SCIENTIFIC UTILITY IN ECOLOGICAL EDUCATION PROGRAMS: A CASE STUDY OF THE INLAND SEAS EDUCATION ASSOCIATION, SUTTONS BAY, MI

by

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ABSTRACT

This practicum originated from an internship with the Inland Seas Education Association (ISEA), Suttons Bay, MI in summer of 2009. Through its educational programs aboard schooners on Grand Traverse Bay, MI ISEA generates a large volume of physical and biological data. At its core, this project had three primary objectives:

I. Determine general trends from ISEA's fish, zooplankton, and benthos data
II. Determine the scientific validity and utility of ISEA's data
III. Develop recommendations for ISEA and other programs that would improve the consistency, validity, and applications of water quality or ecological sampling programs

General trends within ISEA data were analyzed by digitizing data from 1989-1992, 1995-2001, and 2005-2010 and generating graphs to display changes in the fish, zooplankton, and benthos populations over time. To determine the scientific validity of the data, independent fish, zooplankton, and benthos samples were collected in June, July, and September, 2010 following currently accepted scientific protocols and compared with ISEA's 2010 data. Based on the comparison, it was determined that ISEA's fish data can be utilized with caution for examining fluctuations in populations, while zooplankton and benthos data are only usable for casual long-term trend analyses. Based on these inferences, a series of recommendations for data processing, data analysis, and volunteer training were generated for ISEA and other ecological education programs to improve the scientific utility of resulting datasets.

ACKNOWLEDGEMENTS

I am truly fortunate to have had the help and support of so many wonderful people throughout this process. Without them this project would have never come to fruition. First and foremost, I would like to thank my family for being so supportive, tolerant, and understanding. Mom, thank you for always knowing how to bring me back down to earth and remind me what I am capable of achieving. I cannot overexpress my gratitude for all you have done for me, including staying up late to talk to me on the phone and taking time off of work to travel to job interviews with me! Dad, you're the best rainy day (or lazy day) taxi service a girl could ask for, and our impromptu lunches were integral in helping me keep my sanity. J.P., your patience, positivity, and lovingness are absolutely extraordinary. You are so much more than my rock; you are my tree (and the love of my life). Heidi, without your help and reassurance, I would still be staring at a sea of Excel data. You don't have to put up with me, but you do anyway. Thanks!

Of course, I couldn't have done this without my advisors, Dave and Tom. Dave, thank you for taking the time out of your busy schedule to travel up north to sample with me. I sincerely appreciate your patience, guidance, and sense of humor in this process! Tom, you were truly the levelheaded, rational voice of reason that I needed! Thank you for helping me keep things in perspective. I would also like to thank John Molenhouse for being so generous with his time and use of the Whaler, and Naomi Lewandowski for taking the time to count zooplankton samples for me. Last but certainly not least, I would like to thank Tom Kelly and Christine Crissman at ISEA for providing me with the opportunity to work with such an amazing organization. Your work inspired not only this project, but my course of study and career as well!

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INTRODUCTION

Inland Seas Education Association

Inland Seas Education Association (ISEA) is a non-profit organization whose primary objective is to give people of all ages the opportunity to experience the Great Lakes firsthand. Based in Suttons Bay, MI, ISEA conducts educational programs about Great Lakes ecosystems for students and adults onboard schooners sailing from Suttons Bay and Grand Traverse Bay, Michigan. Through shipboard and on-shore programs, ISEA hopes to promote increased awareness and understanding of the Great Lakes and the ecological issues that surround them. The ultimate goal of the ISEA program is that students who participate will be motivated to become stewards of the Great Lakes, leading to the programs motto: "*Protecting the Great Lakes through education*".

Thomas Kelly, John Elder, and Peter Dorn founded ISEA in 1989. Kelly, who holds a master's degree from the University of Michigan in Fishery Biology, has served as the Association's Executive Director since that time. Since its creation, ISEA has welcomed aboard 86,393 students of all ages from over 140 different communities within the Great Lakes basin. Classes aboard the tall ships S/V Inland Seas and S/V Manitou consist of lessons pertaining to biology, limnology, ecology, sustainability, and maritime history. Due to the scope of the subject matter taught, ISEA's programs serve to complement traditional classroom courses in biology, ecology, history, geology, geography, chemistry, and meteorology (ISEA 2011). Although most of ISEA's activities take place in the Grand Traverse Bay region, Schooner Inland Seas also does extended trips to locations such as Charlevoix, MI, Escanaba, MI, Milwaukee, WI, and Chicago, IL.

During the school year, ISEA conducts “Schoolship” programs for school groups. These programs are designed for students in grades five through eight, but can be modified for older or younger students. During summer, ISEA’s programs are “Family Science Sails”, which are essentially the same program but for the general public. Aboard the ships, students begin in a large group, where they help the lead instructor collect fish, zooplankton, water, and sediment samples. They then help the ship’s crew weigh anchor and raise the sails. Students are then divided into smaller groups, where they rotate through the fish, sediment and benthos, zooplankton, water chemistry, stewardship, and seamanship stations. A different volunteer instructor teaches the subject matter at each of the stations.

Aside from ISEA’s three fulltime office staff, ISEA relies primarily on volunteer instructors to run their programs. No prior experience is necessary to serve as an instructor, and prospective volunteers are trained through ISEA’s volunteer training program. Ideally, new volunteers attend twelve 2-hour weekly training sessions on the various subject matter and aspects of ISEA’s programs which includes:

1. Introduction to ISEA’s Schoolship and Education Center Programs
2. The Great Lakes and Global Freshwater
3. Sample Collections and Weather
4. Water Chemistry
5. Sediment and Benthos
6. Plankton
7. Fish
8. Stewardship
9. Seamanship
10. Safety Aboard the Schoolship

11. Teaching Strategies
12. Review

Alternatively, volunteers have the option to attend a daylong comprehensive training program that covers all of the aforementioned topics. Volunteers then become the "students" aboard S/V Inland Seas and experience the program firsthand. Volunteers are typically not allowed to instruct given stations before receiving training in that station and shadowing an experienced instructor aboard the ship, Volunteers are also supplied with a Volunteer Instructor Manual, which contains information on the programs and individual stations (ISEA 2011).

Ecological Education

Many different terms have been applied to programs like ISEA. The programs are similar to "citizen science" in that the volunteers essentially serve as citizens monitoring Grand Traverse Bay and collecting scientific data with guidance from trained scientists (Defining Citizen Science 2011). Topics covered during each sail address concepts in biology, chemistry, ecology, etc. but are all under the umbrella of environmental education. Since students are taken on the water and directly take part in sampling and discussion of the health of the bay, ISEA's programs also support an experiential education philosophy (Association for Experiential Education 2011). Smith and Williams (1999) coined the term "ecological education", which they differentiate from other terms by an emphasis on humans being embedded within the natural world. Smith and Williams argued that human-centered and environment-centered approaches do not work because it is impossible and incorrect to separate the two (Smith and Williams 1999). Because of ISEA's focus on building understandings of and connections with the Great Lakes in its students, I feel that ecological education is the term that best describes its programs.

Study Site: Grand Traverse Bay

Grand Traverse Bay is a region of Lake Michigan that is located off the coast of northwest Lower Michigan. Sheltered from west winds by the Leelanau Peninsula, the bay is divided by the Old Mission Peninsula into two sections known as the West Arm and the East Arm of Grand Traverse Bay. The Inland Seas Education Association conducts its programs primarily in the lower west arm of the bay and from headquarters in Suttons Bay, which is located along the eastern shore of the Leelanau Peninsula. The Grand Traverse Bay Watershed is 2,520 km^2 and serves as the drainage basin for Grand Traverse Bay. The vast majority of the surface water flow into the bay comes from the Elk and Boardman Rivers (Canada and U.S.A. 2000).

According to Great Lakes Commission, "specific locational information" such as sampling locations could not be found for programs monitoring fish or benthos in Grand Traverse Bay. Although the assessment states that Michigan Department of Natural Resources and Michigan Department of Environmental Quality survey fish throughout the state's inland lakes and streams and sporadically within the bay, there are no consistent state monitoring programs in the bay that are comparable to ISg (Canada and U.S.A. 2000). The most current ecological data appear to come from Tom Nalepa of the Great Lakes Environmental Research Laboratory (GLERL) and the Grand Traverse Band of Ottawa and Chippewa Indians.

Nalepa led a 5-year effort to monitor *Diporeia* density in Lake Michigan, including Grand Traverse Bay. However, other types of organisms were not monitored in the study (GLERL Fiscal Year 2002). The Grand Traverse Band of Ottawa and Chippewa Indians monitors fish populations in Lake Michigan and Grand Traverse Bay. Their efforts include monitoring commercial *Coregonus clupeaformis* (lake whitefish) harvests, conducting fishery-independent lake whitefish surveys, conducting *Salvelinus namaycush* (lake trout) spawning assessments, monitoring lake trout, lake whitefish, *Lota lota* (burbot), and *Sander vitreus* (walleye) populations, conducting a *Acipenser fulvescens* (lake sturgeon) tagging program, conducting a walleye spawning and predation assessment, and conducting a walleye stocking evaluation (Olsen and Bailey 2010). These efforts contribute substantially to what is known about Grand Traverse Bay fish populations, but differ from ISEA's fish sampling, which focuses on smaller fish that reside on the bottom of the bay. Because of this, the Band does not have the long-term record of *Neogobius melanastomus* (round goby) introductions, and their effect on native fish such as *Perca flavensens* (yellow perch) and *Cottus bairdi* (mottled sculpin).

Much of what is understood about the Grand Traverse Bay ecosystem stems from inferences gained from information collected at monitoring stations near the mouth of the Bay and observation and monitoring by interested and informed citizens. The Laurentian Great Lakes are now home to over 180 known invasive species (GLANSIS 2011), and Grand Traverse Bay may be susceptible to all of them. The potential effects of invasive species are not fully understood, but range from botulism deaths of loons at Sleeping Bear Dunes (Domske and Obert 2001), and depletion and extirpation of native species due to competition over food and spawning resources (Janssen and Jude 2001) to zebra mussel (*Dreissena polymorpha*)-induced oligotrophication in pelagic zones and dense vegetation and algal growth in shallow areas such as Grand Traverse Bay (Fahnenstiel et.

al. 2010). Land-use changes in the bay area also pose concerns, as stormwater and fertilizer runoff are becoming increasingly common and important.

Practicum Rationale and Objectives

Background

This study stemmed from an internship with ISEA in the summer of 2009. As a byproduct of its educational programs, ISEA maintains records of the findings by scientists, volunteer instructors, and students on board. These records contain data pertaining to the populations of fish, zooplankton, and benthic invertebrates in the area, as well as physical data, such as water temperature, wind direction, and weather conditions. Data sheets in which the data are recorded have been kept in multiple formats, stored within three-ring binders inside the ISEA office since the program was founded in 1989. Thomas Kelly, founder and Executive Director of ISEA, and Christine Crissman, the program's Education Director and Chief Scientist, both expressed a desire to see ISEA's data utilized to examine long-term trends in the Grand Traverse Bay ecosystem. Mr. Kelly also expressed interest in utilizing these data as a predictive mechanism for "long range" forecasting" (Kelly 20111, Crissman 2011). With the data handwritten in three-ring binders, these objectives would be impossible to meet.

Rationale

While a substantial amount of literature and research is available on ecosystem changes in the Great Lakes, very little has been done to examine the comprehensive state of ecosystems in more specific regions such as Grand Traverse Bay. The United States Geological Survey (USGS) participated in a long-term study of the region in collaboration with faculty at Michigan State University.

However, their research, along with the majority of recorded data from the region, focused almost solely on characterizing biogeochemical indicators for the ecosystem (Biogeochemical Indicators 2006). Organizations such as the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Laboratory (GLERL) and sometimes regional Sea Grant programs provide continuous monitoring of select Great Lakes ecosystems, but do not offer substantial long-term data specific to the Grand Traverse Bay region (GLERL 2011, Sea Grant 2011). Additionally, the United States Environmental Protection Agency (EPA) and Environment Canada produce *State of the Great Lakes* reports, which provide detailed information on the state of the Great Lakes Basin ecosystems but not regional changes (State of the Great Lakes 2009).

Although ISEA's data may represent the only long-term record of the Grand Traverse Bay ecosystem, its usefulness to the scientific community was previously unknown. Much of the existing information on the state of the bay has been made available through Mr. Kelly and his decades of research through ISEA (Learning How to Save the Great Lakes 2011). More critical analyses and insights could be used to document changes and gain insight into what changes, if any, are needed to improve the scientific utility of the program. In addition, ecological education programs such as ISEA are becoming increasingly popular. Through a thorough examination of the evolution of ISEA's program, it is possible to make recommendations for future programs so they may become effective and efficient as quickly as possible.

Objectives

The primary objectives of this practicum were three-fold:

I. Determine General Trends from ISEA Sampling Data

Regardless of lack of scientific protocol, ISEA followed similar methods over the past 20 years. Therefore, it is reasonable to examine long-term trends from the program and expect consistency. Furthermore, working with the data and looking at trends lend valuable insight into where the program's strengths lie and where there is room for improvement.

II. Determine Scientific Validity and Potential Utility of ISEA Sampling Data

By digitizing and examining the data and the methods by which the data were collected and recorded insight can be gained into how useful these data are to the scientific community or others wishing to use the data for scientific purposes.

III. Develop Recommendations for ISEA and other Environmental Education Programs

Considering one of ISEA's long-term goals is to have a scientifically usable dataset, it is important to generate recommendations for improvements along with the analysis of scientific utility. Ideally, some or all of these recommendations can be utilized by ISEA to make improvements to their program without compromising primary educational objectives. In addition, new and evolving programs can utilize these recommendations to create an effective and efficient program from early in the program's development.

It is important to note that the primary objectives of this practicum do not revolve around performing an extensive analysis of the ISEA dataset. Rather, data were converted to a more accessible format and utilized as a guide for determining the scientific utility of ISEA's programs and where potential for improvement in this area may lie.

EXAMINATION OF LONG-TERM ECOLOGICAL TRENDS FROM ISEA SAMPLING DATA

Introduction

Due to the nature of how data were collected and processed, analyses performed in this study focus on long-term, general trends as opposed to deeper and more complex statistical analyses. By creating charts, graphs, and tables to display the data, the hope was to gain insights into the scope of the data's usefulness and possible unexpected and unforeseen trends. The first step in analyzing ISEA's data was to convert the data from handwritten form to digital, and to try to create as much consistency as possible. After digitization, data were manipulated for standardization where possible and examined to the extent deemed appropriate.

Methods

Data Digitization

Examining the general trends from ISEAs programs first required digitization of their data. In order to digitize data within the timeframe required for the completion of this project, the 1989-1992, 1997-2001, and 2005-2010 datasets were entered into Microsoft Excel. As ISEA had already done some of the digitization, the same Excel template was utilized for this project.

Volunteer instructors who typically lack formal scientific training serve as the primary recorders of ISEA's data. Because of this deficiency, there were some inherent inconsistencies and misinterpretations involved in the recording process. Therefore, it was necessary to develop certain rules for entering the data into Excel in order to create as much consistency as possible.

Throughout the data recovery process, appropriate units were assumed if no unit was indicated. This assumption was, of course, with the exception of obvious errors in which a different unit was incorrectly being used. Personal judgment calls were often necessary, such as in cases where units were recorded incorrectly (i.e., Water temp. = 44°C instead of 44F). Averages were taken for measurements of depth where a range was provided. When a sample from a morning sail was saved for use in the afternoon, only the value from the morning was counted and recorded. These instances were recorded in the “notes” section of the afternoon sample. Some earlier data included typed notes along with student record sheets. For fish counts, typed records were used. For the rest sampling data, averages were taken where possible and the most plausible conclusions were drawn from the pages of hand-written data.

There was a substantial amount of inconsistency in the original recording of biological data. Most of these errors were handled in the data analysis process, but some basic changes were made in the digitization phase. In some cases, phrases such as “most common” were used instead of “A” for abundant, in which case “A” was substituted. For fish, entries that only had an “x” were changed to “1”. Slang terms such as “side-swimmers” and “scuds” (i.e., amphipods) and misspellings such as “cocopods” (i.e., copepods) were corrected at this point. In other cases, recorded data were reclassified to fit within the ISEA digital template. For example, “flatworms” were recorded as “Planaria” in the ISEA digital datasheet. When it was not defined whether or not a species was native or invasive, as in the case of crayfish, the native species was assumed.

Data Analysis

Transferring data from written to digital form allowed me to gain a much deeper understanding of ISEA's sampling and recording processes as well as some of the program's strengths and weaknesses. However, it was necessary to perform some basic data analyses and plotting in order to conclude whether data could be utilized to examine trends over time. Because of substantial differences in how fish, zooplankton, and benthos samples were collected and processed, it was necessary for each "category" to be examined individually, sometimes using different methods.

Fish

Fish data represent ISEA's most complete and consistent dataset. They have sampled fish since the program began, and for the most part have been reliable in recording the duration of the trawls in a standardized manner. As this study focused on Suttons Bay and the lower west arm of Grand Traverse Bay, I altered the fish data by first removing entries from non-traditional sites such as Escanaba and Lake Charlevoix. I standardized all trawl hauls to 10 minutes, then calculated average catch-per-unit effort (CPUE) per 10-minute trawl per year. Because of the large number of fish identified over the years, it became necessary to simplify and narrow the number of species represented in the graphs. This data restructuring was done by taking the top five species per year (six if there was a tie) and including a "miscellaneous" category for the rest. Species included under "miscellaneous" were then noted by year in a separate table (Appendix 1). In some cases, species that made the "top five" for a given year were still removed due to very low frequency of occurrence. Using this procedure, the final analyses included the overall top 13 species.

Trends in fish data were examined by observing changes in species composition from year to year. These observations allowed for insights into changes in populations such as species declines and introductions. It also provided valuable information on ISEA's accuracy, since in some cases species included in the data were highly improbable or not recorded in the dataset until several years after their first confirmed discovery in the area.

Zooplankton

ISEA has transitioned through many different methods of classifying and counting zooplankton. Often, volunteers that remained with the program for an extended period of time utilized different classification methods from what the program was currently using. For example, there may be counts in some cases and ranks in others. Furthermore, ISEA did not provide an indication of the volume of plankton sample examined. This methodological limitation prevents researchers from being able to gain information regarding actual abundance. Because of this limitation, the best way to examine these data was through utilizing a ranking system, since this approach at least gave an indication of relative abundance.

In preparing ISEA's zooplankton data, I first removed data entries that included "X"s or question marks in place of data and then replaced ISEA's abundant, common, and rare (A, C, and R, respectively) rankings with 3, 2, and 1. Unfortunately, very little of the data prior to 2000 contained these rankings, so much of it had to be deleted. To avoid losing too much data, I selected specific bin sizes so that numeric counts could be converted to ranks. The numbers 0-5 were classified as “1” or rare, 6-10 was classified as “2” or common, and counts of 11 or greater were recorded as “3” or abundant. These determinations were made considering my knowledge of the approximate volumes that researchers and students were typically able to examine. I then took the average species ranks per season per year, and included the top five species present in the graphs. As with the fish data, a “miscellaneous” table was also generated (Appendix 2). Given seasonal changes in zooplankton populations, samples collected in April and May (spring), June, July, and August (summer), and September and October (fall) were analyzed separately.

Due to the inconsistent nature in the data analysis and recording, zooplankton data were analyzed based on broad, long-term trends alone. Through these methods, insights could be gained on trends over time as well as seasonal trends. Although not included in the graphs, information pertaining to the arrival of invasive species such as *Bythotrephes longimanus* and *Cercopagis pengoi* could be obtained through the “miscellaneous” tables.

Benthos

The benthos data require the most caution of the three categories, since they contained the most inconsistency. In some cases presence was marked with an actual count, while in others they were ranked, or sometimes a simple “X” or “yes” notation was given. Some cases contained words such as “lots”, “few”, or “tons”. To further complicate matters, while the number of Petite PONAR grabs was often included, the amount of material actually sorted through was not and different students and volunteers were responsible for sorting in each trip. For the purpose of listing the number of replicates per year, entries that did not include a number of PONAR grabs were listed as “1”. Therefore, the only reasonable possibility to examining these data was through number of species present. Again, the species listed were included in a separate table (Appendix 3).

Results

Fish

In ISEA's 20-year history, one of the most striking observed changes has been a massive shift in the fish populations in the bay area. Interestingly, the data do not show a substantial decline in the overall number of species caught per year from 1989 to 2010 in Grand Traverse Bay (Fig. 1) and from 1998 to 2010 in Suttons Bay (Fig. 2), respectively. Thirteen different species of fish were caught in Grand Traverse Bay in 1989, and 10 different species were caught in 2010. With 19 different species recorded, 1999 had the greatest species richness in Grand Traverse Bay. Only nine different fish species were recorded in 1999. In Suttons Bay, 12 fish species were recorded in 1998 and 2010, respectively. The year with the greatest species richness was1999, with 16 different fish species recorded. The fewest species were recorded in 2008, when ISEA observed 11 different species of fish.

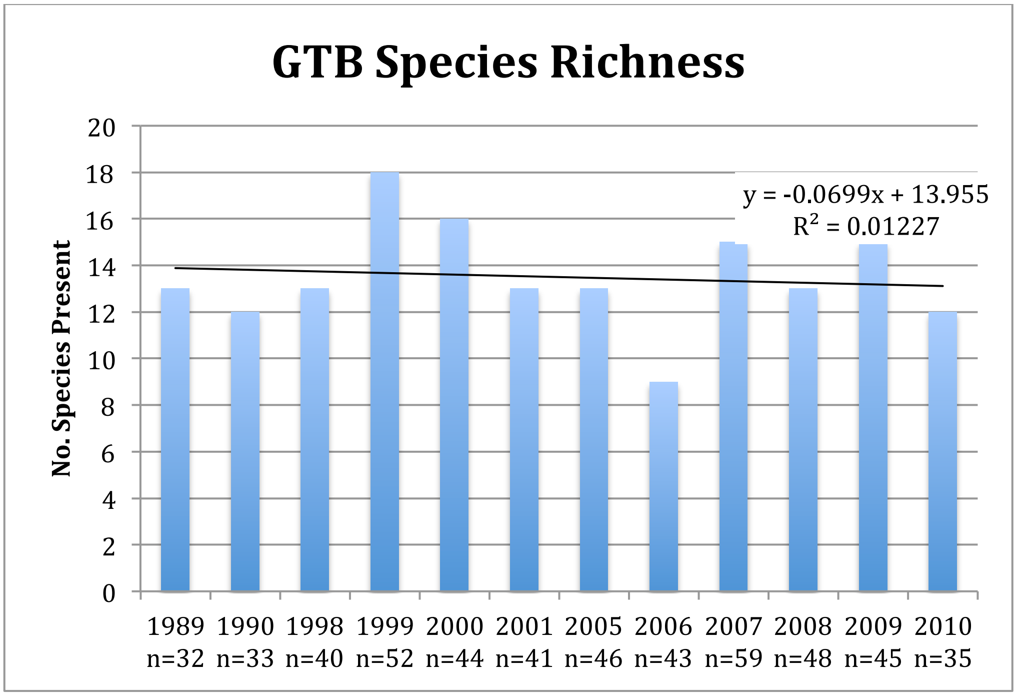

Figure 1: No. of species of fishes (species richness) found in trawl hauls conducted in the lower west arm of Grand Traverse Bay (GTB), MI from 1989 through 2010. Sample size varied from 32 trawls in 1989 to 59 trawls in 2007. Also shown is a trend line over these years.

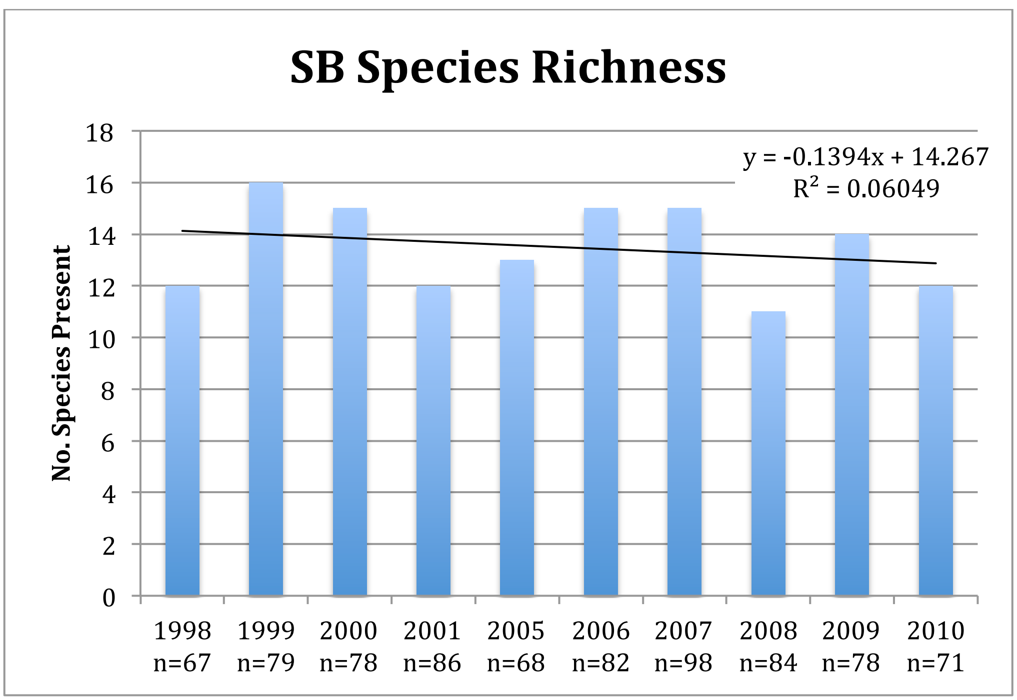

Figure 2: No. of species of fishes (species richness) found in trawl hauls conducted in Suttons Bay, MI from 1998 through 2010. Sample size varied from 67 in 1998 to 98 in 2007. Also shown is a trend line over these years.

However, data show a substantial increase in the number of *Neogobius melanostomus* (round gobies) captured compared with other species in both sampling areas after 2006. In Grand Traverse Bay, the average percentage of the fish caught that were round gobies skyrocketed from 0.06% in 2005 to 83% in 2010 (Fig. 3). Similarly, while an average of 0.27% of the fish caught per trawl in Suttons Bay were round gobies in 2005, round gobies over made up over 88% of the average 2010 catch per trawl (Fig. 4).

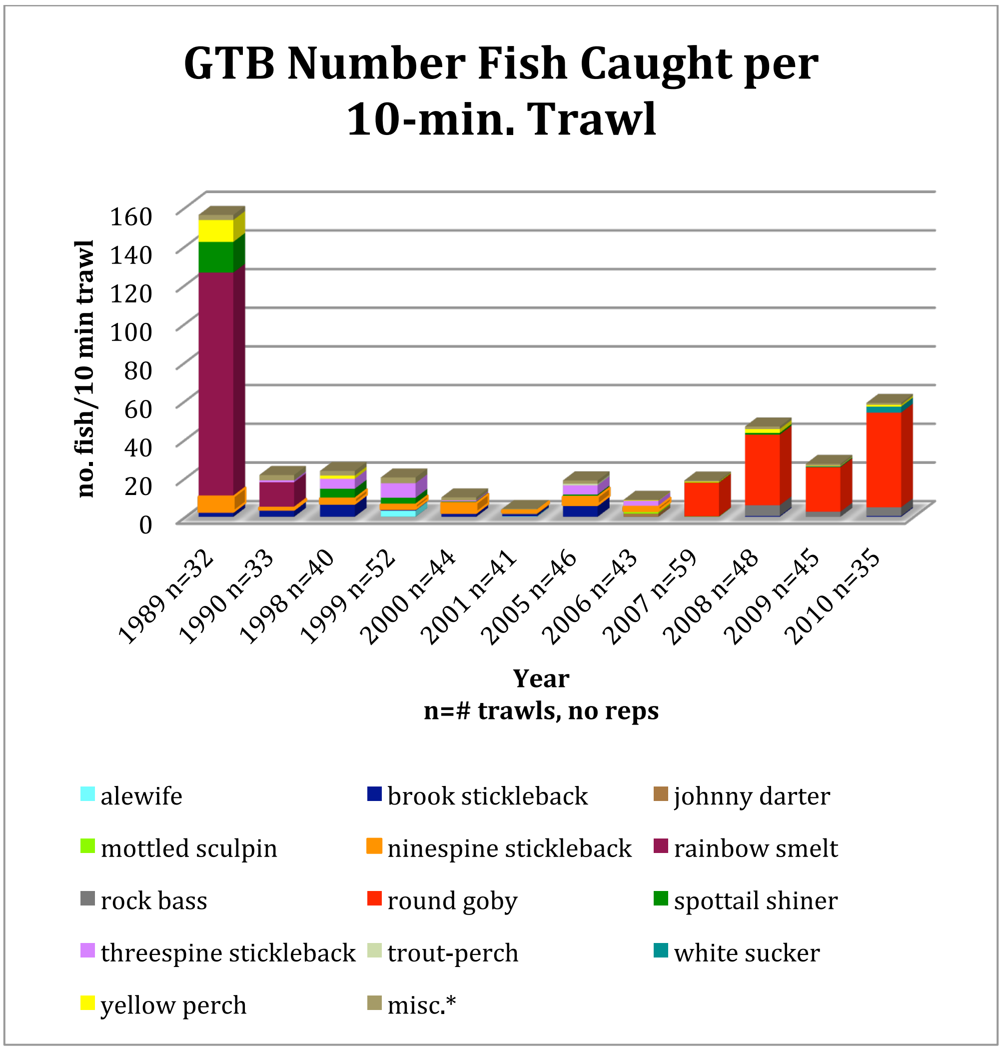

Figure 3: Average number of fishes caught per 10-minute trawl haul conducted in the lower west arm of Grand Traverse Bay (GTB), MI from 1989 through 2010. Sample size varied from 32 in 1989 to 59 in 2007.

