

AQUATIC INVASIVE SPECIES

Dispersal of Exotic Species in the Great Lakes: Crayfish as Model System for Benthic Species

Final Report

Major Goals and Objectives

Overall our goal was to describe the historic and current distribution of the rusty crayfish (*Orconectes rusticus*) in the Great Lakes. We focused particularly on Lake Michigan as a model system for understanding the invasion of other nonindigenous benthic species in the Laurentian Great Lakes. We had previously documented the impact and spread of this species in smaller lakes and streams in northern Wisconsin. Although the rusty crayfish now inhabits the Great Lakes, no previous studies had documented its current distribution or rate of spread and few studies had examined the impacts on resident species.

The specific goals of this project were to:

Objective 1. Reconstruct the chronology of invasions of *Orconectes rusticus* and other nonnative crayfishes into the Great Lakes by:

- a. surveying published historic and recent records of crayfish distributions
- b. seeking information on crayfish distributions from other scientists and government agencies working on Great Lakes benthos
- c. collecting detailed distribution records of *O. rusticus* in the tributaries and offshore locations in Lake Michigan to begin to understand the dynamics of invasions of the other Great Lakes.

Objective 2. Use genetic analyses of the regions in Lake Michigan where *O. rusticus* is displacing *O. propinquus*. The presence of *O. propinquus* alleles in currently allopatric populations of *O. rusticus* would provide evidence of past species displacement.

Objective 3. Predict the future distribution of *O. rusticus* in the Great Lakes by comparing the environmental requirements of *O. rusticus* (especially substrata) with the characteristics of Great Lakes littoral zones.

Summary of Progress

We completed a review of the historic and current published records and made contacts with active researchers to document the changes in the crayfish community of the Great Lakes. Collections of crayfishes in Lake Michigan tributaries and the lake itself were completed and a map of our Lake Michigan results has been submitted for publication. Part of our genetic analysis of sampled individuals has also been submitted for publication. Our results suggest there are only 3 crayfishes commonly found reproducing in the Great Lakes: *O. rusticus* (introduced), *O. propinquus*, and *O. virilis*. There is a small population of the red swamp crayfish *Procambarus clarkii* (introduced and limited to rice fields in Lake Erie) that has been reported by others in Lake Erie. Prediction of the extent of spread of *O. rusticus* in the Great Lakes and estimates of the potential habitats of crayfishes in the Great Lakes was hampered by a lack of available maps substrate maps.

Objective 1

Historical and current published records on the distributions of crayfishes in the Great Lakes are limited or lacking for most regions. We have compiled the results of our literature searches based on records prior to

1940's and post 1940's and used the early records as an indicator of the historic species assemblage (Fig. 1). The recent distribution records of crayfishes in the Great Lakes are often lacking for many parts of the region, but we have used the distribution of crayfishes in the tributaries closest to the lakes as an indicator of the potential for the species to be in the lake proper. The distributions we have presented (Fig. 1) are our best estimates of the distribution of crayfishes in both the tributaries and the lakes themselves. Thus, we accomplished Objective 1.

Objective 2

Because of the lack of published data on crayfishes in the Great Lakes, we contacted all researchers we were aware of that were working in the Great Lakes that might have documented crayfish distributions. As a result of these contacts and our own collections we have been able to document the current distributions of crayfishes, especially *O. rusticus* in Lake Michigan (Figure 2). Based on these surveys, *O. rusticus* appears to occupy areas where there are rocky regions in shallow water nearshore that provide habitat. Records from Nancy Tuckman, Marty Berg and John Janssen (Loyola University) have documented the colonization of the rocky areas off Chicago, IL by *O. rusticus* and the displacement of *O. propinquus* and *O. virilis*. *Orconectes rusticus* has also been documented in the rocky shallows of Traverse Bay in northwest Michigan. However, no records of *O. rusticus* had been published along the eastern shore of Lake Michigan and historically this region was dominated by *O. propinquus* and *O. virilis*. This provided one of the best opportunities to compare the current and historic distributions of crayfishes. Because the spread of *O. rusticus* has been attributed to its use as bait, we sampled the tributaries of the eastern shore of Lake Michigan where boat launches and bait shops are prevalent. After we documented the existence of *O. rusticus* in all tributaries that we examined, we also surveyed the offshore sites to determine if *O. rusticus* had colonized the lake proper (Fig. 2). We documented the presence of *O. rusticus* in all of the major tributaries along the eastern shore and the absence of *O. propinquus* and *O. virilis*, but surveys of offshore areas found that no *O. rusticus* had colonized these areas and the habitat was dominated by *O. propinquus*.

