INVASIVE SPECIES IMPACTS ON ECOSYSTEM STRUCTURE AND FUNCTION

By

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ABSTRACT

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Exotic species invasion is a worldwide threat to the integrity of aquatic ecosystems. To understand ecosystem level response to the introduction of exotic species, I compared food web characteristics of two eutrophic Great Lakes ecosystems - the Bay of Quinte, Lake Ontario, Canada, and Oneida Lake, New York, USA - before and after zebra mussel (*Dreissena polymorpha*) invasion using ecological network analysis (ENA) and a social network analysis method, cohesion analysis (CA). ENA quantifies ecosystem function through an analysis of food web transfers, while CA assesses ecosystem structure by organizing food web members into subgroups of strongly interacting predators and prey. In Oneida Lake and the Bay of Quinte, zebra mussel invasion increased food web organization and the potential for system development. Additionally, zebra mussel invasion stimulated benthic production in both systems. Effects on food web structure were strongest in the Bay of Quinte where zebra mussel invasion removed subgroup structure entirely. In Oneida Lake, over 33% of taxa changed subgroup association after invasion, with benthically associated subgroups gaining the most members. This analysis suggested that the effects of zebra mussel introduction are similar in ecosystems of comparable trophic status and that future invasions of eutrophic systems could have similar impacts on ecosystem structure and function.

Dedicated to the memory of

Beryl Timmer

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This research was linked with another food web modeling effort to understand the effects of zebra mussel invasion on Oneida Lake and the Bay of Quinte. The Bay of Quinte – Oneida Lake Comparative Modelling Project Workgroup, a group composed of many respected scientists including Dr. E. Scott Millard, P.I. (DFO-GLLFAS), Dr. Edward L. Mills, P.I. (Cornell University), and Dr. Marten Koops (DFO-GLLFAS), provided extensive data and guidance. Additionally, Dr. Mills and the staff at the Cornell

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CHAPTER 1

A Prologue and Context to Understanding Invasive Species Impacts on Ecosystems

Andrea L. Jaeger

Aquatic ecosystems worldwide are in the midst of large-scale ecological alteration, including exotic species invasion (Mills et al. 1994; Holeck et al. 2004), fisheries collapse (Pauly et al. 1998; Myers 2003), trophic uncoupling from global climate change (Winder and Schindler 2004), and rapid loss of native biodiversity (Dunne et al. 2002). Exotic species invasion, in particular, is one of the most insidious anthropogenic influences on ecosystems (Mills et al. 1994) and is the most significant worldwide threat to native biota (Hall and Mills 2000). The Laurentian Great Lakes of North America have experienced pronounced invasion pressure for centuries. Exotic species introductions have been documented since the early 1800s (Mills et al. 1993) and number over 170 for recognized invaders (Holeck et al. 2004).[1] Many more species threaten introduction into the Great Lakes, but have yet to become established.

The numerous invasions in the Great Lakes have greatly affected ecosystem integrity (Mills et al. 1994), structure, and function (Vanderploeg et al. 2002), causing substantial economic hardship through damaging highly valued commercial and recreational fisheries and municipal structures (Mills et al. 1994; Facon et al. 2005). The extent and frequency of these disturbances make management of Great Lakes ecosystems challenging. To address these types of challenges, some researchers (e.g. Christensen et

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[1] In this context, we define exotic species as non-indigenous flora and fauna which have successfully established reproducing populations (Mills et al. 1993).

al. 1996; Pauly 2002) advocate an ecosystem management approach. Christensen et al. (1996) define ecosystem management as “management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function.” Many policy makers and managers have embraced this paradigm shift from historical single-species management to ecosystem management. As of 1994, at least 18 Federal agencies committed to ecosystem management (Congressional Research Service 1994) and that number has surely risen in the past decade. However, understanding ecosystem structure and function – which is fundamental to ecosystem management – is a formidable task due to the complexity of ecosystem processes (Gaedke 1995). If we do not have a clear depiction of ecosystem structure and function, then we have no goal for which to manage. Moreover, ecosystems are dynamic, undergoing both natural and anthropogenic change (e.g., exotic species invasion) that can impact ecosystem processes on a continual basis. To meet the goals of ecosystem management, we first need an understanding of ecosystem structure and function, inclusive of ongoing ecological change.

In this research, I used a suite of methods collectively termed network analysis to examine the effects of exotic species invasion on food webs in the Great Lakes basin. Network analysis has wide applicability across disciplines, including ecology, engineering, economics (Ulanowicz 1986), and sociology (Johnson et al. 2001). In the context of ecology, network analysis depicts food webs as networks of exchange and evaluates the efficiency of energy and material flow. On a more comprehensive scale, network analysis examines the development of ecosystems and can be used to study ecosystem change. Network analysis differs from traditional food web analysis by incorporating weighted flows between taxa, as opposed to simply using flow presence or absence data. As such, network analysis allows for a more realistic depiction of food web flow and better understanding of ecosystem processes (Gaedke 1995). Moreover, network analysis offers an objective means to articulate the structure and function of ecosystems.

To evaluate structure and function, I used two network analysis methods: ecological network analysis (ENA), which quantified ecosystem function, and a social network analysis method, cohesion analysis (CA), which quantified structure. Food web structure encompasses the components of ecosystems, including food web taxa and the arrangement of interactions between them, whereas function incorporates the flux processes in food webs, such as production, consumption, and respiration (Stevenson et al. 1996). ENA quantifies function through an analysis of the efficiency of flow between predators and prey, trophic levels, and cumulatively across the entire food web (Ulanowicz 1986). The efficiency of flow corresponds to ecosystem development such that highly developed (mature), stable ecosystems sustain greater flow efficiency than lesser developed or perturbed ecosystems (Ulanowicz 1986). CA quantifies structure by organizing the food web into subgroups of strongly interacting predators and prey (Krause et al. 2003). Subgroup structure is theorized to increase the stability of food webs and buffer ecosystems from perturbation (Krause et al. 2003). In this research, I applied ENA and CA methodologies to understand how exotic species invasion (as an ecosystem perturbation) affects the functional and structural attributes of food webs.

One of the best studied exotic species in the Great Lakes basin is zebra mussels (*Dreissena polymorpha*). Zebra mussels are part of a recent wave of invaders from the Ponto-Caspian region of eastern Europe and Russia. Zebra mussels pose a considerable threat to the Great Lakes through engineering ecosystems (Vanderploeg et al. 2002) and facilitating the establishment of other Ponto-Caspian species (Ricciardi 2001). Zebra mussel impacts have been far-reaching in the Great Lakes, affecting habitat structure, nutrient dynamics, and all trophic levels (Mills et al. 2003). With this research, I examined the effects of zebra mussel invasion in Oneida Lake, New York, USA, and the Bay of Quinte, Lake Ontario, Canada, two eutrophic ecosystems in the Great Lakes watershed. Both systems are valuable recreationally to their surrounding areas and sustain economically important walleye (*Sander vitreus*) and yellow perch (*Perca flavescens*) fisheries which have declined in recent years (Rudstam et al. 2004; Mills et al. 2003). Zebra mussels were discovered in 1991 in Oneida Lake and were established throughout the ecosystem by 1992 (Mayer et al. 2000); zebra mussels colonized the Bay of Quinte in 1993-1994, but were not established until 1995 (Nicholls et al. 2002). The ecology of both systems has been studied since the mid-1900s, making Oneida Lake and the Bay of Quinte ideal systems in which to examine ecological change. Finally, to facilitate this research, I collaborated with researchers in the Bay of Quinte – Oneida Lake Comparative Modelling Project Workgroup who built dynamic simulation models to examine the effects of zebra mussel introduction on these systems.

Our network analysis of Oneida Lake and the Bay of Quinte was guided by three research objectives: 1) quantify zebra mussel impacts on food web subgroup structure; 2) quantify zebra mussel effects on ecosystem function at the full food web and subgroup level; and 3) compare results between Oneida Lake and the Bay of Quinte, assessing whether ecosystems of comparable trophic status respond similarly to zebra mussel invasion. Chapter 2 addresses objectives 1 and 2 in Oneida Lake; Chapter 3 focuses on objectives 1 and 2 for the Bay of Quinte, and concludes with a comparison between Oneida Lake and the Bay of Quinte, addressing objective 3. With this analysis, I tested the hypothesis that zebra mussel invasion led to the benthification of Oneida Lake and the Bay of Quinte. Mills et al. (2003) define benthification as a shift of importance from pelagic to benthic processes promoting bottom-dwelling organisms and benthic sources of production. These changes not only have implications for how these ecosystems should be managed (e.g., for pelagic versus benthic fisheries), but also the prediction of zebra mussel impacts in other systems.

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CHAPTER TWO

Invasive Species Impacts on Ecosystem Structure and Function: A Comparison of Oneida Lake, USA, Before and After Zebra Mussel Invasion

Andrea L. Jaeger, Doran M. Mason, Ann E. Krause, Kenneth A. Frank, William W. Taylor, and Scott D. Peacor

Abstract

Exotic species invasion is one of the greatest ecological restructuring forces. To understand impacts of exotic species on ecosystem level properties, we compared Oneida Lake, New York, USA, food web characteristics before and after zebra mussel (*Dreissena polymorpha*) invasion using ecological network analysis (ENA) and social network analysis (SNA) methods. ENA quantifies ecosystem function through an analysis of food web energy and material transfer. The SNA method we used, cohesion analysis, assesses ecosystem structure by organizing food web members into subgroups of strongly interacting predators and prey. These methods detected direct and indirect effects, changes in trophic flow efficiency, and alterations of food web organization and ecosystem activity resulting from zebra mussel invasion. ENA indicated that zebra mussels altered food web function by shunting energy from pelagic to benthic pathways, increasing dissipative flow loss, and decreasing ecosystem growth. SNA suggested that zebra mussels altered food web structure by reorganizing carbon flow within and between discrete subgroups of predators and prey and also increasing the importance of

benthically associated subgroups. Together, these analyses demonstrate that zebra mussels exert strong influence on food webs and promote the benthification of aquatic ecosystems.

Introduction

Globally, exotic species invasion is one of the greatest restructuring forces to ecosystems (Baxter et al. 2004). Non-native species can impact ecosystems through competition with and predation on native species, and by altering habitats, nutrient cycles, and energy budgets (Mack et al. 2000). Invasions can occur across all trophic levels with effects propagating throughout entire ecosystems via direct and indirect pathways (Crooks 2002). In recent years, vertebrate and invertebrate species from the Ponto-Caspian region of eastern Europe have exerted pronounced invasion pressure in North America, Europe, and Russia (Drake and Bossenbroek 2004). Among the most recognized Ponto-Caspian invertebrate invaders in North America are two species of mussels, the zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels. These invaders exhibit wide environmental tolerances and high phenotypic variability (Reid and Orlova 2002) which make them adaptable to many different ecosystems and thus helps facilitate their invasion into non-native food webs.

Dreissenid mussels pose a considerable threat to aquatic environments by altering food web structure and function (Jones et al. 1994; Vanderploeg et al. 2002). Zebra mussels increase water clarity through filtration (Idrisi et al. 2001) and shunt energy from pelagic to benthic pathways (Rutherford et al. 1999; Mayer et al. 2002). Additionally, dreissenid mussels can affect zooplankton production and abundance through decreasing pelagic primary production and changing nutrient cycling in lakes (Mellina et al. 1995; Johannsson et al. 2000) and rivers (Strayer et al. 1999; Thorp and Casper 2003). Also, dreissenid mussels may facilitate macroinvertebrates, such as amphipod and isopod species, in the Laurentian Great Lakes through pseudofeces deposition which can be used as a food resource (Beekey et al. 2004). Yet, the abundance of some macroinvertebrate species, such as *Diporeia* spp., has precipitously declined in correlation with the invasion and expansion of dreissenids (Nalepa et al. 2000).

Dreissenid invasions may also affect fish communities, although the causal linkages are difficult to establish in some systems. Dreissenids may affect fish recruitment and production through modification or degradation of spawning habitat (Stewart et al. 1999; Marsden and Chotkowski 2001). Additionally, some Great Lakes fishes, such as lake whitefish (*Coregonus clupeaformis*), exhibit decreased body condition and growth potentially due to a diet shift away from high-energy prey, such as *Diporeia*, to the lower-energy dreissenid mussels (Pothoven et al. 2001). Dreissenid impacts on yellow perch (*Perca flavescens*) vary by life stage and ecosystem. For example in Lake Michigan, zebra mussels may have adversely affected larval yellow perch by decreasing zooplankton food resources (Dettmers et al. 2003). Conversely in some inland lakes, zebra mussels have not noticeably affected young yellow perch growth, biomass, or production (Mayer et al. 2000, Idrisi et al. 2001) and may indirectly benefit adult yellow perch and lake sturgeon (*Acipenser fulvescens*) through enhanced benthic invertebrate production (Rutherford et al. 1999; Jackson et al. 2002). Centrarchid fish can also benefit indirectly by zebra mussel facilitation of macrophyte production which serves as habitat (Strayer et al. 2004).

The uncertainty within systems and confounding results of dreissenid impacts between systems highlight the complexities associated with understanding ecosystem level response to invaders. Integrated and quantitative approaches, such as network analyses, offer innovative methods to disentangle the complexities of ecosystems. For network analysis, food webs are depicted as networks of exchange by quantifying (i.e., weighting) feeding interactions and energy flow (Bondavalli et al. 2000). The ability to quantify trophic interactions can contribute significantly to food web analysis (Gaedke 1995; Zorach and Ulanowicz 2003; Krause et al. 2003). Much of the early work conducted on food webs used unweighted flows, frequently over-simplifying or misrepresenting flux processes: the role of minor contributors was exaggerated while the role of major contributors was diminished. By quantifying flows, researchers tease apart these unequal contributions to provide a clearer depiction of food web energy and material transfer, and allow a better understanding of how interactions are transmitted through ecosystems.

Moreover, network analyses are applicable at the whole-system level. By quantifying interactions throughout the entire ecosystem, insight into processes not evident at small-scale resolutions may be gained (Heymans et al. 2002). Bailey et al. (1999) suggested that small-scale impacts may aggregate synergistically and these overall impacts may only be visible when viewed at the ecosystem level. As such, network analysis has proven useful for examining the effects of fisheries harvest (Pauly et al. 1998), fisheries stocking (Fayram et al. *In press*), and nutrient loading (Bondavalli et al. *In press*) on ecosystems, while having implications for managing carbon emissions (Bondavalli et al. 2000) and habitat for endangered species (Heymans et al. 2002). By taking into account entire ecosystems, the use of network analysis in these studies allowed an understanding – distinct from, but complementary to, single-species, species-pair or similar studies – of how changes percolated through entire food webs, including indirect pathways. Moreover, network analysis can give insight into causality between events, not just correlation. The causality aspect makes network analysis a valuable tool for clarifying the effects of ecosystem perturbation, including exotic species invasion. In light of the equivocal effects of dreissenid invasion described above, we seek to elucidate dreissenid impacts at the ecosystem scale using network analysis.

Numerous data exist describing the qualitative effects of dreissenid mussels, especially zebra mussels; however, less literature quantifies these effects at the ecosystem scale, specifically with regard to ecosystem structure and function. Ecosystem structure encompasses the components of a food web, whereas ecosystem function refers to the processes that occur within food webs (Stevenson et al. 1996). Structural characteristics include measurements of system state, such as biomass and taxonomic composition; whereas, functional characteristics deal with rates of change in a system state, including measurements of productivity and respiration (Stevenson et al. 1996). Mills et al. (2003) documented changes in Lake Ontario structure and function after zebra mussel invasion and coined the term “benthification” to encompass these changes. Benthification refers to a shift of importance from pelagic processes to benthic processes, entailing a change in energy flow “favoring colonization of bottom-dwelling organisms, promoting fish communities that make efficient use of the benthic habitat, and enhancing growth rate cycles of benthic algae and submersed aquatic vegetation”. Using Mills et al. (2003) attributes of ecosystem benthification, we examined ecosystem properties of a eutrophic lake, Oneida Lake, New York, USA, to determine if benthification occurred as a result of zebra mussel invasion.

The primary objective of this paper was to quantify zebra mussel impacts on ecosystem structure and function in Oneida Lake, specifically by addressing the following questions:

1. Structure: Do zebra mussels alter the membership of food webs and food web subgroups (defined as clusters of strongly interacting predators and prey)?
2. Function: Does the magnitude of carbon flow within food webs and food web subgroups change as a result of zebra mussel invasion?

Using food web network analysis, we hypothesized that zebra mussels led to the benthification of Oneida Lake with concomitant changes in ecosystem structure and function that promoted benthic communities.

Methods

Study Site

Oneida Lake is a shallow, eutrophic, 207 km^2 lake on the Ontario Lake Plain in central New York with a mean depth of 6.8 m and maximum depth of 16.8 m (Jackson et al. 2002; Rudstam et al. 2004). The lake freezes in winter and mixes continuously during summer except for brief periods of thermal stratification during calm weather (Hansen and Hairston 1998). Oneida Lake supports a valuable warmwater recreational fishery for walleye (*Sander vitreus*) and yellow perch, in addition to multiple other species (VanDeValk et al. 2002). Zebra mussels were discovered in 1991 and were established throughout the ecosystem by 1992 (Mayer et al. 2000). Because of the long-term history of limnological and fishery research on Oneida Lake (e.g., Mills et al. 1978; Mills and Forney 1988), data exist throughout the various stages of invasion - from pre-introduction, to invasion, through establishment, and finally reorganization and accommodation of the ecosystem – to examine the effects of zebra mussel invasion.

Network Construction

We constructed weighted food web networks before and after zebra mussel invasion and analyzed the networks using ecological network analysis (ENA) (Ulanowicz 1986) and a social network analysis (SNA) method, cohesion analysis (CA) (Frank 1995; Krause et al. 2003). We defined the years 1986 to 1991 as the pre-zebra mussel invasion time stanza and the years 1992 to 2002 as the post-zebra mussel invasion time stanza. To construct the networks, we first identified the taxa in the ecosystem (including full-year resident taxa as well as transient taxa), and then quantified material exchange (flows) between taxa and with the environment (we adjusted flows for transient taxa based on duration in the ecosystem). For taxa identification, we attempted to be as thorough as possible and included all species from Oneida Lake for which data were available. Taxonomic resolution affects the study of food webs and lumping organisms into aggregate groups may decrease the ability to detect differences in strengths of connections between functionally different organisms (Abarca-Arenas and Ulanowicz 2002; Krause et al. 2003; Pinnegar et al. 2005). Therefore, wherever possible, we used species level data to avoid information loss and in some cases, e.g., walleye, yellow perch, and seven other fish taxa, species data was sub-divided by life stage. However, in some cases, data limitations forced aggregation of taxa (e.g., age-0 panfish). In some of these situations, we aggregated by “trophospecies”, a collection of species in a food web that share similar predators and prey (Yodzis and Winemiller 1999). This aggregation method is a fundamental unit of study in food web and ecosystem research (Yodzis and Winemiller 1999) and is widely used in food web analysis (e.g., Teal 1962; Moloney and Field 1991; Bondavalli et al. 2000). Where high resolution trophic information was not available (such as for benthic invertebrate and phytoplankton species), clustering adhered closely to taxonomic distinctions as opposed to trophic relationships. Finally, data on the microbial food web was not available for Oneida Lake and was not included in our networks. The complete list of the seventy-seven species and aggregate groups for the pre- and post-zebra mussel invasion networks are listed in Table 2.1.

After identifying the food web components, we created the network connection topography, i.e., food web exchanges. Exchanges occur both within the food web through predator-prey interactions and between the food web and surrounding environment through migration, primary production, respiration, and harvest (Bondavalli et al. 2000). We used carbon as our network currency for biomass (gC m^{-2}) and exchange between taxa (gC m^{-2} yr^{-1}). To estimate carbon exchanges, we obtained data on biomass, production-, consumption-, and respiration-to-biomass ratios, diet proportions, migrations, and harvest for all taxa from the primary literature, field studies, and expert researchers on Oneida Lake (including the Bay of Quinte – Oneida Lake Comparative Modelling Workgroup). These parameters along with their sources are listed in Appendix 2.1. Exchanges either flow into a taxa as a carbon input (e.g., consumption and immigration), or flow out of the taxa as a carbon output (e.g., production, respiration, harvest, and emigration). To calculate production, consumption, and respiration for taxa, we multiplied the production-, consumption-, and respiration-to-biomass ratios by the taxa biomass. To quantify feeding relationships between predatory taxa and prey, we apportioned the predator's consumption among its prey items by multiplying the predator consumption estimate and predator diet vector (a list of predator diet items proportioned by weight). This calculation yielded a vector of carbon exchanges (gC m^{-2} yr^{-1}) between the predator and its prey. Aligning the exchange vectors for every predator in the system creates what is called the exchange matrix. The exchange matrix quantifies all feeding relationships within the network and is the foundation of our network analysis calculations.

Our ENA required networks to be mass-balanced, i.e., a condition where the amount of medium entering any taxa equals the amount leaving (Allesina and Bondavalli 2003). We assessed the flow balance of our networks by comparing inputs and outputs for all taxa. If a flow imbalance existed, we rectified the discrepancy by either assigning a flow to detritus (if inputs exceeded outputs) or changing one or more model inputs. The detrital-balancing approach is partially drawn from mass-balance methods employed in the software EcoPath (Christensen and Pauly 1992) and was our means to assign flow to detritus in lieu of field estimates. When changing a model input to obtain mass-balance, we used factors such as ecological plausibility (i.e., the similarity of the Oneida Lake parameter to other systems of similar trophic status) and confidence in accuracy of parameter estimates as guides to determine which parameter to change. Finally, to resolve any remaining imbalances, we used the DATBAL routine incorporated in the EcoNetwrk software (http://www.glerl.noaa.gov/EcoNetwrk/). These routines resulted in balanced food web networks with as few changes to the original model inputs as possible.

Appendix 2.2 presents the balanced exchange matrices for the pre- and post-zebra mussel invasion networks.

Ecological Network Analysis

After we constructed the networks, we performed the ENA and CA routines to quantify Oneida Lake function (via ENA) and structure (via CA) before and after zebra mussel invasion. ENA is a method that evaluates the efficiency of energy and material flow (e.g., transfers, assimilations, and dissipations) in ecosystems (Ulanowicz 1986). We used three types of ecological network analyses (Ulanowicz 1986): 1) input / output analysis, 2) trophic level analysis, and 3) the calculation of ecosystem indices. To perform the analyses, we used the software package EcoNetwrk, a Windows-based version of the NETWRK software (Ulanowicz & Kay 1991). We provide a brief description of ENA methods below; for greater detail see Ulanowicz (1986) and Ulanowicz (1997).

Input / output analysis (Hannon 1973; Patten et al. 1976) details the direct and indirect linkages between any two taxa in a network, quantifying the requisite carbon needs of any one taxon supplied by any other taxon (Bondavalli et al. 2000). The analysis includes a routine called IMPACTS that quantifies the relative effect of one taxon on another by tracing direct and indirect predatory interactions (Heymans and Baird 2000).

Trophic analysis reinterprets the web of predator-prey transfers in terms of the linear trophic chain concept of Lindeman (Lindeman 1942). Using input / output techniques, the trophic analysis apportions the activities of omnivores among a series of hypothetical integer trophic levels to create the Lindeman spine, which can be used to evaluate the efficiency of carbon flow in the system (Heymans and Baird 2000).

Ecosystem indices quantify abstract system level properties such as growth and development, and provide insight into both the vulnerability and resilience of an ecosystem to perturbation (Ulanowicz 1997). These indices are: total system throughput (TST), average mutual information (AMI), ascendency (A), overhead (O), and development capacity (C). The activity level of the ecosystem is quantified via TST which is simply the sum of all the carbon flows (gC m^{-2} yr^{-1}) in the system. TST relates to the size of an ecosystem gauged similarly to how economic activity is measured (i.e., as the flow of some currency) and can be used to quantify ecosystem growth. AMI is an information theoretic index (Shannon 1948; McEliece 1977) that quantifies the organization of a network based on pathway flow constraints. Ascendency quantifies the growth and development of an ecosystem (Ulanowicz 1986) as well as the network's performance in processing medium. Ascendency is calculated by scaling the AMI with TST: $A = TST \times AMI$. As such, ascendency encompasses both the size (via TST scaling) and organization (via AMI) of an ecosystem. Overhead quantifies the system's inefficiencies at processing material and energy (Heymans et al. 2002) as well as the degree of freedom that the system has to reconfigure itself in the face of perturbation (Heymans and Baird 2000). There are four main contributors to ecosystem overhead: imports (i.e., immigrations) to and exports (i.e., emigrations and fisheries harvest) from the ecosystem, dissipative flow loss due to respiration, and redundant food web flows (i.e., multiple paths over which energy flows between taxa). Overhead is calculated by scaling the system's conditional entropy (Ulanowicz 1986), a measure of the disorganization in a network, by TST: $O = TST \times Conditional\ Entropy$. Development capacity represents the theoretical upper bound on system organization and growth. Capacity subsumes both ascendency and overhead, such that: $C = A + O$.

Cohesion Analysis

Cohesion analysis identifies subgroups in food webs based on the strength of interactions (i.e., predator-prey relationships) within subgroups (Krause et al. 2003), where the maximization of an odds ratio is used as a criterion to assign subgroup membership[2]. CA uses an iterative algorithm that reassigns taxa to subgroups to maximize the odds that interactions occur within subgroups, versus between subgroups. The algorithm uses interaction weight to preferentially assign predators and prey with strong interactions to common subgroups. This algorithm is a robust method for assigning subgroups because it: 1) is an objective technique to assign subgroups; 2) does not require pre-specification of the number of subgroups; 3) identifies discrete (i.e., non-overlapping) subgroups; and 4) tests the statistical significance of the results (Frank 1995; Frank 1996; Krause et al. 2003). To determine the optimized subgroups, the algorithm sums the weight of realized interactions (i.e., predator-prey exchanges) within a subgroup and evaluates that sum against realized interactions that occur between subgroups, in addition to unrealized interactions (i.e., taxa combinations that do not interact) within and between subgroups. Table 2.2 describes this process. The intent is to determine the network structure that maximizes realized interactions within subgroups and unrealized interactions between subgroups while minimizing realized interactions between subgroups and unrealized interactions within subgroups.

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[2] Our use of the term “subgroup” is analogous to the Pimm and Lawton (1980) definition of food web “compartment”. We use the term “subgroup” to avoid confusion between Pimm and Lawton (1980) and Ulanowicz (1986) uses of the term “compartment”.

Using the software Kliquefinder (Frank 1995), we identified subgroups within the Oneida Lake food web networks before and after zebra mussel invasion and compared the grouped webs to reveal changes in food web structure. Although our ENA required balanced networks, our CA did not. Therefore, in order to avoid introducing uncertainty to the CA models from ENA balancing procedures, we used the unbalanced networks for CA of both time stanzas. Furthermore, because we derive detrital diet as a result of balancing procedures, we could not include detrital groups in our CA.

For the pre-zebra mussel invasion network, carbon flows ranged from 8.26×10^{-10} to 8.25 gC m^{-2} yr^{-1}, a difference of 10 orders of magnitude; for the post-invasion network, carbon flows ranged from 7.48×10^{-11} to 18.38 gC m^{-2} yr^{-1}, a difference of 12 orders of magnitude. Kliquefinder accepts flow weights only within 5 orders of magnitude; therefore, we needed to adjust the range of network data. Appendix 2.3 describes, in detail, the method we used. We tested three adjustments of data ranges, and compared the adjustments based on statistical tests of subgroup membership. The three adjustments involved: 1) changing the range of data by one order of magnitude between the schemes; 2) assigning the maximum flow weight to flows above the range of Kliquefinder; and 3) assigning the minimum flow weight to non-zero flows below the range of Kliquefinder. Adjustment one set the highest flows one order of magnitude above the upper range of Kliquefinder, and adjustments two and three set the highest flows two and three orders of magnitude above the upper range for Kliquefinder, respectively. Subgroup membership was similar for all adjustments ($p \leq 0.001$ for all comparisons); we chose adjustment two because it assigned maximum and minimum values to the fewest flows overall.

Kliquefinder incorporates a Monte Carlo-like routine to test the odds ratio of a subgrouped network against a distribution of odds ratios from randomly generated re-combinations of data (Frank 1996). Using this method, we tested the statistical significance of our subgroups against 1,000 randomized versions of our networks. Additionally, using the Quadratic Assignment Procedure (QAP) method (Hubert 1987) for significance testing, we statistically compared subgroup membership between the pre- and post-zebra mussel invasion time stanzas.

We summarized results of the CA as "crystallized sociograms" through multidimensional scaling (Frank 1996) in SAS System for Windows. With this scaling method, proximity of subgroups corresponds to: 1) the strength of predator-prey relationships spanning the subgroups (i.e., closely spaced subgroups have relatively stronger interactions connecting them than subgroups farther apart); 2) connections to similar subgroups; and 3) the subgroup's importance to overall food web structure (i.e., centrally located subgroups are more important to food web structure than peripherally located subgroups). Also, taxa location within a subgroup boundary indicates: 1) the strength of interactions between taxa; and 2) the importance of taxa to the subgroup (i.e., taxa in the center of subgroups relate more strongly to the subgroup, while taxa near subgroup boundaries only experience peripheral relationships to the subgroup).

After we identified cohesive subgroups, we performed ENA on the largest subgroup before and after zebra mussel invasion to evaluate functional linkages. We maintained the same mass-balance in the subgroup analysis as the full food webs by treating all flows to and from taxa outside the subgroup as imports and exports to subgroup taxa. Because detrital groups were not assigned to subgroups, detritus could not be explicitly incorporated into the subgroup ENA. Inclusion of the microbial food web could serve as a surrogate for detritus flow; however, as stated above, microbial data was not available for Oneida Lake. Nevertheless, flow to detritus was implicitly included in the subgroup ENA by treating detrital flow as an export from the subgroup. This procedure had two ramifications: 1) we could address detrital flow, albeit indirectly, in the subgroups; and 2) we maintained the same mass-balance used in the full food web ENA. If, as hypothesized, zebra mussels led to the benthification of Oneida Lake, we expected to see increased importance of benthic pathways within this subgroup.

Results

Ecological Network Analysis – Entire Network

Input / output analysis

Zebra mussels had more negative impacts across all taxa than neutral or positive impacts (Figure 2.1). In general, zebra mussels positively influenced benthic fish such as ictalurids, carp, and lake sturgeon, while negatively affecting pelagic fish, including walleye, yellow perch (pelagic for some life stages), white perch, alewife, and shiners. Some fish, such as gizzard shad and centrarchid species, showed mixed impacts based on life stage (e.g., juvenile gizzard shad were negatively affected while adult gizzard shad were positively affected). Most likely this is due to ontogenetic diet shifts between the juvenile and adult life stages (Werner and Gilliam 1984), although some fish that undergo diet shifts, e.g., yellow perch, did not show a similar pattern. Benthic invertebrates exhibited mixed impacts, with amphipods and isopods benefiting from zebra mussel interaction, while zebra mussels had a large negative influence on themselves due to heavy grazing on their food sources. Zebra mussels also negatively influenced zooplankton and phytoplankton. Zebra mussels had little, if any, effect on some fishes (e.g., smallmouth bass and white bass), invertebrates (e.g., oligochaetes and snails), and periphyton, epiphyton, and macrophytes. Finally, zebra mussel influence on detritus was mixed: pelagic detritus and DOC were negatively affected, most likely through direct consumption by zebra mussels, while sedimented detritus was positively affected likely due to deposition of pseudofeces. The positive effect on sedimented detritus may explain why impacts on benthic invertebrates were mixed. Amphipods and isopods rely more heavily on sedimented detritus and less heavily on plankton resources than do other benthic invertebrates such as chironomids and clams.

Lindeman trophic analysis

We were unable to create the Lindeman trophic spine for the full Oneida Lake food web networks due to computational limitations in the EcoNetwrk software resulting from the complexity of our networks. Although we could not analyze efficiency of flow between trophic levels, we can diagnose the efficiency of flow summed across the entire food web. Flow loss due to respiration in the full food web was 1015.6 gC m^{-2} yr^{-1} before zebra mussel invasion and 777.9 gC m^{-2} yr^{-1} after zebra mussel invasion, a 23% decrease. Total production (i.e., feeding exchanges between taxa plus the usable exports from the system) in the full food web was 624.1 gC m^{-2} yr^{-1} before zebra mussel invasion and 589.1 gC m^{-2} yr^{-1} after zebra mussel invasion, a 5% decrease.

Ecosystem indices

TST decreased from 2653.8 to 2143.6 gC m^{-2} yr^{-1}, approximately a 20% loss in ecosystem activity (Table 2.3). Additionally, the development capacity decreased from

13316.7 to 11037.2 gC-bits m^{-2} yr^{-1} after zebra mussel invasion. Likewise, ascendency dropped after invasion, from 3350.9 to 2926.3 gC-bits m^{-2} yr^{-1} constituting a 13% decrease, as did total overhead, from 9965.9 to 8110.9 gC-bits m^{-2} yr^{-1} representing a 19% decrease. However, these results were partially driven by changes in TST (i.e., system growth), which scales capacity, ascendency, and overhead. To remove the effects of TST scaling on capacity, we divided capacity by TST. Unscaled capacity increased from 5.0 to 5.1 bits, representing a 2% increase in the potential for system development. To remove the effect of TST scaling on ascendency and overhead, and look solely at the amount of organized and disorganized ecosystem function, we divided both indices by the development capacity. This calculation removed the TST scaling through division and yielded the proportion that ascendency and overhead comprised of capacity (expressed as a percent of capacity in Table 2.3), termed "relative ascendency" and "relative overhead", respectively. Ascendency constituted 25.2% of capacity before zebra mussel invasion and 26.5% of capacity after invasion. Overhead represented 74.8% of capacity before zebra mussel invasion and 73.5% after. These results indicate that the Oneida Lake food web is predominantly comprised of disorganized flow, but became slightly more organized after zebra mussel invasion. Considering the ecosystem processes that contribute to system overhead (imports, exports, dissipations, and flow redundancies), the relative overhead indices decreased after zebra mussel invasion between 1% and 22% except for flow redundancies, which increased almost 7%.

Cohesion Analysis

We identified six significant subgroups for the pre-zebra mussel invasion network ($p \leq 0.001$; odds ratio = 15.4) and seven significant subgroups for the post-invasion network ($p \leq 0.001$; odds ratio = 14.7). Tables 2.4 and 2.5 present the subgroup membership for the pre- and post-invasion networks, respectively. Both networks contained three subgroups of predator-prey interactions: 1) a planktivorous food web (including planktivorous fish, zooplankton, and phytoplankton), 2) benthically associated predators and prey, and 3) planktivores and zooplankton prey. Additionally, both networks contained three mostly fish subgroups: 1) panfish, 2) piscivores, and 3) piscivores and invertivores. Finally, the seventh subgroup in the post-invasion network contained mainly low biomass taxa from multiple trophic levels. We loosely named subgroups based on ecological descriptions that represent the majority of taxa within each subgroup. The names are meant as a tool to facilitate discussion of analyses; however, not all taxa fit the subgroup name.

Subgroup membership was similar between the two time stanzas (*Z*-score = 20.60, $p \leq 0.001$) despite a large number of changes to subgroup membership. Of the seventy taxa present for both time stanzas, twenty-three (33% of all taxa) changed subgroup membership after invasion: seventeen fish, five zooplankton, and one benthic invertebrate. Zebra mussels invaded the planktivorous food web subgroup (subgroup 1), the largest subgroup (based on number of taxa) in both time stanzas. Subgroup shifts relevant to Oneida Lake fisheries management include subadult (age 1-3 years) walleye, which moved to the subgroup (subgroup 6) with cormorants (*Phalacrocorax auritus*) after invasion and adult walleye (age 4 years and older), which shifted to the subgroup containing zebra mussels. Juvenile (age-0) yellow perch also transferred to the subgroup containing zebra mussels while subadult (age 1-2 years) yellow perch shifted to the benthically associated subgroup (subgroup 2).

Figures 2.2 and 2.3 summarize the cohesion analysis in crystallized sociograms. Before zebra mussel invasion, the planktivorous food web, benthically associated, and piscivore (subgroup 5) subgroups strongly interacted and played central roles within the food web (Panel A). The remaining subgroups had more peripheral roles. After invasion, the subgroups were more closely related except for the subgroup containing low biomass taxa (subgroup 7). The taxa within the planktivorous food web and benthically associated subgroups strongly interact whereas the taxa in the remaining subgroups are not as cohesive (Panel B). Phytoplankton and zooplankton play central roles within the planktivorous food web subgroup, while benthic invertebrates occupy central positions within the benthically associated subgroup.

Ecological Network Analysis – Grouped Network

Below, we analyze the functional characteristics of the subgroup that zebra mussels invaded, the planktivorous food web subgroup (hereafter also referred to as the zebra mussel subgroup), which is the largest subgroup before and after invasion in terms of number of taxa and TST (Table 2.6).

Input / output analysis

When we deciphered the direct and indirect effects of zebra mussels on their subgroup (via the IMPACTS analysis), we found that zebra mussels negatively affected all their subgroup members (Figure 2.4). Our full food web analysis also indicated that zebra mussels negatively affected these taxa (Figure 2.1); however, the magnitudes of the effects differed slightly in the subgroup analysis. The largest difference involved zebra mussel influence upon themselves. The IMPACTS value changed from -0.33 in the full food web (Figure 2.1) to -0.11 in the subgroup, representing a 67% change. Potentially we see a lessened effect of zebra mussels upon themselves at the subgroup level because detrital groups, including pelagic detritus and DOC, were not included in the analysis. Zebra mussels prey heavily on detrital groups, negatively affecting themselves via depletion of their food supply.