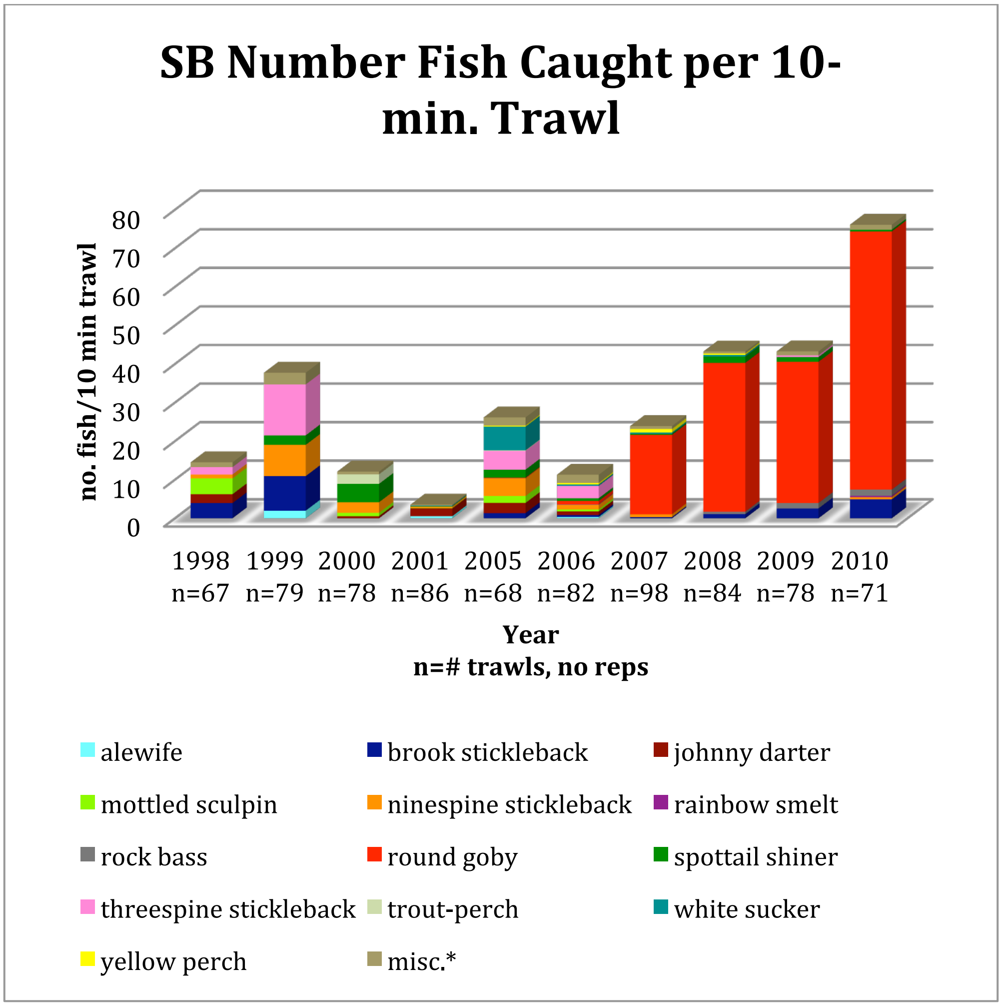

Figure 4: Average number of fishes caught per 10-minute trawl haul conducted in Suttons Bay (SB), MI from 1998 through 2010. Sample size varied from 67 in 1998 to 98 in 2007.

Native fish such as *Perca flavescens* (yellow perch), *Cottus bairdii* (mottled sculpin), and *Pungitius pungitius* (ninespine stickleback) were prevalent in ISEA's trawls prior to 2007 (Fig. 5). In later years, however, only a small portion of the average trawl was composed of these species. This decline appeared to have a strong correlation with the increase in round gobies in both the lower west arm and Suttons Bay after 2006 (Figs. 7-9).

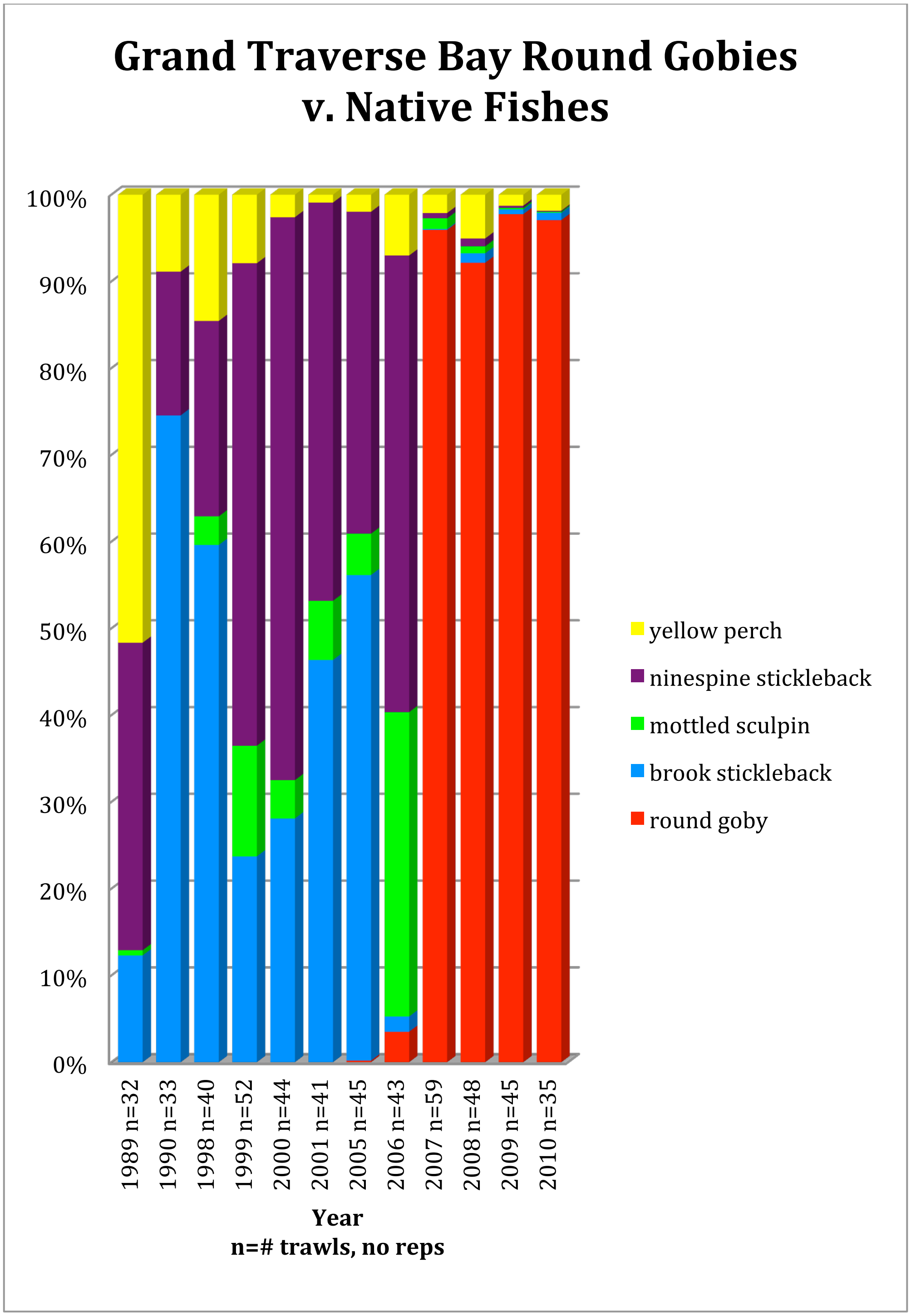

Figure 5: Average species percent composition for native and non-indigenous species found in trawls conducted in the lower west arm of Grand Traverse Bay (GTB), MI from 1989 through 2010. Sample size ranged from 32 in 1989 to 57 in 2007.

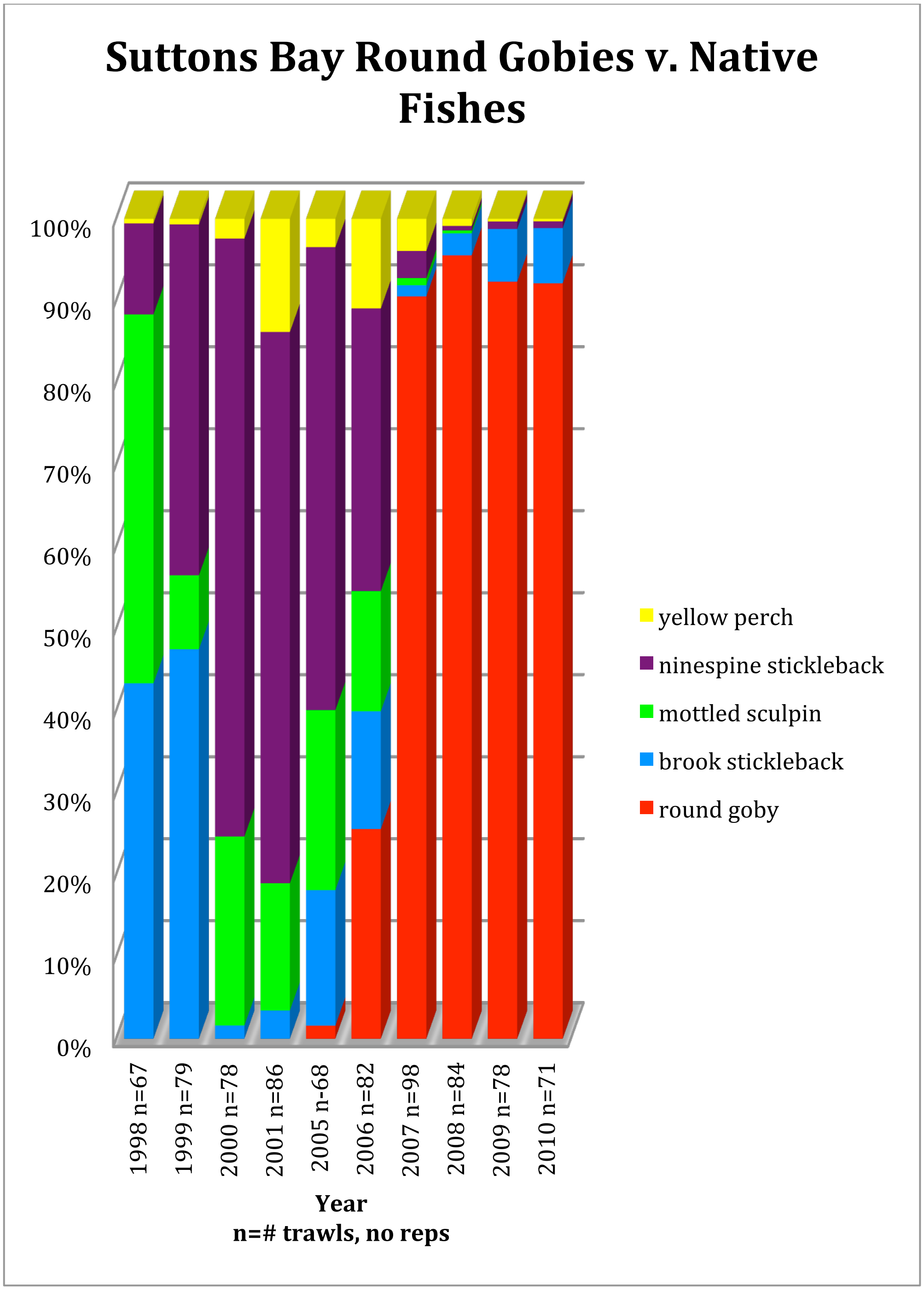

Figure 6: Average species percent composition for native and non-indigenous species found in trawls conducted in Suttons Bay (SB), MI from 1998 through 2010. Sample size ranged from 67 in 1998 to 98 in 2007.

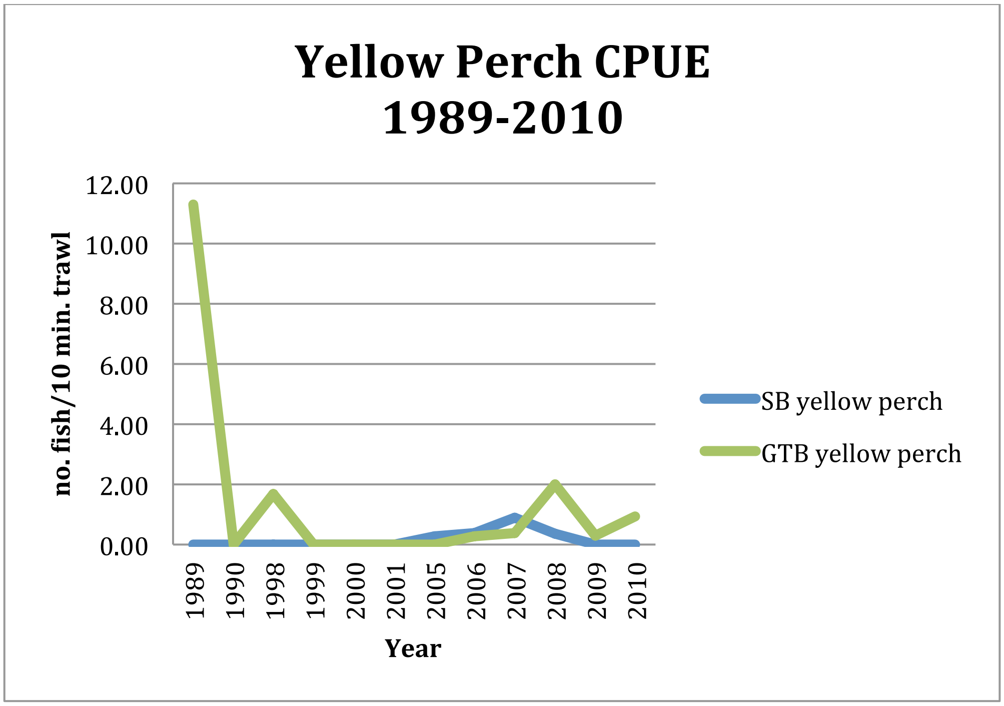

Figure 7: Average number of yellow perch caught per 10-minute trawl haul conducted in the lower west arm of Grand Traverse Bay (GTB), MI and Suttons Bay (SB), MI from 1989 through 2010. Sample size varied from 32 in 1989 to 57 in 2007 in GTB and from 67 in 1998 to 98 in 2007 in SB. No samples were taken in SB in 1989 and 1990.

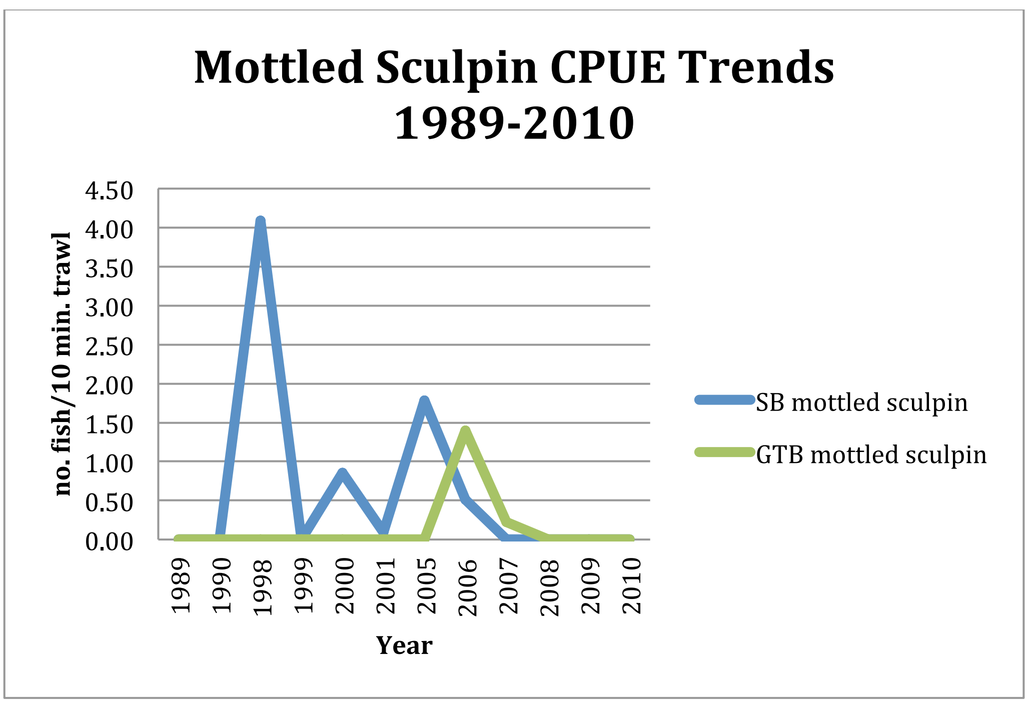

Figure 8: Average number of mottled sculpin caught per 10-minute trawl haul conducted in the lower west arm of Grand Traverse Bay (GTB), MI and Suttons Bay (SB), MI from 1989 through 2010. Sample size varied from 32 in 1989 to 57 in 2007 in GTB and from 67 in 1998 to 98 in 2007 in SB. No samples were taken in SB in 1989 and 1990.

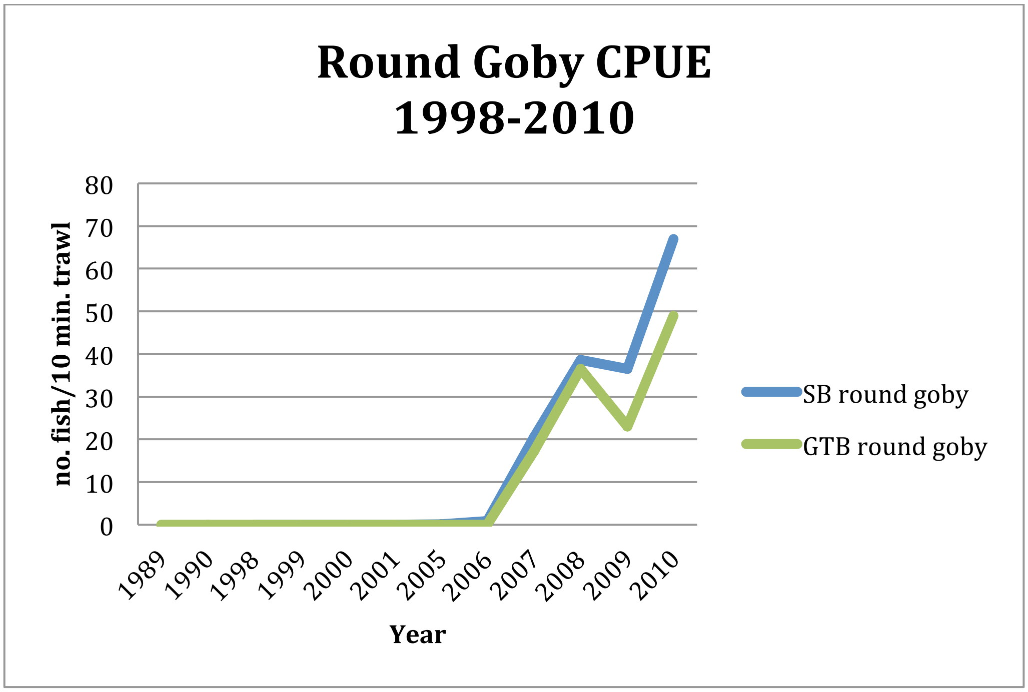

Figure 9: Average number of round goby caught per 10-minute trawl haul conducted in the lower west arm of Grand Traverse Bay (GTB), MI and Suttons Bay (SB), MI from 1989 through 2010. Sample size varied from 32 in 1989 to 57 in 2007 in GTB and from 67 in 1998 to 98 in 2007 in SB. No samples were taken in SB in 1989 and 1990.

Zooplankton

Spring:

Since 2001, species of calanoid and cyclopoid copepods along with copepod nauplii received the highest average ranks by ISEA volunteers in both Grand Traverse Bay (Fig. 10) and Suttons Bay (Fig. 11). In 1998 and 1999, however, *Bosmina* were given a much higher average rank (between 1 and 1.5 in Suttons bay and between 1.5 and 2 in the lower west arm). From 2008 to 2010, calanoid copepods in the lower west arm were given a higher average rank than in previous years. The same was not true of calanoid copepods in Suttons Bay. Although their average rank rose slightly from 2009 to 2010, this increase was not substantial when compared with previous years. At both sampling sites, copepod nauplii received increasingly high average ranks. This increase was most notable from 2009 to 2010 when the average ranks of copepod nauplii jumped by approximately 1.5 (the equivalent of a full step and a half) in the lower west arm and Suttons Bay, respectively.

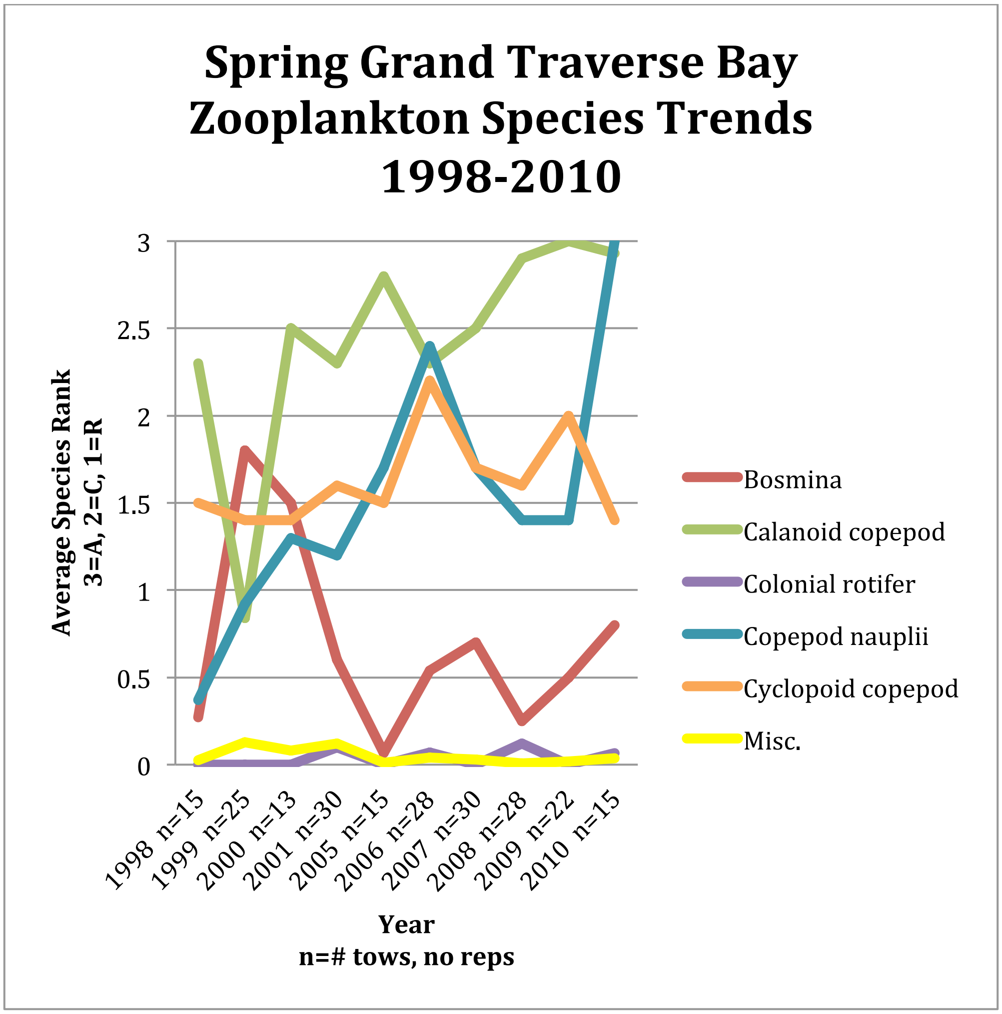

Figure 10: Spring (April-May) zooplankton species abundance. Zooplankton were collected in vertical tows from 1998 through 2010 in the lower west arm of Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Sample sizes ranged from 13 in 2000 to 30 in 2001 and 2007.

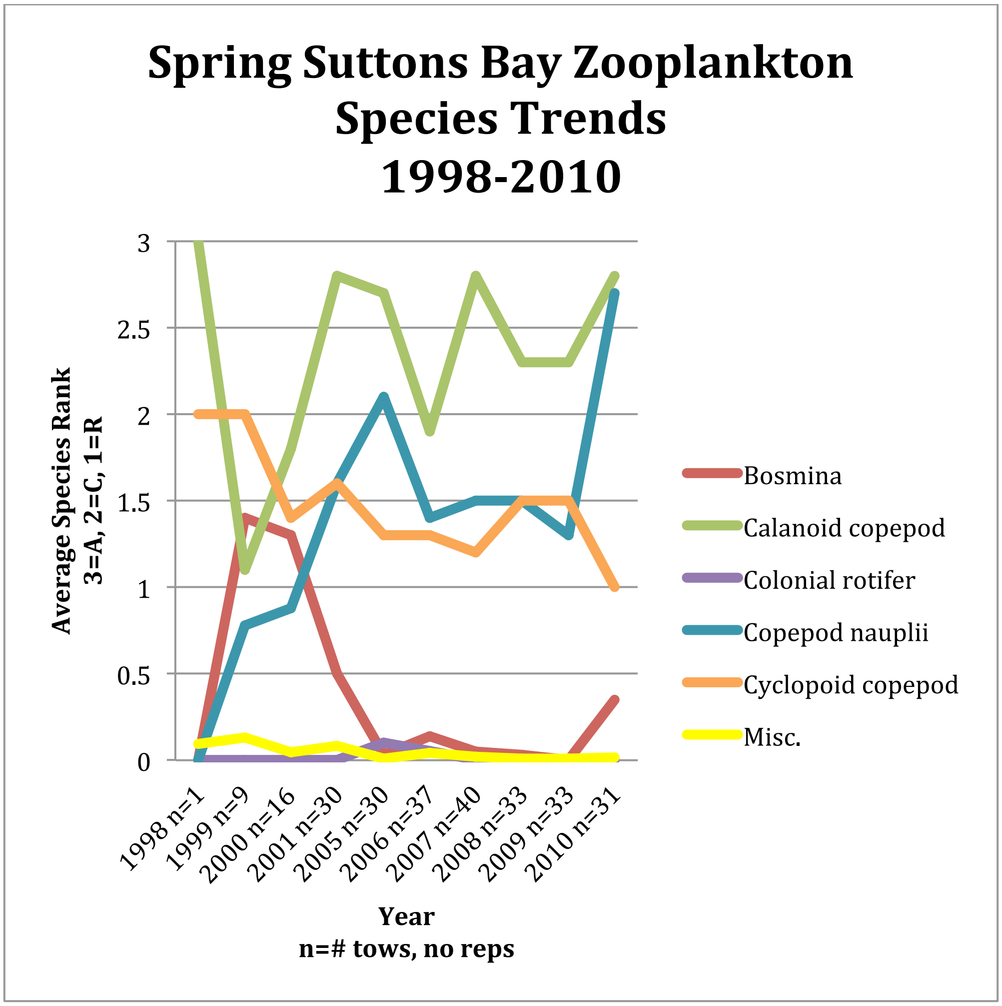

Figure 11: Spring (April-May) zooplankton species abundance. Zooplankton were collected collected in vertical tows from 1998 through 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Sample sizes ranged from 1 in 1998 to 40 in 2007.

<u>Summer:</u>

Calanoid copepods, cyclopoid copepods, and copepod nauplii received the highest average rankings by ISEA volunteers in the summer months (Fig. 12-13). As also noted in spring samples, *Bosmina* were ranked unusually high in 1998 and 1999, with abundance of *Bosmina* during 1999 being the peak. *Bosmina* and colonial rotifer species were more prevalent at both sampling sites during the summer months than during the spring. In the 2008 Suttons Bay sample (Fig. 13), there was an unusually high average rank of colonial rotifers. Although this ranking was lower in subsequent years, it remained higher than average in 2009 as well.

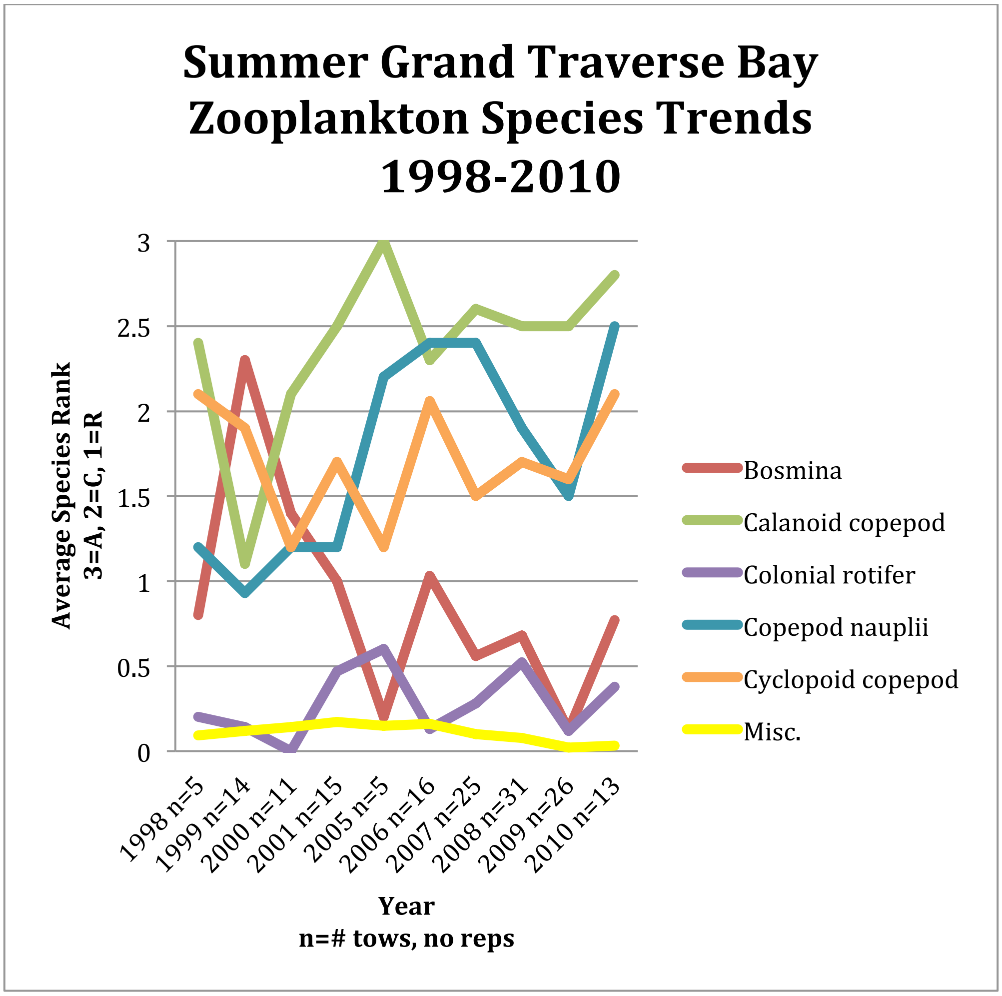

Figure 12: Summer (June-August) zooplankton species abundance. Zooplankton were collected in vertical tows from 1998 through 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Sample sizes ranged from 5 in 1998 and 2005 to 31 in 2008.

