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Type of Organization: College or University

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Project Title: Food Web and Feeding Influences on PCB Bioavailability

Project Category: Contaminated Sediments

Rank by Organization (if applicable): 0

Total Funding Requested ($): 258,747 **Project Duration:** 2 Years

Abstract:

Round gobies (RG) have spread into Great Lakes areas already occupied by zebra mussels (ZM). Given its propensity to ingest ZM, the RG has been implicated as an influential link in contaminant cycling. Previously funded work (GL985599-01-0) has demonstrated an increase in PCB concentration of 2-3 fold at each trophic level in a ZM--RG--smallmouth bass food chain. However, stable isotope analysis of the food chain components indicates that RG and smallmouth bass eat a diversity of organisms. Also, given that feeding habit greatly influences PCB uptake, by changing the feeding habits of the benthic community, these exotic species could alter PCB dynamics. To assess these potential effects of exotic species on contaminant cycling, we will sample two harbor sites in Lake Erie, each paired with a nearby shore site, in both the western (Maumee and Sandusky Harbors) and central basin (Grand and Ashtabula Harbors), in addition to two relatively uncontaminated reference sites (n=6 sites total). We will quantify whole-body PCBs (total arochlor and congener specific) and lipids in ZM, RG, prey of RG, smallmouth bass, and sediments to test our hypotheses that food-web structure affects PCB bioaccumulation and that PCB congener distributions in biota match those of the local sediments. We will then conduct single-species, whole-sediment, bioaccumulation assays using three benthic invertebrates with distinctly different feeding habits (Hexagenia spp., Lumbriculus variegatus, and Gammarus spp.). We will expose each assay organism to sediments from both basins to test the hypothesis that differences in feeding habit, sediment quality, PCB concentration, and PCB congener distribution affect PCB bioaccumulation. Finally, we will conduct whole-sediment bioaccumulation assays in two-species communities (Gammarus and L. variegatus) with and without ZM. By exposing these communities to sediments from each basin, we will test the hypothesis that ZM increase PCB bioavailability.

Geographic Areas Affected by the Project

States:

- [ ] Illinois
- [ ] Indiana
- [ ] Michigan
- [ ] Minnesota
- [ ] New York
- [ ] Pennsylvania
- [ ] Wisconsin
- [x] Ohio

Lakes:

- [ ] Superior
- [ ] Huron
- [ ] Michigan
- [x] Erie
- [ ] Ontario
- [ ] All Lakes

Geographic Initiatives:

- [ ] Greater Chicago
- [x] NE Ohio
- [ ] NW Indiana
- [ ] SE Michigan
- [ ] Lake St. Clair

Primary Affected Area of Concern: Maumee River, OH

Other Affected Areas of Concern: Black River, OH
Ashtabula River, OH
Cuyahoga River, OH

For Habitat Projects Only:

Primary Affected Biodiversity Investment Area:

Other Affected Biodiversity Investment Areas:

Problem Statement:

Despite source reductions, persistence of polychlorinated biphenyls (PCBs) in Lake Erie sport fish will likely continue. Following initial declines during 1977-1982, PCB residues in sport fish have remained relatively constant, even increasing slightly during 1982-1992 (DeVault 1996, Journal of Great Lakes Research 22:884-895). After achieving relatively stable, low levels, much of the variability in sport-fish PCB concentrations can be explained by variability in biotic interactions that affect contaminant bioavailability, including prey-fish dynamics and exotic species interactions (Stow et al. 1995, Ecological Applications 5:248-260; DeVault 1996).

Sport-fish dynamics in Lake Erie are changing. Phosphorus abatement, zebra mussels, and agricultural improvements have reduced primary productivity and bottom anoxia, improving water quality. We, in collaboration with the Ohio Division of Wildlife (ODW), have documented dramatic changes in sport-fish food webs in Lake Erie since the early 1970s. In general, the prey base has shifted from pollution-tolerant, soft-rayed, planktivorous fishes to pollution-intolerant, spiny-rayed, benthivorous fishes (Gopalan et al. 1998, Canadian Journal of Fisheries and Aquatic Sciences 55:2572-2579; Ludsin et al. 1998, Federal Aid in Sport Fish Restoration, Annual Report, ODW, Columbus, OH).