Although we cannot directly conduct an IMPACTS analysis of zebra mussels on the other six subgroups (to conduct the analysis, zebra mussels would need to be present in the subgroup network) we can indirectly detect zebra mussel influence in those subgroups by considering impacts on individual taxa from our full food web analysis (Figure 2.1). Unlike the (wholly negative) zebra mussel influence on taxa in their subgroup, zebra mussel effects on taxa in other subgroups were mixed with no consistent pattern between subgroups. The majority of negative effects were confined to the zebra mussel subgroup while some subgroups, including subgroups 2, 4, 5, and 6, exhibited net positive effects of zebra mussels

Lindeman trophic analysis

The Lindeman trophic analysis identified six trophic levels in the zebra mussel subgroup before invasion and nine trophic levels after invasion (Figures 2.5 and 2.6). Before invasion, age-0 gizzard shad were the top predator in the subgroup and fed up to the sixth trophic level; after invasion and with the addition of multiple fish to this subgroup, adult walleye were the top predator and fed at the ninth trophic level. Zebra mussels fed at the second trophic level; consequential to their invasion, trophic flow efficiency fell almost 10% at trophic level II as respirative losses more than tripled and flow loss to detritus almost doubled. Flow efficiencies at trophic levels IV and higher increased subsequent to invasion.

Total respiration and production decreased in the zebra mussel subgroup after invasion. Flow loss due to respiration was 424.1 gC m^{-2} yr^{-1} before invasion and 396.2 gC m^{-2} yr^{-1} after invasion (6% decrease), while production was 484.7 gC m^{-2} yr^{-1} before invasion and 401.0 gC m^{-2} yr^{-1} after invasion (17% decrease). Subgroup production constituted 78% of the full food web production before invasion, but only 68% after invasion. Furthermore, subgroup respiration contributed 42% to the full food web before invasion, and 51% after invasion.

Ecosystem indices

Similar to the analysis of the full food web, TST and development capacity fell after zebra mussel invasion. Before invasion, TST and capacity were 1705.2 gC m^{-2} yr^{-1} and 7574.4 gC-bits m^{-2} yr^{-1}, respectively; after invasion, throughput and capacity declined to 1415.8 gC m^{-2} yr^{-1} (a 17% decrease) and 6651.5 gC-bits m^{-2} yr^{-1} (a 12% decrease), respectively. Unscaled capacity increased after invasion, from 4.4 to 4.7 bits, a 7% increase. Unlike the full food web ecosystem analysis, relative ascendency decreased over 3% while relative overhead increased by 1% in the subgroup after invasion. Relative overhead on imports and exports decreased by 4% and 28%, respectively, while relative flow redundancies increased by 54% after invasion. These results parallel the full food web analysis, although the increase in relative flow redundancies was substantially greater for the subgroup than the full food web (7% increase). However, unlike the full food web, relative dissipative overhead increased by 4% in the subgroup after invasion. Finally, the subgroup constituted 64% of the full food web TST and 57% of capacity before invasion, and 66% of TST and 60% of capacity after invasion. Essentially, subgroup size and potential for development increased after zebra mussel invasion relative to the full food web, making this subgroup a more important part of the food web.

Discussion

Zebra mussels exerted a far-reaching influence on the Oneida Lake food web, altering the membership of food web subgroups (question 1) and changing the magnitude of carbon flows within the full food web and subgroups (question 2). Our analyses support the hypothesis that zebra mussels lead to the benthification of their invaded ecosystems by shunting energy from pelagic to benthic pathways and promoting benthically associated species. Our research constitutes the first test of this hypothesis using ecosystem level measures. Furthermore, this research is the first application of CA, a social network analysis, in conjunction with ENA. Recent unions of methods from ecology and sociology (e.g., Krause et al. 2003; Zhao and Frank 2003) reveal there is value found in the convergence of these disciplines, especially when applied to food webs. While SNA largely focuses on structural analyses (Mayhew 1980), ENA is a functional analysis (Ulanowicz 1986). However, Johnson et al. (2001) affirm that ENA and SNA are markedly similar mathematically and conceptually. The merging of these two methods to understand the integration of ecosystem structure and function seems a natural extension. Our application of ENA in combination with CA offers a novel analytical technique for understanding zebra mussel impacts on ecosystem processes. We begin our discussion below with CA, and then place the structural findings within the context of the full food web and subgroup ENA, emphasizing the contribution to our knowledge of ecosystems.

Cohesion Analysis - Structure

Almost one-third of all taxa changed subgroups after invasion. Although the difference in subgroup membership between the pre- and post-zebra mussel time stanzas was not statistically significant (despite 33% of all taxa shifting subgroups), we believe these shifts are ecologically significant based on the restructuring of the paths of carbon flow within subgroups. The zebra mussel subgroup underwent the greatest change, increasing membership from twenty-four to twenty-nine taxa, including the addition of zebra mussels as well as multiple fish and zooplankton. These shifts broadened the once pelagic-based subgroup by increasing food chain length and creating important links via benthic pathways. Although this subgroup underwent the greatest change after invasion, the benthically associated subgroup also increased membership by one fish group, while all other subgroups lost members. These subgroup shifts suggest that benthic pathways gained importance as a result of zebra mussel invasion.

According to food web stability theory, a taxon that is not directly affected by a disturbance event, such as exotic species invasion, can still be affected via the transfer of effects over strong interactions (McCann et al. 2005). Within subgroups, the strong interactions among members can transfer the effect of a disturbance throughout the subgroup even if not all members are directly affected by the event. Conversely, taxa in other subgroups will be either weakly impacted or not impacted as the effects must be transferred through the weak interactions between groups. Thus taxa within the subgroup invaded by zebra mussels are especially vulnerable to effects of this exotic species, whereas taxa in other subgroups may be more sheltered from effects. Life stages of walleye and yellow perch comprised a large proportion of the subgroup shifts after zebra mussel invasion. Common subgroup membership offers structural underpinnings for zebra mussel influence on juvenile yellow perch growth rate (Mayer et al. 2000) and adult walleye abundance (Rutherford et al. 1999). Additionally, due to the tight coupling of walleye and yellow perch populations in Oneida Lake (Rose et al. 1999), within-subgroup influence of zebra mussels on these species can cascade to their corresponding life stages in other subgroups, despite the buffering that subgroup structure may offer. After invasion, subadult walleye moved to the subgroup containing piscivore and invertivore taxa (subgroup 6), including cormorants. Common subgroup membership gives structural support for Oneida Lake diet studies that suggest cormorants exert strong predatory pressure on subadult walleye (Forney 1993; VanDeValk et al. 2002; Rudstam et al. 2004). Since subadult walleye composed one-quarter of cormorant diet by weight (Appendix 2.2) and cormorant biomass more than quadrupled from the 1980s to the 1990s (Appendix 2.1), we feel it is likely that cormorants, rather than zebra mussels, influenced the shift of subadult walleye. However, despite strong cormorant predation pressure on all life stages of yellow perch and walleye (totaling over two-thirds of cormorant diet, Appendix 2.2), most life stages were found in benthic pathways after invasion, despite the influence of an important pelagic predator.

Structural analyses also lend insight into the fundamental ecological structure of Oneida Lake. In both time stanzas, one large subgroup dominated food web structure while multiple smaller subgroups played less significant roles. This result differs from CA findings on the Chesapeake Bay by Krause et al. (2003) who identified two subgroups (one benthic, the other pelagic) co-dominating food web structure. Perhaps structure differs between the systems because Oneida Lake is a shallow, well-mixed ecosystem with only brief periods of thermal stratification, while the Chesapeake Bay maintains thermal stratification from late spring to early fall (Bidle and Fletcher 1995), creating distinct structure between the thermal regions. These findings potentially suggest that food web structure is, at least in part, related to physical system structure. Similar to the Chesapeake Bay analysis, bivalve taxa (zebra mussels in Oneida Lake; clams and oysters in the Chesapeake Bay) shared subgroup membership with their pelagic prey. The majority of carbon flow in the zebra mussel subgroup originated in phytoplankton and was immediately routed through zebra mussels, making these mussels the main flow nexus in the system linking pelagic and benthic pathways. Our study suggests that this coupling of pelagic and benthic structure is a central influence of zebra mussels in Oneida Lake.

Ecological Network Analysis - Function

Aquatic ecosystems worldwide are in the midst of large-scale ecological alteration. To address ecosystem level change, we need quantifiable, objective criteria at the whole-system level (Westra et al. 2000), especially with the contemporary emphasis on ecosystem management (Christensen et al. 1996). ENA is a valuable tool for deciphering impacts of perturbations at the ecosystem level because it offers a quantitative depiction of food web functioning, inclusive of all food web taxa (barring data limitations). Ulanowicz (1996) makes predictions for ecosystem level response to perturbation by drawing from Odum's (1969) theory on ecosystem development. Ulanowicz suggested that perturbed ecosystems will have less efficient trophic chains, decreased system throughput, and decreased food web organization. Our analysis supports Ulanowicz (1996) and affirms research question 2: zebra mussels considerably alter the magnitude of carbon flow within ecosystems.

Our IMPACTS analysis suggested that zebra mussels have an overwhelmingly negative effect on food web taxa, especially subgroup members. This analysis is a rigorous way to determine perturbation effects since all food web paths, both direct and indirect, are incorporated in the analysis. Indirect paths are especially important as they may overwhelm direct interactions and even yield an opposite effect than a direct exchange (Patten 1984). In our analysis, the majority of large effects were contained in the zebra mussel subgroup, validating the assumption that subgroup members exert a stronger influence over one another than non-subgroup members. The few positively affected taxa tended to be benthically associated, yet some taxa with benthic life stages, like yellow perch, exhibited wholly negative impacts. However, when interpreting results of the IMPACTS analysis, it is important to bear in mind that we only conducted the analysis using the post-zebra mussel invasion network; changes in species interactions mediated by zebra mussels may have occurred between the time periods. For example, if zebra mussel invasion alleviated deleterious feeding pressure of certain predators on prey present in the pre-invasion time stanza, we might see zebra mussel facilitation of some taxa upon doing a before and after comparison using other measures besides IMPACTS. As an example, to refine the IMPACTS analysis, we can consider the throughput of subadult yellow perch, juvenile yellow perch, and juvenile walleyes before and after invasion. Although the IMPACTS analysis indicated that zebra mussels negatively influenced these life stages, their throughput increased after invasion, perhaps due to changes elsewhere in the food web mediated by zebra mussels. Therefore, to fully understand zebra mussel influence on the Oneida Lake food web, the IMPACTS analysis must be used in conjunction with other functional analyses.

The zebra mussel subgroup is the most important subgroup in Oneida Lake. This subgroup not only dominated food web structure, but also dominated function by sequestering carbon flow. After invasion, we found that the trophic chain increased by three levels and the subgroup garnered more carbon throughput relative to the full food web. Additionally, the development capacity of the subgroup increased compared to the full food web. These results suggest that this subgroup not only increased in functional size, but also became a more complex and integrated part of the food web after invasion. However, despite gaining functional importance, the subgroup contributed proportionally more to food web flow loss after invasion. Respirative flow losses increased (9%) while production decreased (almost 10%) relative to the full food web. Thus, not only do we see evidence of an energy shunt to benthic pathways after zebra mussel invasion, but also indication of energy flow loss to dissipative paths and decreased food web efficiency.

The Lindeman trophic analysis allows further inspection of flow efficiency at each trophic level within the zebra mussel subgroup. After invasion, flow efficiency for trophic level I increased almost 17%, efficiency at trophic level II decreased almost 10%, and the efficiency of the remaining trophic levels marginally changed. The driver of increased efficiency at the first trophic level was probably the decrease in phytoplankton biomass following invasion. With less phytoplankton available for consumption, a greater proportion of biomass passed into the grazing food chain, with less biomass lost to detrital pathways. The efficiency decrease at the second trophic level was potentially due to the high respirative loss of zebra mussels relative to production (Appendix 2.2). In light of the subgroup results, we can conjecture trophic efficiency in the full food web even though we could not create the Lindeman trophic spine. After invasion, phytoplankton biomass and throughput decreased, potentially increasing flow efficiency at trophic level I, as occurred in the subgroup. Although pelagic primary producers exhibited decreased activity after invasion, other sources of primary production, such as macrophytes and detritus (considered a primary source of carbon in ENA), gained functional importance. Before invasion, macrophytes produced 8.0 gC m^{-2} yr^{-1}, compared to 9.0 gC m^{-2} yr^{-1} after invasion, a 13% increase. Detrital groups combined produced 11.6 gC m^{-2} yr^{-1} before invasion and 65.1 gC m^{-2} yr^{-1} after invasion. Despite a small absolute increase in carbon flow, this change represented an over 460% increase in detrital use, illustrating the importance of alternate sources of carbon, especially benthic, after zebra mussel invasion.

Considering the entire food web, Ulanowicz (1996) predicted that that ecosystem organization, as measured by ascendency, will decrease after a perturbation while ecosystem disorganization, measured by overhead, will increase. To understand why system overhead should increase, it is helpful to consider the components of overhead: dissipative flow loss due to respiration, flow redundancies, imports to, and exports from the system. Although these processes can be disadvantageous during benign conditions, overhead can be advantageous if the system is perturbed in a novel fashion. Bondavalli et al. (2000) described overhead as a “strength in reserve of degrees of freedom which the system can call upon to adapt to a new threat.” In general, overhead increases after perturbation due to reorganization of flow structure while the ecosystem adapts. For instance, as an exotic species becomes established in a system, the ecosystem may shift from a stable state to a flux system, with concomitant flow reorganization, interruption of carbon cycling, and even loss of native species.

Considering this flow of events common to exotic species introduction, we were surprised to observe the full food web relative overhead value decrease after zebra mussel invasion. Perhaps the food web exhibited increased organization due to the considerable flow asymmetry present after invasion. Zebra mussels conduct 10% of food web flow, potentially increasing organization by focusing flow (and increasing AMI). However, Ulanowicz's (1996) perturbation theory held for the analysis of the zebra mussel subgroup, which should contain the most pronounced influence of zebra mussels in the food web (according to food web stability theory). Relative ascendency decreased, while relative overhead increased in the subgroup, suggesting that the subgroup underwent reorganization of carbon flow as it accommodated zebra mussel presence (as predicted by Ulanowicz's theory). This finding presents compelling evidence for investigating food web function at multiple structural levels. Despite differences in organization between the subgroup and full food web, we found that (unscaled) development capacity increased at both levels after invasion. The rise in capacity indicates that zebra mussels added a layer of complexity to food web function. Complexity imparts multiple benefits to ecosystems, including more diversity of interconnections which allow alternate routes for taxa to obtain energy in the face of ecological change (Pérez-España and Arreguín-Sánchez 1999). Consequently, despite eliciting several negative effects on Oneida Lake, including decreased food web efficiency and production, zebra mussel invasion conveyed some benefits to the ecosystem.

A limitation of ENA is variability in carbon flow estimates is not incorporated into the analysis. As a result, we cannot discern statistical significance in food web change with ENA. One of the main assumptions of ENA is that ecosystems are in a condition of mass-balance. After constructing a food web network, taxa rarely meet this assumption, as was the case in this analysis. Balancing introduces a degree of uncertainty into the analyses, thus careful choice of methods is imperative. We acknowledge that our balancing routines may have affected our results; however, we were careful to choose balancing methods that yielded ecologically plausible networks. The other critical assumption of this research was that any differences observed in food web structure and function between time stanzas were due to zebra mussel invasion. Although Oneida Lakes has been buffered from most exotic species introductions that plague the Great Lakes (e.g., the spiny (*Bythotrephes longimanus*) and fish-hook (*Cercopagis pengoi*) water fleas, the round goby (*Neogobius melanostomus*), and quagga mussels), zebra mussel invasion is not the only ecological change in recent years. For example, cormorant biomass increased independent of zebra mussel invasion and a lake sturgeon stocking program began in 1995. Although these events may have caused food web alteration, we believe that zebra mussel invasion far outweighed other ecological changes that occurred during our time stanzas. Not only did zebra mussels garner over 10% of total system flow, they also constituted over two-thirds of Oneida Lake's living biomass (gC m^{-2}). These numbers alone suggest that zebra mussel introduction is undoubtedly one the most significant changes to Oneida Lake's ecology in recent years. Given the limitations of ENA, but considering the overwhelming presence of zebra mussels in Oneida Lake, we are confident in the robustness of our results and conclusions.

Moreover, our research corroborates other work conducted on Oneida Lake as well as supports research on the effects of zebra mussel invasion in other systems.

In conclusion, this research supports the work of Mills et al. (2003) who hypothesized that zebra mussels lead to the benthification and reorganization of their invaded ecosystems. Our research presents the first test of this hypothesis using network analysis methods. Network analyses are valuable techniques for illuminating exotic species impacts at the whole-system level while at the same time allowing for inspection of impacts at the level of species or even life stage. We advocate the use of high resolution data for all food web taxa, including microbial pathways (Allesina et al. 2005), to gain a holistic understanding of ecosystem structure and function. As these data were not all available for Oneida Lake, we acknowledge that our aggregation scheme and choice of taxa may have affected results. However, our food web networks, with over seventy taxa and life stages for each time stanza, represent one of the most in-depth treatises of ENA food webs to date. Furthermore, the confluence of network analyses from multiple disciplines allowed us to look at ecosystem structure and function from a new perspective. We suggest network analysis methods be applied to other ecosystems that have experienced exotic species invasion to determine if the results presented here are unique to Oneida Lake, or ubiquitous across invaded ecosystems.

Acknowledgements

We thank Stefano Allesina, Tyler Wagner, and Andrew Fayram for helpful comments, the Bay of Quinte – Oneida Lake Comparative Modelling Project Workgroup, Edward Mills and the staff at the Cornell University Biological Field Station for data contributions and guidance, Anne Clites, Timothy Hunter, and Marten Koops for their computational and programming assistance, and Cathy Darnell for her aid on graphics. This work was supported by a grant from the Great Lakes Fishery Commission.

Table 2.1. List of food web taxa. Cisco were present in the pre-zebra mussel time stanza but not the post-zebra mussel time stanza; lake sturgeon, zebra mussels, and *Camptocercus harpae* were present in the post-zebra mussel time stanza, but not the pre-zebra mussel time stanza.

No.	Common Name	Taxonomic Classification
1	Cormorants	*Phalacrocorax auritus*
2	Walleye Age 4+	*Sander vitreus*
3	Walleye Age 1-3	*Sander vitreus*
4	Walleye Age-0	*Sander vitreus*
5	Yellow Perch Age 3+	*Perca flavescens*
6	Yellow Perch Age 1-2	*Perca flavescens*
7	Yellow Perch Age-0	*Perca flavescens*
8	White Perch Age 1+	*Morone americana*
9	White Perch Age-0	*Morone americana*
10	Black Crappie Age 1+	*Pomoxis nigromaculatus*
11	Bluegill Age 1+	*Lepomis macrochirus*
12	Pumpkinseed Age 1+	*Lepomis gibbosus*
13	Rock Bass Age 1+	*Ambloplites rupestris*
14	Panfish Age-0	Centrarchidae
15	Gizzard Shad Age 1+	*Dorosoma cepedianum*
16	Gizzard Shad Age-0	*Dorosoma cepedianum*
17	Alewife	*Alosa pseudoharengus*
18	Brown Bullhead	*Ameiurus nebulosus*
19	Burbot	*Lota lota*
20	Channel Catfish	*Ictalurus punctatus*
21	Cisco	*Coregonus artedii*
22	Common Carp	*Cyprinus carpio carpio*
23	Darters	*Etheostoma* species
24	Emerald Shiners	*Notropis athernoides*
25	Freshwater Drum	*Aplodinotus grunniens*
26	Golden Shiners	*Notemigonus crysoleucas*
27	Lake Sturgeon	*Acipenser fulvescens*
28	Log Perch	*Percina caprodes*
29	Mottled Sculpin	*Cottus bairdii*
30	Northern Pike	*Esox lucius*
31	Red Horse Sucker	*Moxisoma* species
32	Smallmouth Bass	*Micropterus dolomieu*
33	Trout Perch	*Percopsis omiscomaycus*
34	White Bass	*Morone chrysops*
35	White Sucker	*Catostomus commersonii*
36	Amphipods	Amphipoda
37	Chironomids	Chironomidae
38	Clams	Sphaeriidae
39	Insects	Arthropoda
40	Isopods	Isopoda
41	Leeches	Hirudinea
42	Oligochaetes	Oligochaeta
43	Snails	Gastropoda
44	Zebra Mussels	*Dreissena polymorpha*
45	*Alona* species	*Alona* species
46	*Bosmina longirostris*	*Bosmina longirostris*
47	*Camptocercus harpae*	*Camptocercus harpae*
48	*Ceriodaphnia quadrangula*	*Ceriodaphnia quadrangula*
49	*Chydorus sphaericus*	*Chydorus sphaericus*
50	*Daphnia galeata mendotae*	*Daphnia galeata mendotae*
51	*Daphnia pulicaria*	*Daphnia pulicaria*
52	*Daphnia retrocurva*	*Daphnia retrocurva*
53	*Diaphanosoma* species	*Diaphanosoma* species
54	*Eubosmina coregoni*	*Eubosmina coregoni*
55	*Sida crystallina*	*Sida crystallina*
56	*Leptodora kindtii*	*Leptodora kindtii*
57	*Acanthocyclops vernalis*	*Acanthocyclops vernalis*
58	*Diacyclops thomasi*	*Diacyclops thomasi*
59	*Ergasilus* species	*Ergasilus* species
60	*Mesocyclops edax*	*Mesocyclops edax*
61	*Epischura lacustris*	*Epischura lacustris*
62	*Leptodiaptomus minutus*	*Leptodiaptomus minutus*
63	*Skistodiaptomus oregonensis*	*Skistodiaptomus oregonensis*
64	Nauplii	Copepoda
65	Rotifers	Rotatoria
66	Blue-green Algae	Cyanophyceae
67	Diatoms	Bacillariophyceae
68	Euglena	Euglenophyceae
69	Flagellates	Cryptophyceae & Dinophyceae
70	Golden Algae	Chrysophyceae
71	Green Algae	Chlorophyceae
72	Epiphytes	Epiphytes
73	Macrophytes	Macrophytes
74	Periphytes	Periphytes
75	Pelagic Detritus	Pelagic Detritus
76	Sedimented Detritus	Sedimented Detritus
77	DOC	DOC

Table 2.2. Association between common subgroup membership and the occurrence of ties between predators and prey (adapted from Frank 1995). The odds ratio method maximizes the ratio AD : BC.

		Tie Occurring		
		No	Yes	
Subgroup Membership	Different	A	B	Possible relations between predators and prey in different subgroups
	Same	C	D	Possible relations between predators and prey in the same subgroup
		Unrealized Interactions	Realized Interactions	Total possible relations

Table 2.3. Ecosystem indices for the full Oneida Lake food web network before and after zebra mussel invasion. The percent difference was calculated as:

$$\%Difference = \frac{Post - Pre}{Pre} x100\% .$$

	Pre-Zebra Mussels	Post-Zebra Mussels	% Difference
Index	Value	Value	Value
Total system throughput (gC m^{-2} yr^{-1})	2653.8	2143.6	-19.2
Development capacity (gC-bits m^{-2} yr^{-1})	13316.7	11037.2	-17.1
Ascendency (gC-bits m^{-2} yr^{-1})	3350.9	2926.3	-12.7
Total overhead (gC-bits m^{-2} yr^{-1})	9965.9	8110.9	-18.6
Overhead on imports (gC-bits m^{-2} yr^{-1})	2598.4	1873.0	-27.9
Overhead on exports (gC-bits m^{-2} yr^{-1})	0.4	0.3	-35.0
Dissipative overhead (gC-bits m^{-2} yr^{-1})	3936.3	3203.3	-18.6
Redundancy (gC-bits m^{-2} yr^{-1})	3430.8	3034.3	-11.6
Unscaled capacity (bits)	5.0	5.1	2.0
Ascendency / capacity (%)	25.2	26.5	5.4
Total overhead / capacity (%)	74.8	73.5	-1.8
Overhead on imports / capacity (%)	19.5	17.0	-13.0
Overhead on exports / capacity (%)	0.0	0.0	-21.6
Dissipative overhead / capacity (%)	29.6	29.0	-1.8
Redundancy / capacity (%)	25.8	27.5	6.7

Table 2.4. Subgroups identified for the pre-zebra mussel invasion time stanza. * Refers to taxa present in the pre-zebra mussel time stanza, but not the post-zebra mussel time stanza.

No.	Subgroup 1: Planktivorous Food Web
16	Gizzard Shad Age-0
37	Chironomids
42	Oligochaetes
46	*Bosmina longirostris*
48	*Ceriodaphnia quadrangula*
49	*Chydorus sphaericus*
50	*Daphnia galeata mendotae*
51	*Daphnia pulicaria*
52	*Daphnia retrocurva*
53	*Diaphanosoma* species
54	*Eubosmina coregoni*
58	*Diacyclops thomasi*
60	*Mesocyclops edax*
61	*Epischura lacustris*
62	*Leptodiaptomus minutus*
63	*Skistodiaptomus oregonensis*
64	Nauplii
65	Rotifers
66	Blue-green Algae
67	Diatoms
68	Euglena
69	Flagellates
70	Golden Algae
71	Green Algae

No.	Subgroup 2: Benthically Associated
5	Yellow Perch Age 3+
No.	Subgroup 2 Con't
8	White Perch Age 1+
20	Channel Catfish
22	Common Carp
25	Freshwater Drum
35	White Sucker
36	Amphipods
39	Insects
40	Isopods
41	Leeches
43	Snails
56	*Leptodora kindtii*
72	Epiphytes
73	Macrophytes
74	Periphytes

No.	Subgroup 3: Planktivores & Zooplankton
17	Alewife
21	*Cisco
26	Golden Shiners
33	Trout Perch
45	*Alona* species
55	*Sida crystallina*
57	*Acanthocyclops vernalis*

No.	Subgroup 4: Panfish
10	Black Crappie Age 1+
11	Bluegill Age 1+
No.	Subgroup 4 Con't
12	Pumpkinseed Age 1+
13	Rock Bass Age 1+
23	Darters
28	Log Perch
29	Mottled Sculpin
59	*Ergasilus* species

No.	Subgroup 5: Piscivores
2	Walleye Age 4+
3	Walleye Age 1-3
4	Walleye Age-0
6	Yellow Perch Age 1-2
7	Yellow Perch Age-0
9	White Perch Age-0
19	Burbot
30	Northern Pike
32	Smallmouth Bass
34	White Bass

No.	Subgroup 6: Piscivores & Invertivores
1	Cormorants
14	Panfish Age-0
15	Gizzard Shad Age 1+
18	Brown Bullhead
24	Emerald Shiners
31	Red Horse Sucker
38	Clams

Table 2.5. Subgroups identified for the post-zebra mussel invasion time stanza. * Refers to taxa present in the post-zebra mussel time stanza, but not the pre-zebra mussel time stanza. † Refers to taxa that changed subgroup membership after zebra mussel invasion.

No.	Subgroup 1: Planktivorous Food Web
2	†Walleye Age 4+
7	†Yellow Perch Age-0
9	†White Perch Age-0
16	Gizzard Shad Age-0
24	†Emerald Shiners
37	Chironomids
42	Oligochaetes
44	*Zebra Mussels
46	*Bosmina longirostris*
49	*Chydorus sphaericus*
50	*Daphnia galeata mendotae*
51	*Daphnia pulicaria*
53	*Diaphanosoma* species
54	*Eubosmina coregoni*
56	†*Leptodora kindtii*
57	†*Acanthocyclops vernalis*
58	*Diacyclops thomasi*
60	*Mesocyclops edax*
61	*Epischura lacustris*
62	*Leptodiaptomus minutus*
63	*Skistodiaptomus oregonensis*
64	Nauplii
65	Rotifers
66	Blue-green Algae
67	Diatoms
68	Euglena
69	Flagellates
70	Golden Algae
71	Green Algae

No.	Subgroup 2: Benthically Associated
5	Yellow Perch Age 3+
6	†Yellow Perch Age 1-2
8	White Perch Age 1+
20	Channel Catfish
22	Common Carp
25	Freshwater Drum
32	†Smallmouth Bass
35	White Sucker
36	Amphipods
39	Insects
40	Isopods
41	Leeches
43	Snails
72	Epiphytes
73	Macrophytes
74	Periphytes

No.	Subgroup 3: Planktivores & Zooplankton
14	†Panfish Age-0
26	Golden Shiners
28	†Log Perch
38	†Clams
45	*Alona* species

No.	Subgroup 4: Panfish
11	†Bluegill Age 1+
12	Pumpkinseed Age 1+
13	Rock Bass Age 1+

No.	Subgroup 4 Con't
19	†Burbot
34	†White Bass
59	*Ergasilus* species

No.	Subgroup 5: Piscivores
4	Walleye Age-0
23	†Darters
29	†Mottled Sculpin
30	Northern Pike
33	†Trout Perch

No.	Subgroup 6: Piscivores & Invertivores
1	Cormorants
3	†Walleye Age 1-3
10	†Black Crappie Age 1+
15	Gizzard Shad Age 1+
18	Brown Bullhead
31	Red Horse Sucker

No.	Subgroup 7: Miscellaneous Low Biomass
17	†Alewife
27	*Lake Sturgeon
47	*Camptocercus harpae
48	†*Ceriodaphnia quadrangula*
52	†*Daphnia retrocurva*
55	†*Sida crystallina*

Table 2.6. Throughput of subgroups before and after zebra mussel invasion. Only six subgroups were identified before zebra mussel invasion.

Subgroup	Pre-Zebra Mussels Throughput ($gC\ m^{-2}\ yr^{-1}$)	Post-Zebra Mussels Throughput ($gC\ m^{-2}\ yr^{-1}$)
1	1705.2	1415.8
2	462.9	452.1
3	0.1	0.0
4	0.1	0.2
5	3.9	0.2
6	0.2	0.5
7	Not Present	0.3

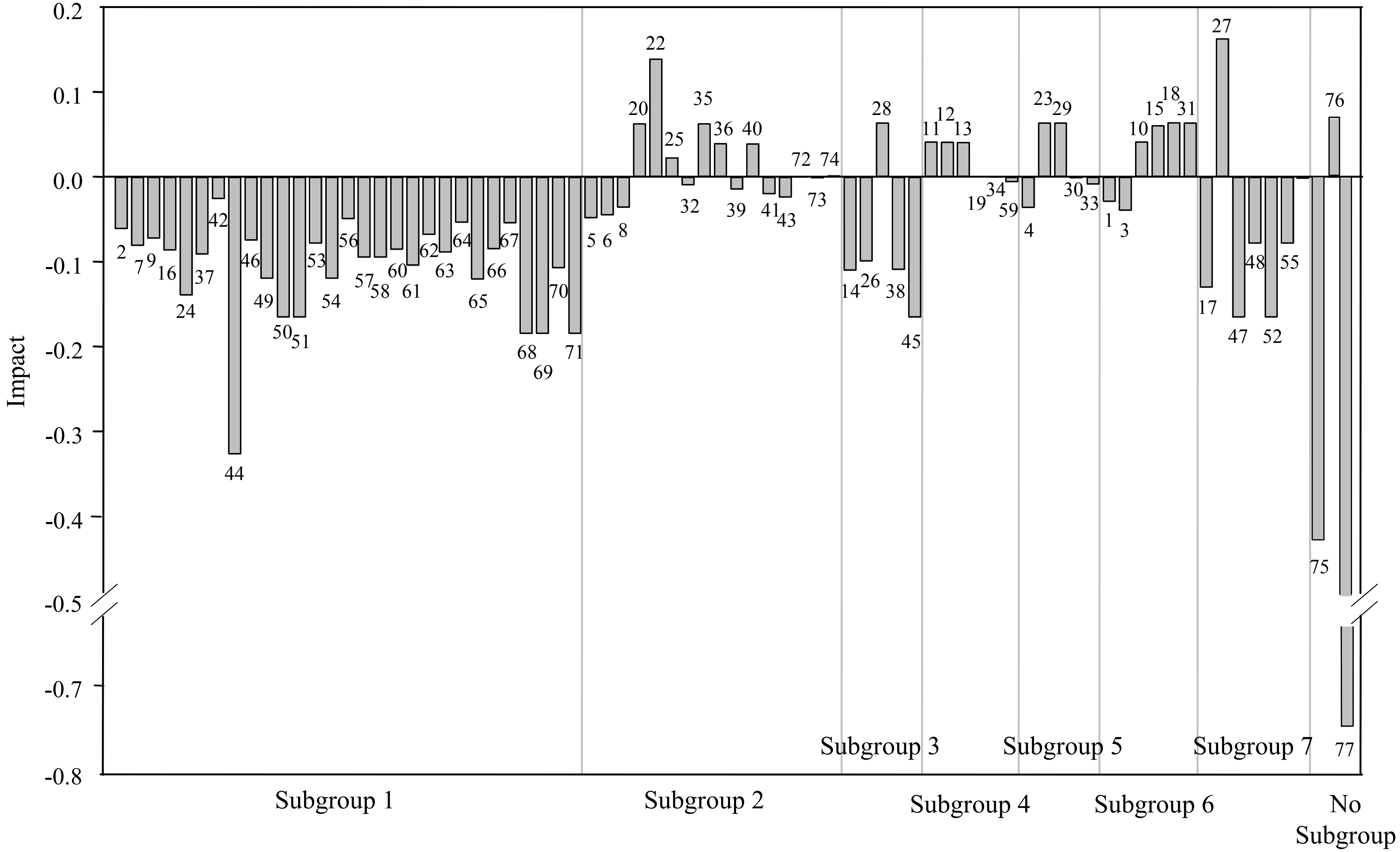
Table 2.7. Ecosystem indices for the zebra mussel subgroup before and after zebra mussel invasion. The percent difference was calculated as:

$$\%Difference = \frac{Post - Pre}{Pre} x100\% .$$

	Pre-Zebra Mussels	Post-Zebra Mussels	% Difference
Index	Value	Value	Value
Total system throughput (gC m^{-2} yr^{-1})	1705.2	1415.8	-17.0
Development capacity (gC-bits m^{-2} yr^{-1})	7574.4	6651.5	-12.2
Ascendency (gC-bits m^{-2} yr^{-1})	1847.8	1567.0	-15.2
Total overhead (gC-bits m^{-2} yr^{-1})	5726.7	5084.5	-11.2
Overhead on imports (gC-bits m^{-2} yr^{-1})	1836.3	1552.4	-15.5
Overhead on exports (gC-bits m^{-2} yr^{-1})	1410.4	890.8	-36.8
Dissipative overhead (gC-bits m^{-2} yr^{-1})	1628.1	1492.5	-8.3
Redundancy (gC-bits m^{-2} yr^{-1})	851.9	1148.8	34.8
Unscaled capacity (bits)	4.4	4.7	6.8
Ascendency / capacity (%)	24.4	23.6	-3.4
Total overhead / capacity (%)	75.6	76.4	1.1
Overhead on imports / capacity (%)	24.2	23.3	-3.7
Overhead on exports / capacity (%)	18.6	13.4	-28.1
Dissipative overhead / capacity (%)	21.5	22.4	4.4
Redundancy / capacity (%)	11.2	17.3	53.6

Figure 2.1. Zebra mussel impacts on the Oneida Lake food web, organized by subgroup. The scale is relative: impacts above the zero line are positive impacts of zebra mussels and impacts below the zero line are negative impacts of zebra mussels. Taxa numbers are placed above or below each bar. Taxon 21 was not present after zebra mussel invasion; taxa 75-77 were not used in the subgroup analysis. See Table 2.1 for taxa codes.

Figure 2.1


Impact
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.7
-0.8
Subgroup 1
Subgroup 2
Subgroup 3
Subgroup 4
Subgroup 5
Subgroup 6
Subgroup 7
No Subgroup
2
7
9
16
24
37
42
44
46
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34
59
4
23
29
30
33
1
3
10
15
18
31
17
27
47
48
52
55
75
76
77

Figure 2.2. Panel A: Crystalized sociogram for the pre-zebra mussel time stanza. Units are relative distances based on the inverse of the density of interactions (see Frank 1996). Subgroups 1 through 6 are plotted with the direction of feeding relationships represented by arrows (e.g., subgroup 6 consumes members of subgroup 1, but not vice versa); thickness of arrow indicates weight of feeding relationships. Panel B: Placement of taxa within subgroups. Circles indicate subgroup boundaries and colors represent general trophic groupings of taxa. Subgroup numbers are located to the upper right of all subgroups.