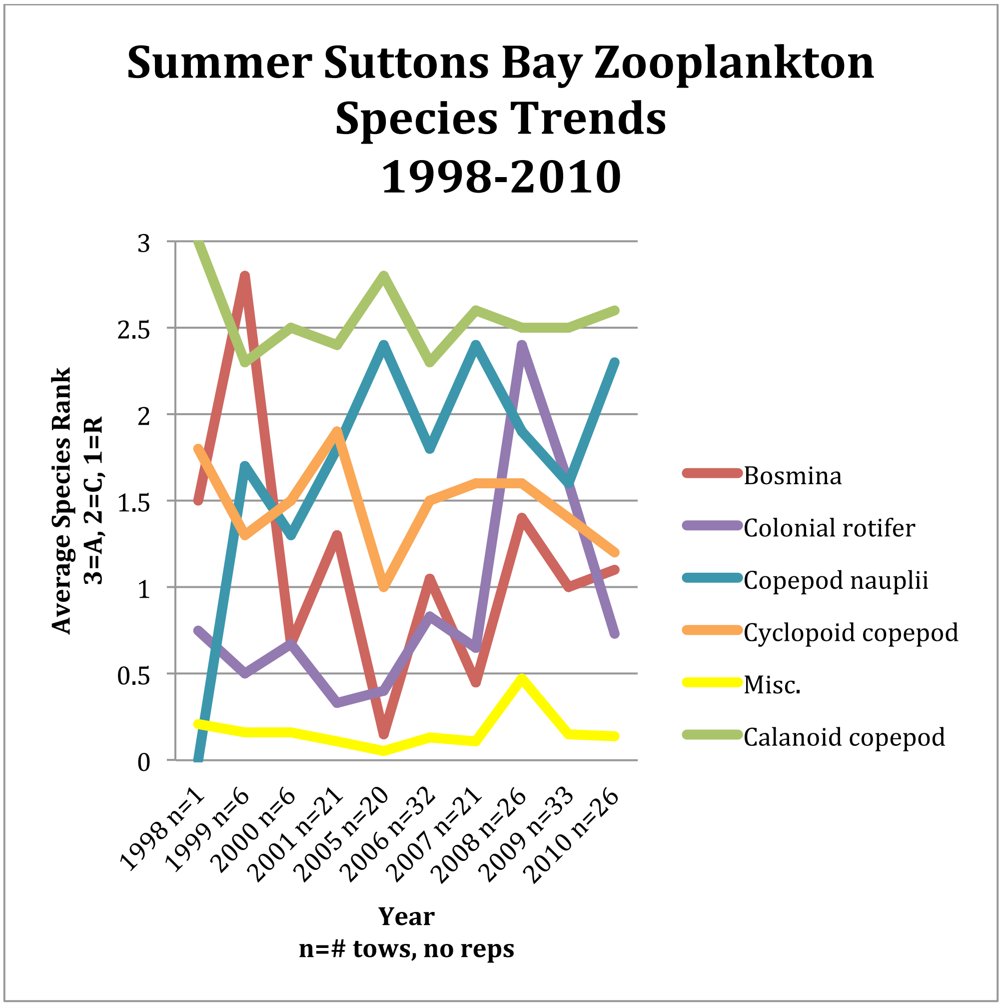

Figure 13: Summer (June-August) zooplankton species abundance. Zooplankton were collected in vertical tows from 1998 through 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Sample sizes ranged from 4 in 1998 to 33 in 2009.

<u>Fall:</u>

Due at least in part to the much smaller sample sizes in the fall months, it was more difficult to decipher clear trends in the average species ranks. In Grand Traverse Bay, calanoid copepods were prevalent in 2000, 2007, and 2009 (Fig. 14). *Bosmina* and colonial rotifers also received very high average ranks in 2000 and 2007, respectively. Copepod nauplii were generally ranked very low in average abundance in 1999 and 2000, but were in the range of "common" from 2007 to 2010. An interesting observation in the fall

Grand Traverse Bay data was that average abundance of the most common species (*Bosmina*, calanoid copepod, colonial rotifer, copepod nauplii, and cyclopoid copepod) appeared to become more similar to one another in 2010.

There was a high degree of variability in the average ranks for zooplankton species in the fall Suttons Bay data (Fig. 15). ISEA volunteers generally ranked calanoid copepod species among the highest in abundance. Trends in copepod nauplii abundance mirrored calanoid copepod abundance trends. The exception to this was in 2000, when nauplii were given extremely low average ranks and calanoid copepods were given the highest possible average rank (3). Cyclopoid copepods reached an average rank of 3 in 1999 then varied substantially from year to year thereafter. *Bosmina* also had a high degree of variability in average rank, but showed a general decline from 1999 to 2010. Rotifers, however, generally increased in average rank from 1998 to 2009, but then declined in abundance in 2010. As was noted in the lower west arm data, average species abundance of species became more similar to one another in 2010.

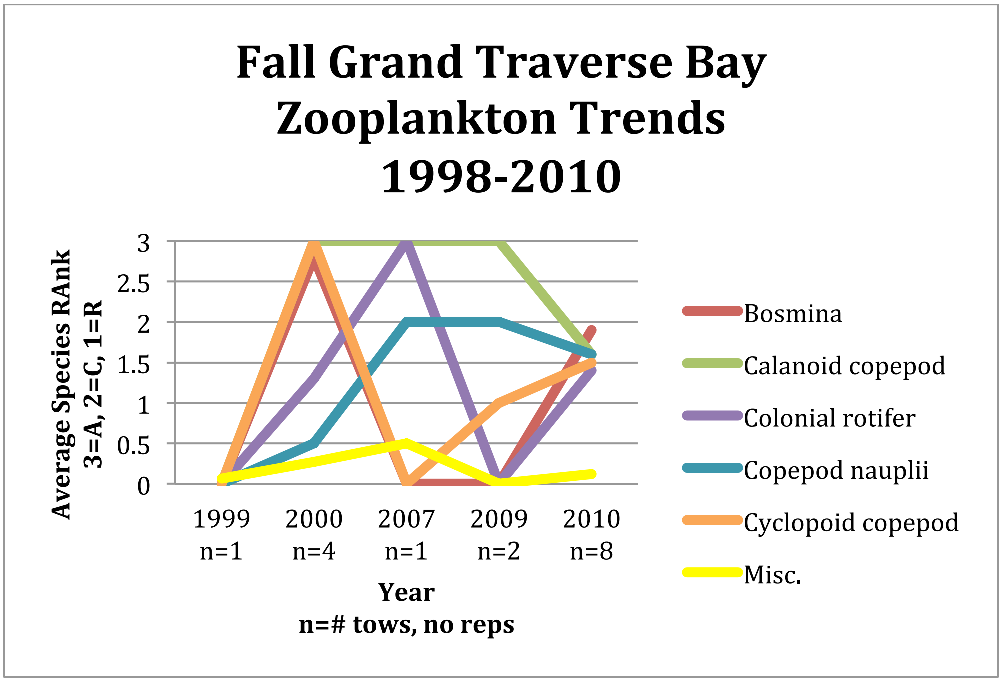

Figure 14: Fall (September-October) zooplankton species abundance. Zooplankton were collected in vertical tows from 1999 through 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Sample sizes ranged from 1 in 1999 and 2007 to 8 in 2010.

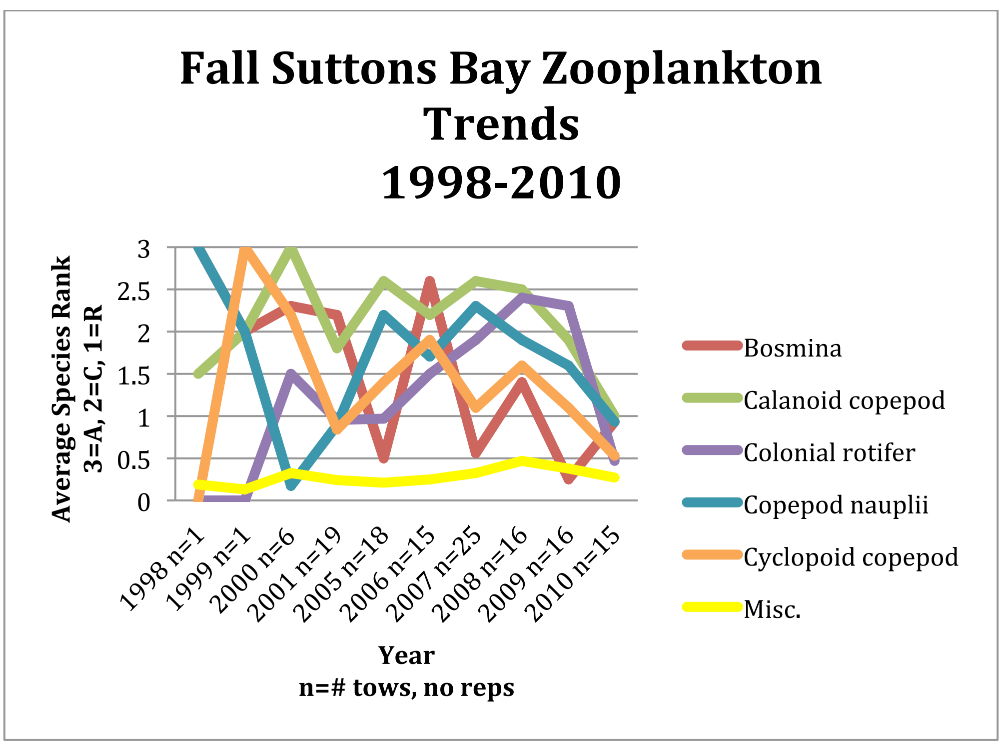

Figure 15: Fall (September-October) zooplankton species abundance. Zooplankton were collected in vertical tows from 1998 through 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Sample sizes ranged from 1 in 1998 and 1999 to 25 in 2007.

<u>Non-native Zooplankton Species:</u>

Although not included in the most abundant species, the non-indigenous *Bythotrephes longimanus* and *Cercopagis pengoi* were present more frequently and received higher average rankings in the fall, than in the spring and summer. In the single fall sample collected in the lower west arm in 2007, *Bythotrephes* was given a rank of “abundant”. In 2005 and 2007 (Fig. 16) in Suttons Bay, *Bythotrephes* had an average rank of 1.5 and 1.4 (between rare and common), respectively (Fig. 17). *Cercopagis* received a rank of 1 (rare) in the only 1999 fall sample in Grand Traverse Bay, and had a peak ranking of 0.3 in the fall 2006 Suttons Bay samples.

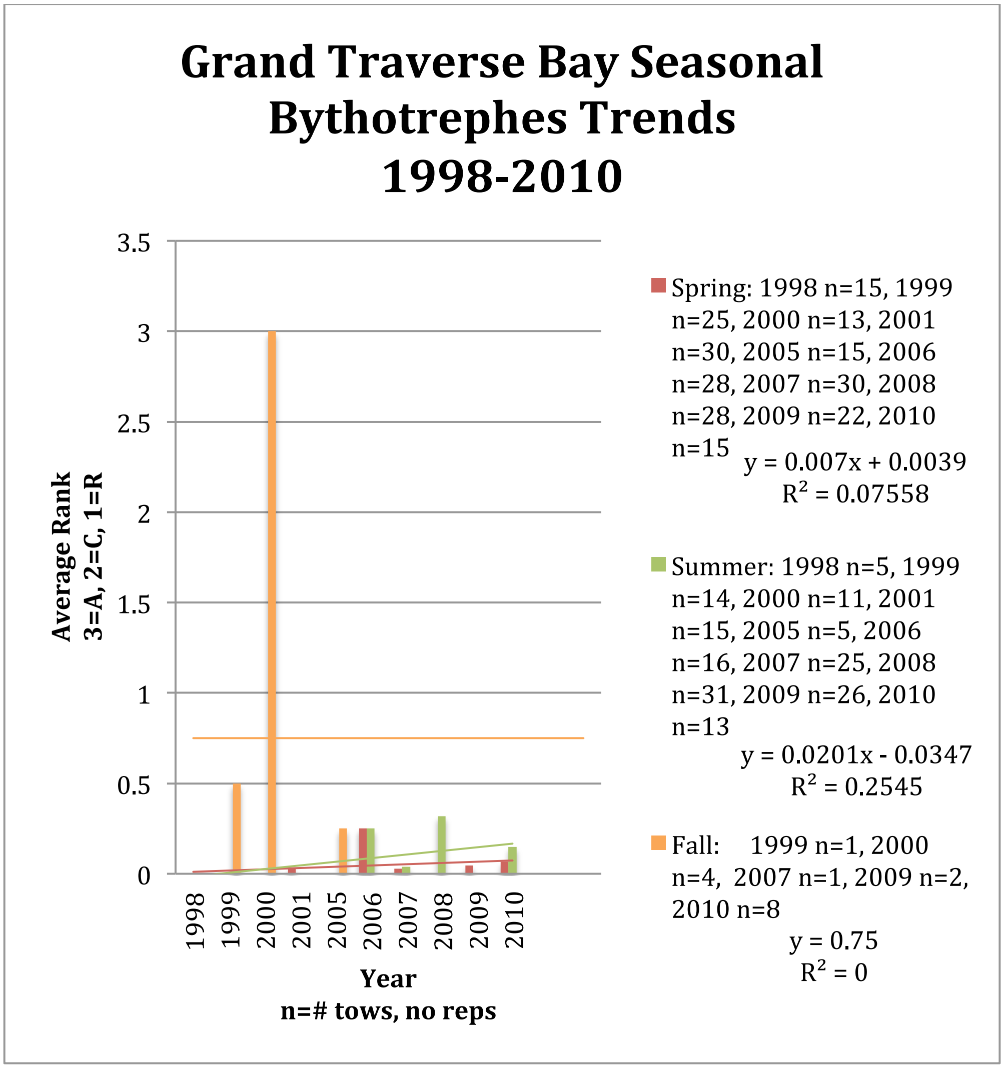

Figure 16: Seasonal *Bythotrephes longimanus* abundance. *Bythotrephes* were collected in vertical tows from 1998 through 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

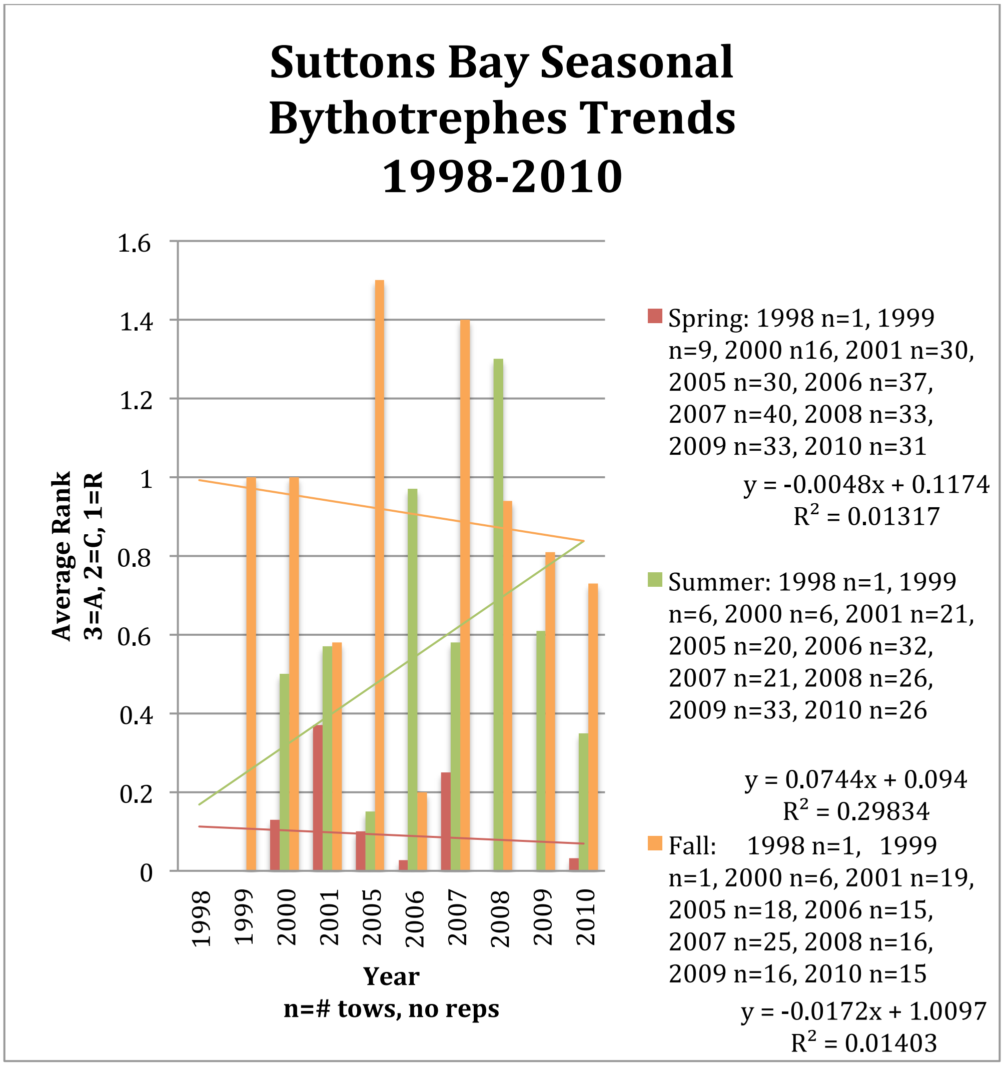

Figure 17: Seasonal *Bythotrephes longimanus* abundance. *Bythotrephes* were collected in vertical tows from 1998 through 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

<u>Cladocera:</u>

The average ranks of *Bosmina* and *Daphnia* in both Suttons Bay and the lower west arm have declined in the years since ISEA began sampling. In the lower west arm, the average ranks of *Bosmina* in spring and summer increased from 1998 to 1999, then showed a general decline until 2009 (Fig. 18). In Suttons Bay, the average ranks of *Bosmina* in spring tows declined until 2009, then increased again in 2010 (Fig. 19). Summer average *Bosmina* ranks spiked to 2.8 in 1999 and were unusually low in 2005 and 2007. Otherwise, ranks were fairly stable between 1 and 1.5. The average ranks of *Bosmina* were highest in the fall, but were lower than average in 2005 and 2007 through 2010.

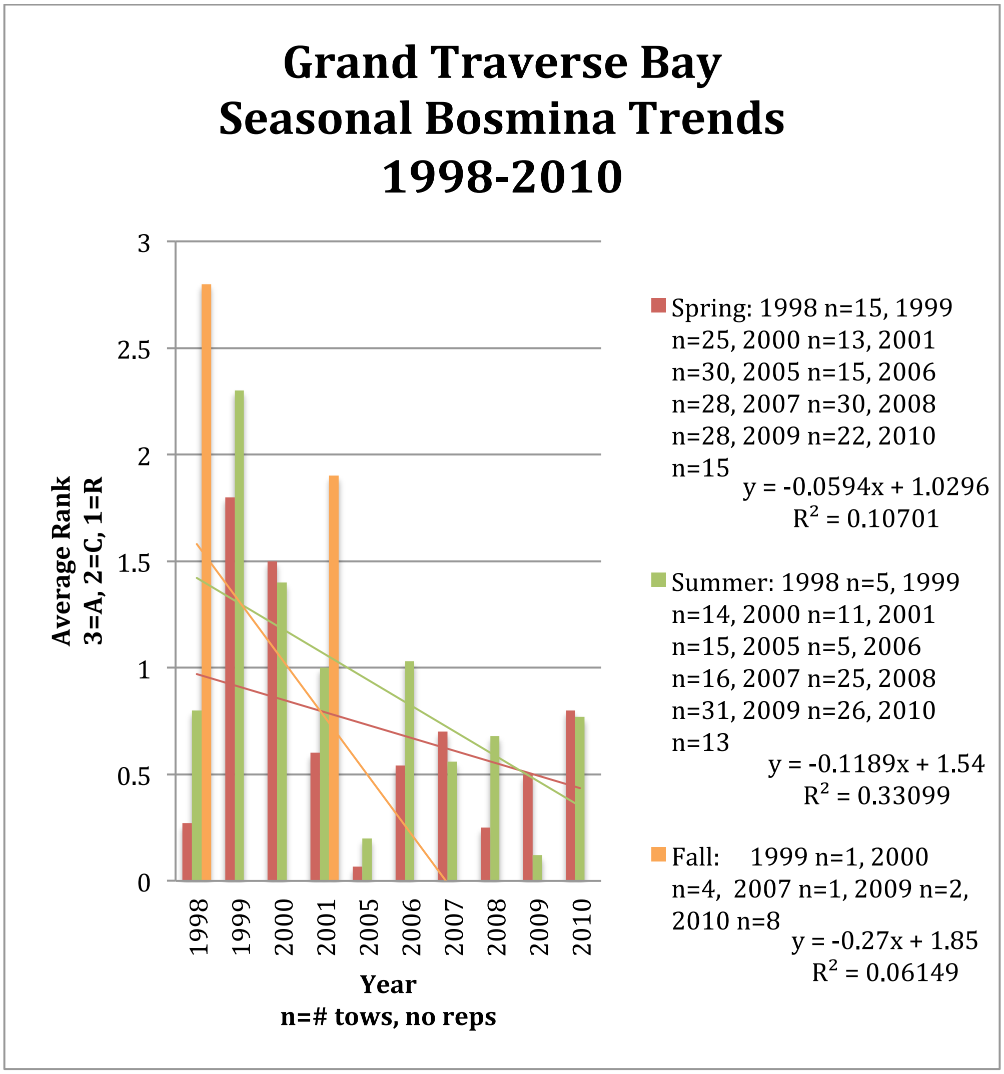

Figure 18: Seasonal *Bosmina* abundance. *Bosmina* were collected in vertical tows from 1998 through 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

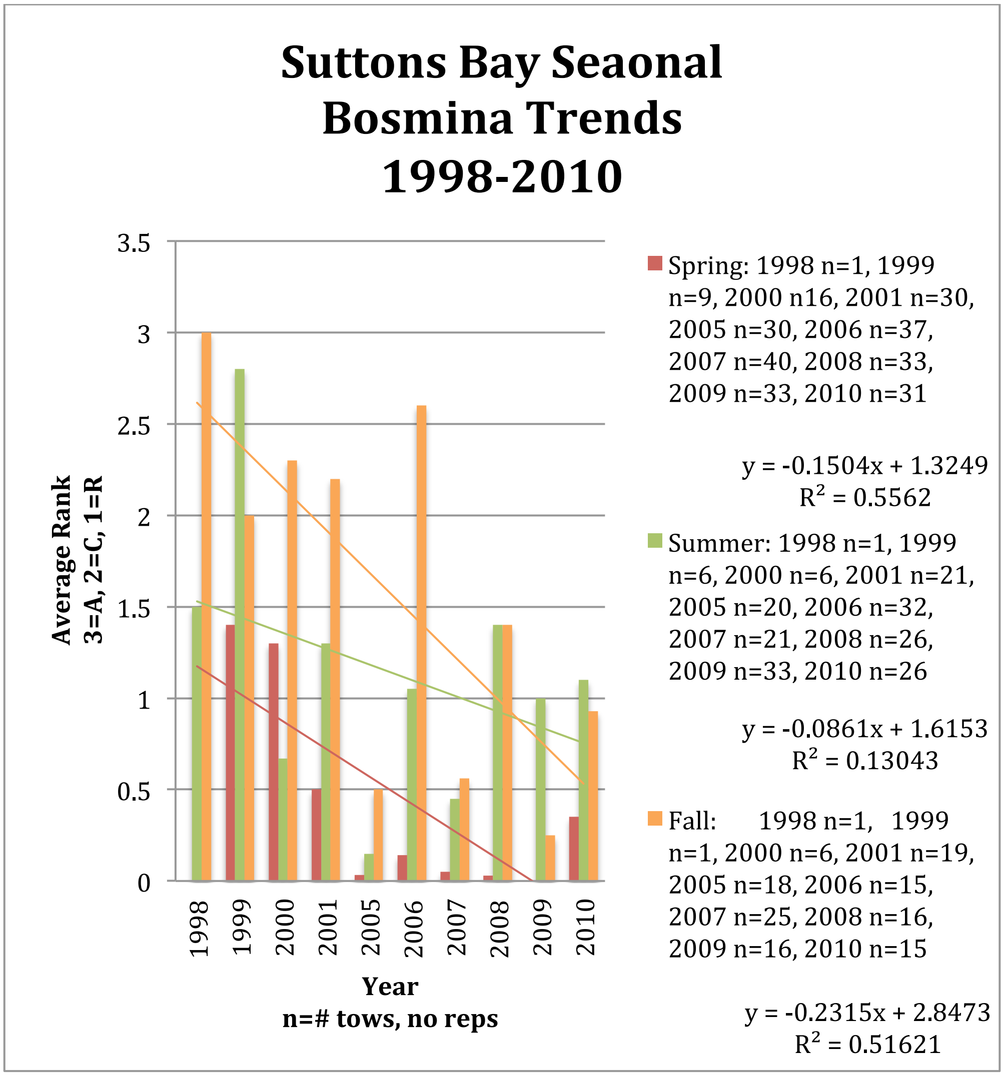

Figure 19: Seasonal *Bosmina* abundance. *Bosmina* were collected in vertical tows from 1998 through 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

Aside from summer of 1998, average *Daphnia* ranks remained low and consistently under 0.5 in the spring and summer tows in the lower west arm (Fig. 20). In fall 2000, the average *Daphnia* rank hit 2.5. *Daphnia* were otherwise absent in the fall samples until 2010, when they received an average rank of 0.5. In Suttons Bay, average spring and summer *Daphnia* ranks were highest in 1998, with average ranks of 1.5 (Fig. 21). Otherwise, average spring daphnia ranks remained below 0.4 and summer ranks were under 1. In the fall Suttons Bay samples, average *Daphnia* ranks hovered around 1 from 1998 to 2000 then bounced between 0.2 and 1 from 2001 to 2010. *Daphnia* were absent in 2008 and 2009.

