RESEARCH PROPOSAL

to

MICHIGAN SEA GRANT CORE RESEARCH PROGRAM

United States Geological Survey, National Oceanic and Atmospheric Administration

https://www.michiganseagrant.org/research/research-approach/

SUBMITTED BY:

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Abstract:

Islands can serve as unique experimental units for a number of areas of research. The traditional theory of island biogeography, in terrestrial context, suggests that isolation of certain environments will lead to faunal composition that is a function of extinction and colonization rates, which themselves are a function of island size and proximity to mainland metapopulations. In the Great Lakes, this concept may apply to nearshore and coastal fish taxa in areas where archipelagos provide habitat patches of different proximities to mainland coastlines. I propose that island biogeography theory can be tested among nearshore fish fauna found at islands in the Beaver Archipelago, located in northern Lake Michigan. Marked fish will be used to determine local migration rates and demographic parameters of many fish taxa in the nearshore zones at seven islands of the Beaver Archipelago, which are isolated from mainland coastal habitat of Wisconsin and Michigan by vast pelagic zones. I hypothesize that nearshore fish community structure will be a function of an island's length of coastline and its proximity to other islands. In addition, these coastal habitats are exposed to frequent intermediate disturbances from severe weather. As climate change threatens to alter coastal habitat through increased severity and frequency of disturbances, the resilience of coastal ecosystems and the taxa that occupy them may rely in dispersal and colonization abilities of specific taxa or taxa groups.

Introduction

The Beaver Island Archipelago in northern Lake Michigan presents a unique research opportunity to study coastal ecosystems in the Great Lakes. The entire archipelago is comprised of some 14 islands and shoals with various embayments, shoreline types, and area of coastal

habitat (Figure 1). Glacial scouring and errata formed the Beaver Archipelago, which has a rich anthropogenic history as well as ecological value. Beaver Island is 30 km from mainland Michigan and is home to about 700 year-round residents. Beaver Island itself is the largest island in Lake Michigan at 145 km^2, and islands in the area range from 20 km^2 to as small as 0.04 km^2, providing an ideal situation to study island biogeography of nearshore fish fauna. The Central Michigan University Biological Station is located on Beaver Island and serves as a base of operations for the CMU Institute for Great Lakes Research.

Figure 1: Map of the Beaver Island Archipelago.

Rates of extinction and colonization are important mechanisms for assembling faunas, but can be difficult to study directly. The insular nature of islands results in habitat patches of varying sizes and proximity to other metapopulations of migratory species. Less isolated insular areas are colonized more frequently (Brown and Kodric-Brown 1977) and are accessible to a wider range of species, including those with low dispersal ability (Carlquist 1966, 1981). Mainland coastal habitat areas lack pelagic zones to isolate fish with less migratory capacity, however, an archipelago within a large pelagic zone can serve as a study system to examine the

effects of island biogeography among islands within the archipelago. Fish communities may be nested, with the number of species present result from a function of the island's isolation from other systems and total habitat area; larger patches tend to have more habitat heterogeneity and more resilience to disturbance. Local fish metapopulations of the Beaver Archipelago present a unique opportunity to study island biogeography theory applied to nearshore fish species of the Great Lakes.

Justification

Numerous studies of nearshore habitat use by fishes exist across all the great lakes (e.g., Uzarski et al. 2005, Seilheimer and Chow-Fraser 2007, Boase et al. 2014), but few exist on mid-lake archipelagos. About 80% of Great Lakes fish species use the nearshore zone, defined from the interface of land and water to a depth of 5m in some way for spawning, feeding, or migration (Jude and Pappas 1992, Mackey and Liebenthal 2005). Nearshore fish habitat along Great Lakes shorelines is patchy and variable, but fishes in these areas are not forced to migrate across vast expanses of pelagic zones that do not provide the same resources and refuge of the coastal zone. The theory of island biogeography has been explored in marine and terrestrial habitats (Lomolino and Smith 2003, Pinheiro et al. 2017), riverine systems (Hoagstrom and Berrry Jr 2006), and isolated lakes (Lassen 1975), however, there is a paucity of research regarding freshwater archipelagos and associated development of the nearshore fish community.