Figure 2.2

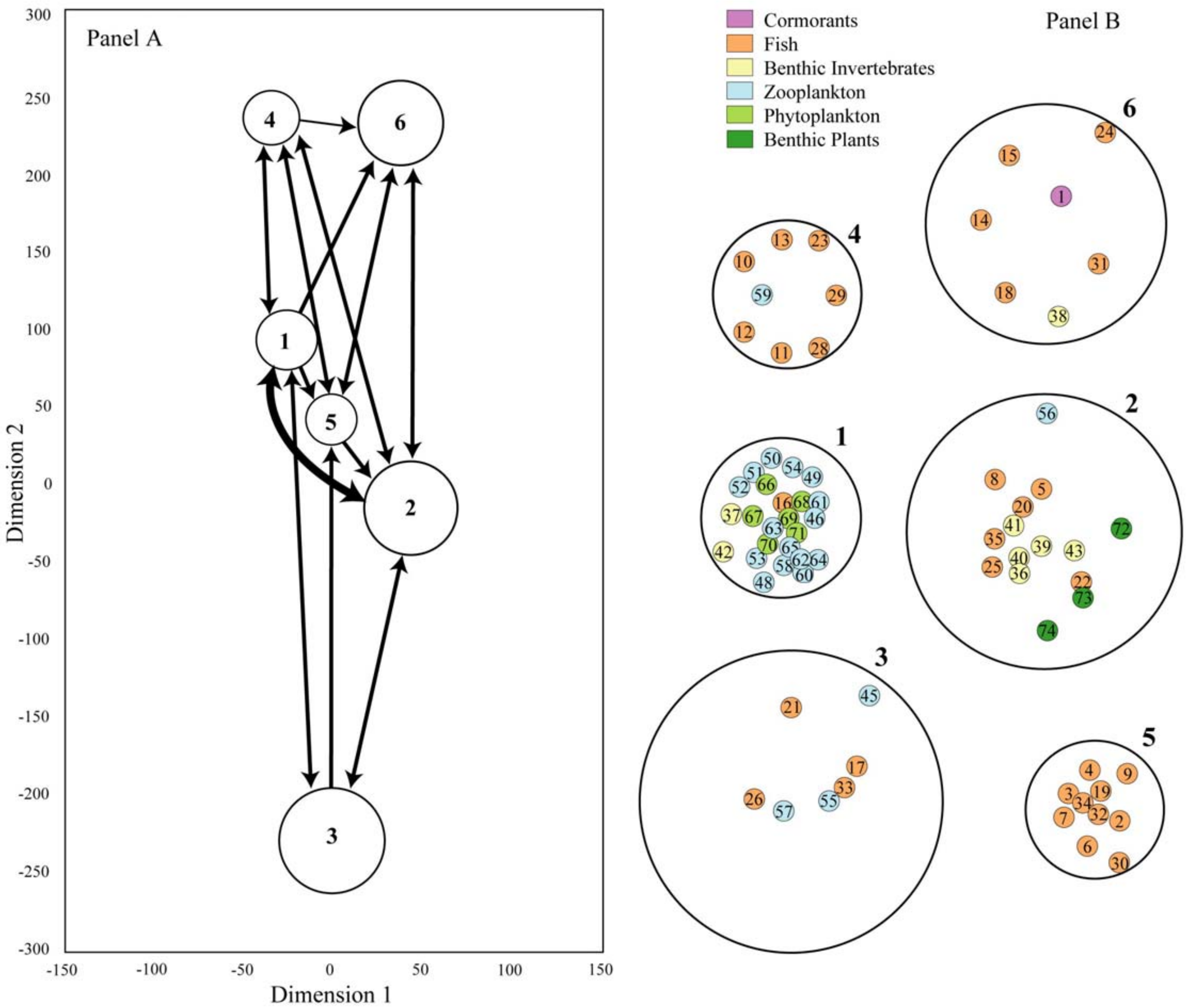

Panel A
Dimension 2
Dimension 1
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-150
-100
-50
0
50
100
150
1
2
3
4
5
6
Panel B
Cormorants
Fish
Benthic Invertebrates
Zooplankton
Phytoplankton
Benthic Plants
6
1
14
15
18
24
31
38
4
10
11
12
13
23
28
29
59
1
16
37
42
46
48
49
50
51
52
53
54
58
60
61
62
63
64
65
66
67
68
69
70
71
2
5
8
20
22
25
35
36
39
40
41
43
56
72
73
74
3
17
21
26
33
45
55
57
5
2
3
4
6
7
9
19
30
32
34

Figure 2.3. Crystalized sociogram for the post-zebra mussel time stanza. See Figure 2.2 for description of panels.

Figure 2.3

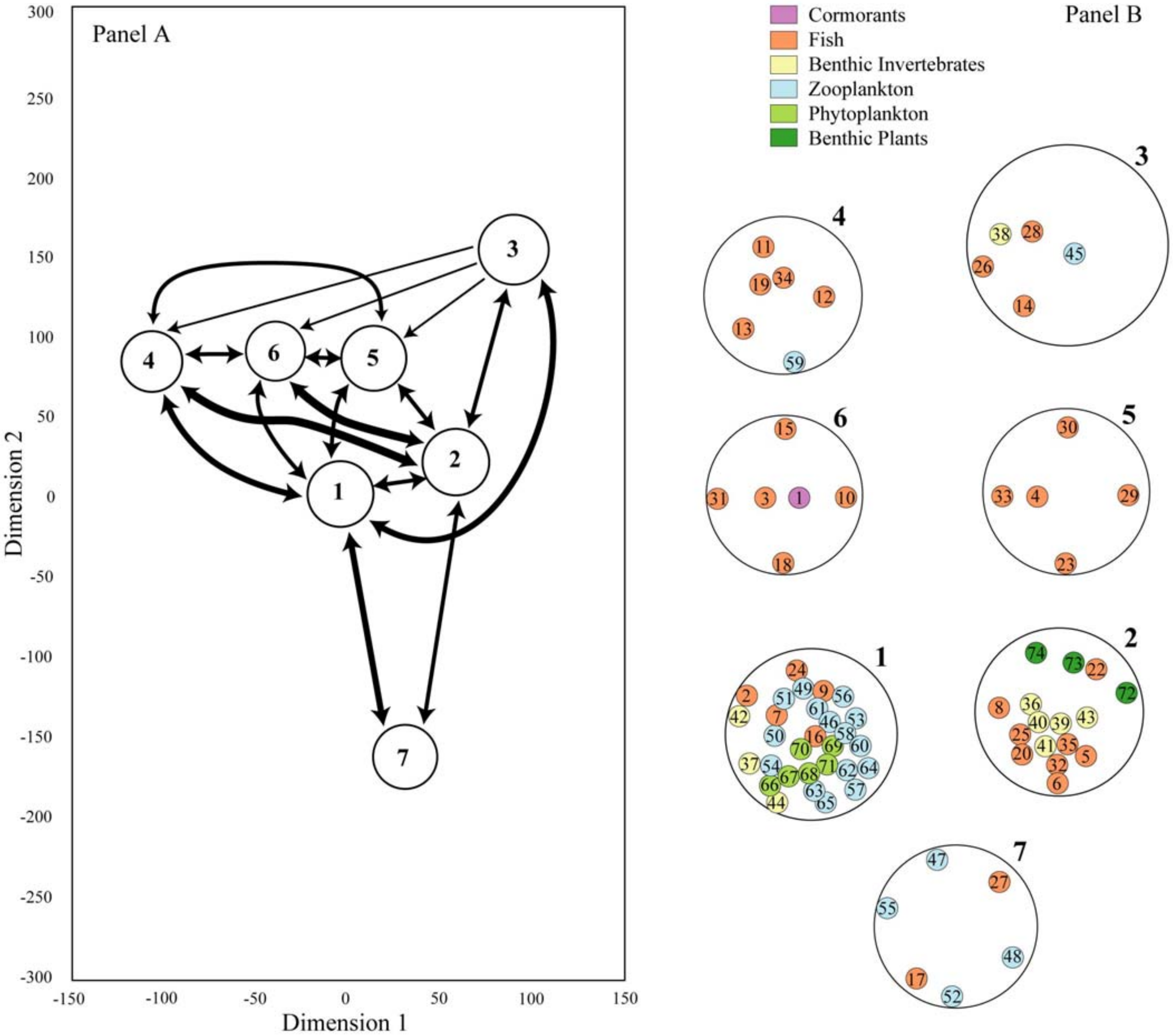

Panel A
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-150
-100
-50
0
50
100
150
Dimension 1
Dimension 2
1
2
3
4
5
6
7
Cormorants
Fish
Benthic Invertebrates
Zooplankton
Phytoplankton
Benthic Plants
Panel B
3
38 28 45 26 14
4
11 19 34 12 13 59
6
15 31 3 1 10 18
5
30 33 4 29 23
1
24 49 9 56 2 51 61 42 7 46 53 50 16 58 69 60 70 37 54 71 62 64 66 67 68 63 57 44 65
2
74 73 22 72 8 36 40 39 43 25 41 35 20 5 32 6
7
47 27 55 48 17 52

Figure 2.4. Zebra mussel impacts on subgroup members. The scale is relative: impacts above the zero line are positive impacts of zebra mussels and impacts below the zero line are negative impacts of zebra mussels.

Figure 2.4

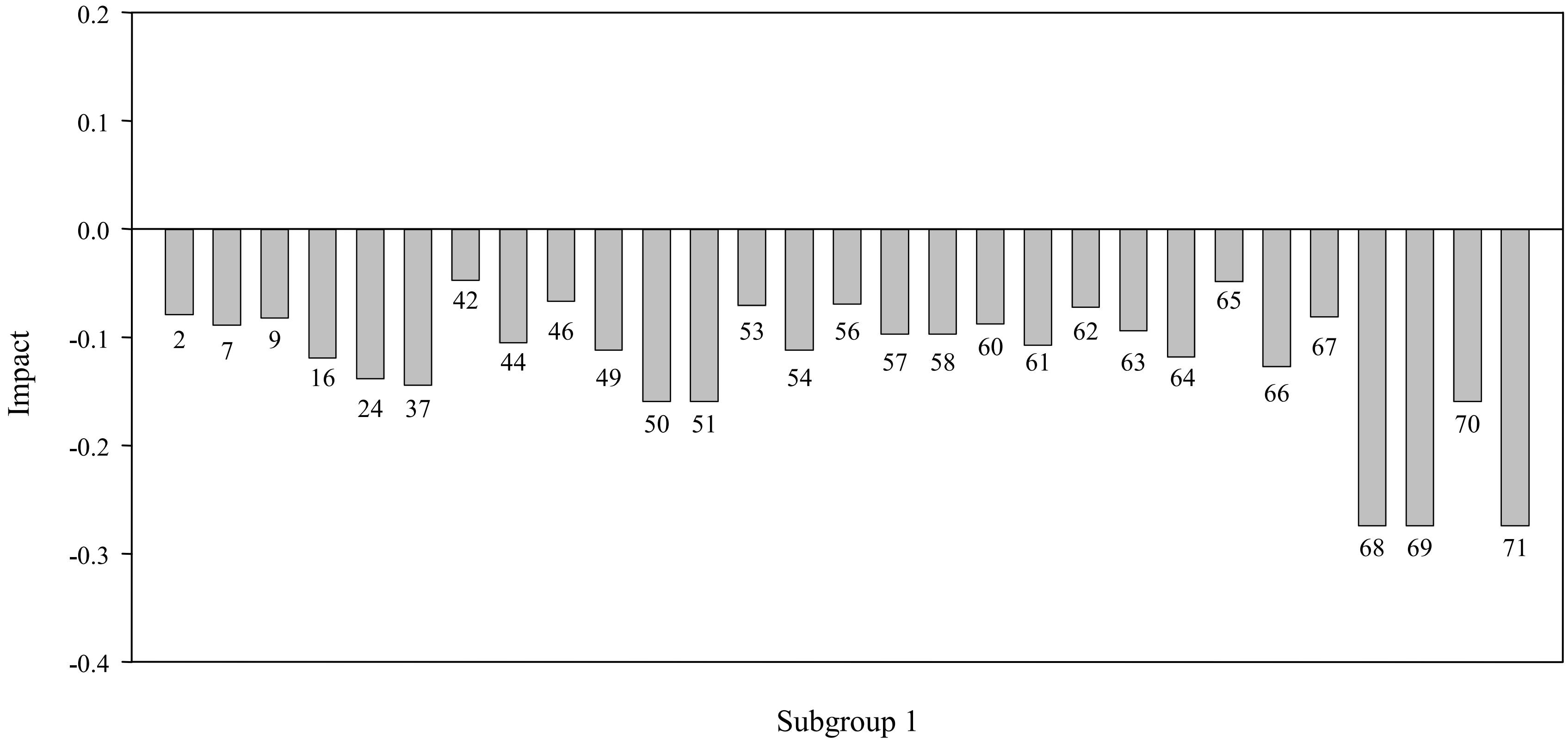
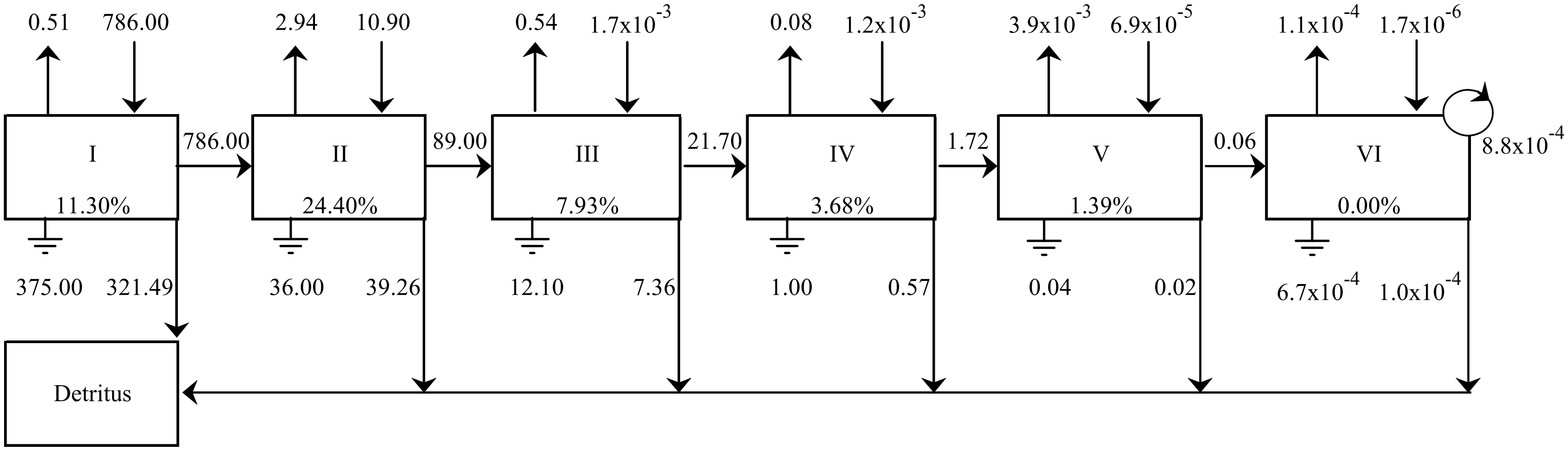

0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
Impact
2
7
9
16
24
37
42
44
46
49
50
51
53
54
56
57
58
60
61
62
63
64
65
66
67
68
69
70
71
Subgroup 1

Figure 2.5. Lindeman trophic spine for the pre-zebra mussel time stanza. Boxes with Roman numerals represent the integer trophic levels; the number within each trophic box is the percent efficiency of that trophic level at processing material. Arrows between the trophic boxes are flows in the grazer food chain, arrows leaving the top of trophic boxes are exports, arrows entering the top of trophic boxes are imports, and arrows leaving the bottom of trophic boxes are flows to detritus, represented by the detrital box. The ground symbol from electronic circuitry represents flow loss due to respiration. All flows are in gC m^{-2} yr^{-1}.

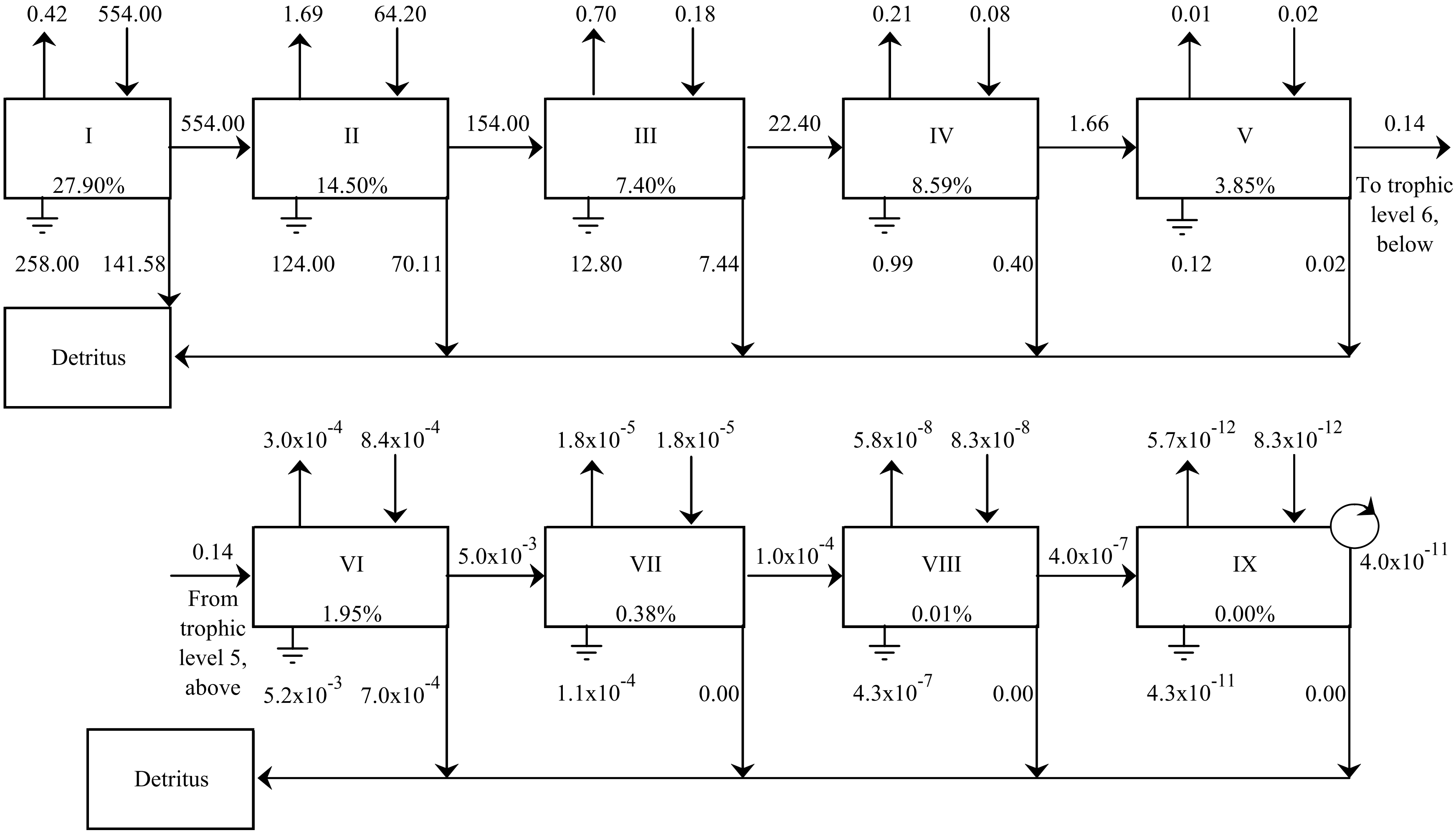
Figure 2.5



0.51
786.00
2.94
10.90
0.54
$1.7x10^{-3}$
0.08
$1.2x10^{-3}$
$3.9x10^{-3}$
$6.9x10^{-5}$
$1.1x10^{-4}$
$1.7x10^{-6}$
I
11.30%
786.00
II
24.40%
89.00
III
7.93%
21.70
IV
3.68%
1.72
V
1.39%
0.06
VI
0.00%
$8.8x10^{-4}$
375.00
321.49
36.00
39.26
12.10
7.36
1.00
0.57
0.04
0.02
$6.7x10^{-4}$
$1.0x10^{-4}$
Detritus

Figure 2.6. Lindeman trophic spine for the post-zebra mussel time stanza. See Figure 2.5 for a description of the figure.

Figure 2.6


0.42
554.00
1.69
64.20
0.70
0.18
0.21
0.08
0.01
0.02
I
27.90%
554.00
II
14.50%
154.00
III
7.40%
22.40
IV
8.59%
1.66
V
3.85%
0.14
To trophic level 6, below
258.00
141.58
124.00
70.11
12.80
7.44
0.99
0.40
0.12
0.02
Detritus
$3.0x10^{-4}$
$8.4x10^{-4}$
$1.8x10^{-5}$
$1.8x10^{-5}$
$5.8x10^{-8}$
$8.3x10^{-8}$
$5.7x10^{-12}$
$8.3x10^{-12}$
0.14
From trophic level 5, above
VI
1.95%
$5.0x10^{-3}$
VII
0.38%
$1.0x10^{-4}$
VIII
0.01%
$4.0x10^{-7}$
IX
0.00%
$4.0x10^{-11}$
$5.2x10^{-3}$
$7.0x10^{-4}$
$1.1x10^{-4}$
0.00
$4.3x10^{-7}$
0.00
$4.3x10^{-11}$
0.00
Detritus

References

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CHAPTER THREE

Invasive Species Impacts on Ecosystem Structure and Function: A Comparison of the Bay of Quinte, Canada, and Oneida Lake, USA, Before and After Zebra Mussel Invasion

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Abstract

To understand impacts of exotic species on ecosystem level properties, we compared food web characteristics of two eutrophic ecosystems - the Bay of Quinte, Lake Ontario (Canada), and Oneida Lake, New York (USA) - before and after zebra mussel (*Dreissena polymorpha*) invasion using ecological network analysis (ENA) and a social network analysis method, cohesion analysis (CA). ENA quantifies ecosystem function through an analysis of food web transfers, while CA assesses ecosystem structure by organizing food web members into subgroups of strongly interacting predators and prey. These methods detected direct and indirect impacts, changes in flow efficiency, and alterations of food web organization and ecosystem activity resulting from zebra mussel invasion. In the Bay of Quinte, zebra mussel introduction increased ecosystem growth (9%), stimulated benthic sources of production (e.g., macrophyte and detrital production increased over 1000%), and disrupted subgroup group structure. Previous research on Oneida Lake indicated zebra mussels diminished ecosystem growth (19%), promoted benthic production (e.g., macrophyte and detrital production increased

13% and 460%, respectively), and altered subgroup composition (33%). Together, these analyses suggested that zebra mussel influence was similar in ecosystems of comparable trophic status, and that comparative studies may be useful for the prediction of effects in other systems.

Introduction

Exotic species invasion is a critical driver of worldwide ecological change (Mills et al. 1994). Exotic species have altered ecosystems by disrupting food web dynamics (Chapter 2), biogeochemical cycles (Holeck et al. 2004), modifying habitats (Hall and Mills 2000), and decreasing native biodiversity (Holeck et al. 2004). Invasive species can also cause health risks and affect socio-economic systems by damaging agriculture, commercial and recreational fisheries, and fouling intake and nautical structures (Mills et al. 1994; Facon et al. 2005). Invasions by dreissenid mussels, including zebra (*Dreissena polymorpha*) and quagga (*Dreissena bugensis*) mussels, have been pervasive in North America, multiple European nations, and Russia (Drake and Bossenbroek 2004). Dreissenid mussels pose a considerable threat to aquatic environments, causing dramatic direct and indirect effects on food webs (Noonburg et al. 2003).

Although dreissenid invasion has led to pronounced changes in aquatic ecosystems, the severity and scope of impacts has varied between ecosystems. In the Great Lakes (Vanderploeg et al. 2002) and some inland waters of North America (MacIsaac 1996; Idrisi et al. 2001), dreissenid invasion increased water clarity and light penetration, which diverted energy from pelagic to benthic pathways (MacIsaac 1996; Mayer et al. 2002; Mills et al. 2003). However, in shallow and/or turbulent ecosystems, such as the Hudson River, Saginaw Bay (Lake Huron), and western Lake Erie, resuspension of dreissenid pseudofeces via water column mixing resulted in lessened effects on water clarity (Vanderploeg et al. 2002). Dreissenid invasion decreased phytoplankton abundance and/or biomass in most ecosystems, including Saginaw Bay (Nalepa et al. 1999), Green Bay (Lake Michigan) (Padilla et al. 1996), western Lake Erie (Leach 1993), Oneida Lake (New York) (Idrisi et al. 2001), and the Hudson River (Strayer et al. 1999); however, changes in phytoplankton resources did not uniformly affect zooplankton communities in all ecosystems. Zooplankton production and/or density decreased in Lake Erie, particularly the unstratified regions (Johannsson et al. 2000), and the Hudson River (Strayer et al. 1999). However, in Oneida Lake, zebra mussel effects on zooplankton were marginal (Idrisi et al. 2001). Likewise modeling studies on Green Bay (Padilla et al. 1996) and mesocosm experiments on the St. Lawrence River (Thorp and Casper 2003) found similar results.

Dreissenid effects on higher trophic levels, including benthic invertebrates and fish, were also mixed. Zebra mussel invasion negatively affected unionid clams in the Great Lakes (Vanderploeg et al. 2002), inland lakes (MacIsaac 1996), and rivers (Strayer et al. 1999). Non-mollusca benthic invertebrates declined in the Hudson River subsequent to invasion (Strayer et al. 1999), while in Lake Erie (Johannsson et al. 2000) and Saginaw Bay (Nalepa et al. 2003), benthic and macroinvertebrate biomass did not decrease. Moreover, dreissenid influence on fish varied by ecosystem. Dreissenid introduction might have indirectly benefited benthic and littoral fish in Oneida Lake (Rutherford et al. 1999; Jackson et al. 2002) and the Hudson River (Strayer et al. 2004); however in Lake Michigan, dreissenids may have negatively affected fish through modification of spawning habitat (Marsden and Chotkowski 2001). Furthermore, young fish, which may directly compete with dreissenids for zooplankton food resources, might have been negatively impacted in Lake Michigan (Dettmers et al. 2003), but showed little effect in Oneida Lake (Mayer et al. 2000) resultant from dreissenid invasion.

Although these studies indicate dreissenid mussels variably affect aquatic ecosystems, there may be trends in ecosystem response. Comparative analyses could be useful for elucidating these commonalities. For example, the effects of dreissenid invasion may vary with ecosystem morphology, ecosystem size, limiting factors to primary production, predator diets (Strayer et al. 2004), or along a trophic gradient (Padilla et al. 1996). Identifying the similarities in invaded ecosystems would aid in not only predicting which ecosystems might be susceptible to future invasions, but also how those ecosystems might be affected (Drake and Bossenbroek 2004). To decipher dreissenid impacts on ecosystems and draw comparisons between systems, we need a comprehensive understanding of ecosystems, including population and community level effects. Moreover, we need to incorporate the interrelationship between populations and communities, i.e., how change at the population level affects the community, which in turn regulates the population (Gaedke 1995). A major constraint to explicating these processes both within and among ecosystems is the complexity of food web interactions, especially indirect food web effects (Strayer et al. 2004).

One tool that is useful for holistically understanding and comparing ecosystems in the face of environmental problems is network analysis (Gaedke 1995). Network analysis examines ecosystems at multiple scales, including at the level of species-pair interaction, trophic level, and whole food web (Heymans et al. 2002) through an analysis of ecosystem structure and function. For network analysis, food webs are depicted as networks of exchange by quantifying feeding interactions and energy flow (Bondavalli et al. 2000). Network analysis has been used to compare ecosystem properties before and after exotic species invasion (Chapter 2), ecosystem dynamics between seasons (Baird and Ulanowicz 1989; Bondavalli et al. 2000), differences in marine upwelling and estuarine systems (Baird et al. 1991; Baird and Ulanowicz 1993), and aquatic ecosystems with and without terrestrial linkages (Heymans et al. 2002). In light of the need to comprehensively understand the effects of dreissenid invasion, we compared zebra mussel impacts within and between two invaded ecosystems using network analysis.

The primary objective of this paper was to quantify zebra mussel impacts on ecosystem structure and function, and to compare these characteristics between ecosystems of similar trophic status, specifically by addressing the following questions:

1. Structure: Did zebra mussel invasion alter the membership of food webs and food web subgroups (defined as clusters of strongly interacting predators and prey) in the Bay of Quinte, Lake Ontario (Canada) ecosystem?
2. Function: Did the magnitude of carbon flow within food webs and food web subgroups change as a result of zebra mussel invasion in the Bay of Quinte ecosystem?
3. Comparison: Do systems of comparable trophic status respond similarly, with respect to direction and magnitude of change, to zebra mussel invasion?

Using food web network analysis, we hypothesized that the Bay of Quinte would respond similarly to Oneida Lake, New York (USA), a system of comparable ecology and trophic status, subsequent to zebra mussel invasion. Previous network analysis examination (Chapter 2) suggested zebra mussel invasion led to the benthification (Mills et al. 2003) of Oneida Lake, i.e., an energy shunt occurred that promoted benthic sources of production and benthically-associated species. Therefore, we hypothesized that the Bay of Quinte would undergo benthification resultant from zebra mussel invasion, with concomitant changes in ecosystem structure and function that promoted benthic communities.

Methods

Study Site

The Bay of Quinte is a narrow, Z-shaped inlet on the northeastern portion of Lake Ontario (Figure 3.1). The Bay of Quinte has three distinct morphological regions, commonly referred to as the upper bay, middle bay, and lower bay, totaling approximately 80 km in length (Diamond et al. 1994) and 257 km^2 surface area (Minns 1995). A strong depth and trophic gradient exists in the Bay of Quinte, ranging from a shallow (mean depth of 3.5 m), eutrophic environment in the upper bay to a deeper (mean depth of 24.4 m), oligotrophic environment in the lower bay (Ridgway et al. 1990; Nicholls et al. 2002), which connects the Bay of Quinte to Lake Ontario. The upper bay is most similar in trophic status and physical characteristics to Oneida Lake (described in Chapter 2); therefore we used only this region in our analysis. The upper bay has a surface area of 134 km^2 and stratifies briefly during the summer months (Strus and Hurley 1992). Zebra mussels colonized the bay in 1993-1994, but were not established until 1995 (Nicholls et al. 2002). Because of the long-term history of limnological research on the Bay of Quinte (e.g., Hurley and Christie 1977) and Oneida Lake (e.g., Mills et al. 1978), ample data exist throughout the invasion history of zebra mussels to study their effects within and between these systems.

Network Construction

We constructed weighted food web networks for the Bay of Quinte before and after zebra mussel invasion and analyzed the networks using ecological network analysis (ENA) (Ulanowicz 1986) and a social network analysis method, cohesion analysis (CA) (Frank 1995; Krause et al. 2003; Chapter 2). We defined the years 1978 to 1994 as the pre-zebra mussel invasion time stanza and the years 1995 to 2002 as the post-invasion time stanza. We created these networks using the same methodology as for Oneida Lake (Chapter 2) and therefore, do not present details on network construction here. To make the Bay of Quinte analysis comparable to Oneida Lake, we did not include the microbial food web. The complete list of eighty food web species and aggregate groups are presented in Table 3.1. Data used to create network flows (i.e., the exchange matrix) were collected from the primary literature, field studies, and expert researchers on the Bay of Quinte (including the Bay of Quinte – Oneida Lake Comparative Modelling Project Workgroup). These parameters along with their sources are listed in Appendix 3.1. Finally, we mass-balanced our networks such that inputs equaled outputs for all taxa (Heymans and Baird 2000). Appendix 3.2 presents the balanced networks.

Ecological Network Analysis

After we completed network construction, we analyzed Bay of Quinte ecosystem structure (via CA) and function (via ENA) before and after zebra mussel invasion. We used the software package EcoNetwrk (http://www.glerl.noaa.gov/EcoNetwrk/) to conduct three ENA routines: 1) input / output analysis, 2) trophic level analysis, and 3) the calculation of ecosystem indices. We provide a brief description of ENA methods below; for greater detail see Ulanowicz (1986) and Ulanowicz (1997).

Input / output analysis (Hannon 1973; Patten et al. 1976) quantifies the amount of carbon supplied to any one taxon by another taxon over all direct and indirect linkages. The analysis includes a routine called IMPACTS that quantifies the relative effect of one taxon on another via direct and indirect paths (Heymans and Baird 2000).

Trophic analysis reinterprets the web of predator-prey transfers in terms of the Lindeman trophic chain concept (Lindeman 1942). Trophic analysis apportions the activities of omnivores among a series of hypothetical integer trophic levels to create the Lindeman spine, which is used to evaluate the efficiency of carbon flow in the system (Heymans and Baird 2000).

Ecosystem indices quantify system level properties such as growth and development, and assess the vulnerability and resilience of an ecosystem to perturbation (Ulanowicz 1997). These indices are: total system throughput (TST), ascendency (A), overhead (O), and development capacity (C). TST quantifies ecosystem size (and thereby growth) as the sum of all carbon flows (gC m^{-2} yr^{-1}) in the system. Ascendency quantifies the growth, development, and efficiency of ecosystem function (Ulanowicz 1986) and is calculated by scaling the average mutual information (AMI) index (Shannon 1948; McEliece 1977), a measure of network organization, with TST: $A = TST \times AMI$. Overhead quantifies the system's functional inefficiencies (Heymans et al. 2002) as well as the resiliency of a system to perturbation (Heymans and Baird 2000). There are four primary contributors to overhead: imports (e.g., immigrations) and exports (e.g., emigrations and fisheries harvest), respirative flow loss, and redundant food web flows (i.e., multiple flow paths connecting taxa). Overhead is calculated by scaling the system's conditional entropy (Ulanowicz 1986), a measure of network disorganization, by TST: $O = TST \times Conditional\ Entropy$. Development capacity is the upper bound on ecosystem growth and development. Capacity subsumes both ascendency and overhead: $C = A + O$.

Cohesion Analysis

Cohesion analysis identifies subgroups in food webs based on strengths of feeding relationships (Krause et al. 2003), where the maximization of an odds ratio is used as a criterion to assign subgroup membership[3]. CA uses an algorithm to iteratively reassign taxa to subgroups to maximize the odds that strong predatory interactions occur within subgroups, versus between subgroups (Frank 1996). The intent of CA is to determine the network structure that maximizes (strong) predator-prey interactions (realized interactions) within subgroups while minimizing predator-prey interactions between subgroups and taxa without connecting flows (unrealized interactions) within subgroups (Table 3.2).

Using the software Kliquefinder (Frank 1995), we identified subgroups within the Bay of Quinte food web networks. We tested the statistical significance of our subgroups against 1000 randomly generated re-combinations of our data (Frank 1996) and inspected the structure of significant subgroups. Although our ENA required balanced networks, our CA did not. In order to avoid introducing uncertainty from ENA balancing procedures, we used the unbalanced networks for CA. As a result, we could not include

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[3] Our use of the term "subgroup" is analogous to the Pimm and Lawton (1980) definition of food web "compartment". We use the term "subgroup" to avoid confusion between Pimm and Lawton (1980) and Ulanowicz (1986) uses of the term "compartment".

detrital groups in our CA because we derived detrital diet via balancing. Furthermore, our CA required us to adjust the network data to meet the range of Kliquefinder. Kliquefinder accepts flow weights only within 5 orders of magnitude; our networks exceeded this range both before (by 8 orders) and after (by 9 orders) invasion. We encountered this problem in our Oneida Lake analysis and used the same method as presented in Chapter 2 to adjust data. The final adjustment scheme increased values less than $1.0\text{x}10^{-6}$ gC m^{-2} yr^{-1} to the minimum Kliquefinder input, and values greater than 1.0 gC m^{-2} yr^{-1} to the maximum Kliquefinder input both pre- and post-zebra mussel invasion.

We summarized results of the CA as “crystallized sociograms” using multidimensional scaling (Frank 1996) in SAS System for Windows. In these diagrams, proximity of subgroups corresponds to: 1) the strength of predator-prey relationships spanning the subgroups (i.e., closely-spaced subgroups are connected by relatively stronger interactions than distant subgroups); 2) the similarity of connections to other subgroups; and 3) the subgroup’s importance to overall food web structure (i.e., centrally located subgroups are more important to food web structure than peripherally located subgroups). Similarly, taxa location within a subgroup indicates the strength of connections between taxa and the importance of taxa to the subgroup.

After we identified network subgroups, we performed ENA on the largest subgroup to evaluate functional linkages. We maintained the same mass-balance in the subgroup analysis as the full food web by treating all flows to and from non-subgroup taxa as imports and exports to the subgroup. Because detrital groups were not assigned to subgroups, detritus could not be explicitly incorporated into the subgroup ENA.

Nevertheless, flow to detritus was implicitly included by treating detrital flow as an export from the subgroup.

Results

Ecological Network Analysis – Entire Network

Input / output analysis

Zebra mussel impacts on the Bay of Quinte food web were predominantly negative (Figure 3.2). Cormorants were positively affected, while effects on fish were mixed. Benthic fish (e.g., ictalurids, carp and freshwater drum) and benthically associated fish (e.g., adult panfish) exhibited positive impacts, while pelagic fish (e.g., white perch, alewife and shiners) and some sportfish (e.g., walleye and smallmouth bass) were negatively affected. Round gobies showed the greatest positive impacts throughout the entire food web. Effects on benthic invertebrate taxa were equally positive and negative, with zebra mussels strongly negatively impacting themselves. Effects on zooplankton and phytoplankton taxa were wholly negative and benthic plants were marginally affected. Finally, zebra mussels positively influenced sedimented detritus, while negatively influencing other detrital groups.

Lindeman trophic analysis

We were unable to conduct the Lindeman trophic analysis on the full food webs due to computational limitations in the EcoNetwrk software resulting from network complexity. However, despite limitations in our trophic analysis, we could nonetheless analyze total food web flow efficiency. Total production (i.e., flow between predators and prey plus the usable exports from the system) was 425.3 gC m^{-2} yr^{-1} before zebra mussel invasion and 624.3 gC m^{-2} yr^{-1} after, a 47% increase. Total flow loss due to respiration was 534.1 gC m^{-2} yr^{-1} pre-invasion, and 510.9 gC m^{-2} yr^{-1} after invasion, a 4% decrease.

Ecosystem indices

The ecosystem analysis indicated that zebra mussel invasion caused moderate-to-strong changes to ecosystem function (Table 3.3, Panel A). TST (i.e., ecosystem growth) increased 10%, as did development capacity (i.e., ecosystem complexity) by 11%. Concomitantly, ascendency (i.e., organization) increased (47%) while overhead (i.e., disorganization) decreased slightly (1%). In part, changes in capacity, ascendency, and overhead were driven by increases in TST. To remove the effects of TST scaling on capacity, we simply divided capacity by TST. Unscaled capacity increased from 4.4 to 4.5 bits (2% increase). To remove TST scaling on ascendency and overhead, and look at the proportion of organized flow relative to disorganized flow in the ecosystem, we divided ascendency and overhead by development capacity, yielding “relative ascendency” and “relative overhead”, respectively. Relative ascendency increased from 25% to 33% following zebra mussel invasion, while relative overhead decreased from 75% to 67%. Finally, considering the contributors to relative overhead, overhead on imports, exports, and dissipative overhead decreased between 10 and 28%, while redundancy increased 9%.

