# Does invasion history matter to the establishment success and impact of non-native species?

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Submitted to the Division of Mathematics and Natural Sciences

Jennifer G. Howeth — February 20, 2014 Date

Patricia A. Sobecky, Chair, Department of Biological Sciences — February 20, 2014 Date

**Abstract**

The objective of this proposal is to evaluate whether the invasion history of a non-native species influences the establishment success and impact of the species in the non-native environment. Aspects of invasion history, particularly the time since invasion of non-native species in a geographic location, may greatly influence population structure, life history traits, and ecological traits of the non-native species. The relative importance of these population-specific parameters in determining establishment and impact of the non-native species in a novel environment as compared to properties of the novel environment, including predators, competitors, and connectivity to similar habitats, is unknown. Here, using the invasive freshwater crustacean *Daphnia lumholtzi*, I test this question for the first time using a rigorous common garden experiment supporting different simulated environments and levels of landscape connectivity. *Daphnia* collected from lakes located in three different geographic locations representing the entire invasion chronosequence in North America: the geographic region of initial introduction (oldest populations, Texas), the invasion mid-point (intermediate-age populations, Alabama), and the most recently invaded region (youngest populations, California) will be exposed to the same simulated environments to evaluate how invasion history and geographic origin can interact with properties of a novel, previously uninvaded environment to influence establishment success and impact of non-native species. The results of this research will generally inform the importance of invasion history in the introduced range in determining what makes non-native species "invasive" and will lead to new and exciting research directions for my laboratory.

**Proposal Objectives**: Identifying factors influencing the establishment success and impact of non-native species serves as the foundation of invasion biology, yet major gaps remain in our knowledge of these factors. Traditional studies of invasion biology focus on the influence of the local environment, including interactions with native species and abiotic factors, in affecting the establishment and impact of non-native species in a single geographic location[1-2]. Few studies acknowledge that effects and interactions occurring at a single location may not be representative of effects at multiple locations within the introduced range of the non-native species[3]. Aspects of invasion history, particularly the time since invasion of the non-native species, can affect ecological (i.e., predator avoidance, competitive ability) and life history (i.e., fecundity, growth rate) traits of individuals within populations, but the related effects on the establishment and impact of non-native species in novel, previously uninvaded environments are unknown.

**The proposed research evaluates the influence of time since invasion and geographic origin on the ecology of non-native populations, and how these effects in turn influence the establishment success and ecological impact of non-native species in novel, previously uninvaded environments.** To address this question, I will use the invasive freshwater crustacean *Daphnia lumholtzi*, a non-native species of zooplankton that currently inhabits lakes and reservoirs located throughout North America (Fig. 1)[4]. *Daphnia lumholtzi* was first introduced to North

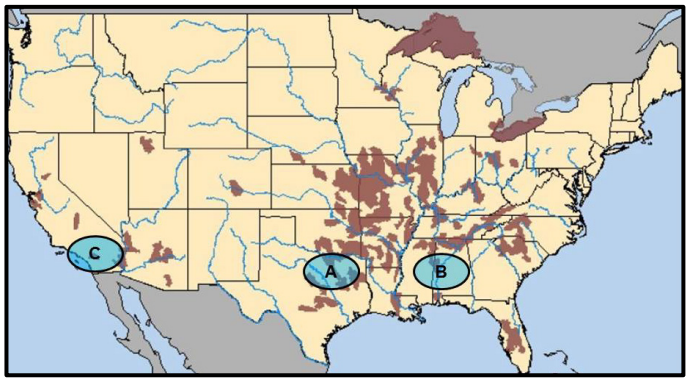


**Fig. 1**. The spatial distribution of *D. lumholtzi* in the US (brown polygons)[4]. *D. lumholtzi* collected from three geographic regions (blue ovals) representing populations of different ages in the non-native range will be included in this study (A = oldest populations; B = intermediate-age populations; C = youngest populations).