Given the variety of island sizes (and thus shoreline lengths) in the Beaver Archipelago provide a framework to test fundamental predictions of island biogeography theory. Migration of Smallmouth bass (*Micropterus dolomieu*) in the Beaver Archipelago was restricted in summer months and fish remained within 5 km of the archipelago (Kaemingk et al. 2011). However, fish from other species may leave and return to the archipelago, or remain isolated to small

geographic habitats. Seiches and wind-driven upwellings may cause temperature and sediment disturbances that cause a shift in fish distribution (Plattner et al. 2006), and islands with embayments may be more resistant to disturbances, and archipelagos with more islands may be more resilient to disturbances (Carlquist 1981, Howe et al. 2007, Gittman et al. 2016). Therefore, this research fills multiple data gaps in existing ecological theory and could provide the framework for a long-term monitoring study of fish communities in the Beaver Archipelago.

Hypothesis

The goal of this study is to test the fundamental predictions of island biography theory on the nearshore fish communities of the Beaver Archipelago. Islands with more proximity to island, longer shorelines, and habitats protected from disturbance are expected to harbor greater abundances and diversity of species compared to smaller, isolated islands that are exposed to more disturbance. Movement of fish taxa between islands will be tracked to quantify patterns of movement between islands in the Beaver Archipelago to test if movement rates increase as a function of decreasing distance between islands (Figure 2).

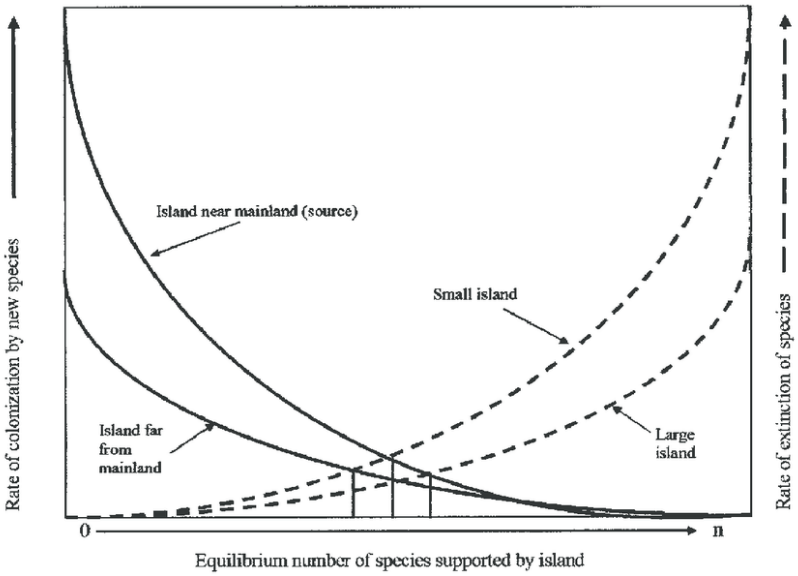

Figure 2: Relationships between island size, distance of island from mainland, and colonization by new species (solid line) and extinction of species (dotted line), from MacArthur and Wilson 1967.

Methods

This research will take place in three summer field seasons between 2021 and 2023. Sampling will take place between May and August of each year, using a variety of fish sampling techniques including gill nets, fyke nets, boat electrofishing, and minnow traps. Sites may be selected from a subset of islands to improve sample efficiency, and the number of sites at each island chosen will be partitioned according to shoreline length (e.g., one site per km of shoreline) and stratified by habitat features (e.g., substrate type, embayment). Because island biogeography theory relies on both dispersal and colonization of species, individually marked tags are critical to collection of appropriate data.

Captured fish will be tagged with an individually numbered floy tag, which is a readily observed and identifiable marker (Floy Tag, Inc., Seattle, WA). Due to the prohibitive nature of sampling fish in small vessels on large lakes, fish tagging will occur at a subset of islands within 8 km the nearest shoreline of Beaver Island. Each island chosen will be sampled at least monthly every field season to quantify rates and magnitude of fish movement among islands.