Cohesion Analysis

We identified six subgroups in the pre-invasion network and eight subgroups in the post-invasion network. Even though the odds ratio was greater post-invasion (odds ratio = 14.6) than pre-invasion (odds ratio = 12.7), the pre-invasion subgroups were borderline statistically significant ($p < 0.07$) and post-invasion subgroups were clearly not statistically significant ($p > 0.5$) (see Appendix 3.3 for a discussion of these results). Therefore, only results for the pre-invasion network (Table 3.4) are described below. We identified three mixed taxa groups: 1) a planktivorous food web group; 2) benthically associated taxa; and 3) panfish and zooplankton[4]. The remaining subgroups were largely composed of piscivorous and invertivorous fish taxa. Interactions between (Panel A) and within (Panel B) subgroups were summarized in a crystallized sociogram (Figure 3.3). The planktivorous food web subgroup (subgroup 1) was fundamental to Bay of Quinte structure, sharing close interactions with all subgroups. Zooplankton and phytoplankton were central to this subgroup and interactions were closely knit. The remaining subgroups illustrated less dense interactions and more peripheral roles in the food web.

Ecological Network Analysis – Grouped Network

Since the post-invasion subgroups were non-significant, we could not conduct the input/output analysis at the subgroup level. Below we analyze the functional characteristics of the planktivorous food web subgroup (pre-invasion) with the remaining ENA methods. This subgroup dominated ecosystem structure (in terms of number of taxa) and size (as quantified by TST) (Table 3.3, Panel B).

Lindeman trophic analysis

The Lindeman trophic analysis identified twelve trophic levels in the planktivorous food web subgroup (Figure 3.4). Adult yellow perch, subadult, and juvenile walleye were the top predators in this subgroup. Flow in the grazer chain decreased substantially as trophic level increased, as did flow to detritus and flow loss

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[4] Subgroup names were based on ecological descriptions that represent the majority of taxa in each subgroup, but some taxa may not fit the subgroup name.

due to respiration. Efficiency was greatest at trophic level II (21%), similar for trophic levels I and III (5-6%), and lowest for all trophic levels IV and above. Total production of the subgroup was 414.7 gC m^{-2} yr^{-1} (97% of full food web) while total respiration was 198.3 gC m^{-2} yr^{-1} (37% of full food web).

Ecosystem indices

Similar to the full food web analysis, the planktivorous food web subgroup was largely composed of disorganized flow (Table 3.3, Panel C). Subgroup throughput amounted to 1192.4 gC m^{-2} yr^{-1}, constituting 52% of total food web flow. Ascendency represented 32% of development capacity, while overhead composed 68% of capacity. Relative overhead on imports and dissipative flow ranged between 18 and 23%, similar to the full food web. However, relative overhead on exports (21%) was greater in the subgroup; whereas relative overhead on redundant flows (7%) was less in the subgroup.

Discussion

Exotic species invasion is a pervasive threat to aquatic ecosystems. As the rate of invasions escalates (Holeck et al. 2004), it is essential that researchers understand ecosystem response to invasion in order to successfully forecast and prevent further spread (Drake and Bossenbroek 2004). In this study, we investigated exotic species perturbation on the Bay of Quinte food web. Our analysis indicated that zebra mussels exerted considerable influence in the Bay of Quinte by not only altering ecosystem structure (question 1), but also affecting ecosystem function (question 2). Moreover, our analyses supported the hypothesis that zebra mussels lead to the benthification of their invaded ecosystems. Below we begin our discussion with the CA structural findings, and then place those results within the ENA functional context. Furthermore, we compare (question 3) zebra mussel effects in the Bay of Quinte to previous research on Oneida Lake (Chapter 2).

Cohesion Analysis – Structure

Structural effects of zebra mussel invasion on the Bay of Quinte were pronounced, as evidenced by a complete disruption of food web subgroup structure. Before invasion, the planktivorous food web subgroup - a primarily pelagic subgroup - dominated structure. The centrality of this subgroup (Figure 3.3) parallels findings on Oneida Lake where we identified a planktivorous subgroup constituting the majority of structure. The prominence of these subgroups makes intuitive sense as both systems were eutrophic and largely comprised of pelagic pathways before invasion. In Oneida Lake, zebra mussels established in the planktivorous subgroup, linking this subgroup to the benthos. However, in the Bay of Quinte, zebra mussel introduction entirely removed subgroup structure. In effect, zebra mussel invasion homogenized the structure of Bay of Quinte food web interactions.

Our method of subgroup identification concentrated strong predator-prey interactions within subgroups, leaving only weak interactions between subgroups. According to food web stability theory, strong interactions can propagate the effects of a disturbance event. In this manner, perturbations can greatly affect subgroup members, but may not affect taxa in other subgroups which are connected through weak ties. In a sense, subgroup structure provides a buffering effect against ecosystem perturbation (Krause et al. 2003). In Oneida Lake, we found that the greatest effects of zebra mussel invasion were restricted to taxa within the planktivorous subgroup, corroborating the subgroup buffering effect. Conversely, as described above, zebra mussel invasion overwhelmed subgroup structure in the Bay of Quinte. This result has two implications: 1) the effects of zebra mussel invasion must have been more severe in the Bay of Quinte than Oneida Lake to have overcome the buffering effect of subgroup structure; and 2) zebra mussel influence can be more expansive in the Bay of Quinte without the confines of subgroup structure.

Ecological Network Analysis - Function

The IMPACTS analysis is a rigorous method to determine perturbation effects over all food web paths, including direct and indirect routes. Indirect paths are especially important as the net indirect effect may overwhelm direct interactions (Patten 1984). Our IMPACTS analysis indicated parallel food web response to zebra mussel invasion in the Bay of Quinte and Oneida Lake. The Bay of Quinte analysis suggested that zebra mussels had largely negative effects on food web taxa, yet zebra mussels positively affected some taxa, especially fish. In both the Bay of Quinte and Oneida Lake, benthic fish and panfish garnered positive impacts, although these effects were more pronounced in the Bay of Quinte. Potentially influence was greater in the Bay of Quinte due to the disruption of subgroup structure and the associated loss of subgroup buffering effects resultant from zebra mussel invasion. Walleye, which declined during the 1990s in both systems, showed negative effects for all life stages in both analyses. In Oneida Lake, the decline of walleye may be partially attributable to double-crested cormorant predation (Rudstam et al. 2004); however, cormorant predation pressure on walleye is not as intense in the Bay of Quinte (Hoyle, J. A. pers. comm.; Appendix 3.2). Therefore, declines in walleye abundance may be more ascribable to zebra mussel influence in the

Bay of Quinte than Oneida Lake, although commercial and recreational fisheries may also have contributed to declines of walleye in the Bay of Quinte (Appendix 3.2). The strongest positive impact in the Bay of Quinte belonged to round gobies, a recent Ponto-Caspian invader not present in Oneida Lake. Our Bay of Quinte research corroborates a facilitative interaction between zebra mussels and round gobies (Simberloff and Von Holle 1999; Ricciardi 2001), and suggests that Oneida Lake may be susceptible to round goby establishment due its similarity in fish community response to zebra mussel invasion. Considering the lower trophic levels, benthic invertebrate (mixed impacts), zooplankton (all negative impacts), and phytoplankton (all negative impacts) taxa exhibited similar response to invasion in both systems.

Changes in trophic flow efficiency were similar in both systems, with the exception of production. Production increased in the Bay of Quinte (47%) after invasion, and decreased in Oneida Lake (5%). The increase in Bay of Quinte production was largely due to greater primary production in benthic pathways, providing evidence for benthification. Macrophyte production increased from 2.9 to 33.4 gC m^{-2} yr^{-1} (1048% increase), while detrital production increased from 4.5 to 70.2 gC m^{-2} yr^{-1} (1462% increase). Oneida Lake macrophyte and detrital production also increased (13% and 460%, respectively) but the growth of benthic production was offset by a decrease in pelagic production. Respiration decreased in both the Bay of Quinte (4%) and Oneida Lake (23%) after invasion. Moreover, trophic chains for the planktivorous food web subgroup were similar in both systems pre-invasion. Although the trophic spine for the Bay of Quinte (12 levels) was longer than Oneida Lake (6 levels), flow efficiency by trophic level decreased with increased trophic level in both systems, and was greatest at trophic level II (21 % - Bay of Quinte; 24% - Oneida Lake). All flows were substantially greater at trophic level I, indicating the importance of lower trophic levels to these systems.

Drawing from Odum's (1969) theory of ecosystem development, Ulanowicz (1996) made predictions for ecosystem level response to perturbation. Ulanowicz suggested that perturbed ecosystems would exhibit decreased system throughput and decreased food web organization (i.e., increased overhead) due to an interruption of the ecological processes that optimize efficient functioning. For example, redundant food web flows, a substantial contributor to overhead, would increase after perturbation as an ecosystem response to maintain food web connectance. Moreover, frequently perturbed systems will adapt to harbor greater overhead values (Ulanowicz 1997). In this sense, overhead is a "strength in reserve of degrees of freedom which the system can call upon to adapt to a new threat" (Bondavalli et al. 2000).

Our analysis indicated that zebra mussel invasion perturbed the Bay of Quinte in a different manner than predicted by Ulanowicz (1996). Contrary to theory, total system throughput and ascendency increased after invasion. We attribute the difference in perturbation response to the overwhelming presence of zebra mussels in the Bay of Quinte. Zebra mussels garnered over 15% of TST and comprised 89% of living biomass. Perhaps the food web exhibited increased organization due to this considerable flow asymmetry: focused flow through zebra mussels would increase AMI, which in turn increases ascendency. Ecosystem organization responded similarly in Oneida Lake where zebra mussels also dominated flow (10% of TST) and living biomass (67%). Moreover, both systems were predominantly comprised of disorganized flow (66-75%), potentially indicative of frequent perturbation, such as exotic species invasion (Prout et al. 1990) and changes in nutrient loading (Mills et al. 2003). Finally, zebra mussel invasion increased development capacity in both systems, adding a layer of functional complexity. Complexity benefits ecosystems by promoting flow diversity, which can buffer future ecological change (Pérez-España and Arreguín-Sánchez 1999) in these systems.

A limitation of ENA is that variability in carbon flow estimates is not incorporated into the analysis. Therefore, we could not discern statistical significance in our ENA findings. Additionally, one of the primary assumptions of ENA is that the food web is mass-balanced. As aquatic ecosystems are dynamic in space and time, this assumption is rarely met. Balancing introduces a degree of uncertainty into ENA, which makes careful choice of balancing methods and inspection of results for ecological plausibility essential. The final critical assumption of this research was that differences in food web structure and function between the time stanzas were attributable to zebra mussel invasion. Round gobies and *Cercopagis pengoi* also invaded the Bay of Quinte during our time periods, and cormorant biomass increased substantially. Although these changes may have altered food web structure and function, we believe zebra mussel introduction far outweighs all other ecological change during our time periods, as evidenced by the dominance of zebra mussel flow and biomass. Therefore, we are confident in the robustness of our results.

In conclusion, zebra mussel invasion exerted a far-reaching influence on the Bay of Quinte ecosystem. Although whole-system analysis is a formidable task due to the complexity of ecosystem structure and function and paucity of long-term data in many systems (Gaedke 1995), the extensive history of data collection by Bay of Quinte researchers and our application of network analysis methods allowed us to decipher zebra mussel impacts at the ecosystem level. Zebra mussel introduction not only caused substantial changes to food web subgroup structure, but also altered food web function by shunting energy from pelagic to benthic pathways. Moreover, zebra mussel effects were similar in Oneida Lake, a system of comparable trophic status. These findings have implications for the prediction of zebra mussel effects in other systems, making network analysis comparisons across invaded ecosystems a valuable endeavor. As exotic species invasion becomes an ever-increasing threat to aquatic ecosystems worldwide, understanding ecosystem dynamics is of paramount importance.

Acknowledgements

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Table 3.1. List of food web taxa. Brook silverside, emerald shiners, largemouth bass, round gobies, zebra mussels, and *Cercopagis pengoi*, were present in the post-zebra mussel time stanza, but not the pre-zebra mussel time stanza.

No	Common Name	Taxonomic Classification	No	Common Name	Taxonomic Classification
1	Cormorants	*Phalacrocorax auritus*	41	Isopods	Isopoda order
2	Walleye Age 4+	*Sander vitreus*	42	Leeches	Hirudinea class
3	Walleye Age 1-3	*Sander vitreus*	43	Oligochaetes	Oligochaeta class
4	Walleye Age-0	*Sander vitreus*	44	Snails	Gastropoda class
5	Yellow Perch Age 1+	*Perca flavescens*	45	Zebra Mussels	*Dreissena polymorpha*
6	Yellow Perch Age-0	*Perca flavescens*	46	*Alona* species	*Alona* species
7	White Perch Age 1+	*Morone americana*	47	*Bosmina longirostris*	*Bosmina longirostris*
8	White Perch Age-0	*Morone americana*	48	*Ceriodaphnia* species	*Ceriodaphnia* species
9	Black Crappie 1+	*Pomoxis nigromaculatus*	49	Chydoridae family	Chydoridae family
10	Bluegill Age 1+	*Lepomis macrochirus*	50	*Daphnia galeata mendotae*	*Daphnia galeata mendotae*
11	*Lepomis* species Age 1+	*Lepomis* genus			
12	Pumpkinseed Age 1+	*Lepomis gibbosus*	51	*Daphnia pulicaria*	*Daphnia pulicaria*
13	Rock Bass Age 1+	*Ambloplites rupestris*	52	*Daphnia retrocurva*	*Daphnia retrocurva*
14	Sunfish family Age 1+	Centrarchidae family	53	*Eubosmina coregoni*	*Eubosmina coregoni*
15	Panfish Age-0	Centrarchidae family	54	Sididae family	Sididae family
16	Alewife	*Alosa pseudoharengus*	55	Large-bodied Cladocerans	Large-bodied Cladocerans
17	American Eel	*Anguilla rostrata*	56	*Cercopagis pengoi*	*Cercopagis pengoi*
18	Brook Silverside	*Labidesthes sicculus*	57	*Leptodora kindtii*	*Leptodora kindtii*
19	Brown Bullhead	*Ameiurus nebulosus*	58	*Acanthocyclops vernalis*	*Acanthocyclops vernalis*
20	Channel Catfish	*Ictalurus punctatus*	59	*Diacyclops thomasi*	*Diacyclops thomasi*
21	Common Carp	*Cyprinus carpio carpio*	60	*Eucyclops* species	*Eucyclops* species
22	Emerald Shiner	*Notropis athernoides*	61	*Mesocyclops* species	*Mesocyclops* species
23	Freshwater Drum	*Aplodinotus grunniens*	62	*Tropocyclops extensus*	*Tropocyclops extensus*
24	Gizzard Shad	*Dorosoma cepedianum*	63	Cyclopoida copepodites	Cyclopoida copepodites
25	Johnny Darter	*Etheostoma nigrum*	64	Diaptomidae family	Diaptomidae family
26	Largemouth Bass	*Micropterus salmoides*	65	Temoridae family	Temoridae family
27	Log Perch	*Percina caprodes*	66	Calanoida copepodites	Calanoida copepodites
28	Longnose Gar	*Lepisosteus osseus*	67	Harpacticoida	Harpacticoida
29	Northern Pike	*Esox lucius*	68	Nauplii	Nauplii
30	Round Goby	*Neogobius melanostomus*	69	Rotifers	Rotifers
			70	Blue-green Algae	Cyanophyceae
31	Smallmouth Bass	*Micropterus dolomieu*	71	Diatoms	Bacillariophyceae
32	Spottail Shiner	*Notropis hudsonius*	72	Flagellates	Cryptophyceae & Dinophyceae
33	Trout-perch	*Percopsis omiscomaycus*			
34	White Bass	*Morone chrysops*	73	Golden Algae	Chrysophyceae
35	White Sucker	*Catostomus commersonii*	74	Green Algae	Chlorophyceae
			75	Epiphytes	Epiphytes
36	Amphipods	Amphipoda order	76	Macrophytes	Macrophytes
37	Chironomids	Chironomidae family	77	Periphytes	Periphytes
38	Clams	Sphaeriidae family	78	Pelagic Detritus	Pelagic Detritus
39	Crayfish	*Orconectes* species	79	Sedimented Detritus	Sedimented Detritus
40	Insects	Arthropoda phylum	80	DOC	DOC

Table 3.2. Association between common subgroup membership and the occurrence of ties between predators and prey (adapted from Frank 1995). The odds ratio method maximizes the ratio AD : BC.

		Tie Occurring		
		No	Yes	
Subgroup Membership	Different	A	B	Possible relations between predators and prey in different subgroups
	Same	C	D	Possible relations between predators and prey in the same subgroup
		Unrealized Interactions	Realized Interactions	Total possible relations

Table 3.3. Ecosystem indices for the full food web (Panel A), subgroup throughput (Panel B), and ecosystem indices for subgroup 1 (Panel C). The percent difference was calculated as: $\%Difference = \frac{Post - Pre}{Pre} x100\%$.

Panel A: Full Food Web	Pre-Zebra Mussels	Post-Zebra Mussels	% Difference
Index	Value	Value	Value
Total system throughput (gC m^{-2} yr^{-1})	2304.2	2505.4	8.7
Development capacity (gC-bits m^{-2} yr^{-1})	10160.5	11281.2	11.0
Ascendency (gC-bits m^{-2} yr^{-1})	2541.1	3726.8	46.7
Total overhead (gC-bits m^{-2} yr^{-1})	7619.3	7554.4	-0.9
Overhead on imports (gC-bits m^{-2} yr^{-1})	2594.2	2591.3	-0.1
Overhead on exports (gC-bits m^{-2} yr^{-1})	893.7	711.7	-20.4
Dissipative overhead (gC-bits m^{-2} yr^{-1})	2096.5	1787.7	-14.7
Redundancy (gC-bits m^{-2} yr^{-1})	2034.9	2463.7	21.1
Unscaled capacity (bits)	4.4	4.5	2.1
Ascendency / capacity (%)	25.0	33.0	32.1
Total overhead / capacity (%)	75.0	67.0	-10.7
Overhead on imports / capacity (%)	25.5	23.0	-10.0
Overhead on exports / capacity (%)	8.8	6.3	-28.3
Dissipative overhead / capacity (%)	20.6	15.8	-23.2
Redundancy / capacity (%)	20.0	21.8	9.0

Panel B: Subgroup TST	
	TST (gC m^{-2} yr^{-1})
Subgroup 1	1192.4
Subgroup 2	16.45
Subgroup 3	0.20
Subgroup 4	0.03
Subgroup 5	0.08
Subgroup 6	0.06

Panel C: Subgroup 1 Indices	Pre-Zebra Mussels
Index	Value
Development capacity (gC-bits m^{-2} yr^{-1})	4041.3
Ascendency (gC-bits m^{-2} yr^{-1})	1282.1
Total overhead (gC-bits m^{-2} yr^{-1})	2759.2
Overhead on imports (gC-bits m^{-2} yr^{-1})	914.1
Overhead on exports (gC-bits m^{-2} yr^{-1})	838.8
Dissipative overhead (gC-bits m^{-2} yr^{-1})	727.2
Redundancy (gC-bits m^{-2} yr^{-1})	279.2
Unscaled capacity (bits)	3.4
Ascendency / capacity (%)	31.7
Total overhead / capacity (%)	68.3
Overhead on imports / capacity (%)	22.6
Overhead on exports / capacity (%)	20.8
Dissipative overhead / capacity (%)	18.0
Redundancy / capacity (%)	6.9

Table 3.4. Subgroups identified for the pre-zebra mussel invasion time stanza.

No.	Subgroup 1: Planktivorous Food Web
3	Walleye Age 1-3
4	Walleye Age-0
5	Yellow Perch Age 1+
7	White Perch Age 1+
8	White Perch Age-0
16	Alewife
24	Gizzard Shad
36	Amphipods
37	Chironomids
38	Clams
40	Insects
47	*Bosmina longirostris*
48	*Ceriodaphnia* species
49	Chydoridae family
50	*Daphnia galeata mendotae*
51	*Daphnia pulicaria*
52	*Daphnia retrocurva*
53	*Eubosmina coregoni*
54	Sididae family
57	*Leptodora kindtii*
58	*Acanthocyclops vernalis*
59	*Diacyclops thomasi*
61	*Mesocyclops* species
62	*Tropocyclops extensus*
63	Cyclopoida copepodites
64	Diaptomidae family
66	Calanoida copepodites
68	Nauplii
69	Rotifers
70	Blue-green Algae
71	Diatoms
72	Flagellates
73	Golden Algae
74	Green Algae
76	Macrophytes
77	Periphytes

No.	Subgroup 2: Benthically Associated
2	Walleye Age 4+
17	American Eel
19	Brown Bullhead
21	Common Carp
35	White Sucker
41	Isopods
42	Leeches
43	Oligochaetes
44	Snails
75	Epiphytes

No.	Subgroup 3: Panfish & Zooplankton
10	Bluegill Age 1+
11	*Lepomis* species Age 1+
14	Sunfish family Age 1+
46	*Alona* species
55	Large-bodied Cladocerans
67	Harpacticoida

No.	Subgroup 4: Piscivores & Invertivores
1	Cormorants
13	Rock Bass Age 1+
15	Panfish Age-0
27	Log Perch
31	Smallmouth Bass
32	Spottail Shiner

No.	Subgroup 5: Piscivores
6	Yellow Perch Age-0
20	Channel Catfish
23	Freshwater Drum
28	Longnose Gar
29	Northern Pike
33	Trout-perch
34	White Bass

No.	Subgroup 6: Invertivores
9	Black Crappie 1+
12	Pumpkinseed Age 1+
25	Johnny Darter
39	Crayfish
60	*Eucyclops* species
65	Temoridae family

Figure 3.1. Map of the Bay of Quinte (Source: Carolyn Bakelaar, Department of Fisheries and Oceans, Canada).

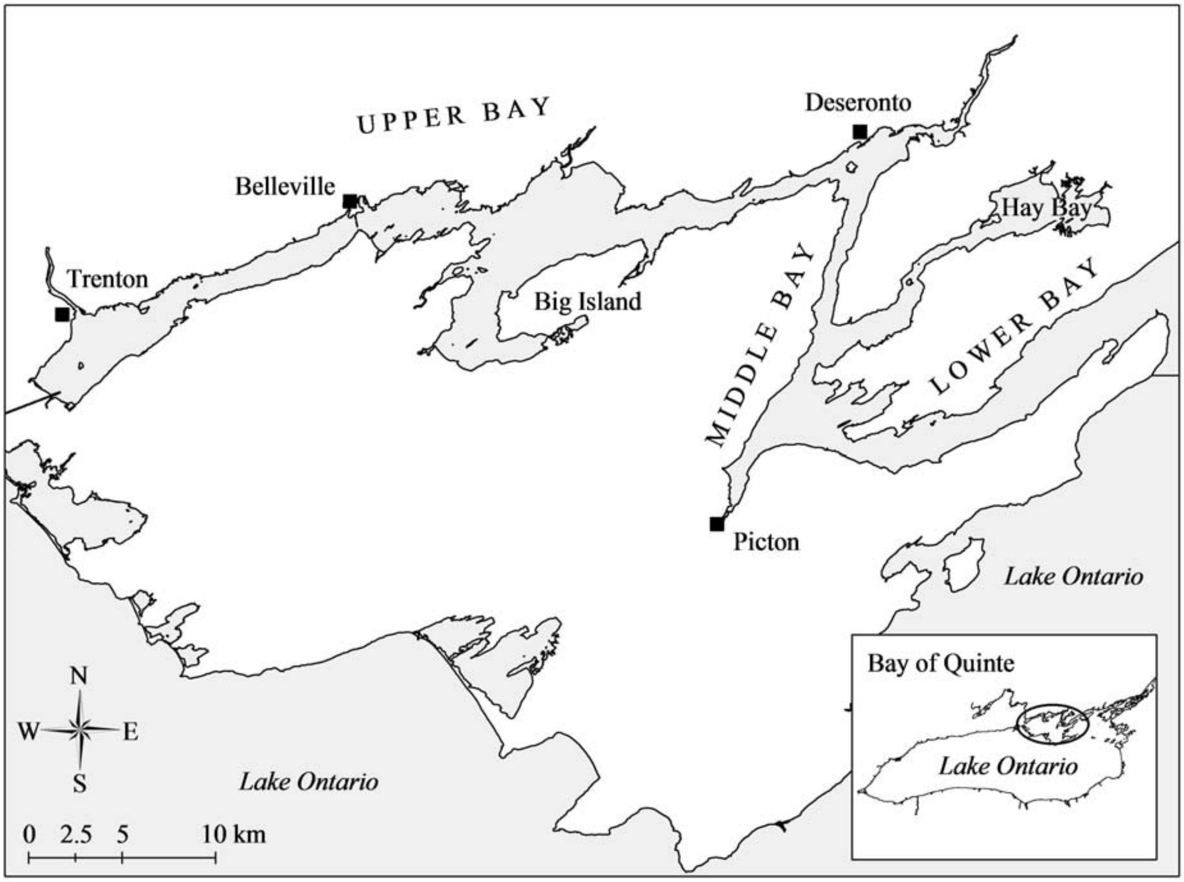

Figure 3.2. Zebra mussel impacts on the Bay of Quinte food web. The scale is relative: impacts above the zero line are positive impacts of zebra mussels and impacts below the zero line are negative impacts of zebra mussels. Taxa numbers are placed above or below each bar. See Table 3.1 for taxa codes.

Figure 3.2

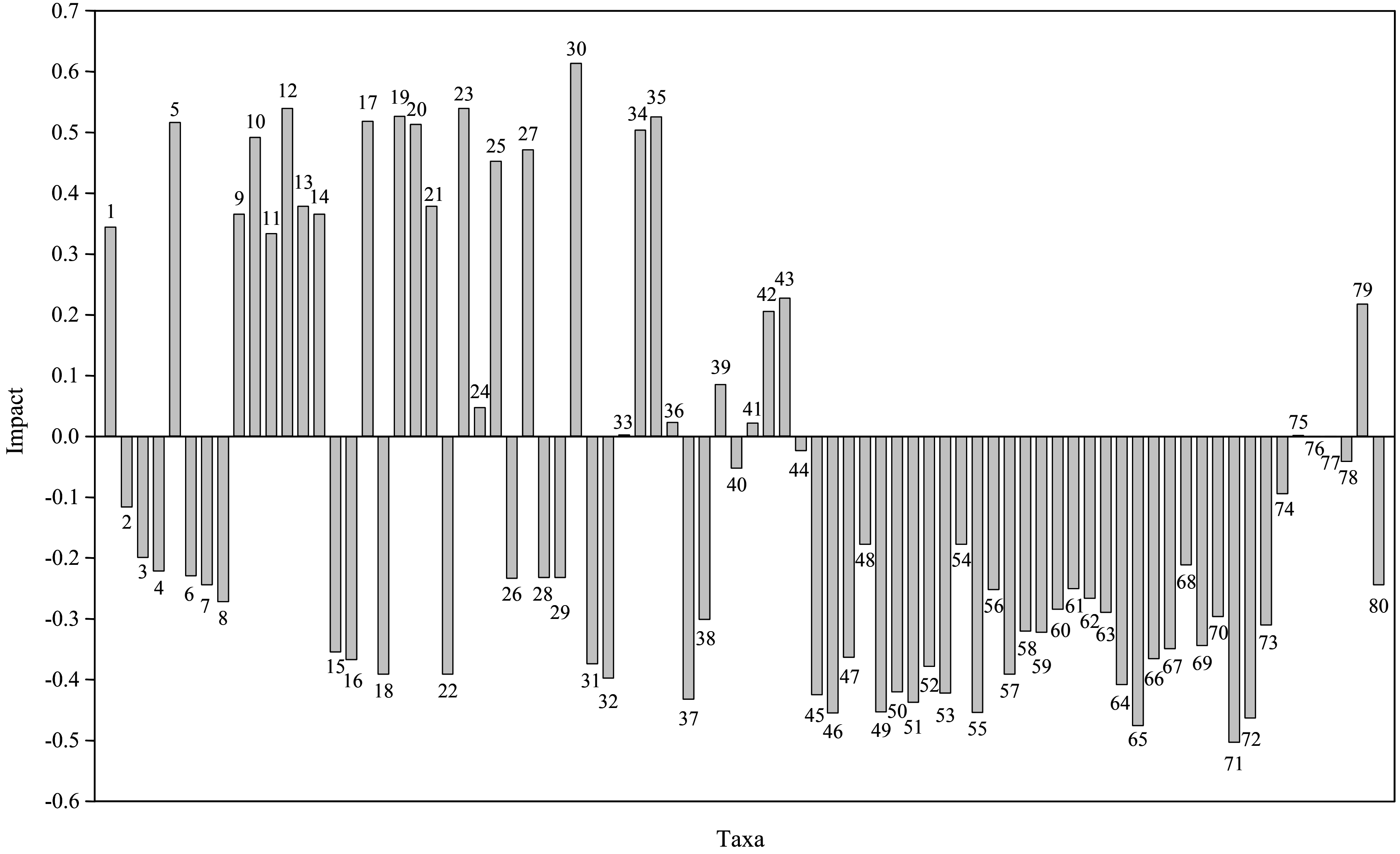

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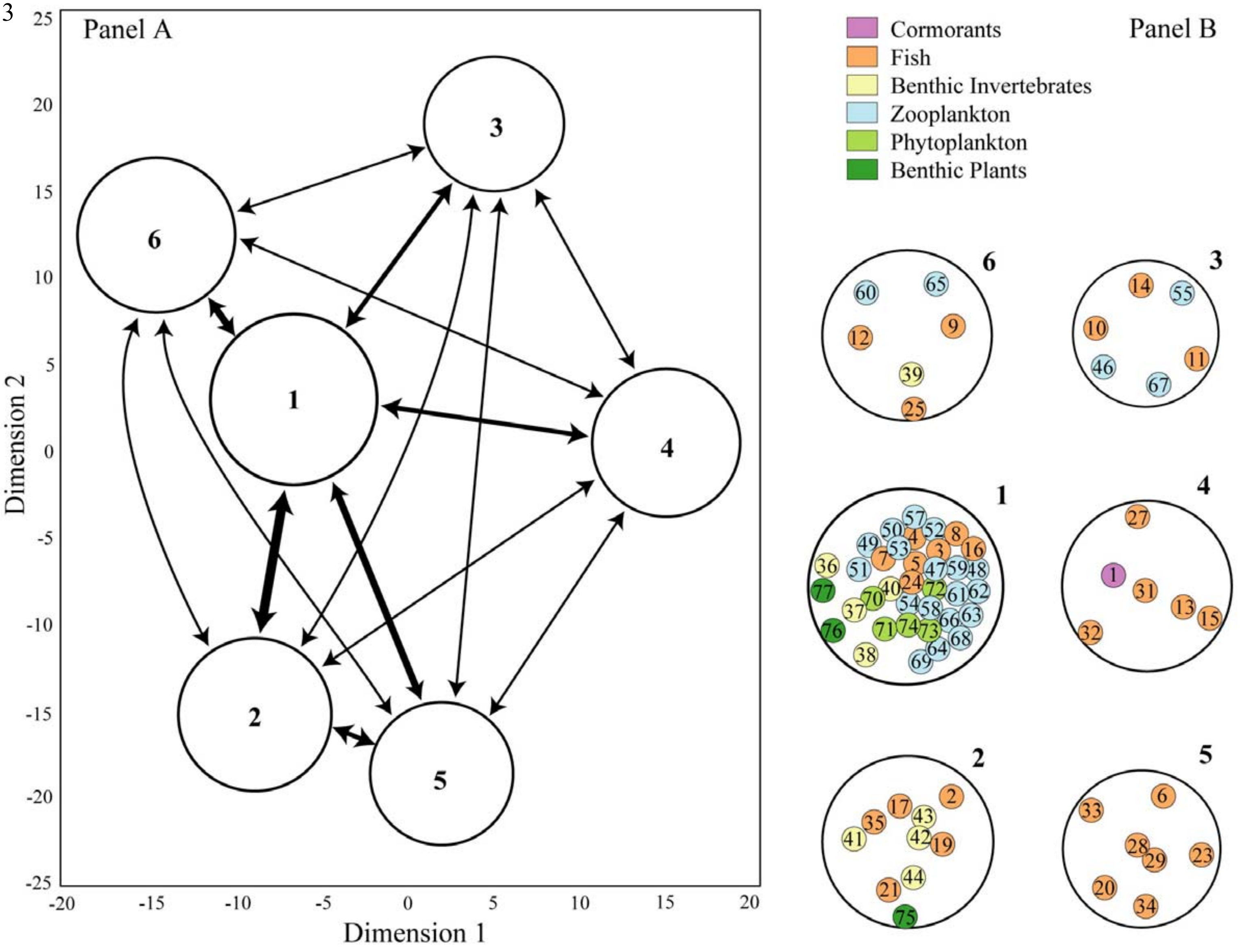
Figure 3.3. Panel A: Crystalized sociogram for the pre-zebra mussel time stanza. Units are relative distances based on the inverse of the density of interactions (see Frank 1996). Subgroups 1 through 6 are plotted with the direction of feeding relationships represented by arrows; thickness of arrow indicates weight of feeding relationships. Panel B: Placement of taxa within subgroups. Circles indicate subgroup boundaries and colors represent general trophic groupings of taxa. Subgroup numbers are located to the upper right of all subgroups.

Figure 3.3


Panel A
Dimension 2
25
20
15
10
5
0
-5
-10
-15
-20
-25
Dimension 1
-20
-15
-10
-5
0
5
10
15
20
1
2
3
4
5
6
Panel B
Cormorants
Fish
Benthic Invertebrates
Zooplankton
Phytoplankton
Benthic Plants
6
60
65
12
9
39
25
3
14
55
10
11
46
67
1
57
50
52
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69
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15
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17
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75
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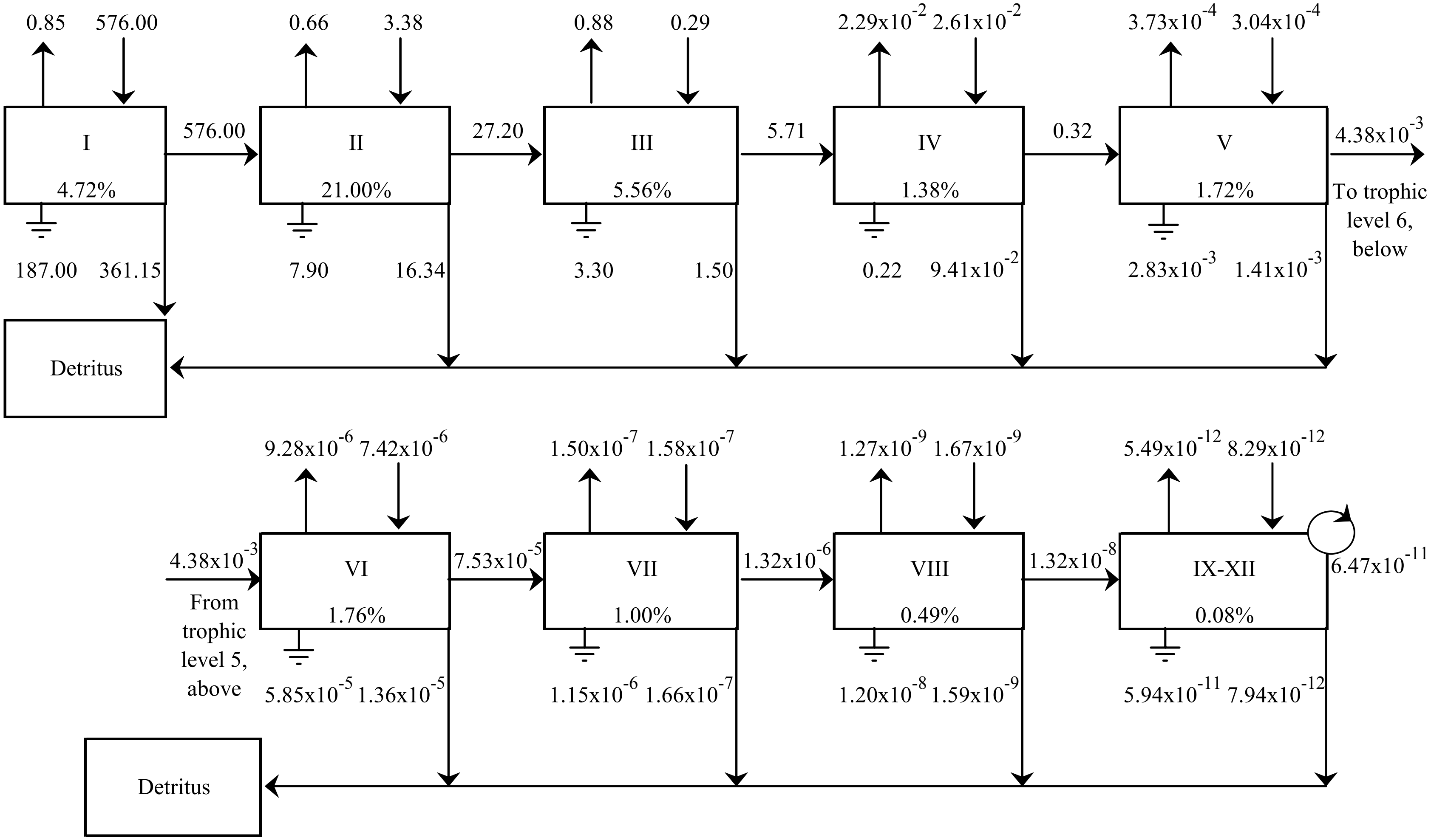
23
20
34

Figure 3.4. Lindeman trophic spine for the pre-zebra mussel time stanza. Boxes with Roman numerals represent the integer trophic levels; the number within each trophic box is the percent efficiency of that trophic level at processing material. Arrows between the trophic boxes are flows in the grazer food chain, arrows leaving the top of trophic boxes are exports, arrows entering the top of trophic boxes are imports, and arrows leaving the bottom of trophic boxes are flows to detritus, represented by the detrital box. The ground symbol from electronic circuitry represents flow loss due to respiration. All flows are in gC m^{-2} yr^{-1}.

