016).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014; 16 climate variables; Euclidean Distance) was high throughout western New England and much of the Midwest, including the Great Lakes. Patches of high match were also apparent in the Interior West. Much of the remainder of the contiguous U.S. was a medium match, with low matches along the Pacific and Gulf of Mexico coasts and across Florida. Climate6 score indicated that the contiguous U.S. has a high climate match. The scores indicating high climate match are 0.103 and greater; Climate6 score of *Bythotrephes longimanus* is 0.433.

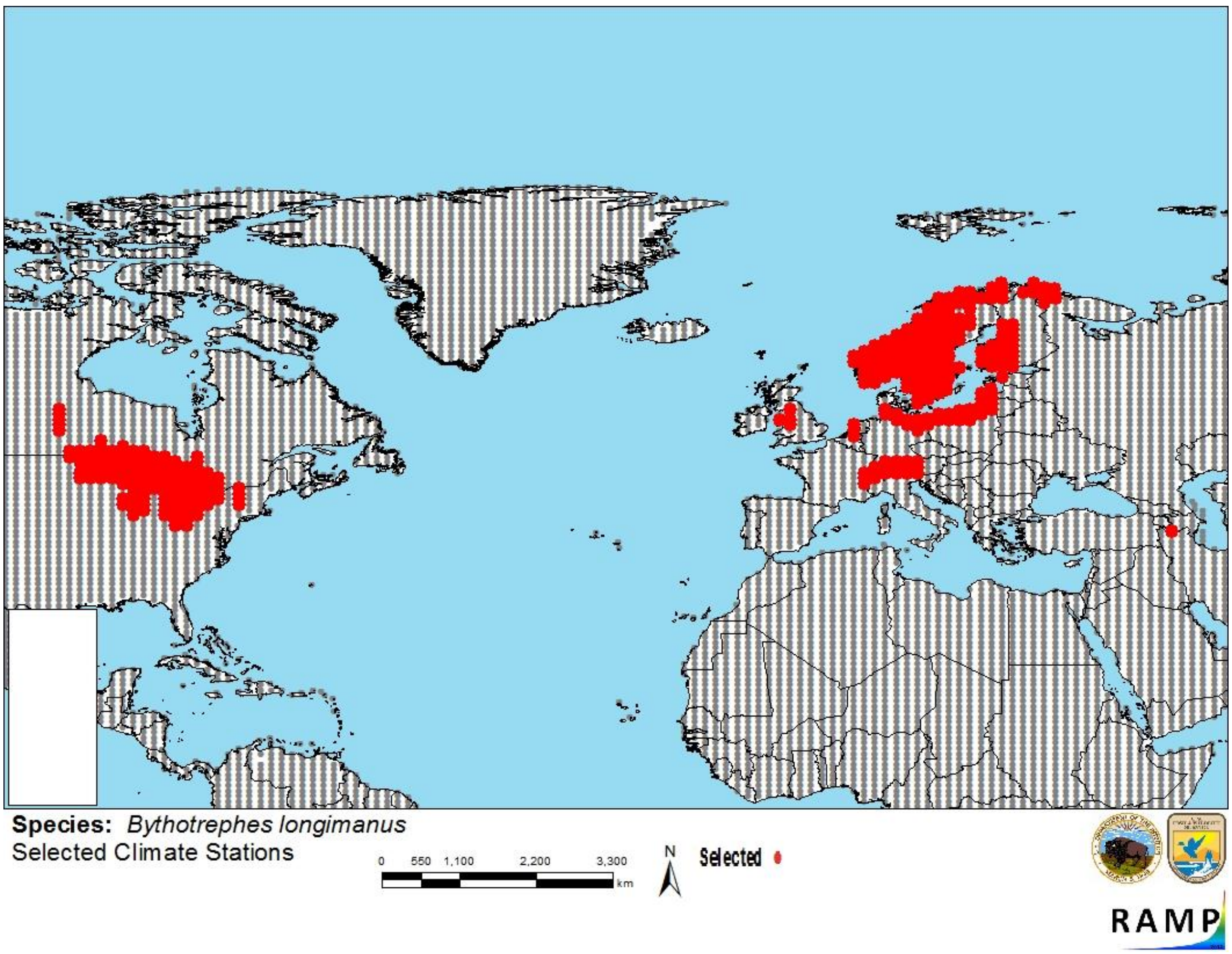

Figure 3. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (blue) for *Bythotrephes longimanus* climate matching. Source locations from Ketelaars and Gille (1994), CABI (2016), GBIF (2016), and Liebig et al. (2016).