America (Texas) from Africa or Asia in 1990[4]. The species spread throughout the midwestern and southeastern US, and now supports the largest introduced geographic range of any freshwater crustacean in the US[4]. The invasion success of *D. lumholtzi* is attributed to inducible anti-predator (fish and invertebrate) traits, including a large head and tail spine[5], and the species ability to coexist with native zooplankton competitors through temperature-based temporal habitat partitioning[6]. The establishment of *D. lumholtzi* alters the composition of zooplankton communities[7], the growth rate of fish[8], and the functioning of lake ecosystems[9]. As a result of these attributes, in addition to a fast (7-10 day) generation time and ease of establishment in lab culture[9-10], *D. lumholtzi* serves as an ideal species in which to address the proposed research.

The specific objectives of this experiment are twofold: 1) test the response (incidence, abundance) of *D. lumholtzi* from populations of different ages/locations to manipulated ecological conditions, including predators, nutrient availability, and landscape connectivity, and 2) evaluate how this response of *D. lumholtzi* affects establishment success (incidence, abundance) and ecological impact (measured by native community composition and ecosystem change). These objectives will be tested with *D. lumholtzi* collected from three geographic regions that represent the invasion chronosequence in North America (Fig 1)[4,11]: the geographic area of initial introduction (oldest populations, Texas), the invasion mid-point (intermediate-age populations, Alabama), and the most recently invaded region (youngest populations, California). *D. lumholtzi* from Alabama and Texas are currently cultured in my lab, and *D. lumholtzi* from California will be collected during summer 2014. Using laboratory "common garden" experiments that expose individuals collected from the different locations to the same manipulated environments, I will test the effects of time since invasion on establishment and "invasiveness" (ecological impact). Experiments will be conducted in 20 L microcosms, where

invertebrate predators, nutrient availability, and landscape connectivity (immigration of native zooplankton collected from the Talladega National Forest) will be manipulated and crossed in a replicated design. I hypothesize that *D. lumholtzi* from long-established populations will have the greatest tolerance to environmental conditions and will have the largest ecological impact, whereas *D. lumholtzi* from the youngest populations will be least tolerant and have less impact. This proposal requests funds to perform the experiment in the Bevill Building greenhouse. This research would not be possible without a CARSCA, as funds are required to purchase chemicals, water filters for a reverse osmosis system in the greenhouse, and other critical supplies.

This work will provide research opportunities for one graduate and several undergraduate students. The results will be disseminated to the scientific community via a peer-reviewed publication, and a presentation at a national conference (the Ecological Society of America). Importantly, the work will provide data for a NSF grant proposal and foundation proposals. Success will be measured by completion of the experiment and associated acquisition of data that will be integrated into grant proposals, published, and presented. The results from this study will provide a foundation for novel research directions in my lab that synthesize invasion biology and landscape ecology, and will aid in attracting top graduate students to my laboratory. Finally, *D. lumholtzi* is an invasive species in rivers and reservoirs of Alabama[4] (e.g., it is established in the Black Warrior River; *D. lumholtzi* used in this experiment will originate from Holt Lake) and its impact on regional freshwater ecosystems is unknown. The results from this study will provide insight into the impact of this invasive freshwater species in Alabama, and how it compares to its impacts in other regions of North America. This information can be incorporated into mathematical models to predict negative effects of *D. lumholtzi* on population growth rates of native Alabama fish species, and effects on nutrient cycling of Alabama reservoirs.

## Budget and Budget Justification

| Items | Use and Justification | Cost |
|---|---|---|
| Chemicals, glassware, and sample containers | Used to make zooplankton and algae growth media; used to preserve and store samples collected weekly from the experiment | (VWR) = $2890 |
| Water filters (pre-filters, carbon cartridges) for a reverse osmosis system in the Bevill Building greenhouse | Filters chloride, fluoride, and other chemicals from the water so it will be non-toxic to zooplankton | (VWR) = $662.47 |
| Sheet insulation board | Lines the concrete floor of the greenhouse and elevates buckets; serves as a thermal buffer and protects buckets from being kicked accidentally | 2”x 4’x 8’ boards, $37 per board (Home Depot) *32 boards = $1184 |
| 20 Liter paint buckets | Serve as microcosms (experimental unit) | 60 buckets (Home Depot) = $179.88 |
| Window screen for bucket tops | Prevents inputs of unwanted insects and debris | 42” x 1200” charcoal fiberglass screen, $83.22 per roll (Home Depot) = $83.22 |
| **Total Requested** | | **$4999.57** |