Figure 3.4


0.85
576.00
0.66
3.38
0.88
0.29
2.29x10-2
2.61x10-2
3.73x10-4
3.04x10-4
I
4.72%
576.00
II
21.00%
27.20
III
5.56%
5.71
IV
1.38%
0.32
V
1.72%
4.38x10-3
To trophic level 6, below
187.00
361.15
7.90
16.34
3.30
1.50
0.22
9.41x10-2
2.83x10-3
1.41x10-3
Detritus
9.28x10-6
7.42x10-6
1.50x10-7
1.58x10-7
1.27x10-9
1.67x10-9
5.49x10-12
8.29x10-12
4.38x10-3
From trophic level 5, above
VI
1.76%
7.53x10-5
VII
1.00%
1.32x10-6
VIII
0.49%
1.32x10-8
IX-XII
0.08%
6.47x10-11
5.85x10-5
1.36x10-5
1.15x10-6
1.66x10-7
1.20x10-8
1.59x10-9
5.94x10-11
7.94x10-12
Detritus

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APPENDICES

Appendix 2.1

List of model inputs and data sources for the unbalanced pre- and post-zebra mussel invasion networks. Diet proportions are not included to conserve space, but sources of diet information are listed. N.P. stands for not present. Biomass units are g m^{-2}, wet weight (WW). Conversions from wet weight to dry weight (DW), and dry weight to carbon, are listed. P/B, C/B, and R/B stand for production-to-biomass, consumption-to-biomass, and respiration-to-biomass ratios, respectively, measured as yr^{-1}. Export includes migrations from the ecosystem and fisheries harvest (g m^{-2} WW). The abbreviation BQ-OL CMP Workgroup refers to the Bay of Quinte – Oneida Lake Comparative Modelling Project Workgroup. The methods for this modeling project, from which much of our data was drawn, are expected to be published in 2006 as a Canadian Technical Report of Fisheries and Aquatic Sciences (Koops, M. A. pers. comm.).

Appendix 2.1

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
1	Cormorants	Biomass WW	$1.73x10^{-4}$	$5.23x10^{-4}$	BQ-OL CMP Workgroup
		WW : DW	$3.50x10^{-1}$	$3.50x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$7.62x10^{-1}$	$6.44x10^{-1}$	BQ-OL CMP Workgroup
		C/B	$7.19x10^{1}$	$7.18x10^{1}$	BQ-OL CMP Workgroup
		R/B	$7.03x10^{1}$	$7.03x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
2	Walleye Age 4+	Biomass WW	$1.89x10^{-1}$	$8.24x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$4.78x10^{-1}$	$3.25x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.96	3.83	BQ-OL CMP Workgroup
		R/B	2.99	2.99	BQ-OL CMP Workgroup
		Export	$1.35x10^{-2}$	$5.88x10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
3	Walleye Age 1-3	Biomass WW	$7.35x10^{-2}$	$2.73x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$4.70x10^{-1}$	$4.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.94	5.54	BQ-OL CMP Workgroup
		R/B	3.86	3.86	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
4	Walleye Age-0	Biomass WW	$3.49x10^{-3}$	$3.74x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	2.42	2.42	BQ-OL CMP Workgroup
		C/B	7.84	$1.46x10^{1}$	BQ-OL CMP Workgroup
		R/B	9.89	9.89	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
5	Yellow Perch Age 3+	Biomass WW	$1.50x10^{-1}$	$7.94x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.99x10^{-1}$	$5.93x10^{-1}$	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
5	Yellow Perch Age 3+	C/B	3.8	4.19	BQ-OL CMP Workgroup
		R/B	3.72	3.72	BQ-OL CMP Workgroup
		Export	$1.74x10^{-2}$	$9.18x10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
6	Yellow Perch Age 1-2	Biomass WW	$2.26x10^{-2}$	$3.37x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.99x10^{-1}$	$5.93x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.8	4.19	BQ-OL CMP Workgroup
		R/B	3.72	3.72	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
7	Yellow Perch Age-0	Biomass WW	$2.02x10^{-2}$	$3.92x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	6.14	7.15	BQ-OL CMP Workgroup
		C/B	$1.53x10^{1}$	$1.94x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.68x10^{1}$	$1.68x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
8	White Perch Age 1+	Biomass WW	$7.05x10^{-2}$	$5.56x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.01x10^{-1}$	$5.86x10^{-1}$	BQ-OL CMP Workgroup
		C/B	4	4.18	BQ-OL CMP Workgroup
		R/B	2.75	2.75	BQ-OL CMP Workgroup
		Export	$1.07x10^{-4}$	$8.46x10^{-5}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
9	White Perch Age-0	Biomass WW	$1.82x10^{-2}$	$1.06x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	4.8	4.8	BQ-OL CMP Workgroup
		C/B	$1.26x10^{1}$	$1.28x10^{1}$	BQ-OL CMP Workgroup
		R/B	7.22	7.22	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
10	Black Crappie Age 1+	Biomass WW	4.70×10^{-4}	4.70×10^{-4}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	7.08×10^{-1}	7.08×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.42	4.42	BQ-OL CMP Workgroup
		R/B	2.77	2.77	BQ-OL CMP Workgroup
		Export	3.24×10^{-5}	3.24×10^{-5}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
11	Bluegill Age 1+	Biomass WW	3.07×10^{-4}	3.07×10^{-4}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	6.12×10^{-1}	6.12×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.22	4.22	BQ-OL CMP Workgroup
		R/B	2.77	2.77	BQ-OL CMP Workgroup
		Export	5.76×10^{-5}	5.76×10^{-5}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
12	Pumpkinseed Age 1+	Biomass WW	6.33×10^{-3}	6.47×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	6.12×10^{-1}	6.12×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.22	4.22	BQ-OL CMP Workgroup
		R/B	2.77	2.77	BQ-OL CMP Workgroup
		Export	6.66×10^{-4}	6.80×10^{-4}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
13	Rock Bass Age 1+	Biomass WW	5.00×10^{-3}	4.85×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	5.15×10^{-1}	5.15×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.03	4.03	BQ-OL CMP Workgroup
		R/B	2.77	2.77	BQ-OL CMP Workgroup
		Export	2.60×10^{-5}	2.52×10^{-5}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
14	Panfish Age-0	Biomass WW	1.68×10^{-4}	7.24×10^{-5}	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
14	Panfish Age-0	WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	1.5	1.5	BQ-OL CMP Workgroup
		C/B	6	1.19×10^{1}	BQ-OL CMP Workgroup
		R/B	1.10×10^{1}	1.10×10^{1}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
15	Gizzard Shad Age 1+	Biomass WW	7.18×10^{-3}	7.58×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	1.43	1.43	BQ-OL CMP Workgroup
		C/B	5.86	5.86	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
16	Gizzard Shad Age-0	Biomass WW	3.54×10^{-1}	8.95×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	1.43	1.43	BQ-OL CMP Workgroup
		C/B	5.96	5.96	BQ-OL CMP Workgroup
		R/B	6.93	6.93	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
17	Alewife	Biomass WW	1.04×10^{-4}	1.87×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	8.65×10^{-1}	8.89×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.68	4.68	BQ-OL CMP Workgroup
		R/B	1.00×10^{1}	1.00×10^{1}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
18	Brown Bullhead	Biomass WW	1.06×10^{-2}	1.10×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	4.24×10^{-1}	3.86×10^{-1}	BQ-OL CMP Workgroup
		C/B	3.85	3.77	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
18	Brown Bullhead	Export	$3.55x10^{-5}$	$3.69x10^{-5}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
19	Burbot	Biomass WW	$6.89x10^{-3}$	$6.61x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.60x10^{-1}$	$2.60x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.52	3.52	BQ-OL CMP Workgroup
		R/B	5.79	5.79	BQ-OL CMP Workgroup
		Export	$7.50x10^{-6}$	$7.20x10^{-6}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
20	Channel Catfish	Biomass WW	$6.11x10^{-2}$	$6.16x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.79x10^{-1}$	$2.17x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.56	3.43	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup
		Export	$2.04x10^{-4}$	$2.06x10^{-4}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
21	Cisco	Biomass WW	$9.27x10^{-4}$	N.P.	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	1.71	N.P.	BQ-OL CMP Workgroup
		C/B	6.42	N.P.	BQ-OL CMP Workgroup
		R/B	1.04	N.P.	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
22	Common Carp	Biomass WW	$5.18x10^{-2}$	$3.40x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$1.56x10^{-1}$	$1.60x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.33	3.33	BQ-OL CMP Workgroup
		R/B	2.4	2.4	BQ-OL CMP Workgroup
		Export	$1.10x10^{-5}$	$7.20x10^{-6}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
23	Darters	Biomass WW	$5.40x10^{-5}$	$1.35x10^{-4}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.70x10^{-1}$	$3.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.74	3.74	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
24	Emerald Shiners	Biomass WW	$2.39x10^{-3}$	$8.60x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	1.71	1.71	BQ-OL CMP Workgroup
		C/B	6.42	6.42	BQ-OL CMP Workgroup
		R/B	5.83	5.83	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
25	Freshwater Drum	Biomass WW	$5.71x10^{-2}$	$1.03x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.64x10^{-1}$	$2.50x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.52	3.52	BQ-OL CMP Workgroup
		R/B	2.57	2.57	BQ-OL CMP Workgroup
		Export	$2.16x10^{-4}$	$3.91x10^{-4}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
26	Golden Shiners	Biomass WW	$1.77x10^{-3}$	$5.40x10^{-5}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	1.71	1.71	BQ-OL CMP Workgroup
		C/B	6.42	6.42	BQ-OL CMP Workgroup
		R/B	5.83	5.83	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
27	Lake Sturgeon	Biomass WW	N.P.	$5.92x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	N.P.	$2.00x10^{-1}$	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
27	Lake Sturgeon	C/B	N.P.	4	BQ-OL CMP Workgroup
		R/B	N.P.	3.3	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
28	Log Perch	Biomass WW	$2.70x10^{-5}$	$6.30x10^{-5}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.70x10^{-1}$	$3.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.74	3.74	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
29	Mottled Sculpin	Biomass WW	$9.00x10^{-6}$	$9.00x10^{-6}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.70x10^{-1}$	$3.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.74	3.74	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
30	Northern Pike	Biomass WW	$7.11x10^{-4}$	$7.11x10^{-4}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.01x10^{-1}$	$1.98x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.4	3.4	BQ-OL CMP Workgroup
		R/B	5.79	5.79	BQ-OL CMP Workgroup
		Export	$8.37x10^{-5}$	$8.37x10^{-5}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
31	Red Horse Sucker	Biomass WW	$5.29x10^{-3}$	$6.72x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.70x10^{-1}$	$3.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.74	3.74	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
32	Smallmouth Bass	Biomass WW	$4.56x10^{-2}$	$4.87x10^{-2}$	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
32	Smallmouth Bass	WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	3.90×10^{-1}	3.68×10^{-1}	BQ-OL CMP Workgroup
		C/B	5.36	5.36	BQ-OL CMP Workgroup
		R/B	3.92	3.92	BQ-OL CMP Workgroup
		Export	2.09×10^{-3}	2.23×10^{-3}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
33	Trout-perch	Biomass WW	9.26×10^{-3}	1.02×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	1.35	1.46	BQ-OL CMP Workgroup
		C/B	5.71	5.91	BQ-OL CMP Workgroup
		R/B	3.19	3.19	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
34	White Bass	Biomass WW	1.06×10^{-2}	1.08×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	2.60×10^{-1}	2.60×10^{-1}	BQ-OL CMP Workgroup
		C/B	3.52	3.52	BQ-OL CMP Workgroup
		R/B	5.79	5.79	BQ-OL CMP Workgroup
		Export	2.40×10^{-4}	2.45×10^{-4}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
35	White Sucker	Biomass WW	4.56×10^{-2}	4.98×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	3.23×10^{-1}	2.68×10^{-1}	BQ-OL CMP Workgroup
		C/B	3.65	3.54	BQ-OL CMP Workgroup
		R/B	2.59	2.59	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
36	Amphipods	Biomass WW	5.19×10^{-2}	4.63×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	1.67×10^{-1}	1.67×10^{-1}	Jørgensen 1979
		DW : Carbon	4.17×10^{-1}	4.17×10^{-1}	Jørgensen 1979
		P/B	5.7	5.7	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
36	Amphipods	C/B	$3.02x10^{1}$	$3.02x10^{1}$	BQ-OL CMP Workgroup
		R/B	4.26	4.26	Quigley et al. 2002
		Diet	.	.	BQ-OL CMP Workgroup
37	Chironomids	Biomass WW	$5.73x10^{-2}$	$4.54x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.62x10^{-1}$	$4.62x10^{-1}$	Jørgensen 1979
		P/B	$1.31x10^{1}$	$1.31x10^{1}$	BQ-OL CMP Workgroup
		C/B	$6.24x10^{1}$	$6.24x10^{1}$	BQ-OL CMP Workgroup
		R/B	4.5	4.5	Johnson and Brinkhur 1971
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
38	Clams	Biomass WW	$7.19x10^{-4}$	$4.45x10^{-4}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$3.99x10^{-1}$	$3.99x10^{-1}$	Jørgensen 1979
		P/B	3.8	3.8	BQ-OL CMP Workgroup
		C/B	$2.44x10^{1}$	$2.44x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.03x10^{1}$	$1.03x10^{1}$	Johnson and Brinkhur 1971
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
39	Insects	Biomass WW	$6.88x10^{-3}$	$6.88x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.46x10^{-1}$	$4.46x10^{-1}$	Jørgensen 1979
		P/B	5.35	5.35	BQ-OL CMP Workgroup
		C/B	$3.18x10^{1}$	$3.18x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.33x10^{1}$	$1.33x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
40	Isopods	Biomass WW	$7.25x10^{-3}$	$1.38x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$3.43x10^{-1}$	$3.43x10^{-1}$	Jørgensen 1979
		P/B	5.7	5.7	BQ-OL CMP Workgroup
		C/B	$3.02x10^{1}$	$3.02x10^{1}$	BQ-OL CMP Workgroup
		R/B	4.26	4.26	Quigley et al. 2002

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
40	Isopods	Diet	.	.	BQ-OL CMP Workgroup
41	Leeches	Biomass WW	$3.29x10^{-3}$	$4.38x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.83x10^{-1}$	$4.83x10^{-1}$	Jørgensen 1979
		P/B	5.35	5.35	BQ-OL CMP Workgroup
		C/B	$3.18x10^{1}$	$3.18x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.33x10^{1}$	$1.33x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
42	Oligochaetes	Biomass WW	$8.98x10^{-3}$	$1.65x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.02x10^{-1}$	$4.02x10^{-1}$	Jørgensen 1979
		P/B	$1.31x10^{1}$	$1.31x10^{1}$	BQ-OL CMP Workgroup
		C/B	$6.24x10^{1}$	$6.24x10^{1}$	BQ-OL CMP Workgroup
		R/B	4.5	4.5	Johnson and Brinkhur 1971
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
43	Snails	Biomass WW	$1.85x10^{-2}$	$3.10x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$3.99x10^{-1}$	$3.99x10^{-1}$	Jørgensen 1979
		P/B	3.5	3.5	BQ-OL CMP Workgroup
		C/B	$1.33x10^{1}$	$1.33x10^{1}$	BQ-OL CMP Workgroup
		R/B	1.8	1.8	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
44	Zebra Mussels	Biomass WW	N.P.	$1.59x10^{1}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$3.99x10^{-1}$	$3.99x10^{-1}$	Jørgensen 1979
		P/B	N.P.	1.35	BQ-OL CMP Workgroup
		C/B	N.P.	8.6	BQ-OL CMP Workgroup
		R/B	N.P.	4.15	Fanslow et al. 2001
		Diet	.	.	BQ-OL CMP Workgroup
45	*Alona* species	Biomass WW	$1.05x10^{-4}$	$3.01x10^{-5}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
45	*Alona* species	P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
46	*Bosmina longirostris*	Biomass WW	$2.59x10^{-2}$	$2.01x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
47	*Camptocercus harpae*	Biomass WW	N.P.	$1.26x10^{-4}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	N.P.	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	N.P.	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	N.P.	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
48	*Ceriodaphnia quadrangula*	Biomass WW	$7.39x10^{-4}$	$5.32x10^{-4}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
49	*Chydorus sphaericus*	Biomass WW	$1.16x10^{-2}$	$2.57x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
49	*Chydorus*	C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
	sphaericus	R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
50	*Daphnia galeata*	Biomass WW	$2.58x10^{-1}$	$1.88x10^{-1}$	BQ-OL CMP Workgroup
	mendotae	WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$5.07x10^{-1}$	$5.07x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
51	*Daphnia*	Biomass WW	$3.15x10^{-1}$	$4.89x10^{-1}$	BQ-OL CMP Workgroup
	pulicaria	WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$5.07x10^{-1}$	$5.07x10^{1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
52	*Daphnia*	Biomass WW	$7.36x10^{-3}$	$8.20x10^{-4}$	BQ-OL CMP Workgroup
	retrocurva	WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$5.07x10^{-1}$	$5.07x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
53	*Diaphanosoma*	Biomass WW	$9.11x10^{-3}$	$9.02x10^{-3}$	BQ-OL CMP Workgroup
	species	WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
53	*Diaphanosoma* species	R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
54	*Eubosmina coregoni*	Biomass WW	$2.09x10^{-2}$	$3.22x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
55	*Sida crystallina*	Biomass WW	$3.27x10^{-5}$	$7.42x10^{-5}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{1}$	$3.80x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.53x10^{2}$	$1.53x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
56	*Leptodora kindtii*	Biomass WW	$4.71x10^{-4}$	$1.57x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.10x10^{1}$	$3.10x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.23x10^{2}$	$1.23x10^{2}$	BQ-OL CMP Workgroup
		R/B	$2.59x^{-1}$	$2.59x10^{-1}$	Hillbricht-Ilkowska and Karabin 1970
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
57	*Acanthocyclops vernalis*	Biomass WW	$1.67x10^{-5}$	$3.54x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
57	*Acanthocyclops*	R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
	vernalis	Diet	.	.	BQ-OL CMP Workgroup Krause 2004
58	*Diacyclops*	Biomass WW	$1.26x10^{-1}$	$5.42x10^{-2}$	BQ-OL CMP Workgroup
	thomasi	WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Hansen and Nelson 1998
59	*Ergasilus* species	Biomass WW	$2.13x10^{-4}$	$2.41x10^{-5}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Hudson and Lesko 2002
60	*Mesocyclops edax*	Biomass WW	$5.65x10^{-2}$	$4.99x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
61	*Epischura*	Biomass WW	$3.68x10^{-2}$	$5.25x10^{-2}$	BQ-OL CMP Workgroup
	lacustris	WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup
		R/B	$2.96x10^{1}$	$2.96x10^{1}$	Banse and Mosher 1980

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
61	*Epischura lacustris*	Diet	.	.	BQ-OL CMP Workgroup Krause 2004
62	*Leptodiaptomus minutus*	Biomass WW	$7.34x10^{-2}$	$6.85x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup
		R/B	$2.96x10^{1}$	$2.96x10^{1}$	Banse and Mosher 1980
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
63	*Skistodiaptomus oregonensis*	Biomass WW	$1.00x10^{-1}$	$1.07x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup
		R/B	$2.96x10^{1}$	$2.96x10^{1}$	Banse and Mosher 1980
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
64	Nauplii	Biomass WW	$5.46x10^{-2}$	$4.40x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.00x10^{1}$	$2.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	$8.20x10^{1}$	$8.20x10^{1}$	BQ-OL CMP Workgroup
		R/B	1.16	1.16	Makarewicz and Likens 1979
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
65	Rotifers	Biomass WW	$7.20x10^{-3}$	$7.20x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.20x10^{1}$	$5.20x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.08x10^{2}$	$2.08x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.16	1.16	Makarewicz and Likens 1979
		Diet	.	.	BQ-OL CMP Workgroup

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
65	Rotifers	Diet	.	.	Pennak 1978
66	Blue-green Algae	Biomass WW	1.38	1.09	BQ-OL CMP Workgroup
		WW : DW	$3.60x10^{-1}$	$3.60x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.60x10^{-1}$	$4.60x10^{-1}$	Jørgensen 1979
		P/B	$8.70x10^{1}$	$9.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	$7.28x10^{1}$	$7.28x10^{1}$	Biddanda and Cotner 2002
67	Diatoms	Biomass WW	1.77	1.62	BQ-OL CMP Workgroup
		WW : DW	$3.30x10^{-1}$	$3.30x10^{-1}$	Jørgensen 1979
		DW : Carbon	$5.17x10^{-1}$	$5.17x10^{-1}$	Jørgensen 1979
		P/B	$8.70x10^{1}$	$9.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	$7.28x10^{1}$	$7.28x10^{1}$	Biddanda and Cotner 2002
68	Euglena	Biomass WW	$3.48x10^{-2}$	$2.25x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$4.00x10^{-1}$	$4.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.81x10^{-1}$	$4.81x10^{-1}$	Jørgensen 1979
		P/B	$8.70x10^{1}$	$9.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	$7.28x10^{1}$	$7.28x10^{1}$	Biddanda and Cotner 2002
69	Flagellates	Biomass WW	$8.50x10^{-1}$	$5.21x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$4.00x10^{-1}$	$4.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$8.70x10^{1}$	$9.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	$7.28x10^{1}$	$7.28x10^{1}$	Biddanda and Cotner 2002
70	Golden Algae	Biomass WW	$3.27x10^{-1}$	$8.77x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$4.00x10^{-1}$	$4.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$8.70x10^{1}$	$9.00x10^{1}$	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	$7.28x10^{1}$	$7.28x10^{1}$	Biddanda and Cotner 2002
71	Green Algae	Biomass WW	$7.87x10^{-1}$	$2.00x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$4.30x10^{-1}$	$4.30x10^{-1}$	Jørgensen 1979

Appendix 2.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
71	Green Algae	DW : Carbon	5.05×10^{-1}	5.05×10^{-1}	Jørgensen 1979
		P/B	8.70×10^{1}	9.00×10^{1}	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	7.28×10^{1}	7.28×10^{1}	Biddanda and Cotner 2002
72	Epiphytes	Biomass WW	9.56×10^{-1}	9.56×10^{-1}	BQ-OL CMP Workgroup
		WW : DW	1.20×10^{-1}	1.20×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	1.20×10^{2}	1.20×10^{2}	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	1.00×10^{2}	9.67×10^{1}	Biddanda and Cotner 2002
73	Macrophytes	Biomass WW	9.45×10^{-1}	1.1	BQ-OL CMP Workgroup
		WW : DW	1.20×10^{-1}	1.20×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	8.8	8.8	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	7.36	7.12	Biddanda and Cotner 2002
74	Periphytes	Biomass WW	1.23×10^{-1}	1.23×10^{-1}	BQ-OL CMP Workgroup
		WW : DW	1.20×10^{-1}	1.20×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	2.65×10^{1}	2.65×10^{1}	BQ-OL CMP Workgroup
		C/B	None	None	BQ-OL CMP Workgroup
		R/B	2.22×10^{1}	2.15×10^{1}	Biddanda and Cotner 2002

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Appendix 2.2

Balanced exchange matrices for the pre- and post-zebra mussel invasion networks. For clarity, the matrix was changed to list format. Flows units are gC m^{-2} yr^{-1} and all zero flows were removed from the list. N.P., Prod., Cons., Resp., Imp., and Exp. stand for not present, production, consumption, respiration, imports, and exports, respectively.

Appendix 2.2

Predator	Prey	Pre Exchange	Post Exchange
1	2	$8.20x10^{-4}$	$2.66x10^{-3}$
1	3	$5.54x10^{-3}$	$2.14x10^{-2}$
1	4	$4.80x10^{-5}$	$1.52x10^{-4}$
1	5	$4.15x10^{-3}$	$1.38x10^{-2}$
1	6	$4.24x10^{-3}$	$1.40x10^{-2}$
1	7	$1.16x10^{-4}$	$3.63x10^{-4}$
1	8	$1.19x10^{-3}$	$3.96x10^{-3}$
1	10	$5.45x10^{-5}$	$1.88x10^{-4}$
1	11	$5.34x10^{-5}$	$1.84x10^{-4}$
1	12	$5.40x10^{-4}$	$1.93x10^{-3}$
1	13	$5.50x10^{-4}$	$1.90x10^{-3}$
1	15	$3.32x10^{-4}$	$1.15x10^{-3}$
1	16	$8.87x10^{-5}$	$2.79x10^{-4}$
1	18	$2.75x10^{-4}$	$8.70x10^{-4}$
1	19	$3.70x10^{-4}$	$1.23x10^{-3}$
1	20	$2.95x10^{-4}$	$1.01x10^{-3}$
1	21	$9.94x10^{-6}$	N.P.
1	23	$2.55x10^{-6}$	$8.71x10^{-5}$
1	24	$5.42x10^{-5}$	$1.68x10^{-4}$
1	25	$1.05x10^{-5}$	$3.38x10^{-5}$
1	26	$5.42x10^{-5}$	$1.68x10^{-6}$
1	28	$2.54x10^{-6}$	$8.72x10^{-6}$
1	29	$2.62x10^{-6}$	$8.71x10^{-6}$
1	30	$3.71x10^{-5}$	$1.20x10^{-4}$
1	31	$2.54x10^{-4}$	$8.71x10^{-4}$
1	32	$5.83x10^{-4}$	$1.98x10^{-3}$
1	33	$1.69x10^{-5}$	$5.57x10^{-5}$
1	34	$3.69x10^{-4}$	$1.23x10^{-3}$
1	35	$2.97x10^{-4}$	$1.02x10^{-3}$
1	39	$8.05x10^{-5}$	$3.09x10^{-5}$
1	41	$1.02x10^{-5}$	$3.71x10^{-5}$
2	4	$2.58x10^{-2}$	$1.16x10^{-2}$
2	5	$2.59x10^{-2}$	$1.22x10^{-2}$
2	6	$2.66x10^{-2}$	$1.24x10^{-2}$
2	7	$4.44x10^{-1}$	$1.96x10^{-1}$
2	9	$9.52x10^{-2}$	$4.28x10^{-2}$
2	14	$2.61x10^{-4}$	$1.17x10^{-5}$
2	15	$3.84x10^{-3}$	$1.89x10^{-3}$
2	16	$1.21x10^{-1}$	$5.41x10^{-2}$
2	18	$3.17x10^{-3}$	$1.42x10^{-3}$
2	19	$1.92x10^{-2}$	$9.08x10^{-3}$
2	20	$3.40x10^{-3}$	$1.65x10^{-3}$
2	21	$2.93x10^{-3}$	N.P.
2	23	$2.94x10^{-5}$	$1.42x10^{-4}$
2	24	$1.58x10^{-2}$	$6.93x10^{-3}$
2	25	$3.06x10^{-3}$	$1.40x10^{-3}$
2	26	$1.58x10^{-2}$	$6.93x10^{-5}$
2	28	$2.92x10^{-5}$	$1.42x10^{-5}$
2	29	$3.01x10^{-5}$	$1.42x10^{-5}$
2	30	$1.93x10^{-3}$	$8.86x10^{-4}$
2	31	$2.92x10^{-3}$	$1.42x10^{-3}$
2	32	$9.62x10^{-3}$	$4.65x10^{-3}$
2	34	$1.91x10^{-2}$	$9.04x10^{-3}$
2	35	$3.43x10^{-3}$	$1.67x10^{-3}$
2	36	$4.10x10^{-2}$	$1.76x10^{-2}$
2	37	$1.84x10^{-1}$	$8.02x10^{-2}$
2	39	$1.15x10^{-2}$	$6.33x10^{-4}$
2	40	$4.89x10^{-3}$	$2.82x10^{-3}$
2	41	$1.47x10^{-3}$	$7.62x10^{-4}$
2	42	$1.10x10^{-1}$	$6.07x10^{-2}$
2	44	N.P.	$8.68x10^{-4}$
2	46	$8.15x10^{-5}$	$2.82x10^{-5}$
2	48	$2.52x10^{-6}$	0
2	49	$6.25x10^{-5}$	$5.75x10^{-5}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
2	50	9.09x10^{-4}	2.76x10^{-4}
2	51	1.11x10^{-3}	7.18x10^{-4}
2	52	2.59x10^{-5}	1.20x10^{-6}
2	53	2.48x10^{-5}	1.14x10^{-5}
2	54	1.12x10^{-4}	7.21x10^{-6}
3	4	1.03x10^{-2}	5.38x10^{-3}
3	5	6.91x10^{-3}	3.78x10^{-3}
3	6	7.07x10^{-3}	3.85x10^{-3}
3	7	1.84x10^{-1}	9.48x10^{-2}
3	9	3.80x10^{-2}	1.99x10^{-2}
3	14	1.04x10^{-4}	5.43x10^{-6}
3	15	1.53x10^{-3}	8.85x10^{-4}
3	16	4.89x10^{-2}	2.48x10^{-2}
3	18	1.27x10^{-3}	6.60x10^{-4}
3	19	7.68x10^{-3}	4.22x10^{-3}
3	20	1.36x10^{-3}	7.70x10^{-4}
3	21	1.15x10^{-3}	N.P.
3	23	1.18x10^{-5}	6.60x10^{-5}
3	24	6.29x10^{-3}	3.22x10^{-3}
3	25	1.22x10^{-3}	6.52x10^{-4}
3	26	6.29x10^{-3}	3.22x10^{-5}
3	28	1.17x10^{-5}	6.61x10^{-6}
3	29	1.21x10^{-5}	6.60x10^{-6}
3	30	7.69x10^{-4}	4.11x10^{-4}
3	31	1.17x10^{-3}	6.60x10^{-4}
3	32	3.83x10^{-3}	2.16x10^{-3}
3	34	7.65x10^{-3}	4.20x10^{-3}
3	35	1.37x10^{-3}	7.78x10^{-4}
3	36	1.64x10^{-2}	8.15x10^{-3}
3	37	7.26x10^{-2}	3.75x10^{-2}
3	39	4.64x10^{-3}	2.93x10^{-4}
3	40	1.94x10^{-3}	1.32x10^{-3}
3	41	5.86x10^{-4}	3.55x10^{-4}
3	42	4.41x10^{-2}	2.82x10^{-2}
3	44	N.P.	2.65x10^{-4}
3	46	4.36x10^{-5}	1.74x10^{-5}
3	48	1.35x10^{-6}	0
3	49	3.29x10^{-5}	3.59x10^{-5}
3	50	4.84x10^{-4}	1.70x10^{-4}
3	51	5.91x10^{-4}	4.43x10^{-4}
3	52	1.38x10^{-5}	0
3	53	1.33x10^{-5}	6.98x10^{-6}
3	54	5.91x10^{-5}	4.51x10^{-6}
4	4	2.09x10^{-3}	3.01x10^{-3}
4	7	1.08x10^{-2}	1.53x10^{-2}
4	9	4.64x10^{-3}	6.69x10^{-3}
4	14	5.34x10^{-4}	7.68x10^{-5}
4	15	4.90x10^{-4}	7.72x10^{-4}
4	16	1.54x10^{-3}	2.20x10^{-3}
4	18	4.04x10^{-4}	5.82x10^{-4}
4	19	2.23x10^{-4}	3.38x10^{-4}
4	20	4.34x10^{-4}	6.75x10^{-4}
4	21	4.95x10^{-4}	N.P.
4	23	3.75x10^{-6}	5.82x10^{-5}
4	24	2.68x10^{-3}	3.77x10^{-3}
4	25	2.36x10^{-3}	3.45x10^{-3}
4	26	2.68x10^{-3}	3.77x10^{-5}
4	28	3.73x10^{-6}	5.83x10^{-6}
4	29	3.85x10^{-6}	5.82x10^{-6}
4	30	2.23x10^{-5}	3.30x10^{-5}
4	31	3.73x10^{-4}	5.82x10^{-4}
4	32	2.77x10^{-3}	4.28x10^{-3}
4	33	2.43x10^{-3}	3.63x10^{-3}
4	34	2.22x10^{-4}	3.36x10^{-4}