For the individuals collected, we examined the diagnostic allozyme markers that reliably distinguish the three species, *O. rusticus*, *O. propinquus*, and *O. virilis*, to estimate the relative time since *O. propinquus* has been extirpated in the harbors of the lake. If in these regions we had found a large number of F1 hybrids between *O. rusticus* and *O. propinquus* it is likely that *O. rusticus* had recently invaded. However, we found most individuals of hybrid ancestry were backcrosses between *O. rusticus* and either F1 hybrids or other backcrosses. By comparison with our genetic analyses of ongoing invasions in inland lakes, these results from Lake Michigan indicated that *O. rusticus* had dominated these areas for several years.

We also examined the genetic structure of *O. propinquus* in the offshore habitats to determine if the *O. propinquus* populations were genetically pure. In examining these individuals, we found several individuals that had both *O. propinquus* and *O. rusticus* diagnostic nuclear markers. This suggests that either *O. rusticus* had been in the habitat at one time and had mated with resident crayfishes or that *O. propinquus* x *O. rusticus* hybrids had migrated to these regions from the harbors. This finding is significant because in our work in inland lakes, we have only rarely found backcrosses that were morphologically indistinguishable from *O. propinquus*. Thus, we fully accomplished Objective 2.

Objective 3

To predict the future distribution of *O. rusticus* in the Great Lakes, information on available habitat for crayfishes is needed and without this information, estimates of their potential for dispersal are unreliable. We have contacted many of the governmental agencies and private agencies that may have information pertaining to this. Unfortunately, there appear to be no data at the appropriate scale to allow even a crude determination of the potential distribution of *O. rusticus* in any of the Great Lakes at this time. There are however, new mapping programs underway that may provide the appropriate information and we are continuing to look for new data.

In addition to the publications already out or submitted (see list below), we are also formatting our data and maps for a manuscript on the current and historic distribution of crayfishes in the Great Lakes. Presentations to regional meetings have also proven useful in developing contacts with researchers who have observed *O. rusticus* in Lake Michigan and other regions of the Great Lakes.

Accomplishments

Our results illustrate that for the rusty crayfish, there have been multiple introductions, primarily in the rivers and streams that flow into Lake Michigan. This distribution pattern strongly implicates the bait trade and anglers has the primary pathway by which the rusty crayfish has been spread. Thus, in 2 articles in Fisheries, we have advocated that the use of live crayfish as bait be outlawed in all Great Lakes states (see list of publications).

Narrative Report

We have examined data and literature pertaining to the historical and current distributions of crayfishes in the Great Lakes with a strong emphasis on Lake Michigan. We have completed the literature survey on crayfishes in the Great Lakes and have begun an analysis of the crayfishes in the tributaries of the Great Lakes. Many of the documented collection sites of crayfishes are from tributaries of the Great Lakes and not from the lakes themselves. We have received responses from the questionnaires sent to all of the scientists around the Great Lakes that may have had information on crayfishes in the Great Lakes. Some replies provided useful data on the distribution of *O. rusticus* in the Great Lakes. These and the published accounts from tributaries provide important information on the potential crayfish community in the lakes themselves. The results for the literature surveys have been interpreted and maps have been made for each of the species (Fig. 1). We have also received species distribution information as a result of our recent talks and this information has proven to be very useful in extending the number of sites where *O. rusticus* has been found in the Great Lakes.