## Timeline

| Component | 2014 | | 2015 | | |
|---|---|---|---|---|---|
| | Summer | Fall | Spring | Summer | Fall |
| Perform experiment | | | | | |
| Identify and enumerate zooplankton, water chemistry analysis | | | | | |
| Data analysis, presentation at the Ecological Society of America meeting | | | | | |
| Write associated grant and manuscript | | | | | |

**References**


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3 Howeth, J. G., A. M. Derry, and A. M. Reitzel. 2010. Metacommunity biology as an eco-evolutionary framework for understanding exotic invasion in aquatic ecosystems. Pages 93-109 *in* P. K. Kemp, editor. Eco-DAS VIII Symposium Proceedings, American Society of Limnology and Oceanography.

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7 Lennon, J. T., V. H. Smith, and A. R. Dzialowski. 2003. Invasibility of plankton food webs along a trophic state gradient. Oikos 103:191-203.

8 Kolar, C. S., and D. H. Wahl. 1998. Daphnid morphology deters fish predators. Oecologia 116:556-564.

9 Stollewerk, A. 2010. The water flea *Daphnia*-a ‘new’ model system for ecology and evolution. Journal of Biology 9:21-25.

10 Miner, B. E., L. De Meester, M. E. Pfrender, W. Lampert, and N. G. Hairston. 2012. Linking genes to communities and ecosystems: *Daphnia* as an ecogenomic model. Proceedings of the Royal Society B-Biological Sciences 279:1873-1882.

11 Frisch, D., J. Havel, and L. Weider. 2013. The invasion history of the exotic freshwater zooplankter *Daphnia lumholtzi* (Cladocera, Crustacea) in North America: a genetic analysis. Biological Invasions 15:817-828.

# CURRICULUM VITAE

## JENNIFER G. HOWETH, Ph.D.

### A. DEPARTMENTAL ADDRESS:


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### B. CURRENT APPOINTMENT:

January 2012 Assistant Professor, Department of Biological Sciences, University of Alabama

### C. PUBLICATIONS:

*(i) Five most closely related to the proposed project*

**Howeth, J. G.** and M. A. Leibold. 2013. Predation inhibits the positive effect of dispersal on intraspecific and interspecific synchrony in pond metacommunities. ***Ecology*** 94: 2220-2228. DOI: 10.1890/12-2066.1

**Howeth, J. G.**, Weis, J. J., Brodersen, J., Hatton, E.C. and D. M. Post. 2013. Intraspecific phenotypic variation in a fish predator affects multi-trophic lake metacommunity structure. ***Ecology and Evolution*** 3: 5031-5044. DOI: 10.1002/ece3.878

**Howeth, J. G.**, Derry A. M. and A. M. Reitzel. 2010. Metacommunity biology as an eco-evolutionary framework for understanding exotic invasion in aquatic ecosystems. In: Kemp, P. F. [Ed.], Eco-DAS VIII Symposium Proceedings, ***American Society of Limnology and Oceanography***, 93-109. DOI: 10.4319/ecodas.2010.978-0-984-5591-1-4.93

**Howeth, J. G.** and M. A. Leibold. 2010. Species dispersal rates alter diversity and ecosystem stability in pond metacommunities. ***Ecology*** 91: 2727-2741. DOI: 10.1890/09-1004.1

**Howeth, J. G.** and M. A. Leibold. 2008. Planktonic dispersal dampens temporal trophic cascades in pond metacommunities. ***Ecology Letters*** 11: 245-257. DOI: 10.1111/j.1461-0248.2007.01143.x

*(ii) Five other significant publications*

Barnes, M. A, Jerde, C. J., Keller, D., Chadderton, W. L., **Howeth, J. G.** and D. M. Lodge. 2013. Viability of aquatic plant fragments following desiccation. ***Invasive Plant Science and Management,*** 6: 320-325. DOI: 10.1614/ISPM-D-12-00060-1