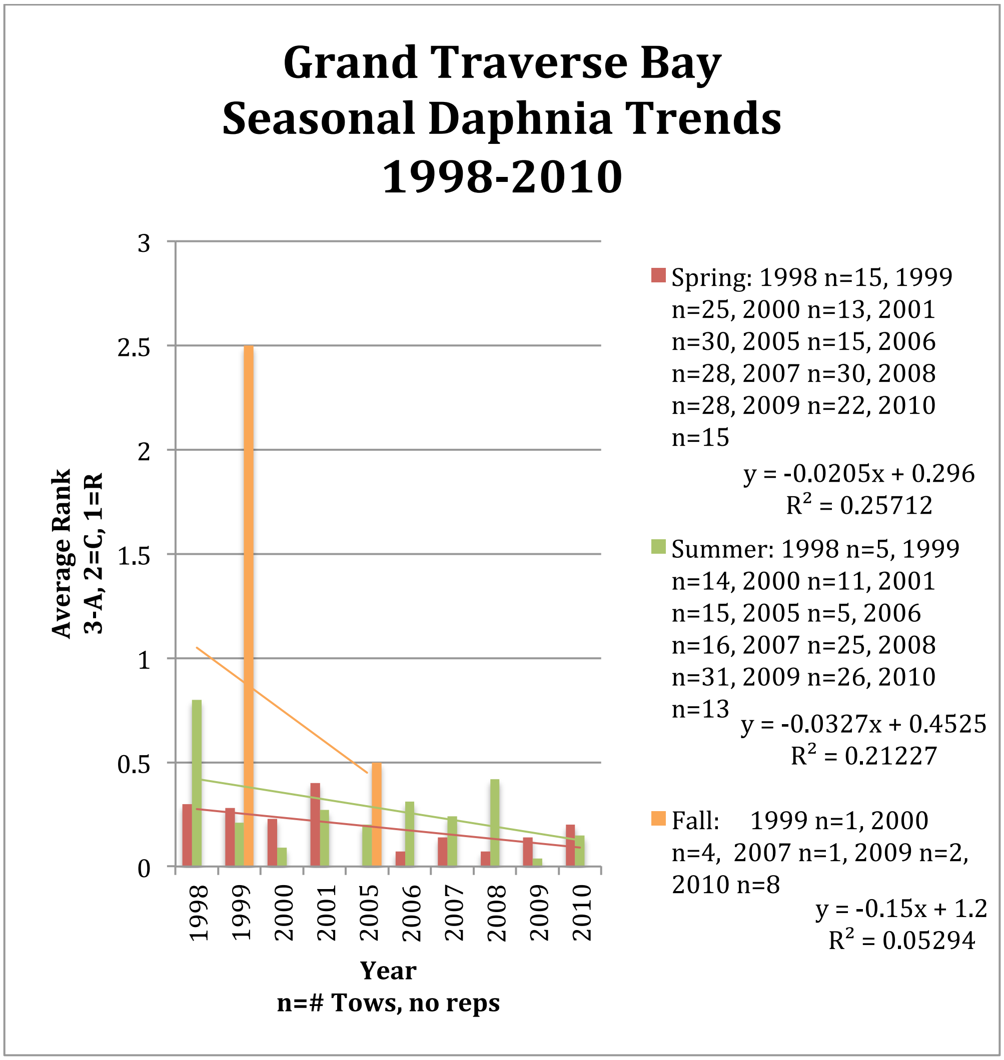

Figure 20: Seasonal *Daphnia* abundance. *Daphnia* were collected in vertical tows from 1998 through 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

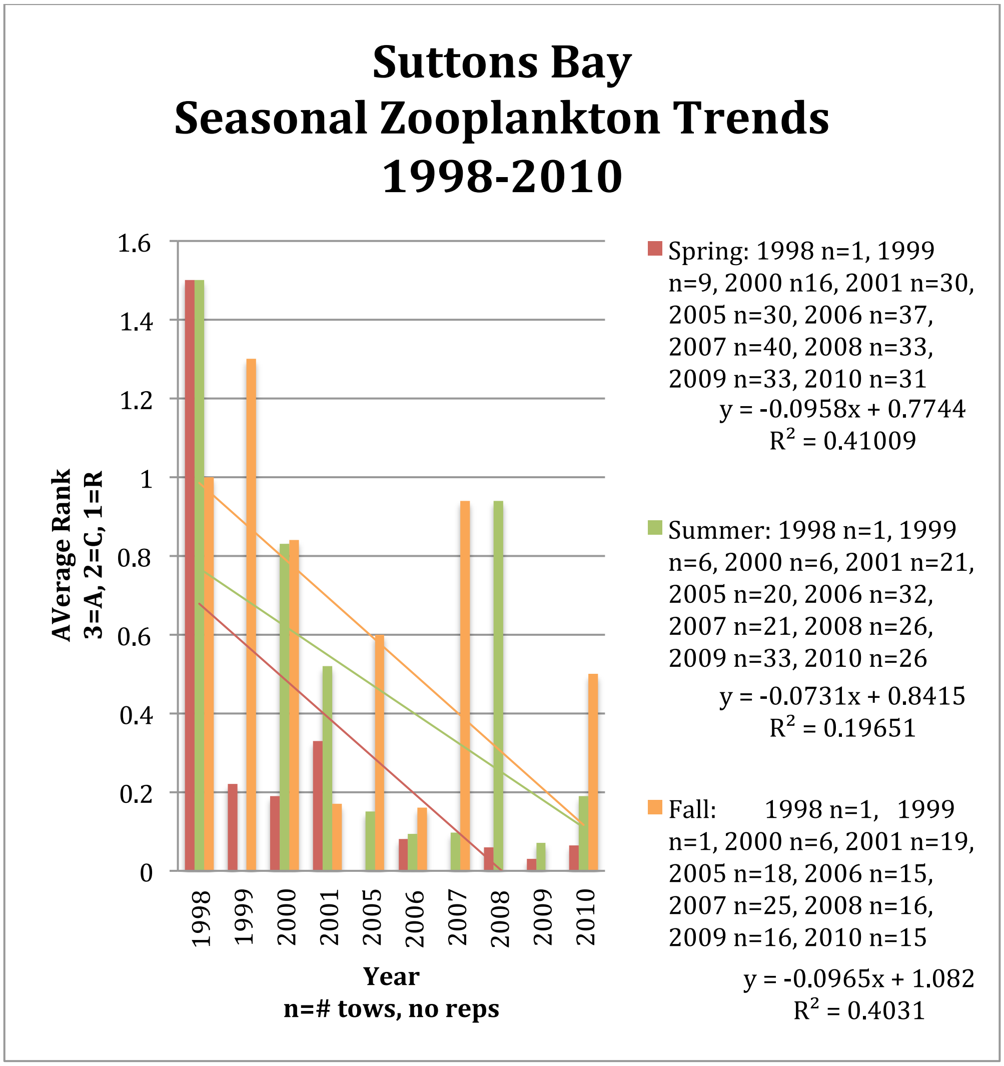

Figure 21: Seasonal *Daphnia* abundance. *Daphnia* were collected in vertical tows from 1998 through 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

<u>*Asplanchna*:</u>

Asplancha were generally relatively rare in ISEA's zooplankton samples, remaining below an average rank of 2. In the lower west arm, *Asplancha* received low average ranks in the spring, remaining at or under 0.3 (Fig. 22). In summer, they received the highest ranks in 2000, 2001, and 2007 with ranks of 0.6, 0.9, and 0.6 respectively. *Aplanchna* was not present in summer tows during 1998, 1999, 2008, and 2010. *Asplanchna* were only seen in fall samples in 2000 and 2010, where they were given ranks of 0.5 and 0.3. In Suttons Bay, *Asplanchna* were first recorded by ISEA in 2000 (Fig. 23). They were very rarely seen in spring tows, and remained under a rank of 1 in summer tows, where they were only recorded from 2001 to 2009. *Asplancha* were most prevalent in Suttons Bay in the fall, where they received ranks of 0.4 to 1.9. Highest average fall ranks were recorded in 2006 and from 2008 through 2010.

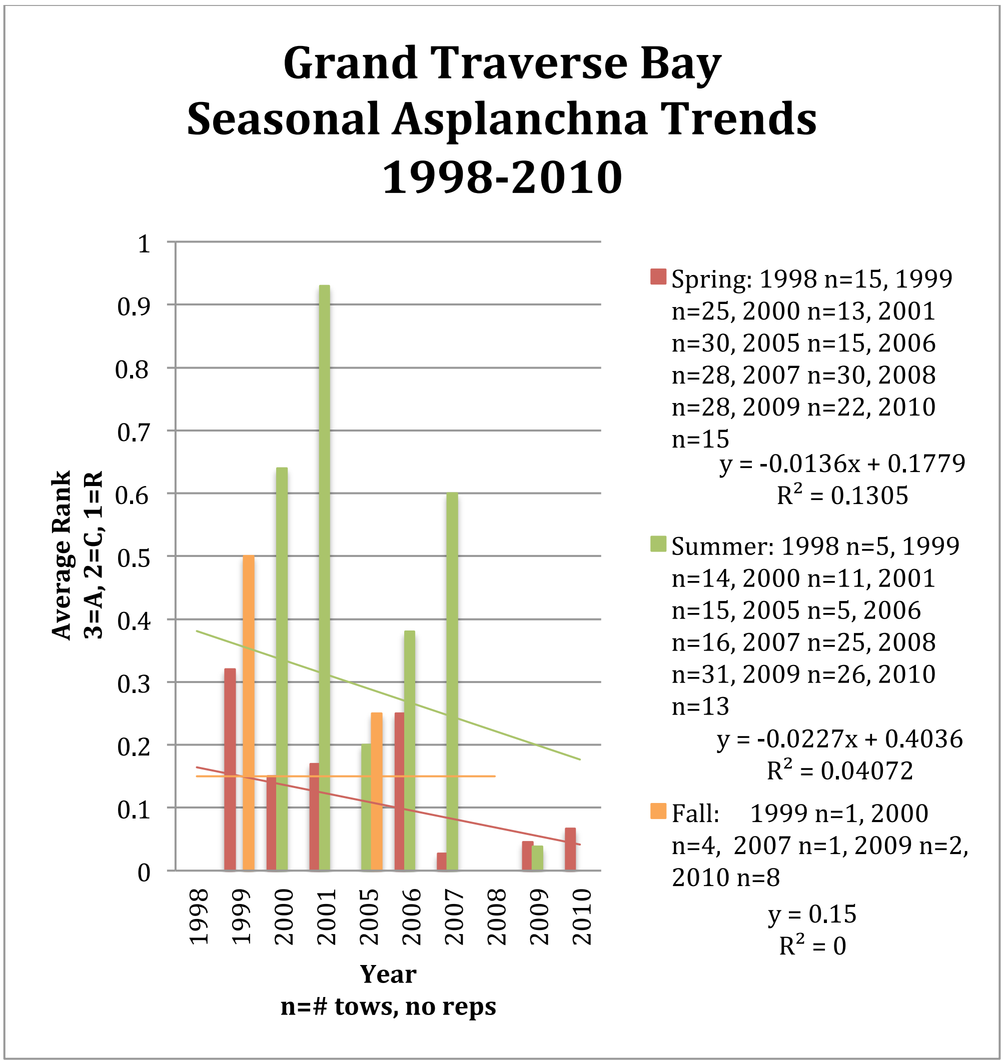

Figure 22: Seasonal *Asplanchna* abundance. *Asplanchna* were collected in vertical tows from 1998 through 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

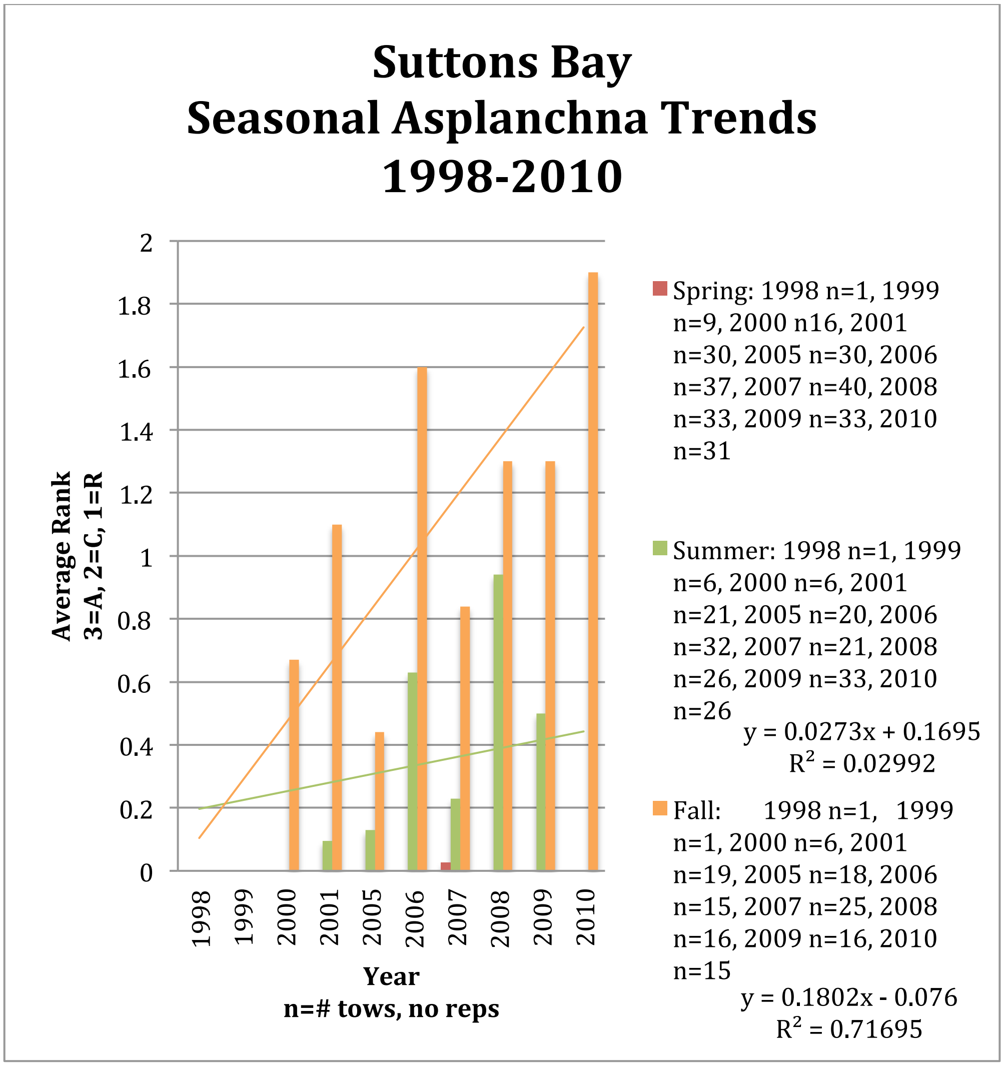

Figure 23: Seasonal *Asplanchna* abundance. *Asplanchna* were collected in vertical tows from 1998 through 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. Also shown are seasonal trend lines over these years.

Benthos

As previously stated, I only plotted species richness for benthos due to the highly inconsistent nature of data collection. In both the lower west arm (Fig. 24) and Suttons Bay (Fig. 25), there was no change in the number of species found per year. In the lower west arm, highest numbers of species per year were found from 1998 to 2007, with a decrease in 2005. In Suttons Bay, highest numbers of species per year were found from 2000 to 2007, with a decrease in 2005.

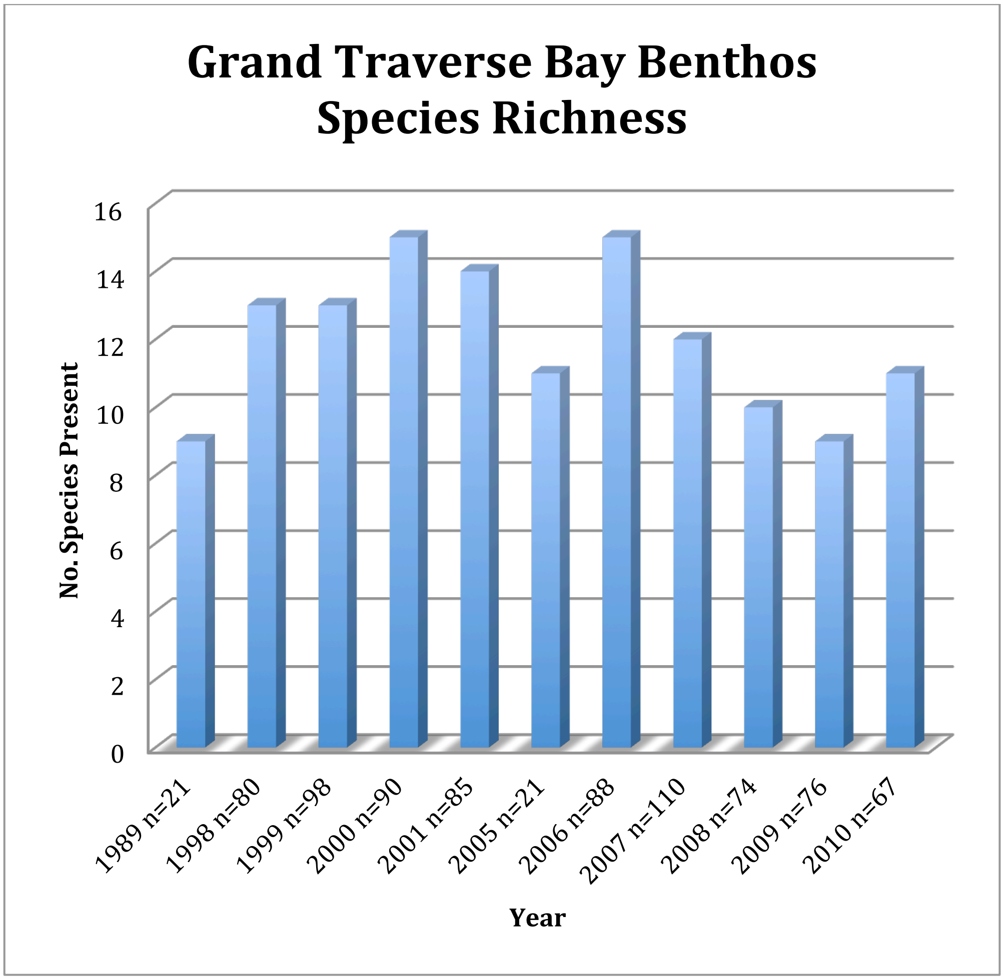

Figure 24: No. of species of benthic invertebrates (species richness) found in petite PONAR grabs collected in the lower west arm of Grand Traverse Bay (GTB), MI from 1989 through 2010. Sample size varied from 21 grabs in 2005 to 98 grabs in 1998.

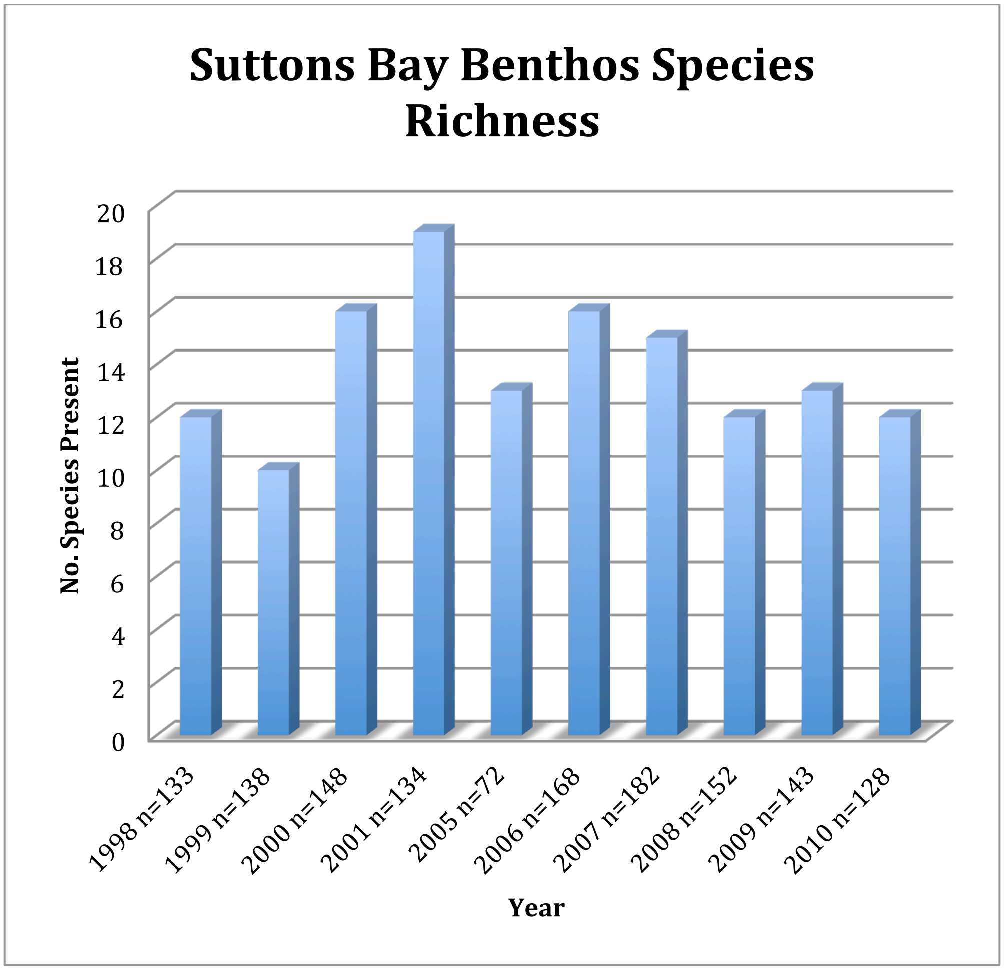

Figure 25: No. of species of benthic invertebrates (species richness) found in petite PONAR grabs collected in Suttons Bay (SB), MI from 1989 through 2010. Sample size varied from 72 grabs in 2005 to 168 grabs in 2006.

Although I only plotted species richness, there were some general trends that were observed in the data. Some types of organisms, including amphipods, isopods, and chironomids ("midge larvae") were present more frequently than others. Another notable trend was the introduction of zebra mussels, of which ISEA began to keep record in 1989. Zebra mussels became increasingly abundant in ISEAs samples until quagga mussels began to appear in the data in 2005. In 2005, zebra and quagga mussel densities were recorded as being similar. After 2005, however, quagga mussels became increasingly abundant as zebra mussels composed a decreasing proportion of the organisms found in the samples.

Discussion

Fish

Proliferation of the round goby had a marked impact on the Grand Traverse Bay ecosystem. As evident in the ISEA data as well as data from the rest of the Great Lakes, round gobies negatively impacted a number of native fish species (Crossman et. al. 1992). This impact is likely due to a combination of factors, including the round goby's voracious appetite, which includes the eggs and fry of native species such as darters, lake trout, and sculpins (Marsden and Jude 1995) and the fact that they feed upon the same organisms as many native fish species, leading to shortages in food resources for those species (French and Jude 2001). There has been a notable decline in mottled sculpin since the introduction of the round goby to the bay, which is most likely the result of competition for spawning sites as well as food (Janssen and Jude 2001).

The substantial jump in the number of round gobies recorded by ISEA from 2006 to 2007 is curious. It would make sense that better volunteer training could account for this difference if more round gobies were identified in 2007, rather than being incorrectly recorded as mottled sculpin. However, the number of mottled sculpin recorded by ISEA in 2006 would not provide full explanation for the large difference. The unusually low average 2001 CPUE in both sites is also unexpected and without explanation.

Zooplankton

From year to year, the most common types of zooplankton detected by ISEA remained constant and consisted of *Bosmina*, colonial rotifers, copepod nauplii, cyclopoid copepods, and calanoid copepods. ISEA does not classify zooplankton by species, or even by genus in most cases. As the primary objective of the program is education, it is more important for students to see and understand basic differences in body types and learn about basic ecosystem functions that zooplankton serve within the bay than to be able to detect subtle differences between individual species. In addition, most identification was done using a microscope attached to a cathode ray tube (CRT) television monitor so multiple students could see what was in the sample. This low resolution would also make seeing fine details difficult.

The increasing number of calanoid copepods and nauplii in the spring and summer months relative to other species could be indicative of unfavorable water conditions, as copepods are a highly tolerant sub class. Further, depending on species, *Bosmina*, calanoid copepods, *Daphnia*, and *Asplancha* may all be indicators of oligotrophic conditions, which may have fluctuated with zebra and quagga mussel populations (Gannon and Stemberger 1978).

Invasive species of zooplankton such as *Bythotrephes longimanus* and *Cercopagis pengoi* have had impacts on the zooplankton community structure and are capable of impacting fish community structure. *Cercopagis* utilizes other zooplankton as a food source, and therefore depletes native zooplankton and acts as a competitor to planktivorous fish such as *Alosa pseudoharengus* (alewife) and *Osmerus mordax* (rainbow smelt) (Bushnoe et. al. 2003). *Bythotrephes* poses a similar threat, consuming smaller species of zooplankton and serving as a direct competitor with larval planktivorous fishes (Berg and Garton 1988, Evans 1988, Vanderploeg et al. 1993).

Benthos

Fluctuations in species diversity for benthos in the ISEA samples were likely due to factors such as the number of PONAR grabs collected during sampling events for any given year. Generally speaking, years with fewer samples had fewer different species present. It is also difficult to draw conclusions about ISEA's benthos data since there was so much variability in the volunteers who recorded the data, students sorting through the sediment, quantity of sediment that was sorted, and sorting methods utilized by each student. Species diversity alone did not show a marked trend that would be indicative of phenomena aside from sampling variability.

Perhaps the most infamous Great Lakes invader is *Dreissena polymorpha*: the zebra mussel. While zebra mussels have been present in ISEA's samples since the program began in 1989, *Dreissena rostriformis bugensis* (the quagga mussel) was not recorded until 2005. Since the distinction between these two species is so subtle, it is very likely that quagga mussels were present and began to outcompete zebra mussels before ISEA detected this transition. Both species, however, led to substantial negative impacts on the Grand Traverse Bay ecosystem.

One of the most visible impacts these invasive bivalves have on the ecosystem is their extreme efficiency in filtering phytoplankton and other suspended materials from water. Since increased water clarity allows more sunlight to penetrate deeper into the water, this leads to increased abundance of macrophytes such as *Cladophora* (Skubinna et. al. 1995). Another potential issue associated with increasing abundance of bivalves such as zebra and quagga mussels is biomagnification of polychlorinated biphenyls (PCBs) through their uptake from filtering algae and detritus from the water column. These toxic substances can then travel through various trophic levels (Snyder et. al. 1997), and may eventually go so far as to impact waterfowl populations that eat dreissenids. Zebra and quagga mussels also affect fish and zooplankton through competition, as they are more efficient at consuming phytoplankton and microzooplankton than many zooplanktivorous fish and larger zooplankton species. Native clams are also negatively impacted through impaired valve operation, shell deformity, siphon obstruction, competition, impaired movement, and metabolic waste deposition, which occurs when dreissenids attach to their shells (Benson and Raikow 2011).

Conclusions

Although ISEA's data are the product of a large degree of variability and change both from year to year and sample to sample, an examination of long-term trends revealed some important insights about the Grand Traverse Bay ecosystem and ISEA's programs. Since ISEA is the only program that is consistently collecting and recording data for physical and biological conditions in the bay, its programs serve an important function in monitoring changes in the ecology of the region. This is one reason why it is essential that ISEA's programs be designed to be as scientifically accurate and efficient as possible.

COMPARISON OF 2010 ISEA SAMPLING DATA AND 2010 QUALITY ASSURANCE SAMPLING DATA

Introduction

In order to gain a better understanding of the degree of accuracy for ISEA's data, some degree of quality assurance (QA) was required. By analyzing data quality, I could then provide some recommendations on potential limitations and caveats surrounding the data to those who may want to utilize the information. The ideal situation for testing the quality of the data would have been to utilize another long-term biological dataset of the Grand Traverse Bay area that was sampled in a similar location and using similar methods. However, as ISEA's is the only long-term dataset for the region, it was necessary to devise another method for comparison. Therefore, in summer of 2010 I traveled to Grand Traverse Bay to sample water quality, fish, zooplankton, and benthos populations using scientifically accepted practices. To ensure that the QA data were comparable to those of ISEA, I followed ISEA's spatial, temporal, and procedural practices whenever possible.

The overarching question behind this part of my research was whether or not ISEA's sampling methods and data recording were thorough enough to derive information about basic population dynamics such as species introductions, losses, and relative abundance. Depending on the thoroughness and reliability of ISEA's data, it may or may not be feasible or scientifically advisable to do any substantial quantitative analysis with their data. Therefore, the hope was that by applying more rigor to ISEA's sampling and recording practices and then compressing the resulting data down to a comparable level, I could determine whether or not my conclusions were the same or similar to ISEA's.

Methods

ISEA Sampling Methods

Over its 20-year history, ISEA has used similar sampling methods for collecting biological data. Fish are collected using an otter trawl towed at 100-150 feet behind the vessel at 2-3 mph (1.7 to 2.6 knots). Trawl time was 10 minutes, but sometimes it varied due to events in the educational program. Typically, the start and end depths of the trawls were included. With help from volunteer instructors, students then identified fish using an illustrated dichotomous key (Appendix 4).

Zooplankton were sampled using a 0.5-m (20-inch) diameter, 153-µm mesh plankton net and raising it in vertical tow. While depth of the tow was usually recorded, revolutions of a flowmeter were not. Depending on age group, the volunteer instructor may place drops from the sample beneath a microscope hooked up to a television monitor for the students to view, or let them handle the samples themselves. The volunteer instructor then worked with students to identify zooplankton species using an illustrated key (Appendix 5). The instructor also kept track of the relative abundance of zooplankton collected throughout the day, reporting “A” for abundant, “C” for common, and “R” for rare. All of ISEA’s samples were taken at the same locations, 44°58N, 85°38W in Suttons Bay and 44°46N, 85°37W in Grand Traverse Bay, respectively.

To collect benthos, the crew and instructors helped the students lower a Petite PONAR dredge to the bottom and collect two separate grabs from the same location. Similar to the fish station, students are guided by volunteer instructors though an illustrated dichotomous key to identify benthos using forceps and magnifying glasses (Appendix 6). At the benthos station, instructors keep track of the number and abundance of organisms present, but not the volume of sample that was sorted. Over time, recording of benthos data has ranged from a simple “X” for presence to including actual counts.

Quality Assurance Sampling Methods

We trawled in the same location as ISEA at a speed of 3 kts using an otter trawl (Jude and Tesar 1985). The trawl was towed behind our Boston Whaler *R/V Trout-Perch* at a length of five times the station depth, approximately 100 m. We trawled twice in Suttons Bay and twice in Grand Traverse Bay in June and September, respectively. We also did two trawls in the morning and two trawls at night in Suttons Bay in July. We did not sample Grand Traverse Bay in July because ISEA typically does not run trips in that portion of the bay when school is not in session. After an initial count was obtained, fish were placed on ice and frozen. Comparison between my data and the ISEA data fish data was fairly straightforward, but it was difficult to gain a substantial amount of information provided I was only able to compare 1 year. Partially due to our relatively small sample size, my data had relatively few species present when compared with ISEA datasets.

Zooplankton were sampled using a 50-cm (20-inch) diameter 153-μm plankton net; a vertical tow was taken from about 1 m off bottom to the surface (Evans and Jude 1986). We sampled twice each in Grand Traverse Bay and Suttons Bay in June and September, and did two morning tows and two afternoon tows in July in Suttons Bay only. Samples were then preserved with 100% alcohol. Our data were counted and classified by an experienced zooplankton taxonomist at the University of Michigan. The first 200 individuals were counted and classified to the species level, with additional species noted as “present”. Our samples did not include copepod nauplii since nauplii are not quantitatively sampled with the mesh size used, and therefore were not counted. However, ISEA did include nauplii, since they were not quantitatively sampling zooplankton. To compare these data with ISEA’s, I grouped species by genus in order to match ISEA’s groupings.

Benthos samples were collected using a Petite PONAR grab sampler. As in the cases of fish and zooplankton sampling, I collected two samples from Grand Traverse Bay and Suttons Bay in June and September, and collected four samples (two in the morning and two in the afternoon) in July. I analyzed the samples by first screening the sediment through a 350-μm screen then systematically viewing the sample under a microscope and counting organisms. Organisms were preserved with 100% alcohol after removal from samples. Due to the nature of ISEA's benthos data, I was forced to also compress my data down to the level of species richness in order to obtain a consistent comparison.