This study design allows for application of analyses including multistate capture-mark-recapture analysis that quantifies emigration rates, and occupancy modeling of cryptic taxa among various habitat types when tagging data is insufficient. Fin clips of specific taxa may be retained for age and genetic analyses. Standard metrics that describe the relative abundance and biodiversity of the nearshore fish community will be paired with both qualitative and quantitative measurements of shoreline habitat features (e.g., bathymetry, vegetation).

Anticipated Results and Deliverables:

We expect that fish taxa richness will be reduced at islands with smaller coastal habitat areas and with increasing distance from source populations. Variation in migration rates among species will be compared, and we expect to find that larger-bodied species migrate farther and more frequently, but migration may be inexorably tied to other behavior (e.g., spawning). Further, multi-state analysis will help inform transition probabilities of fish taxa that spread from island to island. Results from occupancy modeling are anticipated to create a new framework for describing the distribution of freshwater coastal fish taxa in a unique habitat that is relatively unimpacted by humans. Estimates of absolute abundance and survival from capture-mark-recapture analyses are expected to yield valuable information regarding habitat preferences of coastal fish species; if possible models will be developed to incorporate wind- and wave-caused disturbances to the nearshore zone as covariates of fish distribution in the Beaver Archipelago.

This funding requested will provide a full research assistantship to one Ph. D. or two M.S. students, and a half time appointment for one post-doctoral researcher and a half time appointment for one faculty member to serve as the principal investigator. As such, we expect to produce publications in peer-reviewed journals from both applied and theoretical fields of ecology. Funding requests have also been made to accommodate conference travel to communicate results of the research. We expect to coordinate extensively with the Michigan DNR and plan to produce technical bulletins and other public outreach materials.

The final report for this project will broadly summarize the findings of the research project and make future recommendations for shoreline management in the Beaver Archipelago and the rest of the Laurentian Great Lakes.

PROPOSED ANNUAL BUDGET (USD)						
Budget Period: 1/1/2021--12/31/2023	**Annual Cost**	**Effort Sponsor**	**Effort CMU**	**Annual Sponsor Amount**	**Annual University Amount**	**Annual Project Cost**
Faculty, Student, Staff Salaries and Benefits						
Principal Investigator	78,719	30%	20%	23,616	15,744	39,360
Co-investigator	45,500	30%	20%	13,650	9,100	22,750
Graduate Assistantships (1)	18,010	100%	--	18,010	--	18,010
Staff Wages: Boat Captain	35,558	5%	--	1,778	--	1,778
Undergraduate Student Wages	23,040	100%	--	23,040	--	23,040
Faculty Benefits @30%	--	--	--	11,180	--	11,180
Wage Benefits @7.65%	--	--	--	1,899	--	1,899
GSRA Benefits @$485/month	--	--	--	5,280	--	5,280
GSRA Tuition Remission	13,920	--	100%	--	13,920	13,920
Equipment, Supplies, and Travel						
Consumable supplies & materials*	10,258	100%	--	10,258	--	10,258
Travel – Fieldwork**	6,909	100%	--	6,909	--	6,909
Travel – Conference	1,000	100%	--	1,000	--	1,000
Equipment – *One-time in-kind match.*	24,546	--	100%	--	--	24,546 [tt]
CMUBS BI Room & Board**	27,328	--	100%	--	27,328	27,328
CMU Facilities & Service (CMUBS-BI)	18,348	-	100%	--	18,348	18,348

	Sponsor Amount	**University Amount**	**Project Amount**
TOTAL ANNUAL DIRECT COST	**116,620**	**84,440**	**201,060**
TOTAL ANNUAL INDIRECT COST: 53%	**61,809**	**44,753**	**106,652**
GRAND TOTAL – ENTIRE PROJECT [tt]	**713,716**	**541,318**	**1,255,034**

** Includes 10,000 floy tags, applicators, and other consumable field and lab materials expected to be used every year.*

*** Travel for fieldwork includes mileage for University vehicles to Charlevoix, MI, ferry tickets to and from the island and boat fuel for sampling vessels.*

*** In kind contribution of Room & Board calculated at the standard rate of $61 per day per person, for 4 people living, eating and working at the CMU Biological Station on Beaver Island for 16 weeks per year.*

[tt] One-time expense, not calculated into annual costs but added to grand total.

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