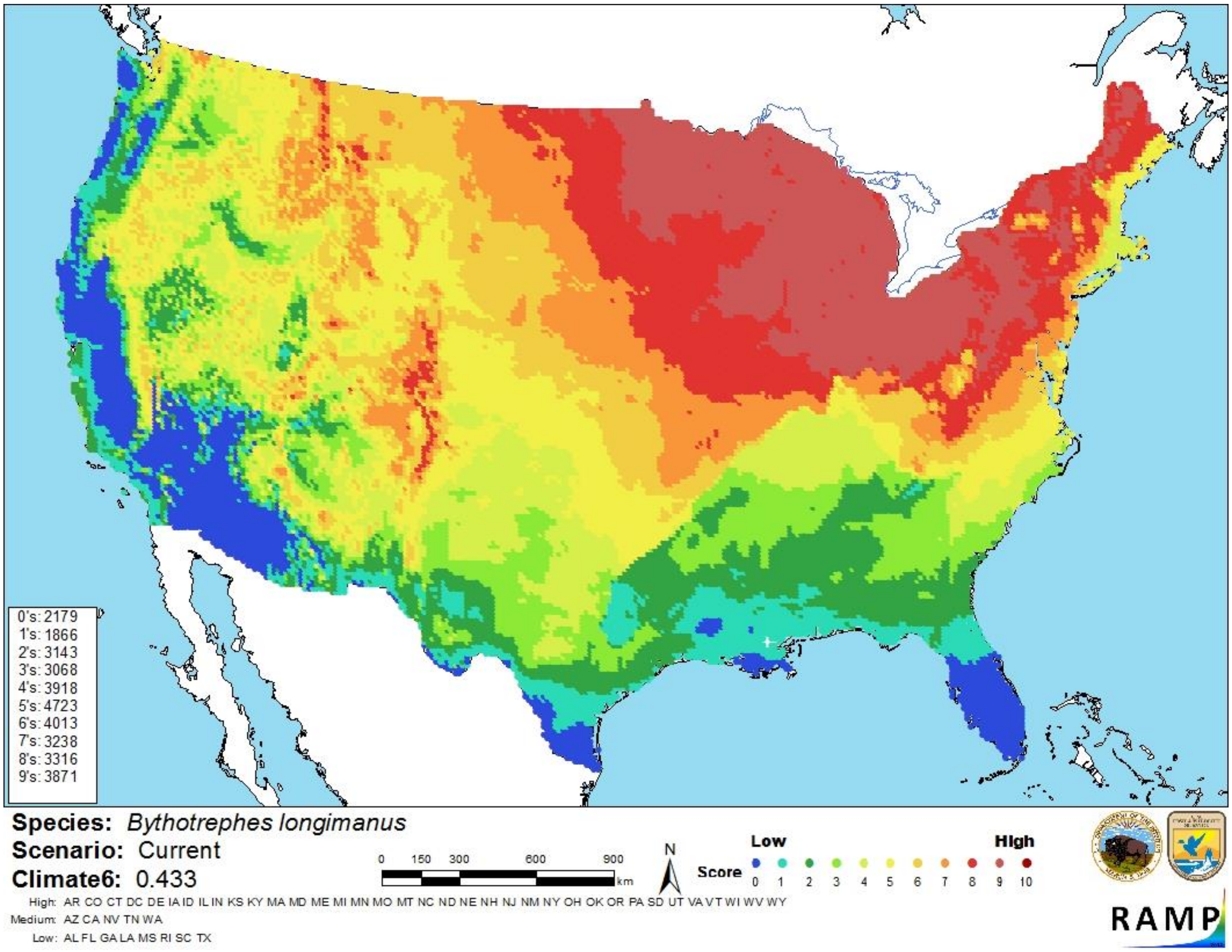

Figure 4. Map of RAMP (Sanders et al. 2014) climate matches for *Bythotrephes longimanus* in the contiguous United States based on source locations reported by Ketelaars and Gille (1994), CABI (2016), GBIF (2016), and Liebig et al. (2016). 0=Lowest match, 10=Highest match.

The "High", "Medium", and "Low" climate match categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
$0.000 \leq X \leq 0.005$	Low
$0.005 < X < 0.103$	Medium
≥ 0.103	High

7 Certainty of Assessment

The biology and ecology of *B. longimanus* are well known. Negative impacts from introductions of this species are documented extensively in the scientific literature. No further information is needed to evaluate the negative impacts the species is having where introduced. Certainty of this assessment is high.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Bythotrephes longimanus has become established across the Great Lakes region of the U.S. and Canada since the 1980s. As a predator, it has been responsible for substantial declines and shifts in the zooplankton community in lakes where it has been introduced. The lost value of the ecosystem services provided one of *B. longimanus*' prey species, *Daphnia pulicaria*, has been estimated at up to US$163 million for one lake in Wisconsin. *B. longimanus* can also get caught on fishing gear and ruin it. Potential vectors for *B. longimanus* spread include ship ballast water and contaminated fishing gear. Climate match to the contiguous U.S. is high. Overall risk for this species is high.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): High**
- **Remarks/Important additional information: Parthenogenic**
- **Overall Risk Assessment Category: High**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

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10 References Quoted But Not Accessed

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