Results

Fish

In 2010, the vast majority of the fish caught per 10-minute trawl was round gobies. This was true both in ISEA's samples, and our QA samples. In the lower west arm, we only caught round gobies in our trawls (Fig. 26). ISEA had far more round gobies than other species, but also caught *Ambloplites rupestris* (rock bass), yellow perch, *Catostomus commersoni* (white sucker), and *Culaea inconstans* (brook stickleback) with some frequency. Our Suttons Bay trawl catches also consisted overwhelmingly of round gobies, but we also caught ninespine stickleback, *Percopsis omiscomaycus* (trout-perch), and one large (~14") white sucker (Fig. 27). In both the lower west arm and Suttons Bay, our QA trawls returned substantially more round gobies than did ISEA's average trawl.

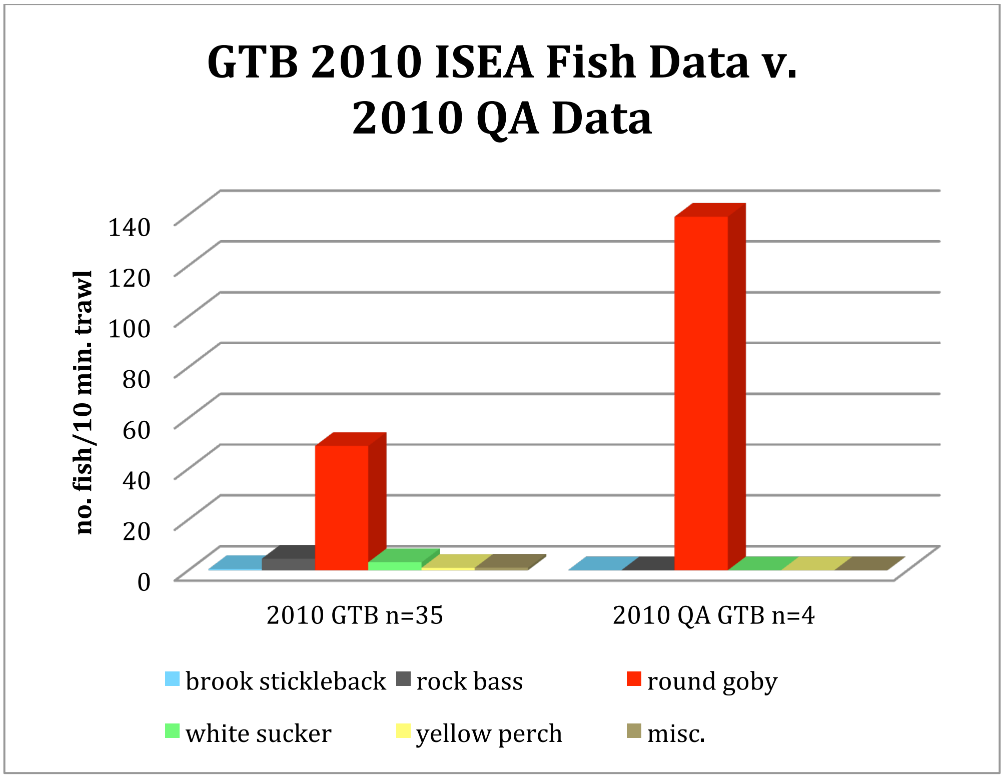

Figure 26: Average number of fishes caught per 10-minute trawl haul conducted in the lower west arm of Grand Traverse Bay (GTB), MI in 2010. QA represents quality assurance sampling.

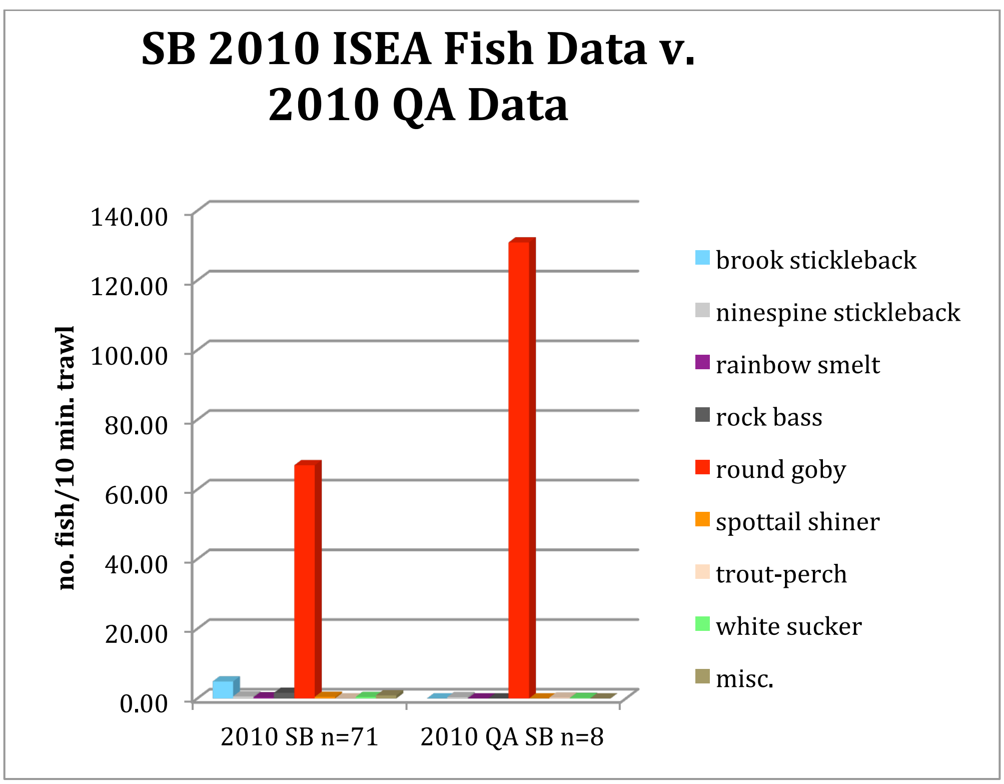

Figure 27: Average number of fishes caught per 10-minute trawl haul conducted in Suttons Bay (SB), MI in 2010. QA represents quality assurance sampling.

Zooplankton

In the lower west arm of Grand Traverse Bay, ISEA's spring and summer samples consisted primarily of calanoid copepod, copepod nauplii, cyclopoid copepod, and *Bosmina* (Fig. 28). Our late spring samples also consisted primarily of calanoid copepods, cyclopoid copepods, and *Bosmina* in similar proportions (Fig. 29). As previously noted, our samples did not include copepod nauplii. ISEA's 2010 fall samples consisted primarily of calanoid copepod, cyclopoid copepod, copepod nauplii, *Bosmina*, and colonial rotifers. There were substantially fewer copepods, but the average ranks of *Bosmina* and colonial rotifers were much higher. These five types of zooplankton were within a half of a rank of one another, with colonial rotifers receiving an average rank of 1.4 and *Bosmina* receiving an average rank of 1.9. Our fall QA samples primarily consisted of calanoid copepods, cyclopoid copepods, and *Bosmina*, with calanoids making up the majority of the sample. No colonial rotifers were found in our samples.

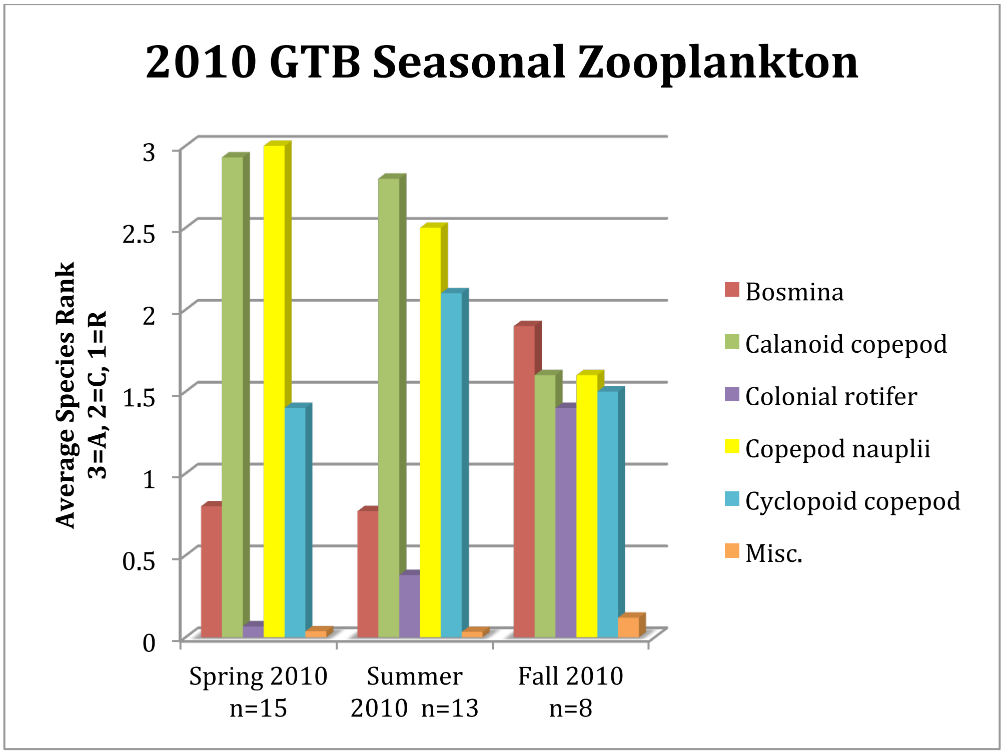

Figure 28: Seasonal zooplankton species abundance. Zooplankton were collected in vertical tows in 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis.

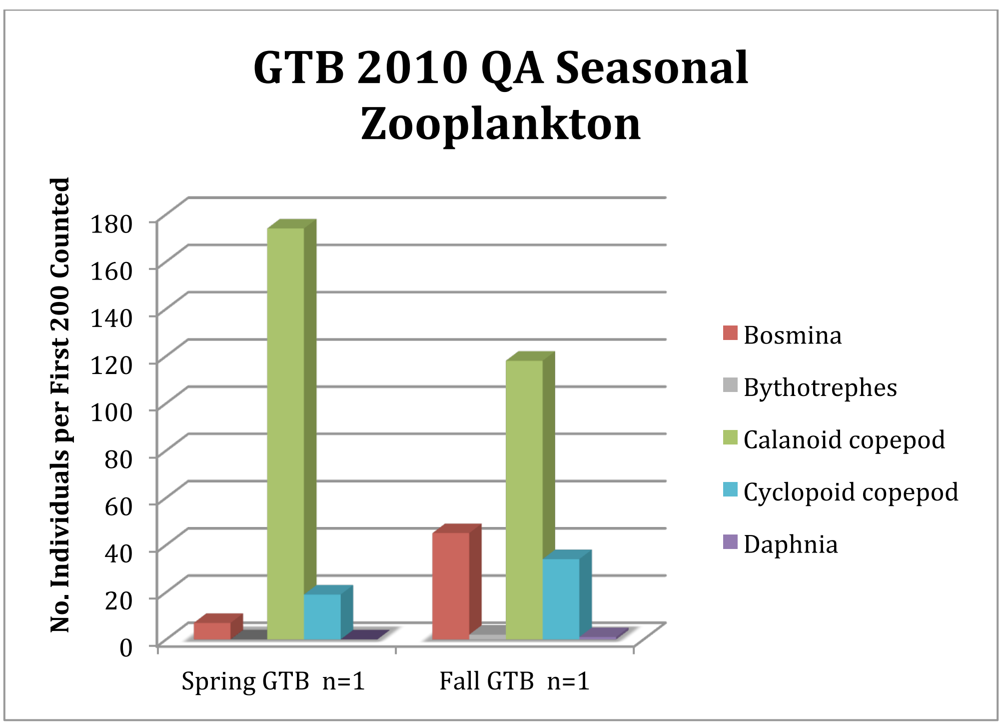

Figure 29: Seasonal zooplankton species abundance. Zooplankton were collected in vertical tows in 2010 in Grand Traverse Bay (GTB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. QA represents quality assurance sampling.

ISEA's spring and summer Suttons Bay samples had very similar composition to what was found in the lower west arm samples (Fig. 30). Calanoid copepods and copepod nauplii received the highest average rankings, while there were also a substantial number of cyclopoid copepods. Compared to summer lower west arm samples, Suttons Bay spring samples had about twice the average ranking of colonial rotifers. Our spring sample was overwhelmingly composed of calanoid copepods and had a few cyclopoid copepods as well (Fig. 31). Our summer samples were similar in composition to ISEA's samples, with calanoid copepods, cyclopoid copepods and *Bosmina* being most abundant. The zooplankton taxonomist did not count colonial rotifers, so they were not quantitatively included in the QA samples. The average fall Suttons Bay zooplankton ranks were about half that of the lower west arm. However, composition was similar, consisting primarily of *Bosmina*, calanoid copepods, and copepod nauplii. Average ranks of cyclopoid copepods and colonial rotifers were lower than in the lower west arm and spring and summer in Suttons Bay, but were present in a substantial portion of the samples. Our fall sample contained calanoid and cyclopoid copepods as well as *Bosmina*. Again, unlike in ISEA's fall samples, we did not find any colonial rotifers.

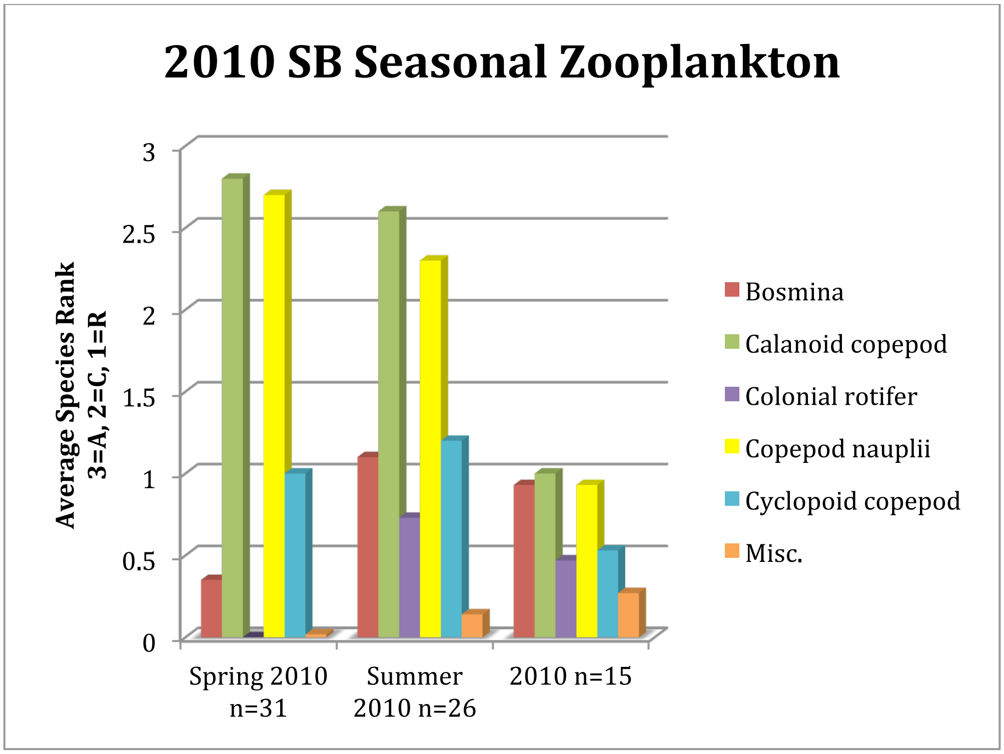

Figure 30: Seasonal zooplankton species abundance. Zooplankton were collected in vertical tows in 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis.

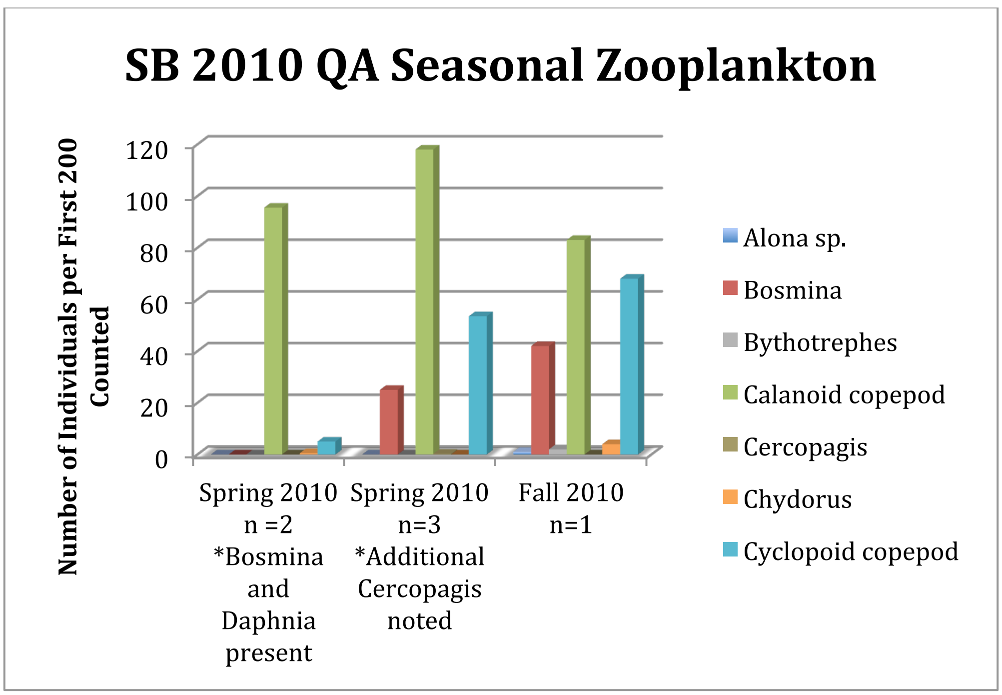

Figure 31: Seasonal zooplankton species abundance. Zooplankton were collected in vertical tows in 2010 in Suttons Bay (SB), MI. Species were originally ranked A (abundant), C (common), or R (rare). Rankings were converted to numeric form for analysis. QA represents quality assurance sampling.

Benthos

In 2010, ISEA collected 11 different “types” of benthos in the lower west arm, including but not limited to amphipods, isopods, midge larvae, aquatic earthworms (oligochaete) and zebra and quagga mussels. Our 2010 QA samples consisted of only six different types of organisms, which also included amphipods and quagga mussels. Unlike ISEA’s samples, our QA samples contained ostracods and round worms, and did not contain any isopods (Fig. 32).

In Suttons Bay, ISEA volunteers and students collected 12 different types of organisms, while we collected 11. ISEA’s samples included amphipods, isopods, round worms, oligochaetes, midge larvae and pupae, and zebra and quagga mussels. The QA samples had a very similar composition, but also included snails, ostracods, and the zooplankters *Cercopagis,* and *Bythotrephes.*

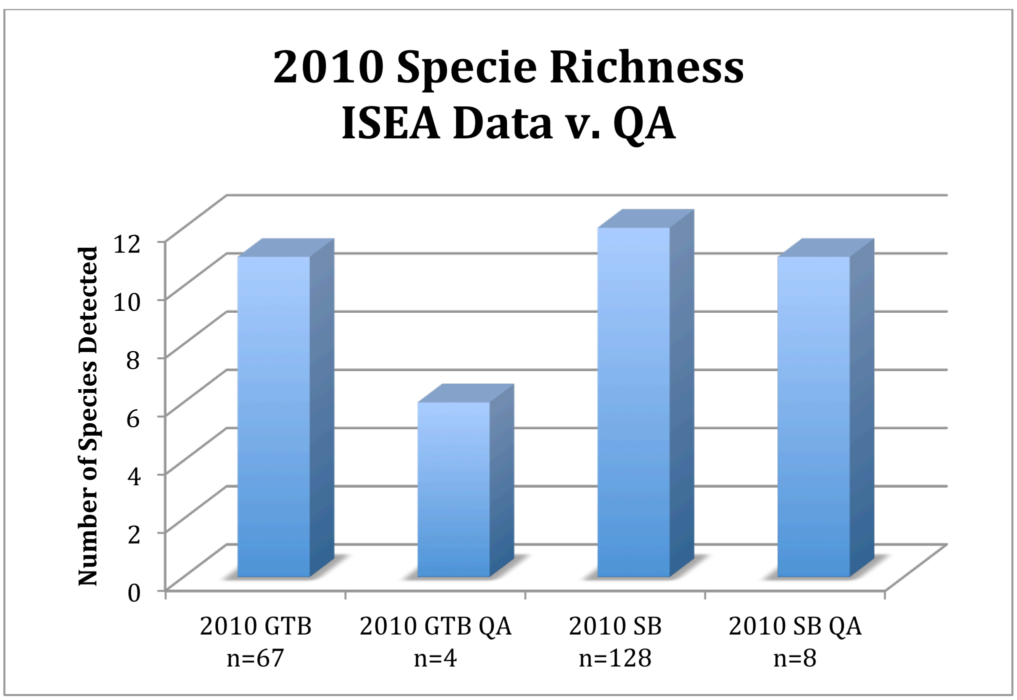

Figure 32: No. of species of benthic invertebrates (species richness) found in Petite PONAR grabs collected in the lower west arm of Grand Traverse Bay (GTB), MI and Suttons Bay (SB), MI in 2010. QA represents quality assurance sampling data.

Discussion

Fish

It is not surprising that we found fewer species in our QA trawls than ISEA personnel found in their 2010 trawls, considering we collected far fewer samples. However, the substantial difference in the average number of round gobies caught per 10-minute trawl is noteworthy. One possibility for the higher numbers could be due to trawl speed. We trawled at 3 kts during each trawl, while ISEA's trawl speeds varied between 1.7 and 2.6 kts. Therefore, the faster speed may have resulted in more round gobies captured

Especially in earlier years, ISEA's trawls were frequently longer or shorter than 10 minutes. Although I standardized counts to a 10-minute trawl, some accuracy is lost in this process. Fish counts may have also been influenced by similar-looking species such as mottled sculpin and round goby, and various types of minnows. In some cases, ISEA noted dead fish that were caught in the trawl. However, it is certainly possible that some volunteers counted dead fish in their total counts and therefore overestimated numbers.

Zooplankton

By comparing relative abundance of zooplankton types between our QA samples and ISEA's 2010 samples, it appeared that ISEA's relative abundances of zooplankton were fairly accurate most of the time. This finding suggests there may be some reliability or usefulness in evaluating ISEA's rankings. With improved sampling and recording procedures, future zooplankton records could be made to be scientifically useful.

ISEA's samples are intrinsically subject to some error due to volunteer instructors classifying zooplankton. However, most zooplankton body types are fairly easy to distinguish from one another, and volunteers that teach the zooplankton station tend to teach that station often and have been with ISEA for many years. Another potential source of error is that depending on weather conditions; ISEA's tows are not always directly vertical, which would also affect sampling consistency. Quality assurance samples may have also been affected by weather conditions. Strong winds and currents in the lower west arm of Grand Traverse Bay during June 6 zooplankton sampling led the net to be towed somewhat diagonally rather than directly vertically, which may have led to some variation in the resulting zooplankton species composition.

Benthos

The methods by which I sorted through the benthos samples were much more rigorous than those of ISEA. ISEA's samples are counted primarily by students using forceps and handheld magnifying glasses and may or may not include the entire sample. I counted samples under a dissecting microscope and went through the entire sample. Because of these differences, it is to be expected that my data would return both more species and more individuals. For example, I found oligochaetes, harpacticoid copepods, and ostracods in my samples. ISEA volunteers sometimes found oligochaetes, but only if they were quite large. There is a strong correlation between the larger organisms that were found as part of ISEA's programs and those that I counted.

ISEA's sampling methods are subject to a substantial amount of error. Because of the sorting methods, students probably only find a fraction of the organisms that were actually present. In addition, not knowing the amount of sediment that was examined makes it difficult to draw conclusions about populations. Volunteer misconceptions may also come into play here, considering ISEA has frequent records of *Chaoborus*, or phantom midges, in their samples. It is likely that these organisms were actually chironomids that were mistakenly classified as *Chaoborus,* since it is highly unlikely *Chaoborus* occurs in Grand Traverse Bay.

A Note on Confirmed Species Introductions

When making data observations based primarily on the most abundant species collected each year, most of the trends in the data are what we would expect to see given what we know about the greater Lake Michigan ecosystem. However, it is important to keep in mind that citizen volunteers collected these data, and therefore it is to be expected that there was a certain degree of uncertainty and error. One area where this may be of concern is when certain shifts in the bay's populations have occurred.

In some cases, species were first found in Lake Michigan a decade or more before first being reported by ISEA (Table 1). While it is likely that there was some lag time between introduction to Lake Michigan and establishment within Grand Traverse Bay, it is unlikely that the true time span was this long. In the case of the quagga mussel and round goby, native species such as the zebra mussel and mottled sculpin could be considered "lookalikes" to the untrained eye. Because of this, it is highly likely that ISEA was overestimating the number of native species present while not realizing that they were actually seeing new species in the bay. However, being the only program that does frequent, consistent monitoring of the bay, Inland Seas has also been the first to report and confirm new species in the Bay, as was the case with *Cercopagis pengoi*. In the case of the zebra mussel, ISEA actually reported having found them in the bay before they were confirmed in Lake Michigan.

Non-native Species Incidences		
	Confirmed in Lake Michigan	**Found by ISEA**
Zebra mussel	1991	1989
Quagga mussel	1997	2005
Cercopagis pengoi	1999	1999
Bythotrephes longimanus	1986	1999
Round goby	1994	2004

Table 1: Comparison of non-native species confirmation in Lake Michigan to when species were first recorded by ISEA (GLANSIS 2011, Crissman 2011)

Conclusions

By comparing ISEA's 2010 data with the QA data, I was able to draw some conclusions regarding the validity of ISEA's data. Fish data were likely accurate, and the larger variety of species that ISEA found was likely a result of a substantially larger number of trawls over longer timeframes. Although ISEA uses rankings to record their zooplankton data and do not record volume of the sample that was examined, an examination of the relative abundance of zooplankton in ISEA's data and the QA data revealed that their general trends were realistic. Since benthos data were so inconsistent, very few conclusions could be drawn. It appears that ISEA missed smaller organisms, and likely misclassified others.

LESSONS LEARNED AND RECOMMENDATIONS FOR ISEA AND OTHER PROGRAMS

ISEA Program Questionnaire

In an e-mail to Tom Kelly, director and Christine Crissman, chief scientist, I asked a series of questions to better gauge their views on the priorities and objectives of their program and what they would like to see improved in the future. The survey questions included:

1. What do you view as the most important aspect/objective of your program?
2. What aspects of the Schoolship Program, if any, are you unwilling to change?
3. What do you view as the shortcomings of the program? Is there anything in particular that you wish you had done/designed differently?
4. For what, if anything, would you ideally like the ISEA data to be used?
5. Looking into the future, where do you see the Schoolship Program going (this can apply to short and/or long-term goals)?

Although their specific responses varied, Tom and Christine's answers were generally in agreement. They both said that the most important aspects of their program revolved around educating students and the public about the Great Lakes ecosystem and why it is an important resource. By giving people the opportunity to actually experience the Great Lakes, they hoped to spread awareness and build a sense of connection and stewardship. In fact, preliminary research has suggested that students who participate in local environment-based programs such as ISEA's may be more interested and driven to participate in civic engagement throughout their lives (Schusler and Krasny 2008). In the same vein, both Tom and Christine said that the only aspects of the program they would be unwilling to change would be educational components and promoting an understanding and stewardship of the Great Lakes.

As far as shortcomings are concerned, Tom mentioned the constant struggle for funding while Christine focused on the constant improvement of ISEA's educational programs and instruction and a desire to have longer-term connections with students within the program. Christine also mentioned that although utilizing volunteers as instructors poses unique challenges, it is also an integral part of ISEA's programs. Both Tom and Christine responded that they would ultimately like to see data used for long-range forecasting and examining historical trends, although they realize that the nature of the data poses challenges for this type of use. In the future, Christine sees the program continuing along its current path while making improvements along the way, while Tom would like to integrate technologies such as virtual field trips (Crissman 2011, Kelly 2011).

Data Collection and Analysis Protocols

Programs such as ISEA that record and maintain scientific data should ideally be following set standards and protocols. However, many researchers, institutions and other groups prefer to have a concept of "guidelines" for research record keeping rather than an official "best practices". Utilizing research training and ethics literature along with policies and guidelines for research records from various research universities, Schreier et al. (2006) devised three lists to summarize best practices for research record keeping for individuals, group leaders, and institutions, respectively (Schreier et. al. 2006)(Appendix 7). These best practice lists could provide guidance to ISEA and other similar programs for how to improve overall quality in the data collection process.

ISEA most likely falls somewhere in between the “individual” and “research group” categories. Among the first criteria listed for individuals Schreier et. al. included “what you did”, “why you did it”, “when you did it”, and “how you did it”. The “what” and “how” represent much of ISEA’s recording shortcomings, in that much more information could be gained from knowing more specifics on how data were collected (e.g., volume of water examined for zooplankton, amount of benthos sorted, sorting and counting procedures, etc.). List 2, which includes best-practice recommendations for research groups, focuses on ensuring quality control through setting standards and enforcing proper training and maintenance. These “standards” should include consistency in how data are recorded. This represents another concern for the ISEA data, as many different recording methods have been used by ISEA as an organization and by individual volunteers over the past 2 decades. It is important to keep in mind that while ISEA has long had an interest in generating a useful dataset, scientific accuracy has not been the program’s primary concern. Therefore, recommendations generated from this report can serve to improve sampling and recording practices in the future (Schreier et. al. 2006).

Recommendations Introduction

During every aspect of this study, I have gained insights into ISEA’s programs and where there may be room for improvement. Many of these insights arose during the data-entry process, when I was able to see the different recording formats and styles. Through sampling and recording data according to protocol, I was able to gain further understanding of what is necessary for data to be scientifically useful in relation to ISEA’s data. There are many improvements that can be made to ISEA’s programs, sampling procedures, and data recording processes. Some of these are simple and can be implemented immediately; others may be more difficult given the program's structure. However, it is my hope that ISEA will be able to implement at least some changes to improve the scientific utility of their resulting data and future programs can utilize these suggestions to develop a useful dataset and avoid a lengthy learning curve.