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
4	35	$4.37x10^{-4}$	$6.81x10^{-4}$
4	36	$7.26x10^{-4}$	$1.00x10^{-3}$
4	37	$4.27x10^{-3}$	$5.97x10^{-3}$
4	39	$8.93x10^{-5}$	$1.57x10^{-5}$
4	40	$8.64x10^{-5}$	$1.60x10^{-4}$
4	41	$1.13x10^{-5}$	$1.89x10^{-5}$
4	42	$2.57x10^{-3}$	$4.53x10^{-3}$
4	45	$1.06x10^{-6}$	0
4	46	$1.52x10^{-4}$	$1.69x10^{-4}$
4	47	N.P.	$1.68x10^{-6}$
4	48	$4.72x10^{-6}$	$5.41x10^{-6}$
4	49	$1.16x10^{-4}$	$3.43x10^{-4}$
4	50	$1.70x10^{-3}$	$1.65x10^{-3}$
4	51	$2.07x10^{-3}$	$4.30x10^{-3}$
4	52	$4.85x10^{-5}$	$7.21x10^{-6}$
4	53	$4.65x10^{-5}$	$6.84x10^{-5}$
5	60	$1.59x10^{-2}$	$9.61x10^{-3}$
4	54	$2.09x10^{-4}$	$4.30x10^{-5}$
4	56	$3.09x10^{-4}$	$2.02x10^{-3}$
4	57	$1.03x10^{-6}$	$3.73x10^{-4}$
4	58	$7.75x10^{-3}$	$5.71x10^{-3}$
4	59	$1.91x10^{-5}$	$4.07x10^{-6}$
4	60	$3.45x10^{-3}$	$5.20x10^{-3}$
4	61	$2.02x10^{-3}$	$4.88x10^{-3}$
4	62	$3.40x10^{-3}$	$5.27x10^{-3}$
4	63	$4.64x10^{-3}$	$8.19x10^{-3}$
5	4	$1.37x10^{-3}$	$7.91x10^{-4}$
5	7	$3.87x10^{-2}$	$2.20x10^{-2}$
5	9	$2.65x10^{-3}$	$1.53x10^{-3}$
5	15	$1.94x10^{-4}$	$1.22x10^{-4}$
5	16	$2.04x10^{-3}$	$1.17x10^{-3}$
5	18	$1.61x10^{-4}$	$9.26x10^{-5}$
5	20	$1.72x10^{-4}$	$1.07x10^{-4}$
5	21	$8.10x10^{-5}$	N.P.
5	23	$1.49x10^{-6}$	$9.26x10^{-6}$
5	24	$4.44x10^{-4}$	$2.50x10^{-4}$
5	26	$4.44x10^{-4}$	$2.51x10^{-6}$
5	28	$1.49x10^{-6}$	0
5	29	$1.53x10^{-6}$	0
5	31	$1.49x10^{-4}$	$9.27x10^{-5}$
5	33	$7.93x10^{-3}$	$4.75x10^{-3}$
5	35	$1.74x10^{-4}$	$1.08x10^{-4}$
5	36	$1.84x10^{-1}$	$1.02x10^{-1}$
5	37	$1.18x10^{-1}$	$6.63x10^{-2}$
5	39	$6.17x10^{-2}$	$4.30x10^{-3}$
5	40	$2.18x10^{-2}$	$1.60x10^{-2}$
5	41	$7.76x10^{-3}$	$5.15x10^{-3}$
5	42	$7.20x10^{-2}$	$5.06x10^{-2}$
5	43	$4.69x10^{-2}$	$3.50x10^{-2}$
5	44	N.P.	$4.57x10^{-3}$
5	45	$6.05x10^{-5}$	$9.24x10^{-6}$
5	46	$8.85x10^{-3}$	$3.93x10^{-3}$
5	47	N.P.	$3.86x10^{-5}$
5	48	$2.73x10^{-4}$	$1.25x10^{-4}$
5	49	$6.66x10^{-3}$	$7.88x10^{-3}$
5	50	$9.83x10^{-2}$	$3.83x10^{-2}$
5	51	$1.20x10^{-1}$	$9.97x10^{-2}$
5	52	$2.81x10^{-3}$	$1.67x10^{-4}$
5	53	$2.71x10^{-3}$	$1.59x10^{-3}$
5	54	$1.20x10^{-2}$	$9.89x10^{-4}$
5	55	$1.25x10^{-6}$	$1.31x10^{-5}$
5	56	$2.82x10^{-2}$	$7.51x10^{-2}$
5	57	$4.75x10^{-6}$	$6.88x10^{-4}$
5	58	$3.57x10^{-2}$	$1.05x10^{-2}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
5	59	$8.72\text{x}10^{-5}$	$7.46\text{x}10^{-6}$
7	45	$1.21\text{x}10^{-4}$	$3.58\text{x}10^{-5}$
5	61	$9.33\text{x}10^{-3}$	$9.02\text{x}10^{-3}$
5	62	$1.58\text{x}10^{-2}$	$9.79\text{x}10^{-3}$
5	63	$2.16\text{x}10^{-2}$	$1.52\text{x}10^{-2}$
6	4	$2.01\text{x}10^{-4}$	$3.31\text{x}10^{-4}$
6	7	$5.66\text{x}10^{-3}$	$9.18\text{x}10^{-3}$
6	9	$3.86\text{x}10^{-4}$	$6.38\text{x}10^{-4}$
6	15	$2.84\text{x}10^{-5}$	$5.12\text{x}10^{-5}$
6	16	$2.95\text{x}10^{-4}$	$4.85\text{x}10^{-4}$
6	18	$2.35\text{x}10^{-5}$	$3.87\text{x}10^{-5}$
6	20	$2.52\text{x}10^{-5}$	$4.48\text{x}10^{-5}$
6	21	$1.20\text{x}10^{-5}$	N.P.
6	24	$6.49\text{x}10^{-5}$	$1.05\text{x}10^{-4}$
6	26	$6.48\text{x}10^{-5}$	$1.05\text{x}10^{-6}$
6	31	$2.17\text{x}10^{-5}$	$3.87\text{x}10^{-5}$
6	33	$1.16\text{x}10^{-3}$	$1.99\text{x}10^{-3}$
6	35	$2.54\text{x}10^{-5}$	$4.52\text{x}10^{-5}$
6	36	$2.68\text{x}10^{-2}$	$4.24\text{x}10^{-2}$
6	37	$1.74\text{x}10^{-2}$	$2.78\text{x}10^{-2}$
6	39	$8.92\text{x}10^{-3}$	$1.80\text{x}10^{-3}$
6	40	$3.19\text{x}10^{-3}$	$6.74\text{x}10^{-3}$
6	41	$1.13\text{x}10^{-3}$	$2.16\text{x}10^{-3}$
6	42	$1.05\text{x}10^{-2}$	$2.11\text{x}10^{-2}$
6	43	$6.76\text{x}10^{-3}$	$1.46\text{x}10^{-2}$
6	44	N.P.	$1.90\text{x}10^{-3}$
6	45	$8.92\text{x}10^{-6}$	$3.88\text{x}10^{-6}$
6	46	$1.29\text{x}10^{-3}$	$1.64\text{x}10^{-3}$
6	47	N.P.	$1.62\text{x}10^{-5}$
6	48	$3.98\text{x}10^{-5}$	$5.23\text{x}10^{-5}$
6	49	$9.82\text{x}10^{-4}$	$3.31\text{x}10^{-3}$
6	50	$1.43\text{x}10^{-2}$	$1.60\text{x}10^{-2}$
6	51	$1.75\text{x}10^{-2}$	$4.16\text{x}10^{-2}$
6	52	$4.09\text{x}10^{-4}$	$6.98\text{x}10^{-5}$
6	53	$3.92\text{x}10^{-4}$	$6.63\text{x}10^{-4}$
6	54	$1.76\text{x}10^{-3}$	$4.15\text{x}10^{-4}$
6	56	$4.21\text{x}10^{-3}$	$3.15\text{x}10^{-2}$
6	58	$5.24\text{x}10^{-3}$	$4.42\text{x}10^{-3}$
6	59	$1.29\text{x}10^{-5}$	$3.14\text{x}10^{-6}$
6	60	$2.33\text{x}10^{-3}$	$4.03\text{x}10^{-3}$
6	61	$1.36\text{x}10^{-3}$	$3.78\text{x}10^{-3}$
6	62	$2.30\text{x}10^{-3}$	$4.09\text{x}10^{-3}$
6	63	$3.14\text{x}10^{-3}$	$6.35\text{x}10^{-3}$
7	36	$9.70\text{x}10^{-2}$	$1.04\text{x}10^{-1}$
7	37	$9.92\text{x}10^{-2}$	$1.07\text{x}10^{-1}$
7	39	$2.51\text{x}10^{-2}$	$3.41\text{x}10^{-3}$
7	40	$1.16\text{x}10^{-2}$	$1.66\text{x}10^{-2}$
7	41	$3.18\text{x}10^{-3}$	$4.10\text{x}10^{-3}$
7	42	$5.96\text{x}10^{-2}$	$8.14\text{x}10^{-2}$
7	46	$1.75\text{x}10^{-2}$	$1.50\text{x}10^{-2}$
7	47	N.P.	$1.50\text{x}10^{-4}$
7	48	$5.42\text{x}10^{-4}$	$4.81\text{x}10^{-4}$
7	49	$1.34\text{x}10^{-2}$	$3.05\text{x}10^{-2}$
7	50	$1.95\text{x}10^{-1}$	$1.47\text{x}10^{-1}$
7	51	$2.38\text{x}10^{-1}$	$3.82\text{x}10^{-1}$
7	52	$5.57\text{x}10^{-3}$	$6.41\text{x}10^{-4}$
7	53	$5.33\text{x}10^{-3}$	$6.07\text{x}10^{-3}$
7	54	$2.40\text{x}10^{-2}$	$3.83\text{x}10^{-3}$
7	55	$2.47\text{x}10^{-6}$	$4.99\text{x}10^{-5}$
7	57	$1.67\text{x}10^{-5}$	$4.67\text{x}10^{-3}$
7	58	$1.25\text{x}10^{-1}$	$7.16\text{x}10^{-2}$
7	59	$3.08\text{x}10^{-4}$	$5.11\text{x}10^{-5}$
7	60	$5.58\text{x}10^{-2}$	$6.52\text{x}10^{-2}$
7	61	$3.26\text{x}10^{-2}$	$6.11\text{x}10^{-2}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
7	62	5.49x10^{-2}	6.59x10^{-2}
7	63	7.50x10^{-2}	1.03x10^{-1}
8	7	1.84x10^{-2}	1.61x10^{-2}
8	14	1.95x10^{-4}	1.73x10^{-5}
8	16	2.21x10^{-2}	1.95x10^{-2}
8	19	2.91x10^{-3}	2.73x10^{-3}
8	21	4.51x10^{-4}	N.P.
8	24	2.40x10^{-3}	2.09x10^{-3}
8	26	2.40x10^{-3}	2.09x10^{-5}
8	30	2.91x10^{-4}	2.66x10^{-4}
8	34	2.90x10^{-3}	2.72x10^{-3}
8	36	1.54x10^{-1}	1.31x10^{-1}
8	37	7.66x10^{-2}	6.62x10^{-2}
8	39	2.82x10^{-2}	3.09x10^{-3}
8	40	1.84x10^{-2}	2.12x10^{-2}
8	41	3.62x10^{-3}	3.74x10^{-3}
8	42	4.52x10^{-2}	4.98x10^{-2}
8	44	N.P.	8.48x10^{-4}
8	45	8.54x10^{-6}	2.01x10^{-6}
8	46	1.21x10^{-3}	8.32x10^{-4}
8	47	N.P.	8.41x10^{-6}
8	48	3.76x10^{-5}	2.68x10^{-5}
8	49	9.41x10^{-4}	1.72x10^{-3}
8	50	1.36x10^{-2}	8.15x10^{-3}
8	51	1.66x10^{-2}	2.12x10^{-2}
8	52	3.87x10^{-4}	3.55x10^{-5}
8	53	3.67x10^{-4}	3.35x10^{-4}
8	54	1.69x10^{-3}	2.15x10^{-4}
8	56	5.10x10^{-3}	2.04x10^{-2}
8	58	6.25x10^{-3}	2.85x10^{-3}
8	59	1.55x10^{-5}	2.06x10^{-6}
8	60	2.78x10^{-3}	2.60x10^{-3}
8	61	1.62x10^{-3}	2.42x10^{-3}
8	62	2.71x10^{-3}	2.59x10^{-3}
8	63	3.70x10^{-3}	4.03x10^{-3}
9	36	2.03x10^{-2}	1.20x10^{-2}
9	37	1.88x10^{-2}	1.14x10^{-2}
9	39	2.61x10^{-2}	1.96x10^{-3}
9	40	2.41x10^{-3}	1.92x10^{-3}
9	41	3.30x10^{-3}	2.36x10^{-3}
9	42	1.14x10^{-2}	8.61x10^{-3}
9	45	3.65x10^{-5}	6.00x10^{-6}
9	46	5.29x10^{-3}	2.52x10^{-3}
9	47	N.P.	2.51x10^{-5}
9	48	1.63x10^{-4}	8.06x10^{-5}
9	49	4.02x10^{-3}	5.12x10^{-3}
9	50	5.88x10^{-2}	2.46x10^{-2}
9	51	7.18x10^{-2}	6.41x10^{-2}
9	52	1.68x10^{-3}	1.07x10^{-4}
9	53	1.61x10^{-3}	1.02x10^{-3}
9	54	7.21x10^{-3}	6.42x10^{-4}
9	56	2.74x10^{-3}	7.80x10^{-3}
9	57	6.83x10^{-6}	1.07x10^{-3}
9	58	5.14x10^{-2}	1.63x10^{-2}
9	59	1.26x10^{-4}	1.17x10^{-5}
9	60	2.29x10^{-2}	1.49x10^{-2}
9	61	1.34x10^{-2}	1.39x10^{-2}
9	62	2.26x10^{-2}	1.50x10^{-2}
9	63	3.08x10^{-2}	2.34x10^{-2}
10	36	4.69x10^{-4}	5.01x10^{-4}
10	37	3.51x10^{-4}	3.76x10^{-4}
10	39	5.75x10^{-4}	7.85x10^{-5}
10	40	5.59x10^{-5}	7.95x10^{-5}
10	41	7.33x10^{-5}	9.41x10^{-5}

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
10	42	$2.09x10^{-4}$	$2.86x10^{-4}$
10	43	$6.83x10^{-4}$	$1.00x10^{-3}$
10	44	N.P.	$4.15x10^{-4}$
10	46	$1.56x10^{-5}$	$1.34x10^{-5}$
10	49	$1.20x10^{-5}$	$2.71x10^{-5}$
10	50	$1.74x10^{-4}$	$1.31x10^{-4}$
10	51	$2.13x10^{-4}$	$3.41x10^{-4}$
10	52	$4.97x10^{-6}$	0
10	53	$4.75x10^{-6}$	$5.44x10^{-6}$
10	54	$2.15x10^{-5}$	$3.40x10^{-6}$
11	36	$2.89x10^{-4}$	$3.13x10^{-4}$
11	37	$2.17x10^{-4}$	$2.35x10^{-4}$
11	39	$3.54x10^{-4}$	$4.90x10^{-5}$
11	40	$3.45x10^{-5}$	$4.97x10^{-5}$
11	41	$4.52x10^{-5}$	$5.88x10^{-5}$
11	42	$1.29x10^{-4}$	$1.79x10^{-4}$
14	40	$2.59x10^{-5}$	$1.23x10^{-5}$
11	43	$4.18x10^{-4}$	$6.26x10^{-4}$
11	44	N.P.	$2.60x10^{-4}$
11	46	$9.61x10^{-6}$	$8.40x10^{-6}$
11	49	$7.42x10^{-6}$	$1.70x10^{-5}$
11	50	$1.07x10^{-4}$	$8.20x10^{-5}$
11	51	$1.31x10^{-4}$	$2.13x10^{-4}$
11	52	$3.07x10^{-6}$	0
11	53	$2.92x10^{-6}$	$3.40x10^{-6}$
11	54	$1.33x10^{-5}$	$2.13x10^{-6}$
12	36	$6.12x10^{-3}$	$6.53x10^{-3}$
12	37	$4.56x10^{-3}$	$4.92x10^{-3}$
12	39	$7.54x10^{-3}$	$1.02x10^{-3}$
12	40	$7.29x10^{-4}$	$1.04x10^{-3}$
12	41	$9.57x10^{-4}$	$1.23x10^{-3}$
12	42	$2.74x10^{-3}$	$3.74x10^{-3}$
12	43	$8.97x10^{-3}$	$1.31x10^{-2}$
12	44	N.P.	$5.40x10^{-3}$
12	45	$1.41x10^{-6}$	0
12	46	$2.04x10^{-4}$	$1.75x10^{-4}$
12	47	N.P.	$1.74x10^{-6}$
12	48	$6.32x10^{-6}$	$5.59x10^{-6}$
12	49	$1.56x10^{-4}$	$3.55x10^{-4}$
12	50	$2.27x10^{-3}$	$1.71x10^{-3}$
12	51	$2.78x10^{-3}$	$4.45x10^{-3}$
12	52	$6.50x10^{-5}$	$7.46x10^{-6}$
12	53	$6.23x10^{-5}$	$7.08x10^{-5}$
12	54	$2.80x10^{-4}$	$4.45x10^{-5}$
13	36	$4.62x10^{-3}$	$4.70x10^{-3}$
13	37	$3.44x10^{-3}$	$3.53x10^{-3}$
13	39	$5.70x10^{-3}$	$7.36x10^{-4}$
13	40	$5.50x10^{-4}$	$7.46x10^{-4}$
13	41	$7.23x10^{-4}$	$8.83x10^{-4}$
13	42	$2.07x10^{-3}$	$2.69x10^{-3}$
13	43	$6.77x10^{-3}$	$9.39x10^{-3}$
13	44	N.P.	$3.89x10^{-3}$
13	45	$1.07x10^{-6}$	0
13	46	$1.54x10^{-4}$	$1.26x10^{-4}$
13	47	N.P.	$1.25x10^{-6}$
13	48	$4.77x10^{-6}$	$4.02x10^{-6}$
13	49	$1.18x10^{-4}$	$2.55x10^{-4}$
13	50	$1.72x10^{-3}$	$1.23x10^{-3}$
13	51	$2.10x10^{-3}$	$3.20x10^{-3}$
13	52	$4.90x10^{-5}$	$5.36x10^{-6}$
13	53	$4.70x10^{-5}$	$5.09x10^{-5}$
13	54	$2.11x10^{-4}$	$3.19x10^{-5}$
14	36	$2.17x10^{-4}$	$7.73x10^{-5}$
14	37	$2.03x10^{-4}$	$7.27x10^{-5}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
14	39	$2.77x10^{-4}$	$1.26x10^{-5}$
16	53	$6.04x10^{-3}$	$1.76x10^{-3}$
14	41	$3.53x10^{-5}$	$1.51x10^{-5}$
14	42	$1.21x10^{-4}$	$5.52x10^{-5}$
14	46	$5.64x10^{-5}$	$1.62x10^{-5}$
14	48	$1.75x10^{-6}$	0
14	49	$4.33x10^{-5}$	$3.27x10^{-5}$
14	50	$6.29x10^{-4}$	$1.58x10^{-4}$
14	51	$7.68x10^{-4}$	$4.12x10^{-4}$
14	52	$1.80x10^{-5}$	0
14	53	$1.71x10^{-5}$	$6.55x10^{-6}$
14	54	$7.78x10^{-5}$	$4.10x10^{-6}$
14	56	$2.98x10^{-5}$	$4.99x10^{-5}$
14	58	$5.52x10^{-4}$	$1.04x10^{-4}$
14	59	$1.36x10^{-6}$	0
14	60	$2.45x10^{-4}$	$9.53x10^{-5}$
14	61	$1.43x10^{-4}$	$8.93x10^{-5}$
14	62	$2.41x10^{-4}$	$9.66x10^{-5}$
14	63	$3.29x10^{-4}$	$1.50x10^{-4}$
15	5	$4.68x10^{-4}$	$5.94x10^{-4}$
15	6	$4.80x10^{-4}$	$6.05x10^{-4}$
15	7	$4.88x10^{-4}$	$5.79x10^{-4}$
15	8	$5.59x10^{-4}$	$7.15x10^{-4}$
15	10	$1.02x10^{-5}$	$1.35x10^{-5}$
15	11	$9.94x10^{-6}$	$1.32x10^{-5}$
15	12	$1.01x10^{-4}$	$1.39x10^{-4}$
15	13	$1.03x10^{-4}$	$1.37x10^{-4}$
15	14	$4.83x10^{-5}$	$5.82x10^{-6}$
15	16	$7.18x10^{-5}$	$8.59x10^{-5}$
15	36	$8.65x10^{-3}$	$9.96x10^{-3}$
15	37	$1.30x10^{-2}$	$1.52x10^{-2}$
15	38	$1.69x10^{-5}$	$2.11x10^{-5}$
15	39	$1.25x10^{-2}$	$1.88x10^{-3}$
15	40	$1.05x10^{-3}$	$1.65x10^{-3}$
15	41	$1.63x10^{-3}$	$2.30x10^{-3}$
15	42	$7.50x10^{-3}$	$1.13x10^{-2}$
15	43	$5.79x10^{-3}$	$9.43x10^{-3}$
15	44	N.P.	$8.40x10^{-3}$
15	76	$3.16x10^{-3}$	$3.95x10^{-3}$
16	39	$1.52x10^{-3}$	$5.30x10^{-5}$
16	41	$1.92x10^{-4}$	$6.36x10^{-5}$
16	45	$1.35x10^{-4}$	$1.03x10^{-5}$
16	46	$1.97x10^{-2}$	$4.35x10^{-3}$
16	47	N.P.	$4.31x10^{-5}$
16	48	$6.10x10^{-4}$	$1.39x10^{-4}$
16	49	$1.49x10^{-2}$	$8.79x10^{-3}$
16	50	$2.19x10^{-1}$	$4.25x10^{-2}$
16	51	$2.68x10^{-1}$	$1.11x10^{-1}$
16	52	$6.26x10^{-3}$	$1.85x10^{-4}$
16	54	$2.68x10^{-2}$	$1.10x10^{-3}$
16	55	$2.78x10^{-6}$	$1.45x10^{-5}$
16	56	$2.38x10^{-3}$	$3.14x10^{-3}$
16	57	$4.18x10^{-5}$	$3.02x10^{-3}$
16	58	$3.15x10^{-1}$	$4.62x10^{-2}$
16	59	$7.69x10^{-4}$	$3.28x10^{-5}$
16	60	$1.40x10^{-1}$	$4.21x10^{-2}$
16	61	$8.20x10^{-2}$	$3.95x10^{-2}$
16	62	$1.39x10^{-1}$	$4.28x10^{-2}$
16	63	$1.89x10^{-1}$	$6.65x10^{-2}$
16	66	$2.46x10^{-1}$	$6.73x10^{-2}$
16	67	$2.46x10^{-1}$	$6.73x10^{-2}$
16	68	$2.46x10^{-2}$	$6.73x10^{-3}$
16	69	$2.46x10^{-1}$	$6.73x10^{-2}$
16	70	$2.46x10^{-1}$	$6.73x10^{-3}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
16	71	$2.46\text{x}10^{-1}$	$6.73\text{x}10^{-2}$
17	36	$4.13\text{x}10^{-6}$	$6.87\text{x}10^{-4}$
17	37	$6.10\text{x}10^{-6}$	$1.03\text{x}10^{-3}$
17	42	$3.70\text{x}10^{-6}$	$7.84\text{x}10^{-4}$
17	46	$1.79\text{x}10^{-5}$	$2.39\text{x}10^{-3}$
17	47	N.P.	$2.36\text{x}10^{-5}$
17	49	$1.35\text{x}10^{-5}$	$4.82\text{x}10^{-3}$
17	50	$1.99\text{x}10^{-4}$	$2.34\text{x}10^{-2}$
17	51	$2.43\text{x}10^{-4}$	$6.08\text{x}10^{-2}$
17	52	$5.68\text{x}10^{-6}$	$1.02\text{x}10^{-4}$
17	53	$5.49\text{x}10^{-6}$	$9.70\text{x}10^{-4}$
17	54	$2.43\text{x}10^{-5}$	$6.04\text{x}10^{-4}$
17	56	$5.30\text{x}10^{-6}$	$4.24\text{x}10^{-3}$
17	58	$1.04\text{x}10^{-4}$	$9.21\text{x}10^{-3}$
17	60	$4.61\text{x}10^{-5}$	$8.40\text{x}10^{-3}$
17	61	$2.70\text{x}10^{-5}$	$7.88\text{x}10^{-3}$
17	62	$4.57\text{x}10^{-5}$	$8.54\text{x}10^{-3}$
17	63	$6.24\text{x}10^{-5}$	$1.33\text{x}10^{-2}$
18	5	$4.87\text{x}10^{-4}$	$6.11\text{x}10^{-4}$
18	6	$4.98\text{x}10^{-4}$	$6.22\text{x}10^{-4}$
18	7	$5.07\text{x}10^{-4}$	$5.97\text{x}10^{-4}$
18	8	$5.76\text{x}10^{-4}$	$7.24\text{x}10^{-4}$
18	10	$1.07\text{x}10^{-5}$	$1.40\text{x}10^{-5}$
18	11	$1.05\text{x}10^{-5}$	$1.37\text{x}10^{-5}$
18	12	$1.06\text{x}10^{-4}$	$1.44\text{x}10^{-4}$
18	13	$1.08\text{x}10^{-4}$	$1.42\text{x}10^{-4}$
18	14	$5.02\text{x}10^{-5}$	$6.00\text{x}10^{-6}$
18	16	$7.62\text{x}10^{-5}$	$9.14\text{x}10^{-5}$
18	36	$9.03\text{x}10^{-3}$	$1.04\text{x}10^{-2}$
18	37	$1.33\text{x}10^{-2}$	$1.53\text{x}10^{-2}$
18	38	$1.78\text{x}10^{-5}$	$2.20\text{x}10^{-5}$
18	39	$1.33\text{x}10^{-2}$	$1.95\text{x}10^{-3}$
18	40	$1.08\text{x}10^{-3}$	$1.65\text{x}10^{-3}$
18	41	$1.70\text{x}10^{-3}$	$2.34\text{x}10^{-3}$
18	42	$7.89\text{x}10^{-3}$	$1.16\text{x}10^{-2}$
18	43	$6.21\text{x}10^{-3}$	$9.83\text{x}10^{-3}$
18	44	N.P.	$8.96\text{x}10^{-3}$
18	76	$3.40\text{x}10^{-3}$	$4.25\text{x}10^{-3}$
19	3	$7.52\text{x}10^{-4}$	$6.31\text{x}10^{-4}$
19	4	$7.87\text{x}10^{-4}$	$5.36\text{x}10^{-4}$
19	5	$9.17\text{x}10^{-3}$	$6.56\text{x}10^{-3}$
19	6	$9.39\text{x}10^{-3}$	$6.68\text{x}10^{-3}$
19	7	$7.63\text{x}10^{-3}$	$5.13\text{x}10^{-3}$
19	8	$4.33\text{x}10^{-3}$	$3.13\text{x}10^{-3}$
19	9	$3.78\text{x}10^{-3}$	$2.58\text{x}10^{-3}$
19	10	$4.04\text{x}10^{-4}$	$3.00\text{x}10^{-4}$
19	11	$3.95\text{x}10^{-4}$	$2.94\text{x}10^{-4}$
19	12	$4.00\text{x}10^{-3}$	$3.09\text{x}10^{-3}$
19	13	$4.08\text{x}10^{-3}$	$3.04\text{x}10^{-3}$
19	14	$5.29\text{x}10^{-4}$	$3.61\text{x}10^{-5}$
19	15	$5.57\text{x}10^{-4}$	$4.18\text{x}10^{-4}$
19	16	$2.88\text{x}10^{-3}$	$1.94\text{x}10^{-3}$
19	18	$4.59\text{x}10^{-4}$	$3.13\text{x}10^{-4}$
19	19	$2.42\text{x}10^{-4}$	$1.74\text{x}10^{-4}$
19	20	$4.93\text{x}10^{-4}$	$3.64\text{x}10^{-4}$
19	21	$4.70\text{x}10^{-5}$	N.P.
19	22	$6.41\text{x}10^{-4}$	$4.56\text{x}10^{-4}$
19	23	$4.26\text{x}10^{-6}$	$3.13\text{x}10^{-5}$
19	24	$2.54\text{x}10^{-4}$	$1.69\text{x}10^{-4}$
19	25	$8.88\text{x}10^{-4}$	$6.16\text{x}10^{-4}$
19	26	$2.54\text{x}10^{-4}$	$1.69\text{x}10^{-6}$
19	28	$4.24\text{x}10^{-6}$	$3.13\text{x}10^{-6}$
19	29	$4.37\text{x}10^{-6}$	$3.13\text{x}10^{-6}$
19	30	$2.43\text{x}10^{-5}$	$1.70\text{x}10^{-5}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
19	31	$4.24x10^{-4}$	$3.13x10^{-4}$
19	32	$7.97x10^{-4}$	$5.85x10^{-4}$
19	33	$9.12x10^{-4}$	$6.50x10^{-4}$
19	34	$2.41x10^{-4}$	$1.73x10^{-4}$
19	35	$4.97x10^{-4}$	$3.68x10^{-4}$
19	39	$1.45x10^{-3}$	$1.21x10^{-4}$
19	41	$1.85x10^{-4}$	$1.46x10^{-4}$
20	5	$2.53x10^{-3}$	$2.97x10^{-3}$
20	6	$2.60x10^{-3}$	$3.03x10^{-3}$
20	7	$2.64x10^{-3}$	$2.90x10^{-3}$
20	8	$3.01x10^{-3}$	$3.55x10^{-3}$
20	10	$5.55x10^{-5}$	$6.79x10^{-5}$
20	11	$5.43x10^{-5}$	$6.65x10^{-5}$
20	12	$5.50x10^{-4}$	$7.01x10^{-4}$
20	13	$5.61x10^{-4}$	$6.88x10^{-4}$
20	14	$2.61x10^{-4}$	$2.92x10^{-5}$
20	16	$3.95x10^{-4}$	$4.39x10^{-4}$
20	36	$4.70x10^{-2}$	$5.03x10^{-2}$
20	37	$6.95x10^{-2}$	$7.53x10^{-2}$
20	38	$9.23x10^{-5}$	$1.07x10^{-4}$
20	39	$6.89x10^{-2}$	$9.48x10^{-3}$
20	40	$5.63x10^{-3}$	$8.13x10^{-3}$
20	41	$8.84x10^{-3}$	$1.15x10^{-2}$
20	42	$4.10x10^{-2}$	$5.66x10^{-2}$
20	43	$3.21x10^{-2}$	$4.76x10^{-2}$
20	44	N.P.	$4.29x10^{-2}$
20	76	$1.75x10^{-2}$	$2.03x10^{-2}$
21	4	$1.04x10^{-5}$	N.P.
21	7	$1.00x10^{-5}$	N.P.
21	9	$9.91x10^{-6}$	N.P.
21	16	$7.16x10^{-6}$	N.P.
21	45	$2.02x10^{-6}$	N.P.
21	46	$2.69x10^{-4}$	N.P.
21	48	$8.45x10^{-6}$	N.P.
21	49	$2.23x10^{-4}$	N.P.
21	50	$3.06x10^{-3}$	N.P.
21	51	$3.73x10^{-3}$	N.P.
21	52	$8.74x10^{-5}$	N.P.
21	53	$7.92x10^{-5}$	N.P.
21	54	$4.00x10^{-4}$	N.P.
21	56	$3.40x10^{-4}$	N.P.
21	58	$1.17x10^{-5}$	N.P.
21	60	$5.20x10^{-6}$	N.P.
21	61	$2.99x10^{-6}$	N.P.
21	62	$4.88x10^{-6}$	N.P.
21	63	$6.66x10^{-6}$	N.P.
22	36	$1.82x10^{-2}$	$9.29x10^{-3}$
22	37	$2.75x10^{-2}$	$1.43x10^{-2}$
22	38	$2.40x10^{-3}$	$1.32x10^{-3}$
22	39	$1.47x10^{-3}$	$9.73x10^{-5}$
22	40	$2.18x10^{-3}$	$1.51x10^{-3}$
22	41	$1.90x10^{-4}$	$1.18x10^{-4}$
22	42	$1.62x10^{-2}$	$1.07x10^{-2}$
22	43	$2.61x10^{-2}$	$1.86x10^{-2}$
22	44	N.P.	$3.04x10^{-2}$
22	72	$2.22x10^{-2}$	$1.13x10^{-2}$
22	73	$6.66x10^{-2}$	$3.40x10^{-2}$
22	74	$2.22x10^{-3}$	$1.13x10^{-3}$
22	76	$2.59x10^{-3}$	$1.43x10^{-3}$
23	5	$2.46x10^{-6}$	$3.67x10^{-5}$
23	6	$2.51x10^{-6}$	$3.74x10^{-5}$
23	7	$2.56x10^{-6}$	$3.59x10^{-5}$
23	8	$2.90x10^{-6}$	$4.36x10^{-5}$
23	36	$4.56x10^{-5}$	$6.23x10^{-4}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
23	37	$6.65x10^{-5}$	$9.21x10^{-4}$
23	39	$6.75x10^{-5}$	$1.17x10^{-4}$
23	40	$5.43x10^{-6}$	$9.93x10^{-5}$
23	41	$8.57x10^{-6}$	$1.41x10^{-4}$
23	42	$4.00x10^{-5}$	$6.99x10^{-4}$
23	43	$3.17x10^{-5}$	$5.90x10^{-4}$
23	44	N.P.	$5.37x10^{-4}$
23	76	$1.73x10^{-5}$	$2.54x10^{-4}$
24	4	$6.31x10^{-5}$	$9.93x10^{-4}$
24	7	$6.12x10^{-5}$	$9.51x10^{-4}$
24	9	$6.06x10^{-5}$	$9.58x10^{-4}$
24	14	$6.06x10^{-6}$	$9.56x10^{-6}$
24	16	$4.64x10^{-5}$	$7.30x10^{-4}$
24	45	$1.17x10^{-5}$	$4.86x10^{-5}$
24	46	$1.69x10^{-3}$	$2.06x10^{-2}$
24	47	N.P.	$2.03x10^{-4}$
24	48	$5.24x10^{-5}$	$6.57x10^{-4}$
24	49	$1.29x10^{-3}$	$4.15x10^{-2}$
24	50	$1.88x10^{-2}$	$2.01x10^{-1}$
24	51	$2.30x10^{-2}$	$5.24x10^{-1}$
24	52	$5.38x10^{-4}$	$8.78x10^{-4}$
24	53	$5.17x10^{-4}$	$8.35x10^{-3}$
24	54	$2.31x10^{-3}$	$5.20x10^{-3}$
24	56	$1.85x10^{-3}$	$1.33x10^{-1}$
24	58	$6.94x10^{-5}$	$5.59x10^{-4}$
24	60	$3.09x10^{-5}$	$5.10x10^{-4}$
24	61	$1.81x10^{-5}$	$4.79x10^{-4}$
24	62	$3.05x10^{-5}$	$5.19x10^{-4}$
24	63	$4.16x10^{-5}$	$8.07x10^{-4}$
25	7	$9.27x10^{-2}$	$1.67x10^{-1}$
25	9	$4.13x10^{-3}$	$7.56x10^{-3}$
25	14	$7.80x10^{-4}$	$1.43x10^{-4}$
25	15	$7.13x10^{-3}$	$1.43x10^{-2}$
25	16	$2.08x10^{-3}$	$3.78x10^{-3}$
25	18	$5.84x10^{-3}$	$1.07x10^{-2}$
25	20	$6.29x10^{-3}$	$1.25x10^{-2}$
25	21	$8.69x10^{-5}$	N.P.
25	23	$5.40x10^{-5}$	$1.07x10^{-3}$
25	24	$4.62x10^{-4}$	$8.27x10^{-4}$
25	26	$4.62x10^{-4}$	$8.27x10^{-6}$
25	28	$5.38x10^{-5}$	$1.07x10^{-4}$
25	29	$5.55x10^{-5}$	$1.07x10^{-4}$
25	31	$5.38x10^{-3}$	$1.07x10^{-2}$
25	32	$2.90x10^{-3}$	$5.72x10^{-3}$
25	33	$8.35x10^{-3}$	$1.59x10^{-2}$
25	35	$6.34x10^{-3}$	$1.26x10^{-2}$
25	36	$7.87x10^{-2}$	$1.38x10^{-1}$
25	37	$3.95x10^{-2}$	$7.02x10^{-2}$
25	39	$1.34x10^{-2}$	$3.03x10^{-3}$
25	40	$9.44x10^{-3}$	$2.23x10^{-2}$
25	41	$1.72x10^{-3}$	$3.66x10^{-3}$
25	42	$2.33x10^{-2}$	$5.28x10^{-2}$
25	43	$2.17x10^{-3}$	$5.26x10^{-3}$
25	44	N.P.	$3.63x10^{-2}$
25	46	$9.98x10^{-5}$	$1.41x10^{-4}$
25	47	N.P.	$1.42x10^{-6}$
25	48	$3.10x10^{-6}$	$4.54x10^{-6}$
25	49	$7.76x10^{-5}$	$2.90x10^{-4}$
25	50	$1.12x10^{-3}$	$1.38x10^{-3}$
25	51	$1.36x10^{-3}$	$3.59x10^{-3}$
25	52	$3.19x10^{-5}$	$6.02x10^{-6}$
25	53	$3.02x10^{-5}$	$5.67x10^{-5}$
25	54	$1.39x10^{-4}$	$3.64x10^{-5}$
26	4	$4.66x10^{-5}$	0

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
26	7	$4.52x10^{-5}$	0
26	9	$4.48x10^{-5}$	0
26	14	$4.48x10^{-6}$	0
26	16	$3.42x10^{-5}$	0
26	45	$8.65x10^{-6}$	0
26	46	$1.25x10^{-3}$	$1.28x10^{-5}$
26	48	$3.87x10^{-5}$	0
26	49	$9.53x10^{-4}$	$2.59x10^{-5}$
26	50	$1.39x10^{-2}$	$1.25x10^{-4}$
26	51	$1.70x10^{-2}$	$3.25x10^{-4}$
26	52	$3.97x10^{-4}$	0
26	53	$3.81x10^{-4}$	$5.18x10^{-6}$
26	54	$1.71x10^{-3}$	$3.24x10^{-6}$
26	56	$1.37x10^{-3}$	$8.28x10^{-5}$
26	58	$5.13x10^{-5}$	0
26	60	$2.28x10^{-5}$	0
26	61	$1.34x10^{-5}$	0
26	62	$2.25x10^{-5}$	0
26	63	$3.07x10^{-5}$	0
27	7	N.P.	$1.97x10^{-4}$
27	36	N.P.	$8.01x10^{-3}$
27	37	N.P.	$4.05x10^{-3}$
27	39	N.P.	$1.02x10^{-4}$
27	40	N.P.	$1.28x10^{-3}$
27	41	N.P.	$1.23x10^{-4}$
27	42	N.P.	$3.06x10^{-3}$
27	43	N.P.	$9.42x10^{-3}$
27	44	N.P.	$9.27x10^{-3}$
27	46	N.P.	$8.35x10^{-6}$
27	49	N.P.	$1.70x10^{-5}$
27	50	N.P.	$8.16x10^{-5}$
27	51	N.P.	$2.12x10^{-4}$
27	53	N.P.	$3.37x10^{-6}$
27	54	N.P.	$2.14x10^{-6}$
28	5	$1.21x10^{-6}$	$3.42x10^{-6}$
28	6	$1.24x10^{-6}$	$3.48x10^{-6}$
28	7	$1.26x10^{-6}$	$3.34x10^{-6}$
28	8	$1.43x10^{-6}$	$4.06x10^{-6}$
28	36	$2.24x10^{-5}$	$5.80x10^{-5}$
28	37	$3.28x10^{-5}$	$8.58x10^{-5}$
28	39	$3.30x10^{-5}$	$1.09x10^{-5}$
28	40	$2.67x10^{-6}$	$9.26x10^{-6}$
28	41	$4.21x10^{-6}$	$1.31x10^{-5}$
28	42	$1.96x10^{-5}$	$6.51x10^{-5}$
28	43	$1.54x10^{-5}$	$5.50x10^{-5}$
28	44	N.P.	$5.00x10^{-5}$
28	76	$8.44x10^{-6}$	$2.37x10^{-5}$
29	5	$4.08x10^{-6}$	$4.92x10^{-6}$
29	6	$4.18x10^{-6}$	$5.01x10^{-6}$
29	7	$4.25x10^{-6}$	$4.81x10^{-6}$
29	8	$4.81x10^{-6}$	$5.84x10^{-6}$
29	36	$7.57x10^{-5}$	$8.36x10^{-5}$
29	37	$1.11x10^{-4}$	$1.23x10^{-4}$
29	39	$1.12x10^{-4}$	$1.57x10^{-5}$
29	40	$9.02x10^{-6}$	$1.33x10^{-5}$
29	41	$1.42x10^{-5}$	$1.89x10^{-5}$
29	42	$6.64x10^{-5}$	$9.36x10^{-5}$
29	43	$5.25x10^{-5}$	$7.92x10^{-5}$
29	44	N.P.	$7.21x10^{-5}$
29	76	$2.87x10^{-5}$	$3.42x10^{-5}$
30	3	$7.50x10^{-5}$	$6.61x10^{-5}$
30	4	$7.84x10^{-5}$	$5.62x10^{-5}$
30	5	$9.14x10^{-4}$	$6.88x10^{-4}$
30	6	$9.35x10^{-4}$	$7.01x10^{-4}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
30	7	$7.61x10^{-4}$	$5.38x10^{-4}$
30	8	$4.31x10^{-4}$	$3.28x10^{-4}$
30	9	$3.77x10^{-4}$	$2.71x10^{-4}$
30	10	$4.02x10^{-5}$	$3.15x10^{-5}$
30	11	$3.94x10^{-5}$	$3.09x10^{-5}$
30	12	$3.99x10^{-4}$	$3.25x10^{-4}$
30	13	$4.06x10^{-4}$	$3.19x10^{-4}$
30	14	$5.27x10^{-5}$	$3.78x10^{-6}$
30	15	$5.55x10^{-5}$	$4.37x10^{-5}$
30	16	$2.87x10^{-4}$	$2.04x10^{-4}$
30	18	$4.58x10^{-5}$	$3.28x10^{-5}$
30	19	$2.41x10^{-5}$	$1.82x10^{-5}$
30	20	$4.91x10^{-5}$	$3.82x10^{-5}$
30	21	$4.69x10^{-6}$	N.P.
30	22	$6.39x10^{-5}$	$4.79x10^{-5}$
30	24	$2.53x10^{-5}$	$1.78x10^{-5}$
30	25	$8.85x10^{-5}$	$6.46x10^{-5}$
30	26	$2.53x10^{-5}$	0
30	30	$2.42x10^{-6}$	$1.78x10^{-6}$
30	31	$4.22x10^{-5}$	$3.29x10^{-5}$
30	32	$7.94x10^{-5}$	$6.13x10^{-5}$
30	33	$9.09x10^{-5}$	$6.80x10^{-5}$
30	34	$2.40x10^{-5}$	$1.82x10^{-5}$
30	35	$4.95x10^{-5}$	$3.86x10^{-5}$
30	39	$1.45x10^{-4}$	$1.27x10^{-5}$
30	41	$1.84x10^{-5}$	$1.53x10^{-5}$
31	5	$2.41x10^{-4}$	$3.65x10^{-4}$
31	6	$2.47x10^{-4}$	$3.72x10^{-4}$
31	7	$2.51x10^{-4}$	$3.57x10^{-4}$
31	8	$2.84x10^{-4}$	$4.34x10^{-4}$
31	10	$5.32x10^{-6}$	$8.36x10^{-6}$
31	11	$5.21x10^{-6}$	$8.20x10^{-6}$