**Howeth, J. G.** and M. A. Leibold. 2010. Prey dispersal rate affects prey species composition and trait diversity in response to multiple predators in metacommunities. ***Journal of Animal Ecology*** 79: 1000-1011. DOI: 10.1111/j.1365-2656.2010.01715.x

**Howeth, J. G.** and W. S. Brown. 2011. *Terrapene coahuila* – Coahuilan box turtle. In: Rhodin, A. G. J., Pritchard, P.C.H., van Dijk, P. P., Saumure, R. A., Buhlmann K. A., Iverson, J. B., and Mittermeier R. A. (Eds). Conservation Biology of Freshwater Turtles and Tortoises: A Project of the IUCN/ SSC Tortoise and Freshwater Turtle Specialist Group. ***Chelonian Research Monographs***, 5: 49.1-49.13. DOI: 10.3854/crm.5.049.coahuila.v1. 2011

**Howeth, J. G.**, McGaugh, S.E. and D. A. Hendrickson. 2008. Contrasting demographic and genetic estimates of dispersal in the endangered Coahuilan box turtle: A contemporary approach to conservation. ***Molecular Ecology*** 17: 4209-4221. DOI**:** 10.1111/j.1365-294X.2008.03904.x

Van Dijk, P. P., Flores-Villela O. and **J. G. Howeth**. 2007. *Terrapene coahuila.* In: ***IUCN Red List of Threatened Species***. http://www.iucnredlist.org/details/21642/0

**D. PRIOR EXTERNAL FUNDING** (*since January 2012*)

| | | |
|---|---|---|
| 2013 | Travel Grant, 2014 Joint Aquatic Sciences Meeting in Portland, Oregon from Assoc. for the Sciences of Limnology and Oceanography | $1,000 |
| 2012-2013 | USFWS/EPA subcontract, University of Notre Dame "GLRI Preventing Invasions from Trade in Live Aquatic Organisms" | $24,708 |

**E. SYNERGISTIC ACTIVITIES:**

**1**. Major advisor to two graduate students (1 female, 1 male) at the University of Alabama. Mentor of six undergraduate researchers (3 female, 3 male) including two from the University of Alabama Emerging Scholars Program, and one Tuscaloosa high school student. Training and mentorship in: water chemistry analyses, zooplankton identification, DNA microsatellites, stable isotopes, mesocosm experiments, and field sampling of diverse freshwater habitats.

**2**. (a) Invited speaker, Organized Oral Session, "Metapopulation and metacommunity approaches to research and management of fragmented aquatic systems," Joint Aquatic Sciences Meeting (annual meeting of 4 societies), Portland, Oregon, May 2014.

(b) Invited speaker, Organized Oral Session, "Community-structuring processes in fragmented freshwater habitats," Annual Meeting of the Ecological Society of America, Minneapolis, Minnesota, August 2013: delivered session opener entitled "The metacommunity concept as a framework for predicting patterns of diversity and stability in fragmented freshwater landscapes."

**3**. Co-organizer and chair, special session, "Integrative approaches to ecological risk assessment of nonindigenous aquatic species," Annual Meeting of the Association for the Science of Limnology and Oceanography, New Orleans, Louisiana, February 2013.

**4**. Participated in workshop, "Synthesizing Ecology and Evolution for the Study of Invasion Biology," Lake Tahoe, California, March 2009.

**5**. Manuscript reviewer for: Biological Invasions, Canadian Journal of Zoology, Diversity and Distributions, Ecology, Ecosphere, Journal of Animal Ecology, Journal of Plankton Research, Journal of Sea Research, Molecular Ecology, Oecologia, Oikos, PLoS ONE. *Grant reviewer for*: NSF Population and Community Ecology Program.

**6.** Relevant teaching at the University of Alabama: Spring 2012, 2014, Community Ecology (BSC 652), Spring 2013, Conservation Biology (BSC 482)

**7**. Invited seminars since January 2012: Dauphin Island Sea Lab, Mississippi State University, Sierra Club of West Alabama, Trinity University, University of Alabama at Birmingham

**8**. Authorship (primary or co-author) on contributed presentations at national/international society meetings since January 2012: 9 total (8 oral, 1 poster)