Data Processing

For fish trawls, ISEA has (almost) always recorded trawl duration on their data sheets. Because of this, those who may want to use the data to examine historical trends in the Bay's fish populations should be able to do so knowing that most trawls were 10 minutes long, and the rest could be standardized accordingly. However, more information could be gained through also recording position (GPS) at the beginning and end of each trawl. This would allow interested individuals to calculate catch per square meter along with catch per unit effort. Unfortunately, those interested in using ISEA's zooplankton and benthos data would be unable to obtain information regarding the volume of the zooplankton sample that was counted or amount of sediment that was examined, since this information is not currently included in the data sheets. Therefore, it is only feasible to use these data very loosely and for long-term trends only.

It would be fairly simple for ISEA to implement some basic changes to their sample processing procedures so that future zooplankton and benthos data could be more useful. Due to classes of widely varying sizes, it is not feasible to examine the same volume of the zooplankton in every trip. However, including the volume that was examined in each trip could be very useful. Since the students and instructors use droppers to examine zooplankton one drop at a time, the volume per drop and volume into which the sample was calculated could be used to calculate the volume of sample examined and percentage of the sample examined. To make sure drops are used, volunteers would need to give explicit instructions to put only x number of drops in the dish at a time. Of course, both students and the volunteers sometimes make mistakes, so some samples may need to be noted in the data sheets as not being suitable for scientific use. Using a flowmeter to record the number of revolutions in the plankton net along with the depth of each plankton tow (which is typically already done) would also be helpful to more accurately calculate the overall volume of the zooplankton sample and assist in calculating density accurately.

Similarly, students sort through benthos samples at different speeds. Therefore, although two PONAR grabs are taken each trip, students sort through a different amount of sediment each time. Standardizing the amount of sediment examined could be done in two different ways. The first would involve mixing then taking the sediment from the main tub using a vessel with a known volume. This method would allow flexibility to account for varying numbers of students and examination speeds. At the end of each trip, the total volume that was examined could be included in the data sheet. The second option would be to allow students to sort through whatever quantity they are able to accomplish during the program in a white pan, then volunteers would sort through the remaining sediment at the end of the program. This would result in the same amount of sample being examined each time, and may increase overall accuracy since the trained volunteers would be able to verify trends in what the students noticed and also possibly detect major changes in species composition. However, this would require a longer time commitment on the part of the volunteers, which may not be ideal.

Preserve and note unusual specimens

The ISEA Volunteer Handbook instructs volunteers to bring any unusual specimens to the attention of the lead instructor and preserve the specimens for further analysis. However, this is rarely done. Keeping unusual specimens for further analysis could contribute to the early detection of new species in the bay as well as possible diseases or mutations that could be afflicting populations. In addition, it would be helpful for ISEA to preserve full samples at regular intervals to verify fish species they are collecting. Individuals from these preserved samples could then be used as a teaching tool both during volunteer training and during on-board programs. Unusual specimens or samples should also be noted in the datasheets to see potential spatial and temporal trends in abnormal samples.

Data Recording

One of the biggest issues that arose when sorting through ISEA's data was lack of standardization in data recording. For fish, most of the terminology was fairly straightforward and volunteers recorded actual counts consistently. However, it was sometimes questionable whether or not volunteers were including dead fish, zooplankton, or benthos in their counts, which may have influenced numbers. Sometimes ISEA kept their samples from their morning program for use in the afternoon program. While this was typically noted, it is important to ensure that volunteers always include this information so samples are not double counted.

Recent zooplankton data are fairly consistently recorded using "abundant, common, rare" designations. However, on occasion volunteers recorded numbers or phrases such as "many" or "few". It is important for volunteers to adhere to a common recording system so all data are comparable to one another. Using abundant, common, and rare will yield information regarding relative abundance among species, but that is all. Ideally, zooplankton should be counted along with information regarding the sample volume so those interested in gaining additional information from the data can have a measure of density rather than simply relative abundance.

Problems with benthos data recording are similar to those of zooplankton data, but exacerbated. The volunteer handbook and datasheets instruct volunteers to record benthos data as actual counts. However, this is the category that has the most inconsistency in terminology. In recent years, consistency has been greatly improved with improved data sheets. However, in past data slang terms such as “scuds” instead of amphipods or “sideswimmers” instead of isopods were used. Abundance designations such as the abundant, common, rare system and phrases such as “tons” and “a couple” were often intermixed with numbers. Numeric rankings were also used on occasion, which leads to confusion between the rankings and actual counts. If volunteers consistently adhere to recording actual numbers along with amount of sediment examined, benthic invertebrate density could be obtained, leading to more useful scientific information.

In addition to standardizing units and terminology, it is also imperative that volunteers adhere to standard units. Past datasheets have included a mix of metric and U.S. measurements. This led to substantial confusion in entering the data. The most recent versions of the datasheets instruct volunteers to record measurements in U.S. units, with water temperature in both Fahrenheit and Celsius. However, some volunteers still record data in metric. Ideally, all data should be recorded in metric units for widespread use and units should always be indicated on the datasheets.

Data sheets should be clear and consistent

The Inland Seas Education Association has used 16 different types of datasheets in its 22-year history (Appendix 8). This inconsistency led to difficulty in digitizing data, and it is highly likely that it has led to volunteer confusion as well. Since datasheets changed units and how data were recorded and units, volunteers that remained with ISEA for many years have had to adapt to the new datasheets and may have missed some changes. This could be one reason for inconsistency in how volunteers recorded data. Attention should also be paid to datasheet layout and clarity. In the recent datasheets, data categories are clearly marked and desired units are indicated.

Volunteer instructors, not the students, should fill out the datasheets that are entered into the database. ISEA has had volunteers complete the datasheets since 1990, but had a mix of student and volunteer records in 1989. Students are given their own data booklets to complete during the program, which enables them to feel involved and like “real scientists” while maintaining overall data quality.

Data should be digitized and backed up as soon as possible

Until I began the data entry phase of this project, the 1989-2006 data were still hand-written in three-ring binders without any backup copies. It is important that data be digitized soon after being collected both to avoid confusion and misunderstandings about the data and to reduce the risk of losing data. If too much time elapses between the time data are collected and the time they are entered, the person entering data loses the ability to ask questions of the data recorder or clarify confusing entries. Waiting to digitize and back up data also increases the risk of losing data.

There should also be measures in place for checking data quality as it is being entered. For example, using the Cornell Laboratory of Ornithology (CLO) as an example to demonstrate how data quality can be maintained in citizen science programs, Johnson and Mappin (1999) advocated careful editing during the data entry process and flagging and checking outliers. In addition, CLO utilizes an electronic data form that is preprogrammed to include only species that are likely to be found and has parameters for likely entry values. If potentially erroneous data are entered, a message appears asking the person who is entering the data to double-check the entry. This approach could be very useful for ISEA's programs (Johnson and Mappin 2009).

Handwriting and writing utensils matter

It is standard scientific protocol to record data using either pencil or waterproof ink. This is particularly important when the data are collected and recorded aboard a ship. ISEA's volunteer instructors have recorded data using water-soluble ink, pencil, and marker. It is important to provide volunteers with appropriate writing utensils and explain the importance of using waterproof ink or pencil. In addition, volunteers should be instructed to always print clearly so the person digitizing the data can enter it easily. Both of these issues would be easy to address during the volunteer training sessions.

Volunteer Training

Proper training is essential

Studies have shown that with proper training and protocols, volunteers and students can collect and record high-quality data (Johnson and Mappin 2009). Generally speaking, ISEA's training program is comprehensive and very high quality. However, other programs can learn from ISEA's early mistakes, and there are some changes that could be made to make ISEA's program even better.

Volunteers should be informed of likely species that they could come across, what they look like, and how they should be classified on the datasheets. It is also essential that volunteers are kept up to date on movement of non-native species and specific details regarding what those species look like. This is particularly valuable in differentiating native species from non-native species. For example, ISEA informs volunteers of differences between round gobies and mottled sculpin, and zebra and quagga mussels. However, it is important that these differences are discussed before the species are first seen in the area, in order to notice them as soon as they arrive.

A high-quality instructor manual is a valuable asset

The ISEA Volunteer Instructor Manual provides comprehensive information covering ISEA's programs, station descriptions, and teaching procedures. In both the manual and guides used aboard the ship (including dichotomous keys used in identification), illustrations are used to identify organisms. While this is very helpful in clarifying and accentuating species traits, it would also be valuable to include photographs and preserved samples so the instructors and students can see what a real specimen looks like. As previously mentioned, it is important that volunteers are trained in proper notation and standardization procedures. Making the desired end use of the data (i.e., scientific examination) known to volunteers should minimize frivolous data recording, such as “usual” for sediment color or “nasty” for sediment texture.

Virtual training can reinforce volunteer knowledge

As an alternative to the face-to-face volunteer training, ISEA has begun utilizing some online training. Currently, some learning stations, such as the benthos station, are covered online through a simple written description of what is covered at that station. However, some learning stations, such as the zooplankton station, include an online, guided presentation that includes images from ISEA’s programs along with illustrations and descriptions. While online training is not ideal as an only mode of training, it is an excellent tool as a supplement to a face-to-face course since volunteers can refer back to it to reinforce their knowledge.

CONCLUSIONS

The Inland Seas Education Association offers a high-quality ecological education program for students and the public. However, some changes would need to be made in data collection and recording in order to generate a dataset that is useful for scientific inquiry. Programs such as ISEA can serve as an excellent tool to provide scientific data in regions where data may not otherwise exist, or as a supplement to existing datasets. In its current form, ISEA serves as an excellent template for new and developing ecological education programs. However, it has had a long learning curve that can be avoided by new and developing programs learning from ISEA’s past mistakes. In addition, new and developing programs that wish to generate scientifically useable data should take this desired result into consideration along with their educational objectives when developing their sampling and data recording procedures. By comparing ISEA's data with my QA data, it appears that they are on the right track when it comes to monitoring fish, zooplankton, and benthos in Grand Traverse Bay, but zooplankton and benthos data are not scientifically useful in their current form due to ISEA's data processing procedures. However, relatively simple procedural changes could lead to greatly improved data quality and provide an invaluable resource to the scientific community.

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APPENDIX 1: Fish species included in the miscellaneous category by year from 1989-2010

Miscellaneous Grand Traverse Bay Fish by Year

1989	1990	1998	1999	2000	2001
Alosa pseudoharengus (alewife)	alewife	*Ameiurus nebulosus* (brown bullhead)	*Pimephales notatus* (bluntnose minnow)	burbot	burbot
Gasterosteid spp.	*Notropis* spp.	burbot	Gasterosteid spp.	Gasterosteid spp.	mottled sculpin
johnny darter	johnny darter	Gasterosteid spp.	*nigrum* (johnny darter)	johnny darter	*Notropis* spp.
mottled sculpin	rock bass	johnny darter	mottled sculpin	larval fish spp.	rainbow smelt
Notropis spp.	*Cottus* spp.	mottled sculpin	*Osmerus mordax* (rainbow smelt)	mottled sculpin	rock bass
rock bass	spottail shiner	rainbow smelt	rock bass	rainbow smelt	threespine stickleback
Notropis hudsonius (spottail shiner)	white sucker	rock bass	*Cottus spp.*	rainbow trout	white sucker
white sucker	yellow perch	white sucker	*Micropterus dolomieu* (smallmouth bass)	trout-perch	yellow perch
			Gasterosteus aculeatus (threespine stickleback)	smallmouth bass	
			walleye	lake whitefish	
			lake whitefish	white sucker	
			white sucker	yellow perch	
			yellow perch		

2005	2006	2007	2008	2009	2010
alewife	brook stickleback	bluntnose minnow	bluntnose minnow	alewife	bluntnose minnow
johnny darter	round goby	brook stickleback	johnny darter	brook stickleback	johnny darter
mottled sculpin	spottail shiner	johnny darter	mottled sculpin	johnny darter	mottled sculpin
rainbow smelt	white sucker	*Micropterus* spp.	ninespine stickleback	ninespine stickleback	ninespine stickleback
round goby		ninespine stickleback	rainbow smelt	rainbow smelt	rainbow smelt
walleye		rock bass		smallmouth bass	smallmouth bass
white sucker		threespine stickleback		threespine stickleback	spottail shiner
yellow perch		trout-perch		trout-perch	
		walleye		*Fundulus diaphanus menona* (western banded killifish)	
		white sucker			

Miscellaneous Suttons Bay Fish by Year

1998	1999	2000	2001	2005
burbot	Gasterosteid spp.	bluntnose minnow	brook stickleback	brook stickleback
rainbow smelt	johnny darter	brook stickleback	Gasterosteid spp.	burbot
rock bass	mottled sculpin	rainbow smelt	rainbow smelt	mottled sculpin
spottail shiner	*Notropis* spp.	smallmouth bass	smallmouth bass	rock bass
trout-perch	rainbow smelt	rock bass	trout-perch	round goby
white sucker	rock bass	*Cottus* spp.	yellow perch	trout-perch
yellow perch	*Cottus* spp.	threespine stickleback		walleye
	smallmouth bass	lake whitefish		yellow perch
	trout-perch	white sucker		
	white sucker	yellow perch		
	yellow perch			

2006	2007	2008	2009	2010
alewife	black crappie	johnny darter	johnny darter	bluntnose minnow
brook stickleback	johnny darter	mottled sculpin	ninespine stickleback	johnny darter
burbot	mottled sculpin	ninespine stickleback	rainbow smelt	threespine stickleback
mottled sculpin	*Percidae* spp.	threespine stickleback	smallmouth bass	walleye
rainbow smelt	rainbow smelt	walleye	trout-perch	white sucker
rock bass	rock bass		walleye	yellow perch
smallmouth bass	round goby		western banded killifish	
trout-perch	smallmouth bass		white sucker	
white sucker	threespine stickleback		yellow perch	
	western banded killifish			

APPENDIX 2: Total number of fishes caught per year in Grand Traverse Bay (GTB) and Suttons Bay (SB) from 1989-2010. QA refers to quality assurance and are the trawls deployed to verify ISEA's dataset

Total Fish Caught per Year

Year	GTB	SB
1989	5075	
1990	844	
1998	875	970
1999	1403	3064
2000	523	996
2001	187	314
2005	974	1671
2006	411	1464
2007	1125	2425
2008	3708	2284
2009	1245	3414
2010	2070	5765
2010 QA	557	1058

APPENDIX 3: Zooplankton and other groups in net tows conducted in Grand Traverse Bay and Suttons Bay from 1998-2010, included in the miscellaneous category collected

Miscellaneous Zooplankton

Asplanchna	*Bythotrephes longimanus*	*Cercopagis pengoi*	*Chydorus*
Daphnia	*Diaphanosoma*	Harpacticoid copepod	*Holopedium*
	Polyphemus	*Leptadora*	

Other Organisms Included in Miscellaneous Zooplankton

Hydracarina	*Keratella*
Ostracod	*Mysis*
Rotifer spp.	Veliger

APPENDIX 4: Benthic groups found in PONAR samples collected in Grand Traverse Bay and Suttons Bay during 1989-2010

2010 Grand Traverse Bay Benthos Present by Year

1989	1998	1999	2000	2001	2005
Amphipod	Amphipod	Amphipod	Amphipod	Amphipod	Amphipod
Trichoptera (caddisfly) larva	Trichoptera	Oligochaeta	Oligochaeta	Oligochaeta	Oligochaeta
Isopod	Crayfish	Trichoptera	Trichoptera	cranefly larvae	Chironomid
Leech	Isopod	Tipulidae	Crayfish	Crayfish	Crayfish
Ephemeroptera (mayfly)	Leech	Isopod	Isopod	Isopod	Isopod
Chironomid	Chironomid	Ephemeroptera	Leech	Leech	Chrionomic
Mysis relicta	*Mysis relicta*	Chironomid	Ephemeroptera	Ephemeroptera	Ephemeroptera
Planaria spp.	Chaoborus	Chaoborus	Chironomid	Chironomid	Chaoborus
Snail	Planaria spp.	Planaria spp.	*Mysis relicta*	Chironomid Pupae	Nematode
	Nematode	Nematode	Chaoborus	Chaoborus	Quagga Mussel
	Snail	Snail	Planaria spp.	Planaria spp.	Zebra Mussel
	Zebra Mussel	Oligochaeta	Nematode	Plecoptera	
		Zebra Mussel	Snail	Zebra Mussel	
			Zebra Mussel		

2006	2007	2008	2009	2010	2010 QA
Amphipod	Amphipod	Oligochaeta	Amphipod	Amphipod	Amphipod
Oligochaeta	Oligochaeta	Isopod	Trichoptera	Oligochaeta	Oligochaeta
Chironomid	Oligochaeta	Chironomid	Isopod	Trichoptera	Chironomid
Chironomid Pupae	Snail	Chironomid Pupae	Ephemeroptera	Isopod	Ostracod
Tipulidae	Isopod	Chaoborus	Chironomid	Ephemeroptera	Quagga Mussel
Isopod	Ephemeroptera	Quagga Mussel	*Mysis relicta*	Chironomid	Nematode
Leech	Chironomid	Nematode	Chaoborus	Chironomid Pupae	
Ephemeroptera	Chaoborus	Snail	Quagga Mussel	Quagga Mussel	
Planaria spp.	Quagga Mussel	Zebra Mussel	Zebra Mussel	Snail	
Chaoborus	Zebra Mussel			Zebra Mussel	
Nematode					
Quagga Mussel					
Zebra Mussel					

2010 Suttons Bay Benthos Present by Year

1998	1999	2000	2001	2005	2006
Amphipod	Amphipod	Amphipod	Amphipod	Amphipod	Amphipod
Oligochaeta	Oligochaeta	Trichoptera	Oligochaeta	Oligochaeta	Oligochaeta
Trichoptera	Isopod	Tipulidae	Oligochaeta	Chironomid	Chironomid
Isopod	Leech	Crayfish	Trichoptera	Crayfish	Crayfish
Hirundinea (leech)	Ephemeroptera	Fingernail Clam	Tipulidae	Tipulidae	Tipulidae
Ephemeroptera	Chironomid	Isopos	Crayfish	Snail	Fingernail Clam
Chironomid	Nematode	Leech	Fingernail Clam	Isopod	Snail
Nematode	Snail	Ephemeroptera	Isopod	Ephemeroptera	Isopod
Snail	Zebra Mussel	Chironomid	Leech	Chaoborus	Leech
Zebra Mussel		Chaoborus	Ephemeroptera	Plecoptera	Ephemeroptera
		Planaria spp.	Chironomid	Quagga Mussel	Planaria spp.
		Nematode	*Mysis relicta*	Zebra Mussel	Chaoborus
		Snail	Chaoborus		Plecoptera
		Hydracarina	Planaria spp.		Quagga Mussel
		Zebra Mussel	Nematode		Zebra Mussel
			Snail		
			Zebra Mussel		

2007	2008	2009	2010	2010 QA
Amphipod	Amphipod	Amphipod	Amphipod	Amphipod
Oligochaeta	Oligochaeta	Oligochaeta	Tipulidae	Oligochaeta
Tipulidae	Tipulidae	Trichoptera (caddisfly) larva	Snail	*Bythotrephes*
Isopod	Fingernail Clam	Tipulidae	Isopod	*Cercopagis*
Leech	Isopod	Snail	Leech	Fingernail Clam
Ephemeroptera	Leech	Isopod	Chironomid	Chironomid
Chironomid	Chironomid	Chironomid	Chironomid Pupae	Chironomid Pupae
Chironomid Pupae	Chironomid Pupae	Chaoborus	Chaoborus	Ostracod
Chaoborus	Chaoborus	Quagga Mussel	Quagga Mussel	Quagga Mussel
Planaria spp.	Quagga Mussel	Nematode	Nematode	Nematode
Quagga Mussel	Nematode	Snail	Oligochaeta	Snail
Snail	Zebra Mussel	Zebra Mussel	Zebra Mussel	
Hydracarina				
Zebra Mussel				

APPENDIX 5: Benthic groups found in quality assurance PONAR samples collected in Grand Traverse Bay and Suttons Bay in 2010

2010 Grand Traverse Bay QA

Sample Depth (ft)	# of Samples	Color	Texture	Amphipod	Oligochaeta	Chironomid larvae	Chironomid pupae	Ostracod	Quagga Mussel	Nematode
81.04	1	olive brown	fine w/ some sand	1	25	9		5	116	3
80.38	1	olive brown	gritty w/ some sand		14	51	1	22		14
78.74	1	olive gray	sandy silt		20			17	1	8
78.74	1	olive gray	sandy silt		19	2		14	1	9

2010 Suttons Bay QA

Sample Depth (ft)	# of Samples	Color	Texture	Amphipod	Oligochaeta	*Bythotrephes*	*Cercopagis*	Fingernail Clam	Chironomid larvae	Chironomid pupae	Ostracod	Quagga Mussel	Nematode	Snail
	1	tan/gray	gritty	6	18				31	5	152		2	
		tan/gray	gritty	3	13				19	1	40		1	
42.65	1	black gray/brown	sand, some OM		5	1			9		37			
41.34	1	black gray/brown	gritty		7			2	11				1	
62.99	1	gray/black/dark			9	2	1		7		69		4	
55.77	1	gray/black/dark			25				41	1	9	77	5	
62.34	1	green/gray	silt w/ calcium bicarbonate and wood		5	1			9		37			x
62.34	1	green/gray	gelatinous silt		6	1			12		25			

APPENDIX 6: ISEA fish identification key used for fish taxonomy in Grand Traverse Bay and Suttons Bay

GRAND TRAVERSE BAY FISH KEY

1a. Body is eel-like, round mouth with circular row of teeth: Lamprey Family (Petromyzondtidae)

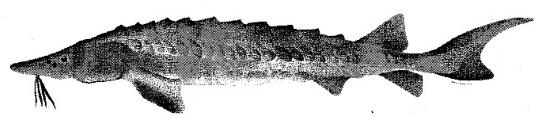
(1)

Sea Lamprey (adults to 3 feet)

1b. Body is not eel-like, mouth is not round (2)

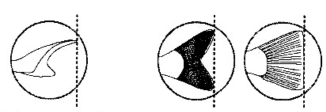
2a. Upper lobe of tail fin is longer than the lower lobe (Heterocercal tail fin): Sturgeon Family (Acipenseridae)

(2)



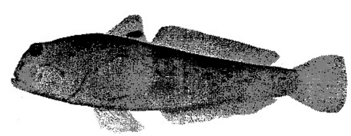
Lake Sturgeon (adults 3-5 feet)

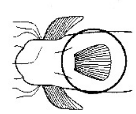
2b. Upper and lower lobes of tail fin are the same size (Homocercal tail fin) (3)



3a. Pelvic fins are fused into a single, circular sucking disk: Goby Family (Gobiidae)

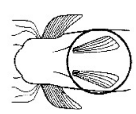
(3)





Round Goby (adults to 10 inches)

3b. Pelvic fins are separate (two distinct fins) (4)



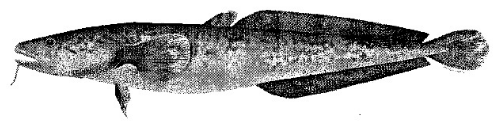
(4)

4a. Barbel(s) present on chin (5)

4b. Barbel(s) absent on chin
Barbels may be present on upper lip or at junction of upper and lower lips (6)

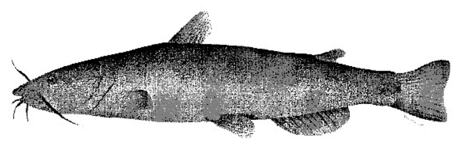
(5)

5a. One barbel present on chin: Cod Family (Gadidae)



Burbot
(adults to 15 inches)

5b. Four pairs of barbels around mouth and 2 pairs of barbels on chin: Catfish Family (Ictaluridae)

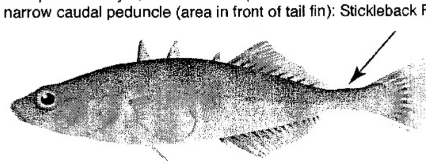


Channel Catfish
(adults 14-21 inches)

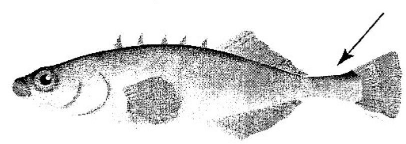
Also: Yellow Bullhead
Black Bullhead

(6)

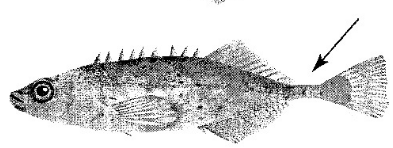
6a. Dorsal fin preceded by 3, 5 or 9 dorsal spines
Very narrow caudal peduncle (area in front of tail fin): Stickleback Family (Gasterosteidae)



Threespine Stickleback
(adults 3.5 inches)



Brook Stickleback
(adults 3.5 inches)



Ninespine Stickleback
(adults 3.5 inches)

6b. No spines in front of dorsal fin (7)

(7)

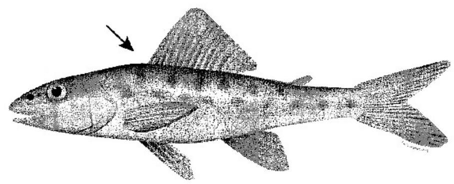
7a. Adipose fin present (8)

7b. Adipose fin absent (11)

---

(8)

8a. Dorsal fin has 2 weak spines, scales rough when rubbed from rear to forward:
Trout-Perch Family (Percopsidae)



Trout-Perch
(adults 3-4 inches)

8b. Dorsal fin has no spines, scales smooth (9)

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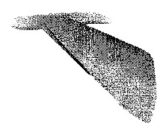
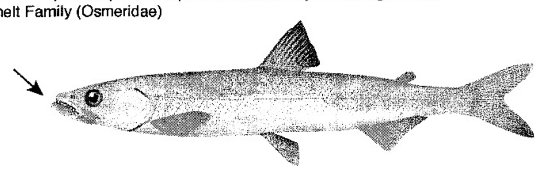
(9)

9a. Small spike on pelvic fin:
Salmon Family (Salmonidae) (10)



9b. No small spike on pelvic fin, prominent teeth in jaws, elongate fish:
Smelt Family (Osmeridae)



Rainbow Smelt
(adults 7-8 inches)

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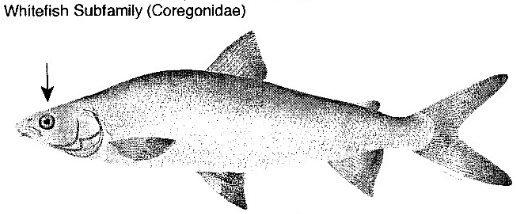
(10)

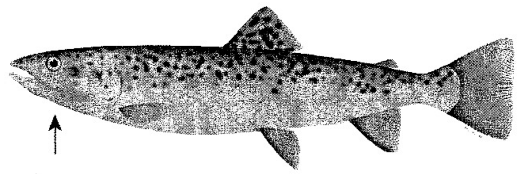
10a. Small mouth, small teeth, jaw not extending past center of eye:
Whitefish Subfamily (Coregonidae)



Shown:
Lake Whitefish
(adults to 15 inches)

Also: Round Whitefish

10b. Large mouth, large teeth, jaw extending past center of eye:
Salmon and Trout Subfamily (Salmonidae)



Shown:
Brown Trout
(adults 16-24 inches)

Also: Coho Salmon
Chinook Salmon
Rainbow Trout
Lake Trout
Brook Trout

---

(11)

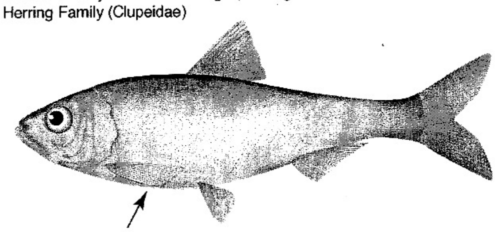
11a. Single dorsal fin
(dorsal fin is single, with no more than one spine) (12)

11b. More than one dorsal fin
(dorsal fin is divided into two distinct parts *or* dorsal fin is single with 4 or more spines) (15)

---

(12)

12a. Midline of belly has saw-like edge (run finger from rear to front so sharp edges can be felt):
Herring Family (Clupeidae)



Shown:
Alewife
(adults 6 inches)

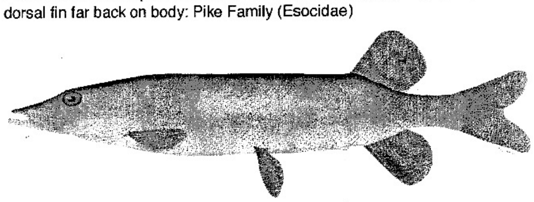
Also: Gizzard Shad

12b. No saw-like edge on belly (13)

---

(13)

13a. Front of head is shaped like a duck's bill, scales on side of head, torpedo-like shape with a single dorsal fin far back on body: Pike Family (Esocidae)

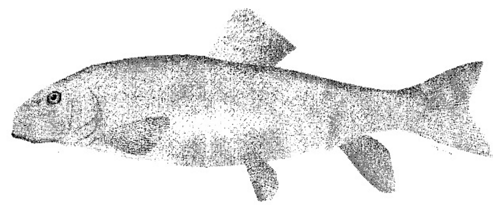


Northern Pike
(adults 2 to 3 feet)

13b. Front of head is not shaped like a duck's bill, no scales on side of head (14)

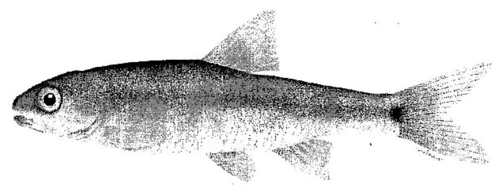
(14)

14a. Mouth points downward, fleshy lips: Sucker Family (Catostomidae)



White Sucker
(adults 12-20 inches)

14b. Mouth points forward: Minnow Family (Cyprinidae)
... see page 13 for a key to the Minnow Family