Predator	Prey	Pre Exchange	Post Exchange
31	12	$5.27x10^{-5}$	$8.63x10^{-5}$
31	13	$5.37x10^{-5}$	$8.47x10^{-5}$
31	14	$2.49x10^{-5}$	$3.59x10^{-6}$
31	16	$3.80x10^{-5}$	$5.45x10^{-5}$
31	36	$4.48x10^{-3}$	$6.20x10^{-3}$
31	37	$6.52x10^{-3}$	$9.16x10^{-3}$
31	38	$8.82x10^{-6}$	$1.31x10^{-5}$
31	39	$6.63x10^{-3}$	$1.17x10^{-3}$
31	40	$5.33x10^{-4}$	$9.89x10^{-4}$
31	41	$8.41x10^{-4}$	$1.40x10^{-3}$
31	42	$3.93x10^{-3}$	$6.95x10^{-3}$
31	43	$3.11x10^{-3}$	$5.87x10^{-3}$
31	44	N.P.	$5.34x10^{-3}$
31	76	$1.70x10^{-3}$	$2.53x10^{-3}$
32	4	$1.37x10^{-2}$	$1.92x10^{-2}$
32	5	$1.27x10^{-2}$	$1.88x10^{-2}$
32	6	$1.30x10^{-2}$	$1.92x10^{-2}$
32	7	$9.11x10^{-2}$	$1.26x10^{-1}$
32	9	$2.62x10^{-2}$	$3.70x10^{-2}$
32	15	$1.94x10^{-3}$	$3.01x10^{-3}$
32	16	$2.97x10^{-2}$	$4.16x10^{-2}$
32	18	$1.59x10^{-3}$	$2.24x10^{-3}$
32	19	$1.26x10^{-2}$	$1.87x10^{-2}$
32	20	$1.71x10^{-3}$	$2.62x10^{-3}$
32	23	$1.47x10^{-5}$	$2.25x10^{-4}$
32	28	$1.46x10^{-5}$	$2.25x10^{-5}$
32	29	$1.51x10^{-5}$	$2.24x10^{-5}$
32	30	$1.26x10^{-3}$	$1.82x10^{-3}$
32	31	$1.46x10^{-3}$	$2.25x10^{-3}$
32	34	$1.25x10^{-2}$	$1.86x10^{-2}$
32	35	$1.73x10^{-3}$	$2.64x10^{-3}$
32	36	$1.13x10^{-2}$	$1.52x10^{-2}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
32	37	$8.52x10^{-3}$	$1.17x10^{-2}$
32	39	$8.23x10^{-2}$	$1.43x10^{-2}$
32	40	$1.35x10^{-3}$	$2.47x10^{-3}$
32	41	$1.06x10^{-2}$	$1.73x10^{-2}$
32	42	$5.03x10^{-3}$	$8.77x10^{-3}$
32	43	$2.83x10^{-3}$	$5.30x10^{-3}$
32	44	N.P.	$1.68x10^{-2}$
32	46	$1.30x10^{-4}$	$1.42x10^{-4}$
32	47	N.P.	$1.43x10^{-6}$
32	48	$4.05x10^{-6}$	$4.57x10^{-6}$
32	49	$1.01x10^{-4}$	$2.93x10^{-4}$
32	50	$1.46x10^{-3}$	$1.39x10^{-3}$
32	51	$1.78x10^{-3}$	$3.62x10^{-3}$
32	52	$4.17x10^{-5}$	$6.06x10^{-6}$
32	53	$3.95x10^{-5}$	$5.71x10^{-5}$
32	54	$1.82x10^{-4}$	$3.67x10^{-5}$
33	36	$4.02x10^{-2}$	$4.56x10^{-2}$
33	37	$2.25x10^{-2}$	$2.60x10^{-2}$
33	39	$4.15x10^{-4}$	$6.07x10^{-5}$
33	40	$4.82x10^{-3}$	$7.43x10^{-3}$
33	41	$5.33x10^{-5}$	$7.37x10^{-5}$
33	42	$1.32x10^{-2}$	$1.95x10^{-2}$
33	46	$7.53x10^{-5}$	$6.90x10^{-5}$
33	48	$2.34x10^{-6}$	$2.23x10^{-6}$
33	49	$5.88x10^{-5}$	$1.43x10^{-4}$
33	50	$8.44x10^{-4}$	$6.76x10^{-4}$
33	51	$1.03x10^{-3}$	$1.76x10^{-3}$
33	52	$2.41x10^{-5}$	$2.95x10^{-6}$
33	53	$2.28x10^{-5}$	$2.77x10^{-5}$
33	54	$1.06x10^{-4}$	$1.79x10^{-5}$
33	58	$4.68x10^{-5}$	$2.84x10^{-5}$
33	60	$2.08x10^{-5}$	$2.59x10^{-5}$
33	61	$1.21x10^{-5}$	$2.42x10^{-5}$
33	62	$2.02x10^{-5}$	$2.58x10^{-5}$
33	63	$2.76x10^{-5}$	$4.02x10^{-5}$
34	3	$7.73x10^{-4}$	$1.05x10^{-3}$
34	4	$8.08x10^{-4}$	$8.92x10^{-4}$
34	5	$9.42x10^{-3}$	$1.09x10^{-2}$
34	6	$9.64x10^{-3}$	$1.11x10^{-2}$
34	7	$7.84x10^{-3}$	$8.54x10^{-3}$
34	8	$4.44x10^{-3}$	$5.19x10^{-3}$
34	9	$3.88x10^{-3}$	$4.30x10^{-3}$
34	10	$4.15x10^{-4}$	$5.00x10^{-4}$
34	11	$4.06x10^{-4}$	$4.90x10^{-4}$
34	12	$4.11x10^{-3}$	$5.16x10^{-3}$
34	13	$4.19x10^{-3}$	$5.06x10^{-3}$
34	14	$5.44x10^{-4}$	$6.01x10^{-5}$
34	15	$5.71x10^{-4}$	$6.93x10^{-4}$
34	16	$2.97x10^{-3}$	$3.25x10^{-3}$
34	18	$4.72x10^{-4}$	$5.21x10^{-4}$
34	19	$2.49x10^{-4}$	$2.89x10^{-4}$
34	20	$5.06x10^{-4}$	$6.06x10^{-4}$
34	21	$4.83x10^{-5}$	N.P.
34	22	$6.59x10^{-4}$	$7.61x10^{-4}$
34	23	$4.37x10^{-6}$	$5.22x10^{-5}$
34	24	$2.61x10^{-4}$	$2.82x10^{-4}$
34	25	$9.11x10^{-4}$	$1.02x10^{-3}$
34	26	$2.61x10^{-4}$	$2.82x10^{-6}$
34	28	$4.35x10^{-6}$	$5.22x10^{-6}$
34	29	$4.49x10^{-6}$	$5.22x10^{-6}$
34	30	$2.49x10^{-5}$	$2.83x10^{-5}$
34	31	$4.35x10^{-4}$	$5.22x10^{-4}$
34	32	$8.18x10^{-4}$	$9.72x10^{-4}$
34	33	$9.37x10^{-4}$	$1.08x10^{-3}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
34	34	$2.48x10^{-4}$	$2.88x10^{-4}$
34	35	$5.10x10^{-4}$	$6.11x10^{-4}$
34	39	$1.49x10^{-3}$	$2.02x10^{-4}$
34	41	$1.90x10^{-4}$	$2.43x10^{-4}$
35	5	$1.93x10^{-3}$	$2.47x10^{-3}$
35	6	$1.98x10^{-3}$	$2.51x10^{-3}$
35	7	$2.01x10^{-3}$	$2.41x10^{-3}$
35	8	$2.29x10^{-3}$	$2.95x10^{-3}$
35	10	$4.24x10^{-5}$	$5.62x10^{-5}$
35	11	$4.14x10^{-5}$	$5.51x10^{-5}$
35	12	$4.20x10^{-4}$	$5.81x10^{-4}$
35	13	$4.28x10^{-4}$	$5.70x10^{-4}$
35	14	$1.99x10^{-4}$	$2.42x10^{-5}$
35	16	$3.01x10^{-4}$	$3.63x10^{-4}$
35	36	$3.58x10^{-2}$	$4.16x10^{-2}$
35	37	$5.30x10^{-2}$	$6.24x10^{-2}$
35	38	$7.04x10^{-5}$	$8.82x10^{-5}$
35	39	$5.25x10^{-2}$	$7.86x10^{-3}$
35	40	$4.30x10^{-3}$	$6.75x10^{-3}$
35	41	$6.74x10^{-3}$	$9.50x10^{-3}$
35	42	$3.12x10^{-2}$	$4.69x10^{-2}$
35	43	$2.44x10^{-2}$	$3.94x10^{-2}$
35	44	N.P.	$3.55x10^{-2}$
35	76	$1.34x10^{-2}$	$1.68x10^{-2}$
36	36	$1.53x10^{-1}$	$1.37x10^{-1}$
36	40	$1.87x10^{-2}$	$2.31x10^{-2}$
36	73	$3.47x10^{-1}$	$3.13x10^{-1}$
36	74	$2.35x10^{-1}$	$2.11x10^{-1}$
36	76	$5.82x10^{-1}$	$5.73x10^{-1}$
37	66	$3.88x10^{-1}$	$3.61x10^{-1}$
37	67	$3.88x10^{-1}$	$3.61x10^{-1}$
37	68	$3.88x10^{-2}$	$3.61x10^{-2}$
37	69	$3.88x10^{-1}$	$3.61x10^{-1}$
37	70	$3.88x10^{-1}$	$3.61x10^{-2}$
37	71	$3.88x10^{-1}$	$3.61x10^{-1}$
37	74	$1.31x10^{-1}$	$1.22x10^{-1}$
37	76	$1.93x10^{-1}$	$2.00x10^{-1}$
38	67	$3.37x10^{-3}$	$2.69x10^{-3}$
38	70	$3.37x10^{-3}$	$2.69x10^{-4}$
38	76	$6.90x10^{-3}$	$6.03x10^{-3}$
38	77	$9.76x10^{-4}$	$8.11x10^{-4}$
39	36	$7.27x10^{-3}$	$3.21x10^{-3}$
39	37	$4.62x10^{-2}$	$2.10x10^{-2}$
39	38	$6.84x10^{-4}$	$3.27x10^{-4}$
39	39	$2.26x10^{-2}$	$1.30x10^{-3}$
39	40	$8.78x10^{-4}$	$5.37x10^{-4}$
39	41	$2.93x10^{-3}$	$1.59x10^{-3}$
39	42	$2.68x10^{-2}$	$1.55x10^{-2}$
39	43	$3.61x10^{-3}$	$2.25x10^{-3}$
39	45	$3.29x10^{-6}$	0
39	46	$4.57x10^{-4}$	$1.63x10^{-4}$
39	47	N.P.	$1.70x10^{-6}$
39	48	$1.43x10^{-5}$	$5.34x10^{-6}$
39	49	$3.62x10^{-4}$	$3.48x10^{-4}$
39	50	$5.15x10^{-3}$	$1.60x10^{-3}$
39	51	$6.28x10^{-3}$	$4.17x10^{-3}$
39	52	$1.47x10^{-4}$	$7.00x10^{-6}$
39	53	$1.38x10^{-4}$	$6.50x10^{-5}$
39	54	$6.51x10^{-4}$	$4.36x10^{-5}$
39	58	$2.11x10^{-3}$	$5.06x10^{-4}$
39	59	$5.30x10^{-6}$	0
39	60	$9.39x10^{-4}$	$4.61x10^{-4}$
39	61	$5.45x10^{-4}$	$4.26x10^{-4}$
39	62	$9.06x10^{-4}$	$4.50x10^{-4}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
39	63	$1.24x10^{-3}$	$7.00x10^{-4}$
39	64	$3.93x10^{-3}$	$1.68x10^{-3}$
39	65	$5.41x10^{-3}$	$2.47x10^{-3}$
39	66	$5.82x10^{-4}$	$2.49x10^{-4}$
39	67	$5.82x10^{-4}$	$2.49x10^{-4}$
39	68	$5.82x10^{-5}$	$2.49x10^{-5}$
39	69	$5.82x10^{-4}$	$2.49x10^{-4}$
39	70	$5.82x10^{-4}$	$2.49x10^{-5}$
39	71	$5.82x10^{-4}$	$2.49x10^{-4}$
39	72	$8.73x10^{-3}$	$3.74x10^{-3}$
39	73	$1.92x10^{-1}$	$8.22x10^{-2}$
39	74	$6.11x10^{-2}$	$2.62x10^{-2}$
39	76	$8.21x10^{-2}$	$3.88x10^{-2}$
40	36	$2.05x10^{-2}$	$3.76x10^{-2}$
40	40	$2.53x10^{-3}$	$6.58x10^{-3}$
40	73	$4.54x10^{-2}$	$8.05x10^{-2}$
40	74	$3.06x10^{-2}$	$5.43x10^{-2}$
40	76	$7.68x10^{-2}$	$1.53x10^{-1}$
41	36	$4.31x10^{-3}$	$6.18x10^{-3}$
41	37	$2.72x10^{-2}$	$4.00x10^{-2}$
41	38	$4.06x10^{-4}$	$6.29x10^{-4}$
41	39	$1.34x10^{-2}$	$2.50x10^{-3}$
41	40	$5.19x10^{-4}$	$1.02x10^{-3}$
41	41	$1.73x10^{-3}$	$3.05x10^{-3}$
41	42	$1.59x10^{-2}$	$2.97x10^{-2}$
41	43	$2.15x10^{-3}$	$4.32x10^{-3}$
41	45	$1.94x10^{-6}$	0
41	46	$2.72x10^{-4}$	$3.14x10^{-4}$
41	47	N.P.	$3.24x10^{-6}$
41	48	$8.45x10^{-6}$	$1.02x10^{-5}$
41	49	$2.13x10^{-4}$	$6.61x10^{-4}$
41	50	$3.05x10^{-3}$	$3.08x10^{-3}$
41	51	$3.72x10^{-3}$	$8.02x10^{-3}$
41	52	$8.70x10^{-5}$	$1.34x10^{-5}$
41	53	$8.19x10^{-5}$	$1.26x10^{-4}$
41	54	$3.83x10^{-4}$	$8.29x10^{-5}$
41	58	$1.25x10^{-3}$	$9.65x10^{-4}$
41	59	$3.12x10^{-6}$	0
41	60	$5.55x10^{-4}$	$8.79x10^{-4}$
41	61	$3.22x10^{-4}$	$8.16x10^{-4}$
41	62	$5.37x10^{-4}$	$8.66x10^{-4}$
41	63	$7.33x10^{-4}$	$1.35x10^{-3}$
41	64	$2.35x10^{-3}$	$3.31x10^{-3}$
41	65	$3.22x10^{-3}$	$4.78x10^{-3}$
41	76	$4.90x10^{-2}$	$7.54x10^{-2}$
42	67	$2.80x10^{-1}$	$5.16x10^{-1}$
42	70	$2.80x10^{-1}$	$5.16x10^{-2}$
42	74	$3.15x10^{-2}$	$5.80x10^{-2}$
42	76	$4.53x10^{-2}$	$9.36x10^{-2}$
43	72	$6.31x10^{-2}$	$9.00x10^{-2}$
43	73	$4.21x10^{-2}$	$6.00x10^{-2}$
43	74	$6.31x10^{-2}$	$9.00x10^{-2}$
43	76	$4.93x10^{-2}$	$7.92x10^{-2}$
44	66	N.P.	$1.51x10^{1}$
44	67	N.P.	$1.51x10^{1}$
44	68	N.P.	1.51
44	69	N.P.	$1.51x10^{1}$
44	70	N.P.	1.51
44	71	N.P.	$1.51x10^{1}$
44	75	N.P.	$2.78x10^{1}$
44	77	N.P.	$2.24x10^{1}$
45	66	$1.76x10^{-3}$	$5.92x10^{-4}$
45	67	$1.76x10^{-3}$	$5.92x10^{-4}$
45	68	$1.76x10^{-4}$	$5.92x10^{-5}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
45	69	$1.76x10^{-3}$	$5.92x10^{-4}$
45	70	$1.76x10^{-3}$	$5.92x10^{-5}$
45	71	$1.76x10^{-3}$	$5.92x10^{-4}$
45	75	$1.17x10^{-3}$	$3.95x10^{-4}$
46	66	$4.36x10^{-1}$	$3.95x10^{-1}$
46	67	$4.36x10^{-1}$	$3.95x10^{-1}$
46	68	$4.36x10^{-2}$	$3.95x10^{-2}$
46	69	$4.36x10^{-1}$	$3.95x10^{-1}$
46	70	$4.36x10^{-1}$	$3.95x10^{-2}$
46	71	$4.36x10^{-1}$	$3.95x10^{-1}$
46	75	$2.90x10^{-1}$	$2.63x10^{-1}$
47	66	N.P.	$2.47x10^{-3}$
47	67	N.P.	$2.47x10^{-3}$
47	68	N.P.	$2.47x10^{-4}$
47	69	N.P.	$2.47x10^{-3}$
47	70	N.P.	$2.47x10^{-4}$
47	71	N.P.	$2.47x10^{-3}$
47	75	N.P.	$1.65x10^{-3}$
48	66	$1.20x10^{-2}$	$9.88x10^{-3}$
48	67	$1.20x10^{-2}$	$9.88x10^{-3}$
48	68	$1.20x10^{-3}$	$9.88x10^{-4}$
48	69	$1.20x10^{-2}$	$9.88x10^{-3}$
48	70	$1.20x10^{-2}$	$9.88x10^{-4}$
48	71	$1.20x10^{-2}$	$9.88x10^{-3}$
48	75	$8.03x10^{-3}$	$6.59x10^{-3}$
49	66	$1.90x10^{-1}$	$4.88x10^{-1}$
49	67	$1.90x10^{-1}$	$4.88x10^{-1}$
49	68	$1.90x10^{-2}$	$4.88x10^{-2}$
49	69	$1.90x10^{-1}$	$4.88x10^{-1}$
49	70	$1.90x10^{-1}$	$4.88x10^{-2}$
49	71	$1.90x10^{-1}$	$4.88x10^{-1}$
49	75	$1.27x10^{-1}$	$3.25x10^{-1}$
50	66	4.96	4.27
50	67	4.96	4.27
50	68	$4.96x10^{-1}$	$4.27x10^{-1}$
50	69	4.96	4.27
50	70	4.96	$4.27x10^{-1}$
50	71	4.96	4.27
50	75	3.31	2.85
51	66	6.06	$1.11x10^{1}$
51	67	6.06	$1.11x10^{1}$
51	68	$6.06x10^{-1}$	1.11
51	69	6.06	$1.11x10^{1}$
51	70	6.06	1.11
51	71	6.06	$1.11x10^{1}$
51	75	4.04	7.4
52	66	$1.42x10^{-1}$	$1.86x10^{-2}$
52	67	$1.42x10^{-1}$	$1.86x10^{-2}$
52	68	$1.42x10^{-2}$	$1.86x10^{-3}$
52	69	$1.42x10^{-1}$	$1.86x10^{-2}$
52	70	$1.42x10^{-1}$	$1.86x10^{-3}$
52	71	$1.42x10^{-1}$	$1.86x10^{-2}$
52	75	$9.45x10^{-2}$	$1.24x10^{-2}$
53	66	$1.72x10^{-1}$	$1.95x10^{-1}$
53	67	$1.72x10^{-1}$	$1.95x10^{-1}$
53	68	$1.72x10^{-2}$	$1.95x10^{-2}$
53	69	$1.72x10^{-1}$	$1.95x10^{-1}$
53	70	$1.72x10^{-1}$	$1.95x10^{-2}$
53	71	$1.72x10^{-1}$	$1.95x10^{-1}$
53	75	$1.15x10^{-1}$	$1.30x10^{-1}$
54	66	$3.42x10^{-1}$	$6.12x10^{-2}$
54	67	$3.42x10^{-1}$	$6.12x10^{-2}$
54	68	$3.42x10^{-2}$	$6.12x10^{-3}$
54	69	$3.42x10^{-1}$	$6.12x10^{-2}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
54	70	$3.42x10^{-1}$	$6.12x10^{-3}$
54	71	$3.42x10^{-1}$	$6.12x10^{-2}$
54	75	$2.28x10^{-1}$	$4.08x10^{-2}$
55	66	$6.19x10^{-4}$	$1.60x10^{-3}$
55	67	$6.19x10^{-4}$	$1.60x10^{-3}$
55	68	$6.19x10^{-5}$	$1.60x10^{-4}$
55	69	$6.19x10^{-4}$	$1.60x10^{-3}$
55	70	$6.19x10^{-4}$	$1.60x10^{-4}$
55	71	$6.19x10^{-4}$	$1.60x10^{-3}$
55	75	$4.13x10^{-4}$	$1.07x10^{-3}$
56	46	$1.95x10^{-3}$	$5.54x10^{-3}$
56	48	$6.18x10^{-5}$	$1.81x10^{-4}$
56	49	$1.68x10^{-3}$	$1.18x10^{-2}$
56	50	$2.24x10^{-2}$	$5.45x10^{-2}$
56	51	$2.74x10^{-2}$	$1.42x10^{-1}$
56	52	$6.41x10^{-4}$	$2.37x10^{-4}$
56	53	$5.65x10^{-4}$	$2.21x10^{-3}$
56	54	$3.02x10^{-3}$	$1.48x10^{-3}$
56	58	$5.89x10^{-3}$	$1.16x10^{-2}$
56	59	$1.54x10^{-5}$	$8.57x10^{-6}$
56	60	$2.62x10^{-3}$	$1.06x10^{-2}$
56	61	$1.49x10^{-3}$	$9.81x10^{-3}$
56	62	$2.40x10^{-3}$	$1.04x10^{-2}$
56	63	$3.28x10^{-3}$	$1.61x10^{-2}$
56	64	$3.59x10^{-4}$	$1.51x10^{-3}$
57	46	$1.92x10^{-4}$	$4.43x10^{-2}$
57	48	$6.02x10^{-6}$	$1.46x10^{-3}$
57	53	$5.67x10^{-5}$	$1.75x10^{-2}$
57	60	$4.70x10^{-5}$	$1.03x10^{-2}$
57	62	$4.43x10^{-5}$	$9.97x10^{-3}$
57	63	$6.05x10^{-5}$	$1.55x10^{-2}$
57	64	$2.49x10^{-4}$	$5.67x10^{-2}$
57	65	$3.57x10^{-4}$	$8.54x10^{-2}$
57	68	$8.30x10^{-6}$	$1.89x10^{-3}$
57	69	$8.30x10^{-5}$	$1.89x10^{-2}$
57	70	$8.30x10^{-5}$	$1.89x10^{-3}$
57	71	$8.30x10^{-5}$	$1.89x10^{-2}$
58	46	1.44	$6.78x10^{-1}$
58	48	$4.53x10^{-2}$	$2.24x10^{-2}$
58	53	$4.26x10^{-1}$	$2.69x10^{-1}$
58	55	$2.08x10^{-4}$	$2.21x10^{-3}$
58	60	$3.54x10^{-1}$	$1.58x10^{-1}$
58	62	$3.33x10^{-1}$	$1.53x10^{-1}$
58	63	$4.55x10^{-1}$	$2.38x10^{-1}$
58	64	1.87	$8.68x10^{-1}$
58	65	2.68	1.31
58	68	$6.24x10^{-2}$	$2.89x10^{-2}$
58	69	$6.24x10^{-1}$	$2.89x10^{-1}$
58	70	$6.24x10^{-1}$	$2.89x10^{-2}$
58	71	$6.24x10^{-1}$	$2.89x10^{-1}$
59	2	$3.63x10^{-3}$	$4.45x10^{-4}$
59	3	$3.31x10^{-3}$	$4.96x10^{-4}$
59	5	$3.22x10^{-3}$	$4.04x10^{-4}$
59	6	$3.31x10^{-3}$	$4.13x10^{-4}$
59	10	$4.16x10^{-4}$	$5.47x10^{-5}$
59	11	$4.05x10^{-4}$	$5.35x10^{-5}$
59	12	$4.12x10^{-3}$	$5.67x10^{-4}$
59	13	$1.40x10^{-3}$	$1.85x10^{-4}$
59	20	$1.75x10^{-3}$	$2.27x10^{-4}$
59	32	$1.77x10^{-3}$	$2.28x10^{-4}$
60	46	$6.41x10^{-1}$	$6.22x10^{-1}$
60	48	$2.02x10^{-2}$	$2.05x10^{-2}$
60	53	$1.89x10^{-1}$	$2.46x10^{-1}$
60	55	$9.25x10^{-5}$	$2.03x10^{-3}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
60	62	$4.65x10^{-1}$	$4.60x10^{-1}$
60	64	$8.28x10^{-1}$	$7.94x10^{-1}$
60	65	1.19	1.2
60	68	$2.76x10^{-2}$	$2.65x10^{-2}$
60	69	$2.76x10^{-1}$	$2.65x10^{-1}$
60	70	$2.76x10^{-1}$	$2.65x10^{-2}$
60	71	$2.76x10^{-1}$	$2.65x10^{-1}$
61	46	$2.99x10^{-1}$	$4.62x10^{-1}$
61	49	$2.40x10^{-1}$	$9.79x10^{-1}$
61	54	$4.32x10^{-1}$	$1.23x10^{-1}$
61	64	$6.54x10^{-1}$	1.01
61	65	$9.14x10^{-1}$	1.48
61	68	$2.18x10^{-2}$	$3.36x10^{-2}$
61	69	$2.18x10^{-1}$	$3.36x10^{-1}$
61	70	$2.18x10^{-1}$	$3.36x10^{-2}$
61	71	$2.18x10^{-1}$	$3.36x10^{-1}$
62	64	1.48	1.49
62	65	2.09	2.19
62	66	$3.30x10^{-1}$	$3.30x10^{-1}$
62	67	$3.30x10^{-1}$	$3.30x10^{-1}$
62	68	$3.30x10^{-2}$	$3.30x10^{-2}$
62	69	$3.30x10^{-1}$	$3.30x10^{-1}$
62	70	$3.30x10^{-1}$	$3.30x10^{-2}$
62	71	$3.30x10^{-1}$	$3.30x10^{-1}$
63	64	2.07	2.36
63	65	2.9	3.46
63	66	$4.60x10^{-1}$	$5.24x10^{-1}$
63	67	$4.60x10^{-1}$	$5.24x10^{-1}$
63	68	$4.60x10^{-2}$	$5.24x10^{-2}$
63	69	$4.60x10^{-1}$	$5.24x10^{-1}$
63	70	$4.60x10^{-1}$	$5.24x10^{-2}$
63	71	$4.60x10^{-1}$	$5.24x10^{-1}$
64	67	1.77	2.09
64	68	$1.77x10^{-1}$	$2.09x10^{-1}$
64	69	1.77	2.09
64	70	1.77	$2.09x10^{-1}$
64	71	1.77	2.09
65	66	1.5	1.73
65	67	1.5	1.73
65	68	$1.50x10^{-1}$	$1.73x10^{-1}$
65	69	1.5	1.73
65	70	1.5	$1.73x10^{-1}$
65	71	1.5	1.73
65	75	2.25	2.59
75	8	$4.89x10^{-3}$	$4.49x10^{-3}$
75	17	$2.24x10^{-5}$	$4.09x10^{-3}$
75	66	$5.84x10^{1}$	$2.95x10^{1}$
75	67	$7.69x10^{1}$	$5.41x10^{1}$
75	68	$3.04x10^{-1}$	0
75	69	$2.88x10^{1}$	0
75	70	1.73	1.59
75	71	$2.56x10^{1}$	0
75	72	$9.00x10^{1}$	$8.56x10^{1}$
75	73	5.86	6.66
75	74	$4.95x10^{-1}$	$4.62x10^{-1}$
76	1	$2.19x10^{-4}$	$6.40x10^{-4}$
76	2	$1.56x10^{-1}$	$4.80x10^{-2}$
76	3	$4.60x10^{-2}$	$3.15x10^{-3}$
76	5	$1.53x10^{-2}$	$5.82x10^{-3}$
76	8	$4.43x10^{-2}$	$4.16x10^{-2}$
76	15	$2.74x10^{-3}$	0
76	16	$4.02x10^{-1}$	$4.06x10^{-3}$
76	17	$1.28x10^{-4}$	$2.40x10^{-2}$
76	20	$1.21x10^{-2}$	$4.54x10^{-3}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
76	22	$1.00x10^{-2}$	$7.06x10^{-3}$
76	25	$2.05x10^{-2}$	$4.58x10^{-2}$
76	27	N.P.	$2.04x10^{-3}$
76	32	$7.02x10^{-3}$	$1.36x10^{-2}$
76	33	$2.67x10^{-3}$	$3.04x10^{-3}$
76	35	$1.02x10^{-2}$	$4.69x10^{-3}$
76	37	$7.80x10^{-1}$	$5.84x10^{-1}$
76	38	$3.26x10^{-6}$	0
76	44	N.P.	$2.76x10^{1}$
76	45	$8.35x10^{-3}$	$2.37x10^{-3}$
76	47	N.P.	$9.91x10^{-3}$
76	49	$6.82x10^{-1}$	1.05
76	50	$1.35x10^{1}$	9.77
76	51	$1.65x10^{1}$	$2.54x10^{1}$
76	52	$3.85x10^{-1}$	$4.26x10^{-2}$
76	54	1.23	$1.32x10^{-1}$
76	55	$1.46x10^{-3}$	0
76	56	$2.40x10^{-2}$	0
76	57	$5.27x10^{-4}$	$1.22x10^{-1}$
76	58	3.97	1.87
76	59	$9.69x10^{-3}$	$1.33x10^{-3}$
76	60	1.4	1.53
76	61	1.03	1.6
76	62	$8.70x10^{-1}$	1.05
76	63	1.89	2.42
76	66	$1.97x10^{1}$	$1.05x10^{1}$
76	67	$2.60x10^{1}$	$1.92x10^{1}$
76	68	$1.03x10^{-1}$	0
76	69	9.73	0
76	70	$5.85x10^{-1}$	$5.64x10^{-1}$
76	71	8.64	0
76	72	$2.28x10^{1}$	$2.28x10^{1}$
76	73	1.48	1.77
76	74	2	1.97
77	45	$9.29x10^{-4}$	$2.49x10^{-4}$
77	47	N.P.	$1.04x10^{-3}$
77	49	$7.59x10^{-2}$	$1.10x10^{-1}$
77	50	1.5	$9.94x10^{-1}$
77	51	1.83	2.59
77	52	$4.29x10^{-2}$	$4.33x10^{-3}$
77	54	$1.36x10^{-1}$	$1.38x10^{-2}$
77	55	$1.62x10^{-4}$	0
77	56	$2.66x10^{-3}$	0
77	57	$5.87x10^{-5}$	$1.27x10^{-2}$
77	58	$4.41x10^{-1}$	$1.94x10^{-1}$
77	59	$1.08x10^{-3}$	$1.41x10^{-4}$
77	60	$1.55x10^{-1}$	$1.59x10^{-1}$
77	61	$1.15x10^{-1}$	$1.65x10^{-1}$
77	62	$9.69x10^{-2}$	$1.07x10^{-1}$
77	63	$2.10x10^{-1}$	$2.46x10^{-1}$
77	66	$1.98x10^{1}$	9.06
77	67	$2.60x10^{1}$	$1.66x10^{1}$
77	68	$1.03x10^{-1}$	0
77	69	9.76	0
77	70	$5.87x10^{-1}$	$4.88x10^{-1}$
77	71	8.66	0
Prod.	1	$2.19x10^{-4}$	$6.40x10^{-4}$
Prod.	2	$1.61x10^{-1}$	$5.11x10^{-2}$
Prod.	3	$5.64x10^{-2}$	$2.68x10^{-2}$
Prod.	4	$5.52x10^{-2}$	$4.29x10^{-2}$
Prod.	5	$9.34x10^{-2}$	$8.00x10^{-2}$
Prod.	6	$8.00x10^{-2}$	$7.56x10^{-2}$
Prod.	7	$9.08x10^{-1}$	$6.69x10^{-1}$
Prod.	8	$6.63x10^{-2}$	$6.72x10^{-2}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
Prod.	9	1.79×10^{-1}	1.24×10^{-1}
Prod.	10	1.45×10^{-3}	1.23×10^{-3}
Prod.	11	1.42×10^{-3}	1.21×10^{-3}
Prod.	12	1.44×10^{-2}	1.27×10^{-2}
Prod.	13	1.19×10^{-2}	1.21×10^{-2}
Prod.	14	3.60×10^{-3}	4.33×10^{-4}
Prod.	15	1.94×10^{-2}	2.34×10^{-2}
Prod.	16	6.37×10^{-1}	1.59×10^{-1}
Prod.	17	1.50×10^{-4}	2.81×10^{-2}
Prod.	18	1.37×10^{-2}	1.75×10^{-2}
Prod.	19	4.35×10^{-2}	3.68×10^{-2}
Prod.	20	2.86×10^{-2}	2.51×10^{-2}
Prod.	21	5.32×10^{-3}	N.P.
Prod.	22	1.14×10^{-2}	8.32×10^{-3}
Prod.	23	1.27×10^{-4}	1.75×10^{-3}
Prod.	24	2.87×10^{-2}	2.50×10^{-1}
Prod.	25	2.91×10^{-2}	5.30×10^{-2}
Prod.	26	2.87×10^{-2}	1.78×10^{-4}
Prod.	27	N.P.	2.04×10^{-3}
Prod.	28	1.26×10^{-4}	1.75×10^{-4}
Prod.	29	1.30×10^{-4}	1.75×10^{-4}
Prod.	30	4.36×10^{-3}	3.59×10^{-3}
Prod.	31	1.26×10^{-2}	1.75×10^{-2}
Prod.	32	3.02×10^{-2}	3.42×10^{-2}
Prod.	33	2.45×10^{-2}	3.12×10^{-2}
Prod.	34	4.33×10^{-2}	3.66×10^{-2}
Prod.	35	2.51×10^{-2}	2.52×10^{-2}
Prod.	36	9.90×10^{-1}	9.50×10^{-1}
Prod.	37	1.71	1.36
Prod.	38	3.70×10^{-3}	2.53×10^{-3}
Prod.	39	4.73×10^{-1}	6.17×10^{-2}
Prod.	40	1.19×10^{-1}	1.87×10^{-1}
Prod.	41	6.04×10^{-2}	7.45×10^{-2}
Prod.	42	5.53×10^{-1}	5.87×10^{-1}
Prod.	43	1.79×10^{-1}	2.32×10^{-1}
Prod.	44	N.P.	2.78×10^{1}
Prod.	45	9.68×10^{-3}	2.74×10^{-3}
Prod.	46	2.44	1.86
Prod.	47	N.P.	1.15×10^{-2}
Prod.	48	6.73×10^{-2}	4.62×10^{-2}
Prod.	49	1.04	2.26
Prod.	50	1.57×10^{1}	1.13×10^{1}
Prod.	51	1.91×10^{1}	2.95×10^{1}
Prod.	52	4.48×10^{-1}	4.94×10^{-2}
Prod.	53	6.34×10^{-1}	5.56×10^{-1}
Prod.	54	1.88	2.83×10^{-1}
Prod.	55	1.93×10^{-3}	4.57×10^{-3}
Prod.	56	7.32×10^{-2}	2.77×10^{-1}
Prod.	57	6.60×10^{-4}	1.47×10^{-1}
Prod.	58	4.96	2.25
Prod.	59	1.21×10^{-2}	1.60×10^{-3}
Prod.	60	2.15	2.02
Prod.	61	1.29	1.92
Prod.	62	2.01	1.95
Prod.	63	2.89	3.18
Prod.	64	6.91	6.58
Prod.	65	9.8	9.73
Prod.	66	1.13×10^{2}	8.37×10^{1}
Prod.	67	1.46×10^{2}	1.27×10^{2}
Prod.	68	2.32	3.76
Prod.	69	6.65×10^{1}	3.76×10^{1}
Prod.	70	2.13×10^{1}	6.46
Prod.	71	6.10×10^{1}	3.76×10^{1}
Prod.	72	1.13×10^{2}	1.08×10^{2}