Benthic communities in Lake Erie also are changing, likely affecting contaminant uptake. Exotic species colonization (e.g., zebra mussel and round goby) and the dramatic recovery of nearly extirpated species (e.g., Hexagenia) have greatly influenced benthic community structure. Zebra mussels alter nutrient pathways, increasing total macroinvertebrate biomass and density of selected species (e.g., amphipods; Stewart et al. 1998, Journal of Great Lakes Research 24:868-879). Contaminant-exposure routes differ among taxa, including direct uptake from sediments by Hexagenia (Corkum et al. 1997, Journal of Great Lakes Research 23:383-390), ingestion of zebra mussel feces by amphipods (Bruner et al. 1994, Journal of Great Lakes Research 20:735-750), ingestion of amphipods or contaminated zebra mussels by round gobies (Ray and Corkum 1997; Environmental Biology of Fishes 50:267-273), and selective ingestion of sediment particles by invertebrates (Wood et al. 1997, Environmental Toxicology and Chemistry 16:283-292). As a result of these different exposure routes, PCB congener patterns in biota can differ greatly from sediment patterns (Wood et al. 1997). Therefore, by changing the feeding habits of the benthic community, exotic species can alter PCB bioavailability.

Consumption of benthic prey by sport fish can transfer and biomagnify PCBs. We have found that round gobies, Hexagenia, and amphipods are becoming more common in sport-fish diets (Ludsin et al. 1998) and PCBs increase 2-3 fold at each trophic level in a zebra mussel--round goby--smallmouth bass food chain (GLNPO project GL985588-01-0). However, using stable isotope analysis, we have demonstrated that round gobies and smallmouth bass feed on a variety of prey, in addition to the ones included in the simplistic food chain upon which the previous work was predicated. If the influence of round gobies on contaminant cycling is to be truly understood, the contribution of these other species to the body burdens of PCBs at each trophic level must be assessed.

Finally, differences between basins in Lake Erie obscure lake-wide trends in contaminants and sport fisheries. Since the early 1970s, water clarity in the western basin has increased and fish species richness has declined (Gopalan et al. 1998, Ludsin et al. 1998). Sediments in the western basin have higher PCB concentrations than the central basin (Oliver and Bourbonniere 1985, Journal of Great Lakes Research 11:366-372); thus, re-suspension of more heavily contaminated sediments in the western basin yields higher water-column PCB concentrations than the central basin (Anderson et al. 1999, Journal of Great Lakes Research 25:160-170), greatly influencing PCB concentrations in fish (Morrison et al. 2000, Ecological Modelling 125:279-294). Unlike the western basin, the deeper central basin may be less affected by such sediment re-suspension. Because of these abiotic (sediment), biotic (food web), and spatial (basin) differences, discerning lake-wide trends in contaminants and sport fisheries is problematic.

Proposed Work Outcome:

Proposed Work:

In our view, food-web changes, exotic species invasions, ongoing oligotrophication, and feeding selectivity by benthic organisms all affect contaminant bioavailability. However, to connect sport fish, benthic communities, and contaminants, inter-basin differences in food webs and sediments must be understood, given that sediments and food webs differ between basins. By influencing PCB bioavailability, these differences ultimately determine inter-basin differences in PCB residues in sport fish. We will deconstruct these differences by 1) analyzing inter-basin differences in PCB congener distribution in biota and sediments, 2) conducting laboratory studies to assess sediment differences by measuring their bioaccumulation in identical assay organisms, and 3) inferring and modeling the influence of food webs on PCB bioavailability. By "reconstructing" these components, we can determine how much of the contaminant differences between basins can be attributed to food webs and to sediments.