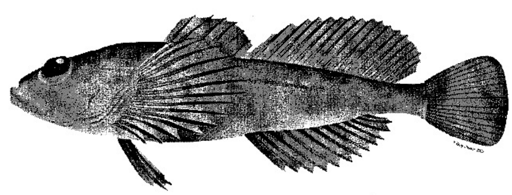
Spottail Shiner
(adults 3-4 inches)

---

(15)

15a. Body covered with scales (16)

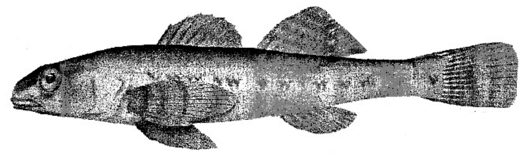
15b. Body has no scales. Large pectoral fins, eyes on top of head: Sculpin Family (Cottidae)
... see page 15 for a key to the Sculpin Family



Shown:
Mottled Sculpin
(adults to 3 inches)

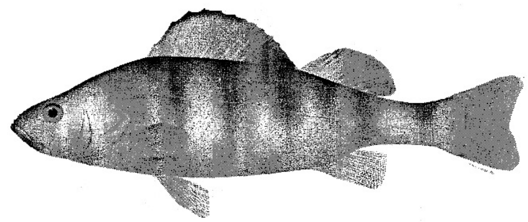
Also: Slimy Sculpin
Spoonhead Sculpin
Deepwater Sculpin

16a. Anal fin has 1 or 2 spines: Perch Family (Percidae)
... see page 10 for a key to the Perch Family



Johnny Darter
(adults to 2.5 inches)
• looks like a row of w's along lateral line

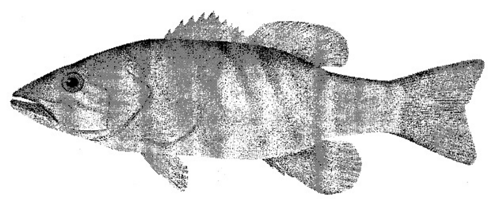
16



Shown:
Yellow Perch
(adults to 15 inches)
• 6 to 8 dark vertical bars on sides

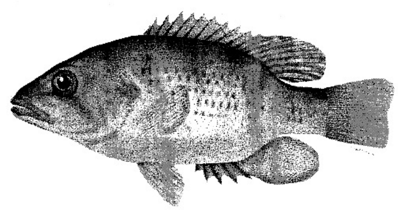
Also: Walleye

16b. Anal fin has 3 or more spines: Sunfish Family (Centrarchidae)
... see page 12 for a key to the Sunfish Family



Shown:
Smallmouth Bass
(adults 8 to 15 inches)

Also: Largemouth Bass

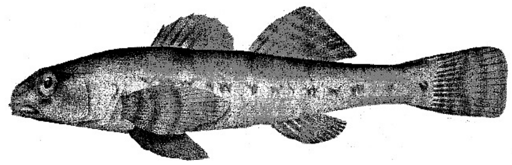


Rock Bass
(adults 8 to 15 inches)

PERCH KEY: FAMILY PERCIDAE

1a. Small mouth does not extend past front edge of eye
Body has brown w-shaped markings on sides

(1)

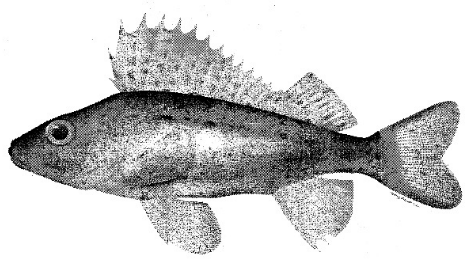


Johnny Darter
(adults to 3 inches)

1b. Large mouth extends to midpoint of eye or beyond
No w-shaped markings on sides (2)

2a. Large continuous dorsal fin
Rows of dark spots between dorsal spines

(2)

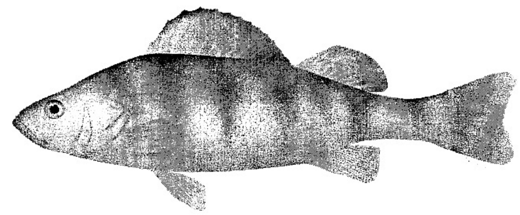


Ruffe
(adults 4-6 inches)

2b. Separate or nearly separate dorsal fins
Dark saddles extend down sides (3)

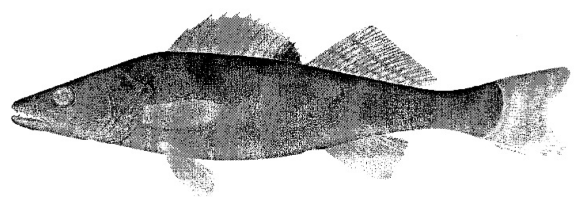
3a. Deep body, no canine teeth and 6-8 anal fin rays

(3)



Yellow Perch
(adults to 15 inches)

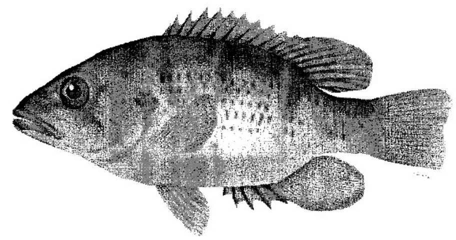
3b. Long slender body, large canine teeth and 11-14 anal fin rays
White tips on anal and caudal fins, opaque silver eye on adults



Walleye
(adults to 36 inches)

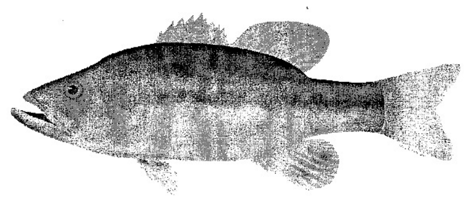
SUNFISH KEY: FAMILY CENTRARCHIDAE

1
- **1a.** 3 anal fin spines (2)
- **1b.** 5-8 anal fin spines, deep body, rows of black/brown spots along side



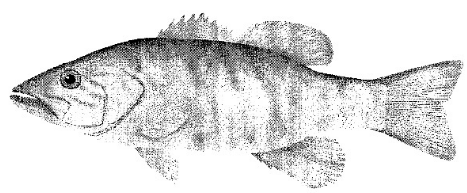
Rock Bass
(adults to 15 inches)

2
- **2a.** Dorsal fin is nearly separated into two, large mouth extends past the eye
Broad black stripe (often broken into blotches) along side



Largemouth Bass
(adults to 38 inches)

- **2b.** Dorsal fin well connected, smaller mouth does not extend far past the eye
No black stripe along side, but series of vertical bars present



Smallmouth Bass
(adults to 27 inches)

MINNOW KEY: FAMILY CYPRINIDAE

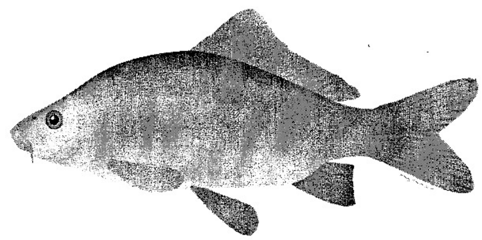
1

1a. Long dorsal fin base (more than 11 soft dorsal rays)
Dorsal and anal fins each have strong spine, large scales — 2

1b. Short dorsal fin base (less than 11 soft dorsal rays)
No spines in dorsal or anal fins — 3

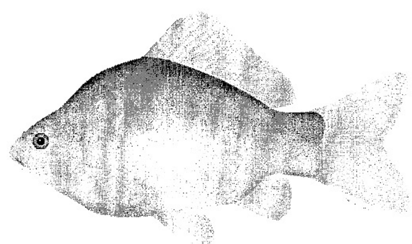
2

2a. Two pairs of long barbels on upper jaw



Common Carp
(adults to 48 inches)

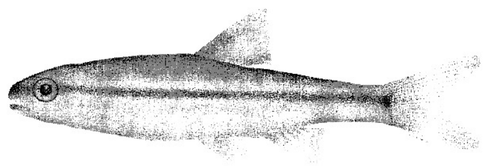
2b. No barbels on upper jaw



Goldfish
(adults to 16 inches)

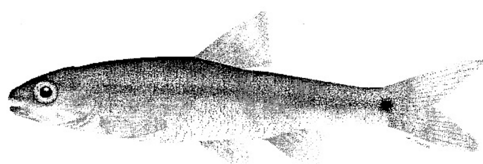
3a. Blunt snout overhangs small mouth
Body is nearly square in cross section with a flat head
Dark strip extends from caudal fin through eye to snout
Dark spot (sometimes faint) at front of dorsal fin
Predorsal scales are small and crowded

3



Bluntnose Minnow
(adults to 2.5 inches)

3b. Short rounded snout, mouth is nearly horizontal
Dark stripe on side does not extend through eye to snout
Large eye and large black spot at base of caudal fin

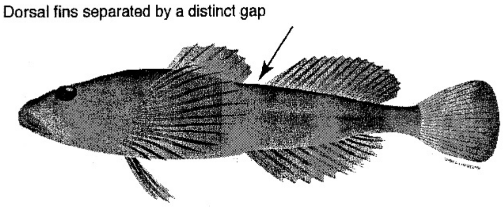


Spottail Shiner
(adults to 3 inches)

SCULPIN KEY: FAMILY COTTIDAE

1a. Dorsal fins separated by a distinct gap

(1)

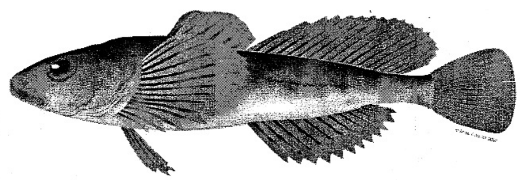


Deepwater Sculpin
(adults to 9 inches)

1b. Dorsal fins not separated by a distinct gap (2)

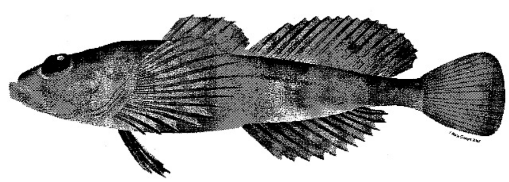
2a. 3 pelvic fin rays

(2)



Slimy Sculpin
(adults to 4.5 inches)

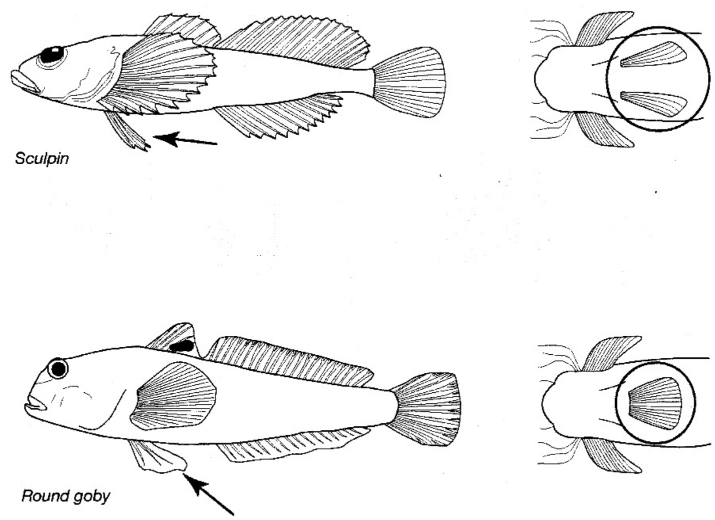
2b. 4 pelvic fin rays



Mottled Sculpin
(adults to 6 inches)

How to Distinguish Between Native Sculpins and Exotic Gobies

To distinguish between sculpins and gobies, use the diagram below. Sculpins have separate pelvic fins, while round gobies have fused pelvic fins (resembling a suction disc).



APPENDIX 7: ISEA zooplankton identification key for zooplankton taxonomy in Grand Traverse Bay and Suttons Bay

water column each day. During daylight hours, these plankton avoid predation by moving below the zone of light penetration (aphotic zone). During the evening hours, they migrate to shallower waters for food.

Different zooplankton emerge at different times of the year. Calanoid and Cyclopoid copepods with eggs are especially abundant in May. Cladocerans such as *Daphnia* and *Bosmina* become more abundant in late May and June as the water warms. Rotifers are more common in the summer and the exotic spiny water flea (*Bythotrephes*) doesn't appear in samples until mid-August. The seasonal succession of zooplankton abundance can be found in the Plankton Station Manual (also on page 103 of this manual).

Bioaccumulation

Bioaccumulation (or bioconcentration) refers to the accumulation of contaminants in the tissues of organisms. Many contaminants are *hydrophobic* (water-hating or lipid-loving). This means they prefer to be in the lipids or fats of an organism rather than in the water, and will partition themselves there. Because these contaminants are lipid soluble and are stored in the lipids of organisms, they are not easily excreted. The risk of toxicological effects to the organism increases as more and more contaminants accumulate in their tissues.

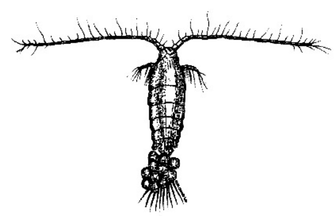
If the compounds are not metabolized as fast as they are consumed, there can be significant accumulation of contaminants in an organism's tissues. Organisms at higher trophic (feeding) levels on food webs tend to have greater concentrations of bioaccumulated contaminants stored in their bodies than those lower on food webs. The increase in the concentration of contaminants in each successive trophic (feeding) level is called *biomagnification* (or biological amplification). he concern about bioaccumulation and biomagnification comes mainly from experience with chlorinated compounds, especially pesticides and PCBs, and their deleterious effects on vulnerable species of birds, frogs, and fish.

Common Zooplankton Found in Grand Traverse Bay

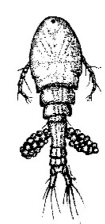
The main groups of zooplankton found in Grand Traverse Bay are: (A) Copepods; (B) Cladocerans; (C) Rotifers; (D) Ostracods, (E) Mysids, and; (F) exotic species.

A. Copepods

1. **Calanoid Copepods**
   - Long antennae (as long as the body)
   - Single egg sac (if present)
   - Eye not visible
   - Numerous caudal setae (hairs) on tail
   - Filter-feeder
   - Example: *Diaptomus* sp.
   - Very common aboard the Schoolship



2. **Cyclopoid Copepods**
   - Short antennae (less than half of the length of the body)
   - Two lateral egg sacs (if present)
   - Single eye
   - Four caudal setae (hairs) on tail
   - Single eye
   - Raptorial feeder
   - Example: *Cyclops* sp.
   - Very common aboard the Schoolship

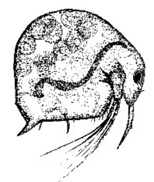


3. **Harpacticoid Copepods**
    - Very short antennae
    - Metasome (head and thorax) and urosome (abdomen and genital segment) are not distincly separate
    - Benthic copepod

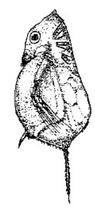
4. **Copepod nauplii**
    - Early life history stage (larval stage) of all copepods
    - Unable to distinguish at this stage which type of copepod
    - Copepod nauplii go through several molts before reaching an "adult-like" stage called a copepodite, which molts several more times before reaching adulthood (adults do not molt)
    - Observed in Schoolship samples in early summer

B. Cladocerans

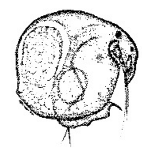
1. ***Bosmina* sp.**
    - Body enclosed in a folded shell or carapace
    - Large first antennae
    - Appears to have a very long beak
    - Two short spines on posterior
    - Often becomes trapped on the surface (surface tension)
    - Filter-feeders
    - Very common aboard the Schoolship



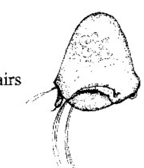
2. ***Daphnia* sp.**
    - Single, long posterior spine
    - Head in the shape of a helmet
    - First antennae small or inconspicuous
    - Diurnal migration in water column
    - Filter-feeders
    - Very common aboard the Schoolship



3. ***Chydorus* sp.**
    - Very spherical or round in appearance
    - Lacks long 'beak' of *Daphnia*
    - Lacks spines on posterior that are evident on *Daphnia*

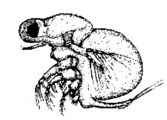


4. ***Holopedium gibberum***
    - Large first antennae that end in 3 long hairs
    - Very humpbacked
    - Gelatinous sheath may cover animal

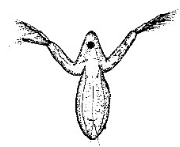


5. ***Leptodora kindtii***
   - Long, transparent body (up to 18 mm.)
   - Carapace does not cover body
   - Very large swimming antennae
   - Legs clearly segmented

6. ***Polyphemus pediculus***
   - Very large compound eye that dominates head
   - Small swiimming antennae
   - Carapace does not cover body
   - Legs clearly segmented



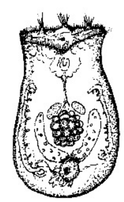
7. ***Diaphanosoma birgei***
   - Rounded head
   - Large second antennae



C. Rotifers

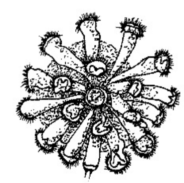
Rotifers are microscopic animals that are transparent and are often mistaken for single-celled animals. Their name comes from the rotating movement of their hair-like projections (cilia) that create a current to bring food into their mouths. Rotifers feed on a variety of things – some feed on algae, some pierce plant stems and suck out the juices, and others are predators. The three common types of rotifers found in the Schoolship samples are *Asplanchna*, *Keratella,* and *Conochilus*. *Asplanchna* looks like a miniature plastic baggy floating through the sample. *Keratella* is much smaller and pointed than *Asplanchna*. *Conochilus* is a colonial rotifer – although it appears to be a single organism, it is actually a collection of tube-like animals joined together by mucus secreted from their tails.

Asplanchna

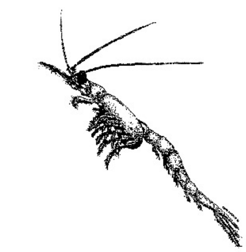


Keratella

Conochilus (colonial)



D. Ostracods
- Body enclosed by two oval shells
- Limbs emerge from shells when swimming
- Head not distinct



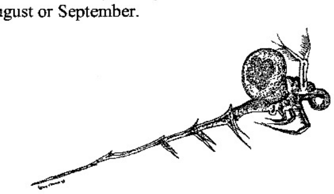
E. Mysids

Mysis relicta

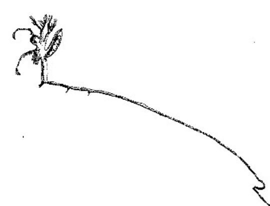
- Shrimp-like appearance
- Obvious segmentation
- Deep water glacial relict
- Very important food source for forage fish and game fish
- Diurnal migrations through the water column
- Although common in Grand Traverse Bay, mysids are rarely found in the zooplankton sample because they are large, proficient swimmers and can more easily avoid the plankton net

F. Exotic Species

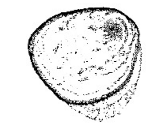
1. ***Bythotrephes cederstroemi* (spiny water flea)**
Bythotrephes cederstroemi, referred to as the spiny water flea, is a carnivorous plankton introduced into the Great Lakes from Europe. This crustacean was most likely brought here in the ballast water of European freighters. *Bythotrephes* has a small head with a large eye filled with black pigment. It also has four pairs of legs, and the first pair is much longer than the others. The most obvious physical feature of *Bythotrephes*, however, is its long, spiny tail. Like other crustaceans, *Bythotrephes* sheds its exoskeleton, but it keeps the portion that covers the tail spine. This means that it is never without its long spiny tail. Scientists believe this fact suggests the tail has an important protective function. Young fish have great difficulty swallowing *Bythotrephes* because of the spine. As a result, *Bythotrephes* are rarely found in the stomachs of fish less than 5 cm. long. *Bythotrephes* are predators of *Daphnia*, rotifers, and other zooplankton. They directly compete with small fish for food. *Bythotrephes* are common in plankton samples aboard the Schoolship in late August or September.



2. ***Cercopagis pengoi* (fish hook water flea)**
Cercopagis pengoi, referred to as the fish hook water flea because its spine hooks at a right angle from its body, was first discovered in the Great Lakes in 1998 (Lake Ontario). It was first discovered in Lake Michigan by the Schoolship in 1999. *Cercopagis* has spread to the Finger Lakes in New York, Grand Traverse Bay, and southern Lake Michigan near Waukegan. Like *Bythotrephes*, *Cercopagis* is thought to have entered the Great Lakes in the ballast water of a ship and feeds upon other zooplankton. *Cercopagis* can reproduce at a very fast rate – in 7-10 days, a female can produce a brood of 8-13 young.



3. **Zebra and Quagga Mussel Veligers**
   - Larval form of the zebra mussel
   - After drifting for 3-4 weeks, they settle onto firm substrates and associate with other zebra mussels in clumps



Note – all illustrations are by:

Balcer, M.D., N.L. Korda, and S. Dodson. 1984. *Zooplankton of the Great Lakes: A Guide to the Identification and Ecology of the Common Crustacean* Species. Reprinted by permission of the University of Wisconsin Press).

Remy Champt (ISEA).

H. REFERENCES

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Reid, G.K. 1987. *Pond Life* (Golden Guide). Golden Press, New York, NY.

<u>Internet sites of interest</u>:

http://www.enchantedlearning.com/subjects/invertebrates/crustacean/Copepod.html (basic copepod biology)

http://www.epa.gov/glnpo/monitoring/data_proj/glenda/species_list/zooplankton_species.pdf (results of EPA's zooplankton sampling)

www.sgnis.org/kids/factsheets.html

http://www.seagrant.umn.edu/exotics/spiny.html (Minnesota Sea Grant)

http://www.epa.gov/glnpo/monitoring/indicators/exotics/cercopagis.html (Environmental Protection Agency)

http://www.zin.ru/projects/invasions/gaas/cerpen.htm

http://www.redpath-staff.mcgill.ca/ricciardi/cercopagis.html

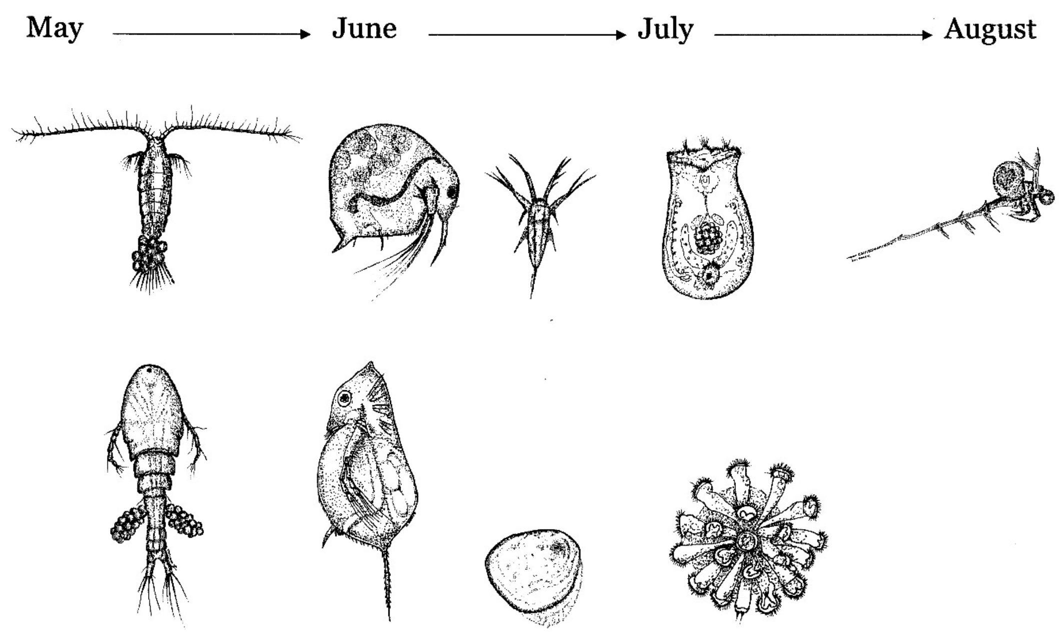
www.glerl.noaa.gov/res/Task_rpts/1994/nsvader10-2.html (changes in the pelagic food web of southern Lake Michigan)

www.miseagrant.umich.edu/ais/zoo/html (aquatic invasive zooplankton)

I. DIAGRAMS & RELEVANT DATA

1. Seasonal succession of zooplankton abundance (page 103)
2. Plankton pronunciation key (page 104)

SEASONAL SUCCESSION OF ZOOPLANKTON ABUNDANCE



APPENDIX 8: ISEA benthos identification key for benthos taxonomy in Grand Traverse Bay and Suttons Bay

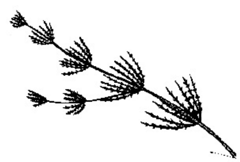
all trophic levels. It is important students recognize benthic organisms as food for fish and "recyclers" of organic material. More information on food webs and feeding relationships is on page xx of this manual.

Students will identify the benthic organisms in this station using the Schoolship plant and benthos keys. The plants and organisms described below are found in these keys. The plant and benthos keys can be found in the Benthos Station manual (also on page 92-93 of this manual).

Plants

Stonewart or the genus *Chara* is a green alga that lies along the lake bottom in nearshore areas. Its stems have whorls of stiff, short branches that are gray-green and often encrusted with lime. This plant thrives in alkaline water. *Chara* is commonly found in Grand Traverse Bay and is our most common plant collected aboard the Schoolship. Other common plants found in our trawl samples are Eurasian Milfoil (*Myriophyllum spicatum*) and Canadian Waterweed (*Elodea canadensis*).

Chara sp.



Whorls of stiff, short branches

Myriophyllum sp.

Feathery looking leaves; whorls of 4

Elodea sp.

Thick leaves; whorls of 3

Benthic Organisms

Non-Segmented Worms

Phylum Platyhelminthes – Free-living Flatworms

Class Turbellaria – **Flatworms & Planarians**

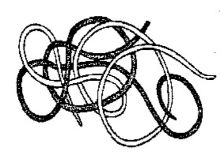
- Flat with a distinct head, eyespots very prominent
- Can be confused with leeches, but do not have suckers
- Gastrovascular cavity noticeable, mouth usually on underside
- Found moving along bottom material
- Feeds upon dead animals

Phylum Nematoda – **Roundworms**

- Length usually less than 1 cm
- Characteristic whip-like motion
- Eats detritus and small plants and animals

Class Nematomorpha – **Gordion Worms**

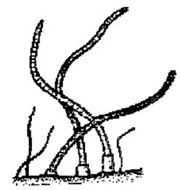
- Rounded, often appear tangled
- Length 10 cm. to 70 cm.
- Slow, clumsy swimmers



Segmented Worms

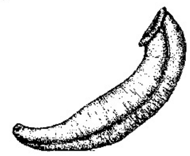
Phylum Annelida – Worms & Leeches

Class Oligochaeta – **Aquatic Earthworms**



- Segmented body
- No legs
- No suckers
- Look similar to terrestrial earthworms

Class Hirudinea – **Leeches**



- Suckers fore and aft
- Feed upon snails, insect larvae, worms and crustaceans
- Scavengers (only a few kinds suck blood)
- Slow, shape-changing movements

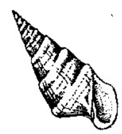
Clams & Snails

Phylum Mollusca – Clams & Snails

Class Gastropoda – **Snails & Limpets**

- Single shell
- Crawls with a fleshy foot
- Host to parasites
- Feeds upon attached algae and dead organisms
- Eaten by fish and ducks

Gilled Snails

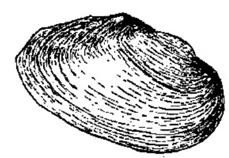


- Have gills
- Have an operculum
- Example – *Pleurocera* sp.

Pulmonate Snails

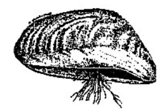
- Have no gills (have "lung" for respiration)
- Have no operculum
- Example – *Physa* sp. or *Helisoma* sp.

Class Bivalvia – **Mussels & Clams**



- 2 shells (bivalves)
- 2 siphons (water in and water out), used to bring in food and oxygen and force out waste
- Most bury themselves in the sediment
- Larvae are parasitic on fish, except for the zebra mussel larva, which is planktonic
- Common small mussels: *Sphaerium* sp. and *Psidium* sp.
- Common large mussel: *Anodonta grandis*

Zebra Mussels (*Dreissena polymorpha*)



- mussel shaped
- striped shell
- often seen clumped together
- exotic species (native to the Caspian Sea)
- triangular-shaped shell
- cover native clams and spawning beds

Quagga Mussels (*Dreissena bugensis*)

- mussel shaped
- dark concentric rings around shell
- rounder shells than zebra mussels
- exotic species (native to the Ukraine)
- inhabit deeper, colder waters than zebra mussels

It can be difficult to distinguish between zebra and quagga mussels. In terms of habitat, quagga mussels prefer deeper, colder waters than zebra mussels, although there is a lot of overlap. Both zebra and quagga mussels are found in the samples taken on the Schoolship. The main differences in physical features are described below.

	Zebra Mussel	**Quagga Mussel**
Shell color	Dark, concentric circles	Dark, concentric circles (white edge near hinge)
Shell shape	Triangular with ridges	Round without ridges
Ventral side	Flattened	Convex
Byssal groove	Large; middle of ventral side	Small, near hinge of ventral side
Depth preference	Shallow	Deep, cool water
Habitat preference	Attach to hard substrate	Attach to hard or soft (sandy) substrate)

More information on zebra and quagga mussels can be found on pages xx of this manual.