Because of the lack of published records on the distribution of crayfishes in the lakes, we focused on the past and recent distribution of *O. rusticus* in Lake Michigan. The historical surveys clearly show that *O. propinquus* and *O. virilis* were the only species present in the tributaries and *O. propinquus* may have been the only species in the lake itself. Using this information and that gathered from recent publications combined with discussion with numerous researchers working in this region and we have obtained information on potential zones of contact and age of contact between *O. rusticus* and *O. propinquus*. For this aspect of the project, we focused on the southern half of Lake Michigan, particularly an area north of Chicago where preliminary samples have shown extensive hybridization. We have examined the putative hybrid zones in this area and the dynamics are similar to those observed in inland lakes.

Because locations of crayfish populations along the eastern shore have not been examined recently, we surveyed harbors and streams focusing on areas where *O. rusticus* would most likely have been introduced. Monospecific populations of *O. rusticus* exist in most of the harbors surveyed, but we have not been able to identify any populations in the Lake Michigan itself even with extensive SCUBA surveys in the areas surrounding the harbors containing *O. rusticus* populations. Genetic analyses of the individuals in the harbors revealed that many of the *O. rusticus* individuals are of hybrid ancestry between *O. rusticus* and *O. propinquus* and few F1 hybrids were found suggesting the invasion occurred some time ago. Populations of *O. propinquus* in offshore sites, however, had individuals with mixed *O. rusticus* and *O. propinquus* genetic markers indicating a hybrid origin. This scenario is quite different than that observed in inland lakes where individuals morphologically identifiable as *O. propinquus* are displaced and introgression of *O. propinquus* markers is nearly unidirectional into *O. rusticus* populations as *O. propinquus* are driven extinct.

The literature surveys and collections from the Lake Michigan have allowed us to modify our current understanding of the distribution of crayfish in Lake Michigan. The literature survey suggests that *O. rusticus* may be established in many of the larger tributaries and harbors along the western and eastern shores of

Lake Michigan. The surveys of the lake suggest rocky habitat may be limiting and that *O. rusticus* may not have begun to colonize the lake in the regions that we have sampled. Thus, the invasion of the Great Lakes by *O. rusticus* may be occurring from multiple locations, i.e., harbors where bait shops are located, into the lake itself. This scenario may be envisioned as a halo of *O. rusticus* around the deltas of the tributaries rather than one large invasion front as expected from our understanding of smaller inland systems.

Brief Summary

The goals of this research were to document the historic biodiversity of the crayfishes in the Great Lakes and how this has changed in the last several decades as a result of introductions by humans of crayfishes from other parts of North America. We were particularly interested in how the invasion of the rusty crayfish affected changes in resident crayfish populations and how we can use this invasion to understand the invasion of other bottom dwelling species. Crayfish were a focus for this study because they are one of the most threatened and endangered taxa in the world and the US has the greatest biodiversity in the world with over 300 species. However, the biodiversity of crayfishes in the Great Lakes was relatively unknown and the changes over time of these populations was also unknown even though it was well documented that the Great Lakes underwent dramatic changes in other components of the food web. Crayfish are an important part of the ecosystem, often controlling the structure and function of aquatic food webs. Although rusty crayfish look similar to other species of crayfishes, they are better competitors for food and shelter and are less susceptible to predation by fishes. Introductions of rusty crayfish can thus have dramatic effects on the food webs.

In the initial phase of our project, the goal was to document the historic biodiversity of the Great Lakes using published records and museum specimens. We then collected published records and unpublished records from other researchers in the region to determine how the distributions have changed and what the extent of the invasion of the rusty crayfish was. We documented several populations of the rusty crayfish that have been established in the Great Lakes and also in harbors primarily along the eastern side of Lake Michigan. Because rusty crayfish hybridize with one of the resident species of crayfish, we have been able to use DNA markers to help understand how long rusty crayfish have been in the area. Results suggest that they have been present for many years. The project has produced the best documentation ever of which crayfish occur in the lake (rather than in the tributary rivers). Results suggest that anglers using live crayfish as bait have been the primary pathway by which the rusty crayfish has been introduced

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