Objective 1- During 2000 and 2001, we will analyze PCBs, both total arochlors and congener-specific values, in biota and sediments from Lake Erie. We will sample two harbor sites, each paired with a nearby shore site (500 m from each harbor), in both the western (Maumee and Sandusky Harbors) and the central basins (Grand and Ashtabula Harbors), in addition to two relatively uncontaminated reference sites (South Bass Island and the Ottawa National Wildlife Refuge). From this, we can assess the generality of harbor results within each basin. We will quantify whole-body PCB concentrations and lipids in round goby, round goby prey (e.g., dragonfly naiads, zebra mussels, Hexagenia), round goby predators (e.g., smallmouth bass), and sediments at each site. We can compare the distribution of PCB congeners in organisms to sediment profiles to evaluate the relative contributions of sediment and the food chain as sources of contamination for each trophic level. These data will also be used to calculate toxicity equivalents (TEQs) based on the identity of individual PCB congeners for each species and each trophic level. From this, we will test our hypotheses that food-web structure affects PCB bioaccumulation and that PCB congener distributions in biota reflect those of the local sediments. If highly chlorinated PCB congeners with accentuated biological activity, including dioxin-like activity, are being retained, this may help to explain the continuation of these effects at higher trophic levels, despite declines in total PCB residues.

Objective 2- During 2001 and 2002, we will conduct two laboratory experiments. We will first conduct single-species, whole-sediment, bioaccumulation assays using three benthic invertebrates with distinctly different feeding habits (Hexagenia spp., Lumbriculus variegatus, and an amphipod Gammarus spp.). We will expose each assay organism to selected sediments from both basins to test the hypothesis that differences in feeding habit, sediment quality (e.g., organic enrichment), PCB concentrations, and PCB congener distribution affect PCB bioaccumulation in identical organisms. Then, we will conduct whole-sediment bioaccumulation assays in two-species communities (Gammarus and L. variegatus) with and without zebra mussels. By exposing these communities to sediments from each basin, we will test the hypothesis that zebra mussels increase PCB bioavailability to benthic communities.

Objective 3- During 2002, we will combine these data into models that describe PCB movement through round goby-facilitated food chains and synthetically analyze changes in benthic food webs, exotic species, and contaminated sediments. We will assess food-web contributions to PCB bioaccumulation differences between basins. We will use multivariate analysis to discriminate PCB-congener distribution within and among trophic levels. We will use PCB profiles at each trophic level to parameterize a fugacity-based model, describing PCB movement in food webs. We will also parameterize bioenergetics models for smallmouth bass and walleye (Kershner et al. 1999, Canadian Journal of Fisheries and Aquatic Sciences 56:527-538). With bioenergetic estimates of assimilation efficiency and consumption, we can predict how contaminant body burdens are influenced by prey availability, predation, and growth rates (Jackson 1996, Ecological Applications 6:1355-1364).

Outcome:

Contaminants, such as PCBs, can be transferred through food webs, eventually exposing humans. This capacity is exaggerated with certain exotic species. These species can colonize, often in high numbers due to their high fecundities, high tolerances to diverse conditions, and few native predators and parasites (Johnson and Carlton 1996, Ecology 77:1686-1690). Two species that exemplify this pattern in the Great Lakes are round gobies and zebra mussels. Singularly, each species can negatively affect native species via consumption and competition for limited food resources. Taken together, however, these two exotic species can alter energy and contaminant dynamics greater than merely the sum of their individual effects. These species have formed part of a revised food web in the Great Lakes and likely play pivotal roles in contaminant cycling, funneling persistent contaminants into higher trophic levels.

The research outlined in this proposal will determine the extent of the synergism between round gobies and zebra mussels, in relation to their influence on PCB bioavailability. By assessing contaminant loads in key species across specific areas, we will provide a spatial context for our findings. While lake-wide sediment PCB characterizations are available, only total arochlor amounts are reported. These total arochlor data can not be translated into congener-specific values. Hence, our work will provide these needed congener-specific concentrations. With our combination of field and laboratory approaches, we can place the role of these exotics into a broader context, allowing us to generalize to both harbor and non-harbor nearshore areas of Lake Erie.

By understanding interactions among exotic species, sport-fish food webs, and contaminants, we will provide management recommendations for programs geared toward sport-fish management, exotic species control, and contaminant reduction (letters of support available upon request). Our work will couple community-based, food-web dynamics with individual-based, contaminant dynamics and build upon bioaccumulation models for the western basin of Lake Erie (Morrison et al. 1998, Environmental Science and Technology 32:3862-3867). Our study will evaluate the potential of biotic control to influence PCB movement from sediments to smallmouth bass. From this, we can predict how current trends in the western and central basins (i.e., exotic species, altered benthic communities, oligotrophication, and angler harvest) will affect future management to protect valuable sport fisheries against the negative consequences of exotic species. We believe that better-informed (with scientific data) management agencies are better equipped to make policy decisions. Therefore, our results will form the basis for future remediation efforts aimed at virtual elimination of PCBs.