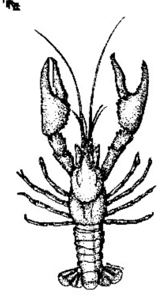
Phylum Arthropoda – Insects, Arachnids, & Crustaceans

Class Arachnida – **Water Mites**

- 8 legs like a spider (larval form has 6 legs)
- No antennae
- Round body, often red or reddish-orange
- Crawls along the bottom or cruises above the bottom
- Feeds upon insects and worms

Class Malacostraca

Order Decapoda – **Crayfishes**

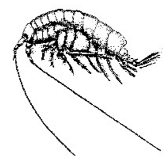


- Hard exoskeleton, carapace covers thorax
- Large pincer claws
- Omnivorous/scavenger
- Food for fish, birds and muskrats
- Generally captured in fish trawl rather than in Ponar dredge

<u>Order Isopoda</u> – **Isopods (aquatic sowbugs)**

- Flattened top-to-bottom
- 7 pairs of legs
- Usually found on vegetation or under rocks and sticks
- Scavengers
- Similar to terrestrial sow bugs or pill bugs
- *Asellus* is a common genus in the Great Lakes

<u>Order Amphipoda</u> – **Amphipods (side-swimmers)**



- Flattened side-to-side
- Lives on the bottom
- Omnivorous, feeds at night
- Food of fish and aquatic insects
- *Diporeia* sp. Common in Great Lakes

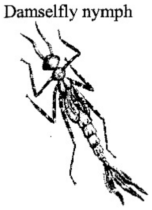
<u>Class Hexapoda</u> – Insects
- Segmented body and jointed legs
- Chitinous exoskeleton, shed as the animal grows
- Metamorphosis
    - Complete: egg → larva → pupa → adult
    - Incomplete: egg → nymph → adult
- Larva is the longest lived stage in most aquatic insects

<u>Order Ephemoroptera</u> – **Mayflies** (nymphs)

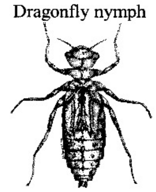
- Nymphs have gills along sides of abdomen
- Three long filamentous/hairlike tails
- Only order of aquatic insects that molts after the nymph stage
- Adults don't eat
- Most lake forms burrow into the sediment
- Presence indicates good water quality

<u>Order Odonata</u> – **Damselflies & Dragonflies** (nymphs)
- Dragonfly nymphs are spider-like, with heavy bodies
- Damselfly nymphs are more slender
- Damselflies have gills at the end of abdomen (three plate-like tails)
- Dragonflies have internal gills in abdomen
- Both damselflies and dragonflies are predators (feed on aquatic insects, worms, crustaceans)
- Dragonfly adults are larger than damselfly adults and hold their wings horizontally outward
- Damselfly adults are more delicate and hold their wings parallel to the body, or tilted upward

Damselfly nymph



Dragonfly nymph



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- 7 pairs of legs
- Usually found on vegetation or under rocks and sticks
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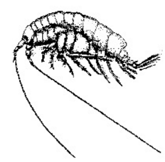
Order Amphipoda – **Amphipods (side-swimmers)**



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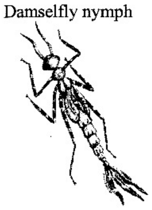
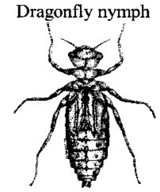
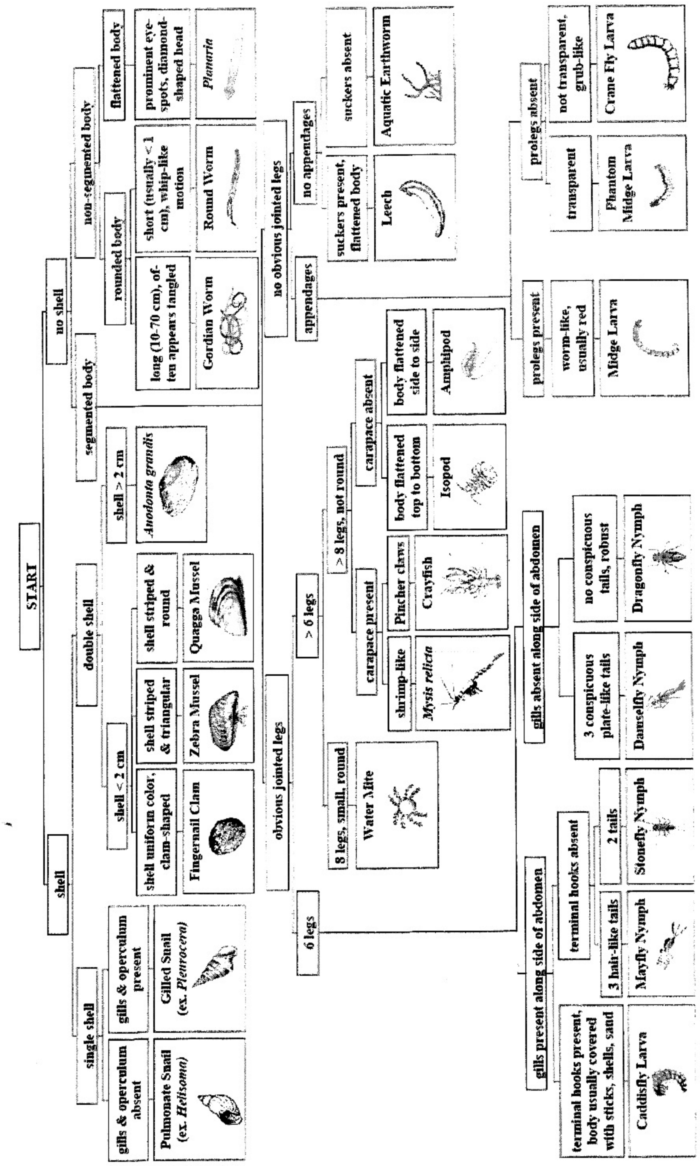
Damselfly nymph



Dragonfly nymph




START
shell
no shell
single shell
double shell
segmented body
non-segmented body
gills & operculum absent
gills & operculum present
Pulmonate Snail (ex. Helisoma)
Gilled Snail (ex. Pleurocera)
shell < 2 cm
shell > 2 cm
shell uniform color, clam-shaped
shell striped & triangular
shell striped & round
Fingernail Clam
Zebra Mussel
Quagga Mussel
Anodonta grandis
rounded body
flattened body
long (10-70 cm), often appears tangled
short (usually < 1 cm), whip-like motion
prominent eye-spots, diamond-shaped head
Gordian Worm
Round Worm
Planaria
obvious jointed legs
no obvious jointed legs
appendages
no appendages
suckers present, flattened body
suckers absent
Leech
Aquatic Earthworm
6 legs
> 6 legs
8 legs, small, round
> 8 legs, not round
Water Mite
carapace present
carapace absent
shrimp-like
Pincher claws
body flattened top to bottom
body flattened side to side
Mysis relicta
Crayfish
Isopod
Amphipod
prolegs present
prolegs absent
worm-like, usually red
transparent
not transparent, grub-like
Midge Larva
Phantom Midge Larva
Crane Fly Larva
gills present along side of abdomen
gills absent along side of abdomen
terminal hooks present, body usually covered with sticks, shells, sand
terminal hooks absent
3 hair-like tails
2 tails
3 conspicuous plate-like tails
no conspicuous tails, robust
Caddisfly Larva
Mayfly Nymph
Stonefly Nymph
Damselfly Nymph
Dragonfly Nymph

APPENDIX 9: Shreier et. al. Academic Research Record-Keeping Best Practices

List 1

Best Practice Principles for Individual Researchers*

Useful (good) research records explain

- what you did,
- when you did it,
- why you did it,
- how you did it,
- who you are (the person creating the record),
- what project(s) it was a part of,
- who thought of it if not you,
- what special materials and instruments you used,
- where you obtained the materials and instruments,
- what happened and what did not happen (data),
- how you manipulated and analyzed the results,
- your interpretation (and the interpretations of others if important), and
- what will be the next steps in the project based on these results.

In addition, good research records

- are legible if handwritten,
- are recorded using reliable materials and tools,
- are well organized (e.g., well labeled, indexed, catalogued, etc.),
- are accurate and complete; they include (1) all original data and important study details (meta-data) and (2) successful and unsuccessful studies and activities,
- describe and date all alterations and changes in records,
- allow repetition of your procedures and studies by yourself and others,
- are accessible (physically and/or electronically) to others both short term and long term,
- are stored and backed-up properly for the short and long term (archiving),
- are witnessed where needed to protect intellectual property rights,
- are in compliance with departmental, institutional, and federal regulatory requirements, with special care given to human and animal research, and
- are the research diaries of the researcher's work and thoughts.

*Researchers may be at any level from student and staff to senior faculty if they are personally performing hands-on research. Research records are defined briefly as recorded information, regardless of media, that is necessary for the reconstruction and evaluation of the research. An individual record element may not need all the above attributes, but the whole record probably does.

Source: This list adopted from Table 11.1 from *Scientific Integrity: An Introduction with Case Studies*, by Francis L. Macrina, ASM Press (2000), with permission.

List 2

Best Practice Principles for Leaders of Research Groups

Research group leaders should

- set standards for record-keeping practices for individuals in their group in areas such as
  (1) research studies/activities within the group (handwritten and electronic notes, data, and other documentation),
  (2) labeling and cataloging of experimental samples, tangible products of research, etc.,
  (3) communications with collaborating researchers, such as letters, e-mails, minutes of meetings (face-to-face or teleconference), etc.,
- provide/assure that group members receive training in record-keeping practices,
- provide motivation by emphasizing the benefits of good records and the problems associated with poor records,
- provide examples of well-maintained records and good record-keeping practices,
- clarify data and research record ownership and access rights,
- perform periodic reviews of the records of the members of your group,
- delegate, as needed, oversight and training duties for group records to senior members of your group and perform periodic checks on the performance of these duties and modify/reassign duties as needed,
- provide the tools (paper-based notebooks or electronic hardware/software),
- establish temporary storage areas for records in use (both paper and electronic) and appropriate backup facilities/methods,
- require adherence to group record-keeping standards by group members,
- promote communication of research information within the group,
- have a plan to assure the transmission of important research information (accessible and understandable records/notebooks) from departing group members,
- require adherence to departmental, institutional, and legal requirements,
- seek to assure the long-term accessibility of records for a set period of time (archiving) after completion of the research, and
- update records standards as needed.

List 3

Departmental and Institutional Best Practices for Research Record-keeping

Department/School Level

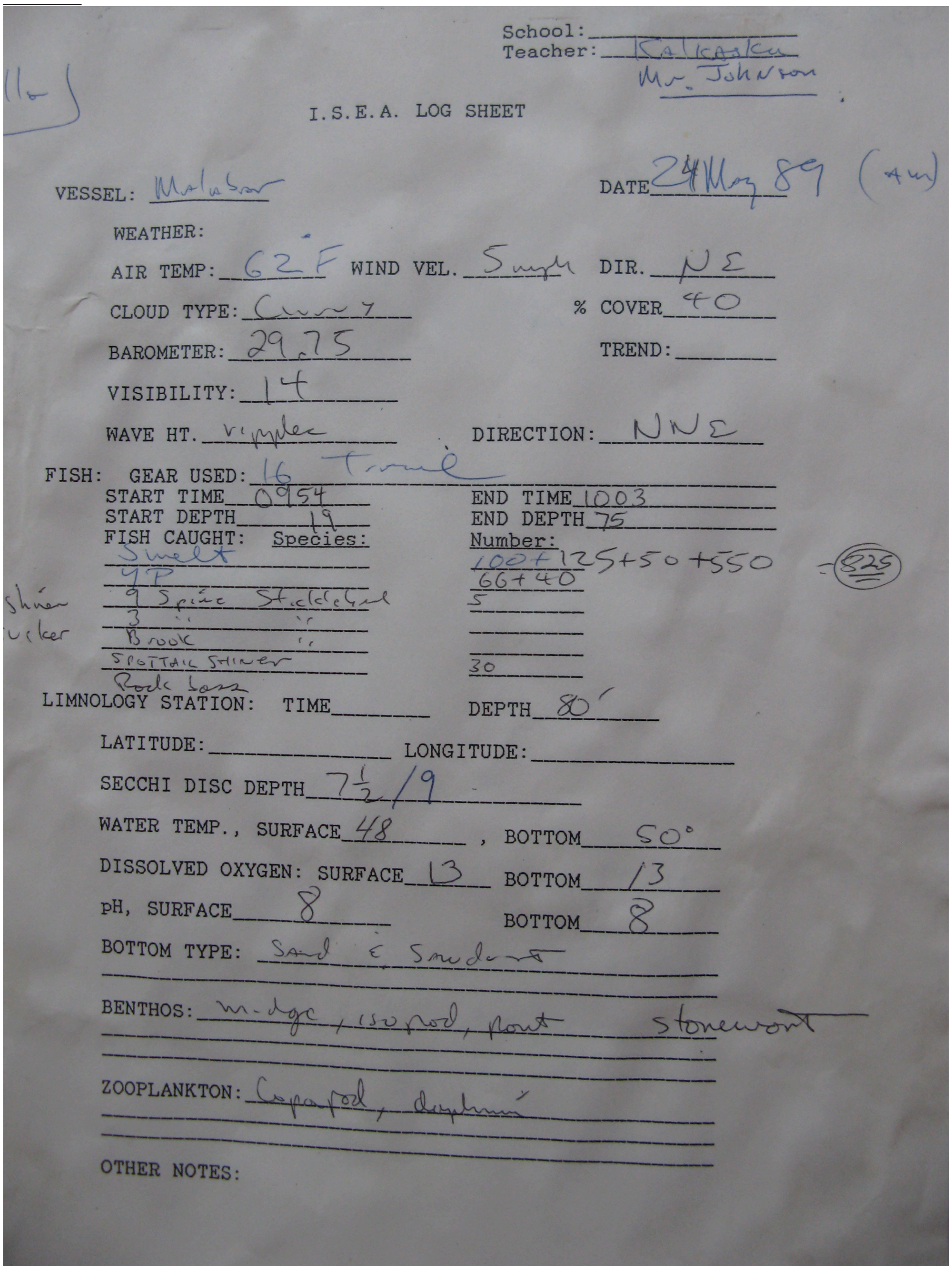
- Make available training/mentoring to faculty (especially new faculty) on research group/lab management skills and practices. Include best practices in scientific record-keeping.
- Encourage faculty members to have a strategy/plan (preferably written) for research record-keeping. The strategy should adopt "individual best practices" to the research group's circumstances and include active mentoring and oversight of trainees and staff.
- Provide record-keeping materials and resources if possible (e.g., research journals, lab notebooks, specialized software, bar-coding equipment, dedicated servers [computers] for storing electronic records.

University Level

- Provide clear policies on research record ownership, access, retention, transfer, and destruction. What constitutes research records should be clearly defined and should include paper, electronic, and tangible forms of research information.
- Provide Institutional facilities for archiving records (all media). Many institutions already have this service through their university libraries.
- To help assert university ownership of research records, provide record-keeping materials for the departments/units to distribute (e.g., research journals, lab notebooks, specialized software, dedicated servers [computers] for storing electronic records).
- Provide resources to help departments/units provide training in research record-keeping (e.g., training materials, examples of good records and practices, a Web-based tutorial in record-keeping practices).
- Provide resources to help assure the long-term accessibility of electronic records (i.e., help protect against hardware/software obsolescence and availability issues for older data and records).

APPENDIX 10: ISEA Data Recording Sheet Examples

1989



School: Kalkaska
Teacher: Mr. Johnson

I.S.E.A. LOG SHEET

VESSEL: Malabar
DATE 24 May 89 (am)

WEATHER:

AIR TEMP: 62°F WIND VEL. 5 mph DIR. NE

CLOUD TYPE: Cirrus % COVER 40

BAROMETER: 29.75 TREND:

VISIBILITY: 14

WAVE HT. ripples DIRECTION: NNE

FISH: GEAR USED: 16 Trawl

START TIME 0954 END TIME 1003

START DEPTH 19 END DEPTH 75

FISH CAUGHT: Species: Number:

Species	Number
Smelt	100+125+50+550 = 825
YP	66+40
9 Spine Stickleback	5
3 " "	
Brook "	
Spottail Shiner	30
Rock bass	

shiner
sucker

LIMNOLOGY STATION: TIME DEPTH 80'

LATITUDE: LONGITUDE:

SECCHI DISC DEPTH $7\frac{1}{2}$/9

WATER TEMP., SURFACE 48, BOTTOM 50°

DISSOLVED OXYGEN: SURFACE 13 BOTTOM 13

pH, SURFACE 8 BOTTOM 8

BOTTOM TYPE: Sand & Sawdust

BENTHOS: midge, isopod, plant stonewort

ZOOPLANKTON: Copepod, daphnia

OTHER NOTES:

1999

1999 SCHOOLSHIP SCIENCE LOG - DAILY FIELD SHEET 16

DATE 5 /17 /99	SHIP S/V INLAND SEAS
GROUP Kalkaska	PARTICIPANTS
LOCATION GTBay, SUTTONS BAY	LATITUDE N 44 ° 58.85
RECORDER MKM	LONGITUDE W 85 ° 37.92

>30´ z

FISH

Time in	0858	Time out	0909	Elapsed Time	11 min.
Start Depth	55 ft.	End Depth	55 ft.	Surf. Water Temp.	°C/ F

Species	No.	Species	No.
Threespine Stickleback	9	Mottled Sculpin	3
Brook Stickleback	9	White Sucker	2
Ninespine Stickleback	12	Rainbow Smelt	3
Rock Bass	1		
Johnny Darter	2	Crayfish	6

WEATHER

TIME	0918	% CLOUD COVER	95+ %
AIR TEMP	16.5 ° C/F	VISIBILITY	6-15 Statute Miles
BARO. PRESS.	"	WAVE HEIGHT	½" Feet
TREND	Rise/Steady/Fall	REL. HUMIDITY	— %
WIND DIRECT.	SW	DEW POINT	— °C/F
WIND SPEED	2 Knots/mph	PRECIPITATION	—
CLOUDS	nimbostratus, altostratus	% CLOUD COVER	%

LIMNOLOGY

TIME	0918	BOTTOM TEMP.	8 °C/F
STA. DEPTH	69 → 30 Ft.	BOTTOM pH	8
SAMPLE DEPTH	? Ft.	BOTTOM D. O.	11.5 mg/l
SECCHI DISK	12 m	D.O. SATURATION	— %
SURFACE TEMP.	10.8 °C/F	NOTES	—

boat was drifting

SAMPLE DEPTH____Ft **ZOOPLANKTON** Gear: 153u mesh, 20" dia.

Type	Abundance*	Type	Abund.
Rotifers	M		
Cyclops			

*Most, Common, Rare, Present

SEDIMENT/BENTHOS

GEAR Petite Ponar ✓	No. of SAMPLES 2 (hove to)
TEXTURE silty sand	COLOR dark gray

Organism	No.	Organism	No.
Midge Larvae			
		z=65´	

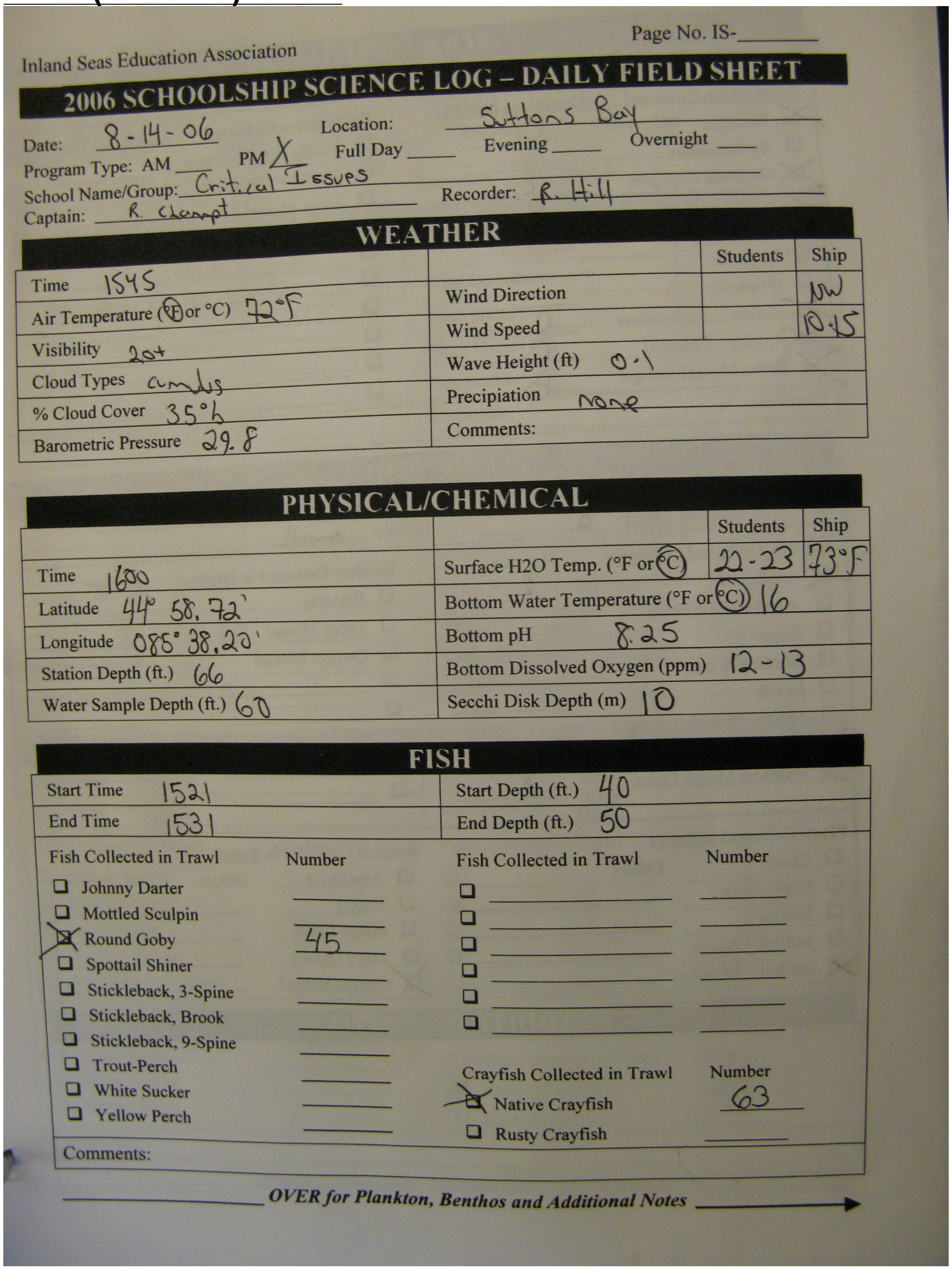
FROM TRAWL- PLANTS

Chara		

PLANT EPI-BENTHOS-Organism	Abun.	Organism	Abun.
Zebra Mussel		Gastropods	
Chironomids		Caddisfly	1
Amphipods			
Isopods			

MORE NOTES ON BACK: Y/N SCILOG99.DOC

2006 (Present) Front



Page No. IS-________

Inland Seas Education Association

2006 SCHOOLSHIP SCIENCE LOG – DAILY FIELD SHEET

Date: 8-14-06 Location: Suttons Bay

Program Type: AM ____ PM X Full Day ____ Evening ____ Overnight ____

School Name/Group: Critical Issues

Captain: R. Champt Recorder: R. Hill

WEATHER

			Students	Ship
Time	1545	Wind Direction		NW
Air Temperature (°F or °C)	72°F	Wind Speed		10-15
Visibility	20+	Wave Height (ft)	0-1	
Cloud Types	cumulus	Precipiation	none	
% Cloud Cover	35%	Comments:		
Barometric Pressure	29.8			

PHYSICAL/CHEMICAL

			Students	Ship
Time	1600	Surface H2O Temp. (°F or °C)	22-23	73°F
Latitude	44° 58.72'	Bottom Water Temperature (°F or °C)	16	
Longitude	085° 38.20'	Bottom pH	8.25	
Station Depth (ft.)	66	Bottom Dissolved Oxygen (ppm)	12-13	
Water Sample Depth (ft.)	60	Secchi Disk Depth (m)	10	

FISH

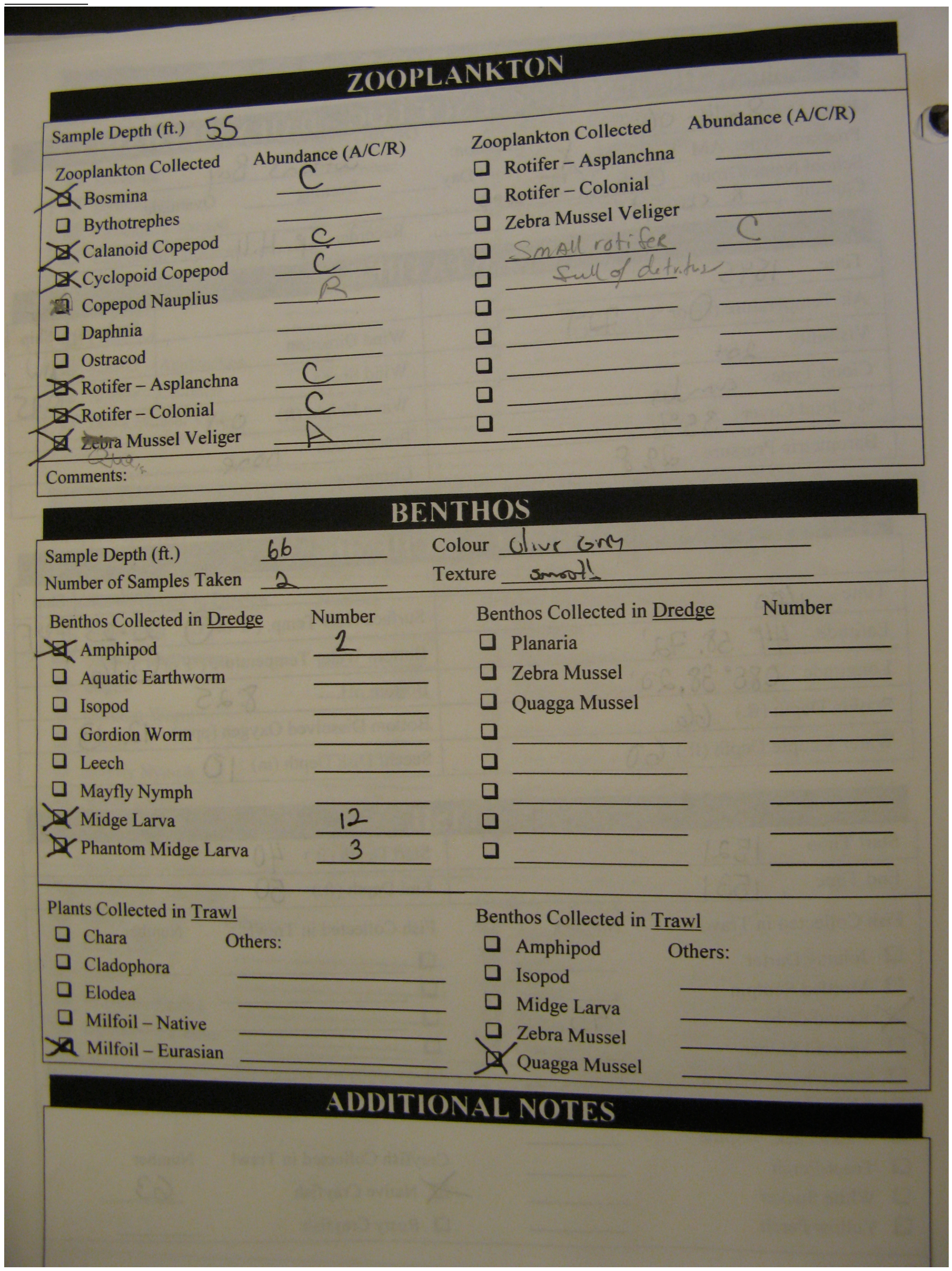
Start Time	1521	Start Depth (ft.)	40
End Time	1531	End Depth (ft.)	50

Fish Collected in Trawl	Number	Fish Collected in Trawl	Number
☐ Johnny Darter		☐	
☐ Mottled Sculpin		☐	
☒ Round Goby	45	☐	
☐ Spottail Shiner		☐	
☐ Stickleback, 3-Spine		☐	
☐ Stickleback, Brook		☐	
☐ Stickleback, 9-Spine			
☐ Trout-Perch		**Crayfish Collected in Trawl**	**Number**
☐ White Sucker		☒ Native Crayfish	63
☐ Yellow Perch		☐ Rusty Crayfish	

Comments:

OVER for Plankton, Benthos and Additional Notes →

Back



ZOOPLANKTON

Sample Depth (ft.) 55

Zooplankton Collected	Abundance (A/C/R)	Zooplankton Collected	Abundance (A/C/R)
☒ Bosmina	C	☐ Rotifer – Asplanchna	
☐ Bythotrephes		☐ Rotifer – Colonial	
☒ Calanoid Copepod	C	☐ Zebra Mussel Veliger	
☒ Cyclopoid Copepod	C	☐ Small rotifer	C
☒ Copepod Nauplius	R	☐ full of detritus	
☐ Daphnia		☐	
☐ Ostracod		☐	
☒ Rotifer – Asplanchna	C	☐	
☒ Rotifer – Colonial	C	☐	
☒ ~~Zebra~~ Quagga Mussel Veliger	A	☐	

Comments:

BENTHOS

Sample Depth (ft.) 66 Colour olive grey

Number of Samples Taken 2 Texture smooth

Benthos Collected in Dredge	Number	Benthos Collected in Dredge	Number
☒ Amphipod	2	☐ Planaria	
☐ Aquatic Earthworm		☐ Zebra Mussel	
☐ Isopod		☐ Quagga Mussel	
☐ Gordion Worm		☐	
☐ Leech		☐	
☐ Mayfly Nymph		☐	
☒ Midge Larva	12	☐	
☒ Phantom Midge Larva	3	☐	

Plants Collected in Trawl	Others:	Benthos Collected in Trawl	Others:
☐ Chara		☐ Amphipod	
☐ Cladophora		☐ Isopod	
☐ Elodea		☐ Midge Larva	
☐ Milfoil – Native		☐ Zebra Mussel	
☒ Milfoil – Eurasian		☒ Quagga Mussel	

ADDITIONAL NOTES