Project Milestones:	**Dates:**
Project Start	10/2000
Finish Fall 2000 Sampling & PCB Analysis	03/2001
Finish Spr. 2001 Sampling & PCB Analysis	08/2001
Finish Bioacculuation Study and Analysis	12/2001
Perform TEQ and Food-chain Analysis	04/2002
Model Verification and Validation	06/2002
Final Report and Journal Publication	08/2002
Project End	10/2002

☒ Project Addresses Environmental Justice

If So, Description of How:

Ingestion of PCB-contaminated fish is a primary exposure route for humans. In addition to this exposure risk, the areas included in this proposal contain coastal communities whose economic well being is reliant on good water quality. Finally, within the areas of study, subsistence fishers can benefit from reductions in contaminant exposure, especially those in under-represented groups (e.g., urban, low-income, subsistence fishers).

☒ Project Addresses Education/Outreach

If So, Description of How:

A graduate student will be supported by this grant.

Our progress will be shared with the public and scientific community. We will disseminate our results and their implications to the general public through the Ohio Sea Grant communications office and extension network. Our results will be communicated to regulatory and management communities through the communication networks of the Ohio Environmental Protection Agency, ODW, and the Great Lakes Fishery Commission (letters of support are available upon request). In order to provide reliable information, we will develop and adhere to a rigorous quality assurance plan. We will inform our scientific peers by presentations at selected scientific meetings, (e.g., meetings of the International Association for Great Lakes Research). Finally, we will publish our results in peer-reviewed journals, such as the Journal of Great Lakes Research and the Canadian Journal of Fisheries and Aquatic Sciences.

Project Budget:

	Federal Share Requested ($)	Applicant's Share ($)
Personnel:	131,276	62,240
Fringe:	19,028	11,818
Travel:	7,920	0
Equipment:	9,000	0
Supplies:	10,000	0
Contracts:	0	0
Construction:	0	0
Other:	0	10,000
Total Direct Costs:	177,224	84,058
Indirect Costs:	81,523	38,667
Total:	258,747	122,725
Projected Income:	0	0

Funding by Other Organizations (Names, Amounts, Description of Commitments):

Ohio Sea Grant Project R/ER-55
Modeling Smallmouth Bass Consumption of Round Goby in Lake Erie: Implications for Predator Growth and Contaminant Transfer
3/1/2000 - 2/28/2003
Principal Investigator: Roy A. Stein
Co-PIs: Elizabeth A. Marschall and Susan W. Fisher
Total Sea Grant Funds: $144,340.00
Match Funds: $84,953.00

Description of Collaboration/Community Based Support:

The proposed research is collaborative effort of three co-principal investigators from The Ohio State University, Drs. Susan W. Fisher (SWF), Elizabeth A. Marschall (EAM), and Roy A. Stein (RAS). It is the logical culmination of their previous and ongoing research programs. This proposal builds upon earlier work by SWF to understand the role of zebra mussels in contaminant cycling and the environmental fate and toxicological effects of persistent contaminants. Our work complements the work of EAM to explore interfaces between populations and spatial patterns in resources and between individual behaviors and population dynamics. Finally, this effort fits into the research of RAS to understand fish community processes in the Great Lakes and how major processes, such as predation, competition, and keystone species, structure freshwater food webs. Because of their previous experience, their seniority, and their active laboratories, most of the methods and equipment required to undertake the proposed research are in place in their laboratories. Rapid progress is, thus, assured if this work is funded.

We are aware of complementary work in Lake Michigan funded by USEPA-GLNPO to M. Berg et al. We have contacted this group, with the goal of building upon, rather than duplicating, their research. Also, we are aware of an existing bioaccumulation model specific to the western basin (Morrison et al. 1997, 1998, and 2000). Our proposed work will build upon these existing data and models to generate a synthetic view of changes in Lake Erie.