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
Prod.	73	8.03	9
Prod.	74	3.05	2.99
Prod.	75	$1.05x10^{1}$	$4.14x10^{1}$
Prod.	76	1.13	1.27
Prod.	77	$9.76x10^{-4}$	$2.24x10^{1}$
Cons.	1	$2.04x10^{-2}$	$7.07x10^{-2}$
Cons.	2	1.2	$5.34x10^{-1}$
Cons.	3	$4.79x10^{-1}$	$2.48x10^{-1}$
Cons.	4	$6.93x10^{-2}$	$9.64x10^{-2}$
Cons.	5	$9.45x10^{-1}$	$5.97x10^{-1}$
Cons.	6	$1.38x10^{-1}$	$2.50x10^{-1}$
Cons.	7	1.14	1.27
Cons.	8	$4.35x10^{-1}$	$3.87x10^{-1}$
Cons.	9	$3.77x10^{-1}$	$2.29x10^{-1}$
Cons.	10	$2.86x10^{-3}$	$3.36x10^{-3}$
Cons.	11	$1.76x10^{-3}$	$2.10x10^{-3}$
Cons.	12	$3.74x10^{-2}$	$4.38x10^{-2}$
Cons.	13	$2.83x10^{-2}$	$3.15x10^{-2}$
Cons.	14	$4.03x10^{-3}$	$1.47x10^{-3}$
Cons.	15	$5.57x10^{-2}$	$6.70x10^{-2}$
Cons.	16	2.69	$6.96x10^{-1}$
Cons.	17	$8.15x10^{-4}$	$1.48x10^{-1}$
Cons.	18	$5.83x10^{-2}$	$6.93x10^{-2}$
Cons.	19	$5.65x10^{-2}$	$3.89x10^{-2}$
Cons.	20	$3.03x10^{-1}$	$3.37x10^{-1}$
Cons.	21	$8.27x10^{-3}$	N.P.
Cons.	22	$1.88x10^{-1}$	$1.34x10^{-1}$
Cons.	23	$2.95x10^{-4}$	$4.16x10^{-3}$
Cons.	24	$5.05x10^{-2}$	$9.42x10^{-1}$
Cons.	25	$3.14x10^{-1}$	$6.00x10^{-1}$
Cons.	26	$3.73x10^{-2}$	$5.85x10^{-4}$
Cons.	27	N.P.	$3.58x10^{-2}$
Cons.	28	$1.45x10^{-4}$	$3.88x10^{-4}$
Cons.	29	$4.90x10^{-4}$	$5.58x10^{-4}$
Cons.	30	$5.63x10^{-3}$	$4.08x10^{-3}$
Cons.	31	$2.90x10^{-2}$	$4.14x10^{-2}$
Cons.	32	$3.47x10^{-1}$	$4.12x10^{-1}$
Cons.	33	$8.35x10^{-2}$	$1.01x10^{-1}$
Cons.	34	$5.80x10^{-2}$	$6.47x10^{-2}$
Cons.	35	$2.31x10^{-1}$	$2.79x10^{-1}$
Cons.	36	1.33	1.26
Cons.	37	2.3	1.84
Cons.	38	$1.46x10^{-2}$	$9.80x10^{-3}$
Cons.	39	$4.86x10^{-1}$	$2.11x10^{-1}$
Cons.	40	$1.76x10^{-1}$	$3.32x10^{-1}$
Cons.	41	$1.31x10^{-1}$	$1.88x10^{-1}$
Cons.	42	$6.38x10^{-1}$	$7.19x10^{-1}$
Cons.	43	$2.18x10^{-1}$	$3.19x10^{-1}$
Cons.	44	N.P.	$1.13x10^{2}$
Cons.	45	$1.02x10^{-2}$	$2.88x10^{-3}$
Cons.	46	2.51	1.92
Cons.	47	N.P.	$1.20x10^{-2}$
Cons.	48	$6.95x10^{-2}$	$4.81x10^{-2}$
Cons.	49	1.1	2.38
Cons.	50	$2.86x10^{1}$	$2.08x10^{1}$
Cons.	51	$3.49x10^{1}$	$5.40x10^{1}$
Cons.	52	$8.17x10^{-1}$	$9.05x10^{-2}$
Cons.	53	$9.91x10^{-1}$	$9.48x10^{-1}$
Cons.	54	1.97	$2.98x10^{-1}$
Cons.	55	$3.57x10^{-3}$	$7.79x10^{-3}$
Cons.	56	$7.38x10^{-2}$	$2.78x10^{-1}$
Cons.	57	$1.27x10^{-3}$	$2.83x10^{-1}$
Cons.	58	9.55	4.33
Cons.	59	$2.33x10^{-2}$	$3.07x10^{-3}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
Cons.	60	4.19	3.93
Cons.	61	3.21	4.79
Cons.	62	5.26	5.06
Cons.	63	7.32	8.02
Cons.	64	7.24	6.7
Cons.	65	9.91	9.84
Cons.	75	$2.88x10^{2}$	$1.78x10^{2}$
Cons.	76	$1.34x10^{2}$	$1.30x10^{2}$
Cons.	77	$6.95x10^{1}$	$3.07x10^{1}$
Resp.	1	$2.02x10^{-2}$	$7.00x10^{-2}$
Resp.	2	1.01	$4.72x10^{-1}$
Resp.	3	$4.22x10^{-1}$	$2.21x10^{-1}$
Resp.	4	$1.40x10^{-2}$	$5.35x10^{-2}$
Resp.	5	$8.24x10^{-1}$	$5.01x10^{-1}$
Resp.	6	$5.80x10^{-2}$	$1.74x10^{-1}$
Resp.	7	$2.31x10^{-1}$	$6.04x10^{-1}$
Resp.	8	$3.68x10^{-1}$	$3.20x10^{-1}$
Resp.	9	$1.97x10^{-1}$	$1.05x10^{-1}$
Resp.	10	$1.36x10^{-3}$	$2.07x10^{-3}$
Resp.	11	$2.60x10^{-4}$	$7.95x10^{-4}$
Resp.	12	$2.21x10^{-2}$	$2.99x10^{-2}$
Resp.	13	$1.64x10^{-2}$	$1.93x10^{-2}$
Resp.	14	$4.36x10^{-4}$	$1.04x10^{-3}$
Resp.	15	$3.63x10^{-2}$	$4.37x10^{-2}$
Resp.	16	2.05	$5.37x10^{-1}$
Resp.	17	$6.65x10^{-4}$	$1.20x10^{-1}$
Resp.	18	$4.45x10^{-2}$	$5.17x10^{-2}$
Resp.	19	$1.30x10^{-2}$	$2.08x10^{-3}$
Resp.	20	$2.74x10^{-1}$	$3.11x10^{-1}$
Resp.	21	$2.96x10^{-3}$	N.P.
Resp.	22	$1.76x10^{-1}$	$1.26x10^{-1}$
Resp.	23	$1.68x10^{-4}$	$2.41x10^{-3}$
Resp.	24	$2.18x10^{-2}$	$6.93x10^{-1}$
Resp.	25	$2.85x10^{-1}$	$5.46x10^{-1}$
Resp.	26	$8.63x10^{-3}$	$4.07x10^{-4}$
Resp.	27	N.P.	$3.38x10^{-2}$
Resp.	28	$1.84x10^{-5}$	$2.13x10^{-4}$
Resp.	29	$3.59x10^{-4}$	$3.83x10^{-4}$
Resp.	30	$1.14x10^{-3}$	$3.47x10^{-4}$
Resp.	31	$1.63x10^{-2}$	$2.39x10^{-2}$
Resp.	32	$3.13x10^{-1}$	$3.73x10^{-1}$
Resp.	33	$5.90x10^{-2}$	$7.03x10^{-2}$
Resp.	34	$1.43x10^{-2}$	$2.77x10^{-2}$
Resp.	35	$2.06x10^{-1}$	$2.54x10^{-1}$
Resp.	36	$3.45x10^{-1}$	$3.08x10^{-1}$
Resp.	37	$5.96x10^{-1}$	$4.78x10^{-1}$
Resp.	38	$1.09x10^{-2}$	$7.27x10^{-3}$
Resp.	39	$1.33x10^{-2}$	$1.49x10^{-1}$
Resp.	40	$5.72x10^{-2}$	$1.45x10^{-1}$
Resp.	41	$7.10x10^{-2}$	$1.14x10^{-1}$
Resp.	42	$8.50x10^{-2}$	$1.32x10^{-1}$
Resp.	43	$3.85x10^{-2}$	$8.74x10^{-2}$
Resp.	44	N.P.	$8.56x10^{1}$
Resp.	45	$4.76x10^{-4}$	$1.36x10^{-4}$
Resp.	46	$6.94x10^{-2}$	$5.76x10^{-2}$
Resp.	47	N.P.	$5.67x10^{-4}$
Resp.	48	$2.14x10^{-3}$	$1.83x10^{-3}$
Resp.	49	$5.24x10^{-2}$	$1.16x10^{-1}$
Resp.	50	$1.29x10^{1}$	9.44
Resp.	51	$1.58x10^{1}$	$2.45x10^{1}$
Resp.	52	$3.70x10^{-1}$	$4.11x10^{-2}$
Resp.	53	$3.57x10^{-1}$	$3.92x10^{-1}$
Resp.	54	$9.41x10^{-2}$	$1.45x10^{-2}$
Resp.	55	$1.64x10^{-3}$	$3.22x10^{-3}$

Appendix 2.2 (con't)

Predator	Prey	Pre Exchange	Post Exchange
Resp.	56	$6.13x10^{-4}$	$9.78x10^{-4}$
Resp.	57	$6.09x10^{-4}$	$1.36x10^{-1}$
Resp.	58	4.58	2.09
Resp.	59	$1.12x10^{-2}$	$1.48x10^{-3}$
Resp.	60	2.04	1.9
Resp.	61	1.92	2.87
Resp.	62	3.25	3.11
Resp.	63	4.43	4.84
Resp.	64	$3.28x10^{-1}$	$1.19x10^{-1}$
Resp.	65	$1.10x10^{-1}$	$1.14x10^{-1}$
Resp.	66	$1.01x10^{2}$	$7.96x10^{1}$
Resp.	67	$1.29x10^{2}$	$1.18x10^{2}$
Resp.	68	2.53	1.64
Resp.	69	$6.19x10^{1}$	$3.79x10^{1}$
Resp.	70	$2.38x10^{1}$	6.38
Resp.	71	$5.73x10^{1}$	$1.46x10^{1}$
Resp.	72	$9.56x10^{1}$	$9.24x10^{1}$
Resp.	73	6.96	7.8
Resp.	74	2.73	2.64
Resp.	75	$2.78x10^{2}$	$1.37x10^{2}$
Resp.	76	$1.33x10^{2}$	$1.29x10^{2}$
Resp.	77	$6.95x10^{1}$	8.36
Imp.	66	$2.14x10^{2}$	$1.63x10^{2}$
Imp.	67	$2.75x10^{2}$	$2.45x10^{2}$
Imp.	68	4.86	5.4
Imp.	69	$1.28x10^{2}$	$7.55x10^{1}$
Imp.	70	$4.51x10^{1}$	$1.28x10^{1}$
Imp.	71	$1.18x10^{2}$	$5.22x10^{1}$
Imp.	72	$2.08x10^{2}$	$2.01x10^{2}$
Imp.	73	$1.50x10^{1}$	$1.68x10^{1}$
Imp.	74	5.79	5.63
Exp.	2	$2.41x10^{-2}$	$1.12x10^{-2}$
Exp.	5	$2.80x10^{-2}$	$1.62x10^{-2}$
Exp.	8	$2.03x10^{-4}$	$1.77x10^{-4}$
Exp.	10	$4.63x10^{-5}$	$5.24x10^{-5}$
Exp.	11	$8.06x10^{-5}$	$9.15x10^{-5}$
Exp.	12	$9.43x10^{-4}$	$1.13x10^{-3}$
Exp.	13	$3.75x10^{-5}$	$4.13x10^{-5}$
Exp.	18	$5.75x10^{-5}$	$6.22x10^{-5}$
Exp.	19	$1.20x10^{-5}$	$1.26x10^{-5}$
Exp.	20	$3.54x10^{-4}$	$4.02x10^{-4}$
Exp.	22	$1.56x10^{-5}$	$1.11x10^{-5}$
Exp.	25	$4.19x10^{-4}$	$8.03x10^{-4}$
Exp.	30	$1.34x10^{-4}$	$1.43x10^{-4}$
Exp.	32	$3.66x10^{-3}$	$4.37x10^{-3}$
Exp.	34	$3.83x10^{-4}$	$4.27x10^{-4}$

Appendix 2.3

Determination of a re-centering scheme for cohesion analysis.

Carbon flows ranged from $8.26\text{x}10^{-10}$ to 8.25 gC m^{-2} yr^{-1} for the pre-zebra mussel invasion network, a difference of 10 orders of magnitude; carbon flows ranged from $7.48\text{x}10^{-11}$ to 18.38 gC m^{-2} yr^{-1} for the post-zebra mussel invasion network, a difference of 12 orders of magnitude. Kliquefinder accepts flow weights only within 5 orders of magnitude (0 through 99,998); therefore, we had to adjust the range of network data. We first normalized the data to the lowest value in the network, e.g., for the pre-zebra mussel time stanza, we divided all flows by our lowest flow estimate of $8.26\text{x}10^{-10}$ gC m^{-2} yr^{-1}; this changed our data range from 1 to $1.01\text{x}10^{10}$ gC m^{-2} yr^{-1}. After normalization, the data range still exceeded the input range for Kliquefinder, so we further adjusted the data by three re-centering schemes that involved: 1) changing the range of data by one order of magnitude between the schemes; 2) assigning the maximum flow weight (i.e., 99,998) to flows above the range of Kliquefinder; and 3) assigning the minimum flow weight (i.e., 1) to non-zero flows below the range of Kliquefinder. Scheme one set the highest flows one order of magnitude above the upper range of Kliquefinder (i.e., the highest flow and all other flows of the same order of magnitude were assigned the maximum weight; all other flows fell below the upper range of Kliquefinder). Scheme two set the highest flows two orders of magnitude above the upper range for Kliquefinder, and scheme three set the highest flows three orders of magnitude above the upper range of Kliquefinder. As a result, the number of flow weights exceeding both the upper and lower input ranges of Kliquefinder differed by scheme. These re-centering schemes incorporated three assumptions. First, when adjusting the data, maintaining the proportional range between flow weights is more important than simply maintaining the rank. For that reason we did not use a log- or similar transformation that would compress one extreme of values relative to the other extreme (e.g., a log-transformation would compress the high flow range relative to the low flow range). Second, for ENA, small flows (i.e., flows less than one after normalization) are ecologically less significant than large flows because of the quantification of ecosystem activity as the throughput of carbon. Therefore, we chose re-centering schemes that changed a greater number of small flows than large flows, i.e., we assigned more small flows to the minimum weight than assigned large flows to the maximum weight. Third, although we deem small flows ecologically less significant in this context, all non-zero flows represent realized food web connections. Therefore, we chose to retain small flows in the network by assigning the minimum weight instead of reducing them to zero.

To assess the impact of these re-centering schemes on our structural analysis, we compared the Kliquefinder subgroup identification for each scheme in order to select the most robust grouped network with which to conduct ENA. Kliquefinder incorporates a routine that compares subgroup membership of one network to the subgroup membership of another network and calculates a *Z*-score to test the statistical significance using the Quadratic Assignment Procedure (QAP) method (Hubert 1987). For both the pre- and post-zebra mussel invasion networks, all schemes yielded statistically similar subgroup membership ($p \leq 0.001$ for all comparisons). Tables A2.1 and A2.2 present the *Z*-scores and associated *p*-values for all comparisons. Since subgroup membership was similar for all schemes, we chose the scheme that: 1) assigned fewer maximum values to flow weights above the range of Kliquefinder relative to minimum values to flow weights below the range of Kliquefinder (according to assumption two); and 2) assigned maximum and minimum values to the fewest flows overall. Following these criteria, we chose to conduct all subsequent analyses using scheme two for both the pre- and post-zebra mussel invasion networks.

Table A2.1. Results of the significance test for differences between subgroup membership by re-centering scheme for the pre-zebra mussel invasion time stanza. The table displays *Z*-scores for each comparison, with the *p*-value in parentheses.

Scheme	Scheme 1	Scheme 2	Scheme 3
Scheme 1	.	31.91 ($p \leq 0.001$)	25.73 ($p \leq 0.001$)
Scheme 2	28.88 ($p \leq 0.001$)	.	28.91 ($p \leq 0.001$)
Scheme 3	24.98 ($p \leq 0.001$)	28.91 ($p \leq 0.001$)	.

Table A2.2. Results of the significance test for differences between subgroup membership by re-centering scheme for the post-zebra mussel invasion time stanza. The table displays *Z*-scores for each comparison, with the *p*-value in parentheses.

Scheme	Scheme 1	Scheme 2	Scheme 3
Scheme 1	.	28.13 ($p \leq 0.001$)	26.31 ($p \leq 0.001$)
Scheme 2	26.07 ($p \leq 0.001$)	.	24.45 ($p \leq 0.001$)
Scheme 3	27.76 ($p \leq 0.001$)	25.39 ($p \leq 0.001$)	.

References

Hubert, L. 1987. *Assignment Methods in Combinatorial Data Analysis*. Marcel Dekker.

Appendix 3.1

List of model inputs and data sources for the unbalanced pre- and post-zebra mussel invasion networks. Diet proportions are not included to conserve space, but sources of diet information are listed. N.P. stands for not present. Biomass units are g m^{-2}, wet weight (WW) or dry weight (DW) (zooplankton taxa). Conversions from wet weight to dry weight, and dry weight to carbon, are listed. P/B, C/B, and R/B stand for production-to-biomass, consumption-to-biomass, and respiration-to-biomass ratios, respectively, measured as yr^{-1}. Export includes migrations from the ecosystem and fisheries harvest (g m^{-2} WW). The abbreviation BQ-OL CMP Workgroup refers to the Bay of Quinte – Oneida Lake Comparative Modelling Project Workgroup. The methods for this modeling project, from which much of our data was drawn, are expected to be published in 2006 as a Canadian Technical Report of Fisheries and Aquatic Sciences (Koops, M. A. pers. comm.).

Appendix 3.1

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
1	Cormorants	Biomass WW	$1.40x10^{-3}$	$5.90x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$6.00x10^{-1}$	$6.00x10^{-1}$	BQ-OL CMP Workgroup
		C/B	$8.58x10^{1}$	$8.58x10^{1}$	BQ-OL CMP Workgroup
		R/B	$8.39x10^{1}$	$8.40x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
2	Walleye Age 4+	Biomass WW	4.16	$9.43x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.77x10^{-1}$	$2.77x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.64	3.64	BQ-OL CMP Workgroup
		R/B	3.05	2.85	BQ-OL CMP Workgroup
		Export	$1.53x10^{-2}$	$1.10x10^{-1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
3	Walleye Age 1-3	Biomass WW	1.37	$3.10x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$7.99x10^{-1}$	$7.99x10^{-1}$	BQ-OL CMP Workgroup
		C/B	7.14	7.14	BQ-OL CMP Workgroup
		R/B	4.94	4.74	BQ-OL CMP Workgroup
		Export	$2.97x10^{-2}$	$9.99x10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
4	Walleye Age-0	Biomass WW	$1.02x10^{-1}$	$2.31x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	1.47	1.47	BQ-OL CMP Workgroup
		C/B	$2.05x10^{1}$	$2.05x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.61x10^{1}$	$1.53x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
5	Yellow Perch	Biomass WW	$7.00x10^{-1}$	2.35	BQ-OL CMP Workgroup
	Age 1+	WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.50x10^{-1}$	$5.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	4.1	4.14	BQ-OL CMP Workgroup
		R/B	3.57	3.61	BQ-OL CMP Workgroup
		Export	$1.80x10^{-2}$	$9.00x10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
6	Yellow Perch	Biomass WW	$3.71x10^{-2}$	$1.33x10^{-1}$	BQ-OL CMP Workgroup
	Age-0	WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	3.8	3.8	BQ-OL CMP Workgroup
		C/B	$1.54x10^{1}$	$1.54x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.41x10^{1}$	$1.33x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
7	White Perch	Biomass WW	1.19	1.9	BQ-OL CMP Workgroup
	Age 1+	WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.00x10^{-1}$	$5.86x10^{-1}$	BQ-OL CMP Workgroup
		C/B	4	4.18	BQ-OL CMP Workgroup
		R/B	2.7	2.75	BQ-OL CMP Workgroup
		Export	$5.22x10^{-3}$	$1.62x10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
8	White Perch	Biomass WW	$1.08x10^{-1}$	$1.57x10^{-1}$	BQ-OL CMP Workgroup
	Age-0	WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	6	5.1	BQ-OL CMP Workgroup
		C/B	$2.06x10^{1}$	$1.88x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.83x10^{1}$	$1.11x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
8	Wt. Perch Age-0	Diet	.	.	Becker 1983
9	Black Crappie Age 1+	Biomass WW	3.57×10^{-3}	2.48×10^{-2}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	7.08×10^{-1}	7.08×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.24	4.24	BQ-OL CMP Workgroup
		R/B	2.76	2.77	BQ-OL CMP Workgroup
		Export	6.84×10^{-4}	2.23×10^{-3}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
10	Bluegill Age 1+	Biomass WW	3.18×10^{-5}	1.66×10^{-1}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	6.12×10^{-1}	6.12×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.24	4.24	BQ-OL CMP Workgroup
		R/B	2.76	2.77	BQ-OL CMP Workgroup
		Export	6.10×10^{-6}	1.49×10^{-2}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
11	*Lepomis* species Age 1+	Biomass WW	1.10×10^{-5}	1.17×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	6.12×10^{-1}	6.12×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.24	4.24	BQ-OL CMP Workgroup
		R/B	2.76	2.77	BQ-OL CMP Workgroup
		Export	2.12×10^{-6}	1.05×10^{-4}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
12	Pumpkinseed Age 1+	Biomass WW	2.21×10^{-2}	7.24×10^{-1}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	6.12×10^{-1}	6.12×10^{-1}	BQ-OL CMP Workgroup
		C/B	4.24	4.24	BQ-OL CMP Workgroup

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
12	Pumpkinseed	R/B	2.76	2.77	BQ-OL CMP Workgroup
	Age 1+	Export	$4.25x10^{-3}$	$6.52x10^{-2}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
13	Rock Bass	Biomass WW	$9.58x10^{-4}$	$3.11x10^{-3}$	BQ-OL CMP Workgroup
	Age 1+	WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.15x10^{-1}$	$5.15x10^{-1}$	BQ-OL CMP Workgroup
		C/B	4.24	4.24	BQ-OL CMP Workgroup
		R/B	2.76	2.77	BQ-OL CMP Workgroup
		Export	$1.84x10^{-4}$	$2.80x10^{-4}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
14	Sunfish family	Biomass WW	$4.51x10^{-5}$	$2.46x10^{-3}$	BQ-OL CMP Workgroup
	Age 1+	WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$6.21x10^{-1}$	$6.13x10^{-1}$	BQ-OL CMP Workgroup
		C/B	4.24	4.24	BQ-OL CMP Workgroup
		R/B	2.76	2.77	BQ-OL CMP Workgroup
		Export	$8.65x10^{-6}$	$2.21x10^{-4}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
15	Panfish Age-0	Biomass WW	$3.26x10^{-3}$	$3.65x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	6	8	BQ-OL CMP Workgroup
		C/B	$2.07x10^{1}$	$2.45x10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.16x10^{1}$	$1.16x10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
16	Alewife	Biomass WW	1.61	$4.50x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
16	Alewife	P/B	$8.65x10^{-1}$	$8.89x10^{-1}$	BQ-OL CMP Workgroup
		C/B	4.53	4.68	BQ-OL CMP Workgroup
		R/B	2.86	2.95	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
17	American Eel	Biomass WW	$3.57x10^{-1}$	$6.38x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{-1}$	$3.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.8	3.7	BQ-OL CMP Workgroup
		R/B	2.66	2.94	BQ-OL CMP Workgroup
		Export	None	$2.43x10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
18	Brook Silverside	Biomass WW	N.P.	$6.85x10^{-5}$	BQ-OL CMP Workgroup
		WW : DW	N.P.	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	N.P.	$4.50x10^{-1}$	Jørgensen 1979
		P/B	N.P.	1.71	BQ-OL CMP Workgroup
		C/B	N.P.	6.33	BQ-OL CMP Workgroup
		R/B	N.P.	3.36	BQ-OL CMP Workgroup
		Diet	N.P.	.	BQ-OL CMP Workgroup Becker 1983
19	Brown Bullhead	Biomass WW	$9.91x10^{-1}$	$7.48x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{-1}$	$3.86x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.8	3.7	BQ-OL CMP Workgroup
		R/B	2.66	2.94	BQ-OL CMP Workgroup
		Export	$4.39x10^{-2}$	$2.60x10^{-2}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
20	Channel Catfish	Biomass WW	$8.39x10^{-3}$	$6.01x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
20	Channel Catfish	DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$3.80\text{x}10^{-1}$	$2.17\text{x}10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.8	3.7	BQ-OL CMP Workgroup
		R/B	2.66	2.94	BQ-OL CMP Workgroup
		Export	$2.70\text{x}10^{-3}$	$1.73\text{x}10^{-4}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
21	Common Carp	Biomass WW	$6.70\text{x}10^{-1}$	$3.30\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00\text{x}10^{-1}$	$2.00\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$1.56\text{x}10^{-1}$	$1.60\text{x}10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.33	3.33	BQ-OL CMP Workgroup
		R/B	2.51	2.51	BQ-OL CMP Workgroup
		Export	$4.68\text{x}10^{-3}$	$1.44\text{x}10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
22	Emerald Shiner	Biomass WW	N.P.	$6.37\text{x}10^{-6}$	BQ-OL CMP Workgroup
		WW : DW	N.P.	$2.00\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	N.P.	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	N.P.	1.71	BQ-OL CMP Workgroup
		C/B	N.P.	6.33	BQ-OL CMP Workgroup
		R/B	N.P.	3.36	BQ-OL CMP Workgroup
		Diet	N.P.	.	BQ-OL CMP Workgroup Becker 1983
23	Freshwater Drum	Biomass WW	$1.14\text{x}10^{-1}$	$5.10\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00\text{x}10^{-1}$	$2.00\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$2.64\text{x}10^{-1}$	$2.50\text{x}10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.66	3.52	BQ-OL CMP Workgroup
		R/B	2.67	2.57	BQ-OL CMP Workgroup
		Export	$9.90\text{x}10^{-4}$	$3.96\text{x}10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
24	Gizzard Shad	Biomass WW	4.20×10^{-1}	4.50×10^{-1}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	1.43	1.43	BQ-OL CMP Workgroup
		C/B	5.96	5.96	BQ-OL CMP Workgroup
		R/B	3.34	3.34	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
25	Johnny Darter	Biomass WW	3.89×10^{-5}	1.17×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	3.80×10^{-1}	3.70×10^{-1}	BQ-OL CMP Workgroup
		C/B	3.8	3.7	BQ-OL CMP Workgroup
		R/B	2.66	2.94	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
26	Largemouth Bass	Biomass WW	N.P.	4.32×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	N.P.	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	N.P.	4.50×10^{-1}	Jørgensen 1979
		P/B	N.P.	3.08×10^{-1}	BQ-OL CMP Workgroup
		C/B	N.P.	3.51	BQ-OL CMP Workgroup
		R/B	N.P.	4.22	BQ-OL CMP Workgroup
		Diet	N.P.	.	BQ-OL CMP Workgroup Becker 1983
27	Log Perch	Biomass WW	8.70×10^{-5}	1.72×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	2.00×10^{-1}	2.00×10^{-1}	Jørgensen 1979
		DW : Carbon	4.50×10^{-1}	4.50×10^{-1}	Jørgensen 1979
		P/B	3.80×10^{-1}	3.70×10^{-1}	BQ-OL CMP Workgroup
		C/B	3.8	3.7	BQ-OL CMP Workgroup
		R/B	2.66	2.94	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
28	Longnose Gar	Biomass WW	2.13×10^{-1}	3.76×10^{-3}	BQ-OL CMP Workgroup

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
28	Longnose Gar	WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.12x10^{-1}$	$1.86x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.24	3.51	BQ-OL CMP Workgroup
		R/B	2.36	4.22	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
29	Northern Pike	Biomass WW	$9.17x10^{-2}$	$1.80x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$2.40x10^{-1}$	$1.98x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.24	3.51	BQ-OL CMP Workgroup
		R/B	2.36	4.22	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
30	Round Goby	Biomass WW	N.P.	$8.10x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	N.P.	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	N.P.	$4.50x10^{-1}$	Jørgensen 1979
		P/B	N.P.	1.33	BQ-OL CMP Workgroup
		C/B	N.P.	5.78	BQ-OL CMP Workgroup
		R/B	N.P.	3.3	BQ-OL CMP Workgroup
		Diet	N.P.	.	BQ-OL CMP Workgroup Becker 1983
31	Smallmouth Bass	Biomass WW	$2.90x10^{-2}$	$2.10x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.90x10^{-1}$	$3.68x10^{-1}$	BQ-OL CMP Workgroup
		C/B	5.65	5.8	BQ-OL CMP Workgroup
		R/B	4.13	4.24	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
32	Spottail Shiner	Biomass WW	$2.90x10^{-2}$	$8.09x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
32	Spottail Shiner	DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	1.71	1.71	BQ-OL CMP Workgroup
		C/B	6.33	6.33	BQ-OL CMP Workgroup
		R/B	3.36	3.36	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
33	Trout-perch	Biomass WW	$3.70x10^{-2}$	$1.81x10^{-2}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	1.35	1.46	BQ-OL CMP Workgroup
		C/B	5.4	5.84	BQ-OL CMP Workgroup
		R/B	2.97	3.21	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
34	White Bass	Biomass WW	$1.37x10^{-2}$	$4.72x10^{-3}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{-1}$	$3.70x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.8	3.7	BQ-OL CMP Workgroup
		R/B	2.66	2.94	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
35	White Sucker	Biomass WW	$8.22x10^{-1}$	$7.29x10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$2.00x10^{-1}$	$2.00x10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$3.80x10^{-1}$	$2.68x10^{-1}$	BQ-OL CMP Workgroup
		C/B	3.8	3.7	BQ-OL CMP Workgroup
		R/B	2.66	2.94	BQ-OL CMP Workgroup
		Export	$1.36x10^{-3}$	$1.40x10^{-3}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup Becker 1983
36	Amphipods	Biomass WW	1.18	1.9	BQ-OL CMP Workgroup
		WW : DW	$1.67x10^{-1}$	$1.67x10^{-1}$	Jørgensen 1979

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
36	Amphipods	DW : Carbon	4.17×10^{-1}	4.17×10^{-1}	Jørgensen 1979
		P/B	5.7	5.7	BQ-OL CMP Workgroup
		C/B	3.02×10^{1}	3.02×10^{1}	BQ-OL CMP Workgroup
		R/B	4.26	4.26	Quigley et al. 2002
		Diet	.	.	BQ-OL CMP Workgroup
37	Chironomids	Biomass WW	2.05	1.15	BQ-OL CMP Workgroup
		WW : DW	1.67×10^{-1}	1.67×10^{-1}	Jørgensen 1979
		DW : Carbon	4.62×10^{-1}	4.62×10^{-1}	Jørgensen 1979
		P/B	1.45×10^{1}	1.45×10^{1}	BQ-OL CMP Workgroup
		C/B	6.93×10^{1}	6.93×10^{1}	BQ-OL CMP Workgroup
		R/B	4.5	4.5	Johnson and Brinkhur 1971
		Diet	.	.	BQ-OL CMP Workgroup
38	Clams	Biomass WW	2.57×10^{-1}	2.67×10^{-1}	BQ-OL CMP Workgroup
		WW : DW	1.67×10^{-1}	1.67×10^{-1}	Jørgensen 1979
		DW : Carbon	3.99×10^{-1}	3.99×10^{-1}	Jørgensen 1979
		P/B	3.8	3.8	BQ-OL CMP Workgroup
		C/B	2.44×10^{1}	2.44×10^{1}	BQ-OL CMP Workgroup
		R/B	1.03×10^{1}	1.03×10^{1}	Johnson and Brinkhur 1971
		Diet	.	.	BQ-OL CMP Workgroup
39	Crayfish	Biomass WW	5.40×10^{-3}	5.40×10^{-3}	BQ-OL CMP Workgroup
		WW : DW	1.67×10^{-1}	1.67×10^{-1}	Jørgensen 1979
		DW : Carbon	4.46×10^{-1}	4.46×10^{-1}	Jørgensen 1979
		P/B	1.2	1.2	BQ-OL CMP Workgroup
		C/B	1.04×10^{1}	1.04×10^{1}	BQ-OL CMP Workgroup
		R/B	1.38×10^{1}	1.38×10^{1}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
40	Insects	Biomass WW	1.13	1.62	BQ-OL CMP Workgroup
		WW : DW	1.67×10^{-1}	1.67×10^{-1}	Jørgensen 1979
		DW : Carbon	4.46×10^{-1}	4.46×10^{-1}	Jørgensen 1979
		P/B	5.6	5.6	BQ-OL CMP Workgroup
		C/B	3.61×10^{1}	3.61×10^{1}	BQ-OL CMP Workgroup
		R/B	1.38×10^{1}	1.38×10^{1}	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
41	Isopods	Biomass WW	$1.45\text{x}10^{-1}$	$7.82\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$1.67\text{x}10^{-1}$	$1.67\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$3.43\text{x}10^{-1}$	$3.43\text{x}10^{-1}$	Jørgensen 1979
		P/B	5.7	5.7	BQ-OL CMP Workgroup
		C/B	$3.02\text{x}10^{1}$	$3.02\text{x}10^{1}$	BQ-OL CMP Workgroup
		R/B	4.26	4.26	Quigley et al. 2002
		Diet	.	.	BQ-OL CMP Workgroup
42	Leeches	Biomass WW	$3.46\text{x}10^{-1}$	$1.22\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$1.67\text{x}10^{-1}$	$1.67\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.83\text{x}10^{-1}$	$4.83\text{x}10^{-1}$	Jørgensen 1979
		P/B	2.2	2.2	BQ-OL CMP Workgroup
		C/B	$3.18\text{x}10^{1}$	6.3	BQ-OL CMP Workgroup
		R/B	$1.38\text{x}10^{1}$	$1.38\text{x}10^{1}$	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
43	Oligochaetes	Biomass WW	$5.64\text{x}10^{-1}$	$6.43\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$1.67\text{x}10^{-1}$	$1.67\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.02\text{x}10^{-1}$	$4.02\text{x}10^{-1}$	Jørgensen 1979
		P/B	6.2	6.2	BQ-OL CMP Workgroup
		C/B	$6.20\text{x}10^{1}$	$6.20\text{x}10^{1}$	BQ-OL CMP Workgroup
		R/B	4.5	4.5	Johnson and Brinkhur 1971
		Diet	.	.	BQ-OL CMP Workgroup
44	Snails	Biomass WW	$4.48\text{x}10^{-1}$	$9.13\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$1.67\text{x}10^{-1}$	$1.67\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$3.99\text{x}10^{-1}$	$3.99\text{x}10^{-1}$	Jørgensen 1979
		P/B	3.5	3.5	BQ-OL CMP Workgroup
		C/B	$1.33\text{x}10^{1}$	$1.33\text{x}10^{1}$	BQ-OL CMP Workgroup
		R/B	1.8	1.8	BQ-OL CMP Workgroup
		Diet	.	.	BQ-OL CMP Workgroup
45	Zebra Mussels	Biomass WW	N.P.	$1.04\text{x}10^{3}$	BQ-OL CMP Workgroup
		WW : DW	N.P.	$1.67\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	N.P.	$3.99\text{x}10^{-1}$	Jørgensen 1979
		P/B	N.P.	1.35	BQ-OL CMP Workgroup
		C/B	N.P.	8.6	BQ-OL CMP Workgroup

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
45	Zebra Mussels	R/B	N.P.	4.15	Fanslow et al. 2001
		Diet	N.P.	.	BQ-OL CMP Workgroup
46	*Alona* species	Biomass DW	$7.54x10^{-4}$	$2.42x10^{-3}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.50x10^{1}$	$5.50x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
47	*Bosmina longirostris*	Biomass DW	$1.06x10^{-1}$	$8.47x10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.68x10^{1}$	$5.68x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
48	*Ceriodaphnia* species	Biomass DW	$1.86x10^{-2}$	$1.68x10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$7.57x10^{1}$	$7.57x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
49	Chydoridae family	Biomass DW	$6.53x10^{-2}$	$1.61x10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.16x10^{1}$	$5.16x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
50	*Daphnia galeata mendotae*	Biomass DW	$1.30x10^{-1}$	$2.54x10^{-1}$	BQ-OL CMP Workgroup
		DW : Carbon	$5.07x10^{-1}$	$5.07x10^{-1}$	Jørgensen 1979
		P/B	$4.21x10^{1}$	$4.21x10^{1}$	BQ-OL CMP Workgroup

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
50	*Daphnia galeata mendotae*	C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
51	*Daphnia pulicaria*	Biomass DW	$2.66x10^{-3}$	$4.85x10^{-4}$	BQ-OL CMP Workgroup
		DW : Carbon	$5.07x10^{-1}$	$5.07x10^{-1}$	Jørgensen 1979
		P/B	$3.88x10^{1}$	$3.88x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
52	*Daphnia retrocurva*	Biomass DW	$1.54x10^{-1}$	$1.48x10^{-1}$	BQ-OL CMP Workgroup
		DW : Carbon	$5.07x10^{-1}$	$5.07x10^{-1}$	Jørgensen 1979
		P/B	$3.54x10^{1}$	$3.54x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
53	*Eubosmina coregoni*	Biomass DW	$2.63x10^{-1}$	$1.85x10^{-1}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$6.83x10^{1}$	$6.83x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.86	1.86	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
54	Sididae family	Biomass DW	$1.86x10^{-2}$	$3.72x10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.50x10^{1}$	$5.50x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
55	Large-bodied Cladocerans	Biomass DW	$1.81x10^{-4}$	$1.71x10^{-3}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$5.50x10^{1}$	$5.50x10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.00x10^{2}$	$2.00x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
56	*Cercopagis pengoi*	Biomass DW	N.P.	$1.79x10^{-4}$	BQ-OL CMP Workgroup
		DW : Carbon	N.P.	$4.50x10^{-1}$	Jørgensen 1979
		P/B	N.P.	$4.10x10^{1}$	BQ-OL CMP Workgroup
		C/B	N.P.	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	N.P.	$3.13x10^{1}$	Urabe and Watanabe 1989
		Diet	N.P.	.	BQ-OL CMP Workgroup Krause 2004
57	*Leptodora kindtii*	Biomass DW	$3.12x10^{-3}$	$4.46x10^{-3}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50x10^{-1}$	$4.50x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$3.13x10^{1}$	$3.13x10^{1}$	Hillbricht-Ilkowska and Karabin 1970
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
58	*Acanthocyclops vernalis*	Biomass DW	$1.74x10^{-2}$	$1.26x10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
59	*Diacyclops thomasi*	Biomass DW	$2.41x10^{-3}$	$1.69x10^{-3}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
59	*Diacyclops thomasi*	R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
60	*Eucyclops species*	Biomass DW	$5.97x10^{-4}$	$9.22x10^{-4}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
61	*Mesocyclops species*	Biomass DW	$2.99x10^{-2}$	$4.39x10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
62	*Tropocyclops extensus*	Biomass DW	$9.17x10^{-3}$	$6.72x10^{-3}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
63	Cyclopoida copepodites	Biomass DW	$1.63x10^{-1}$	$1.02x10^{-1}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$1.84x10^{1}$	$1.84x10^{1}$	Urabe and Watanabe 1989
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
64	Diaptomidae family	Biomass DW	$3.12x10^{-3}$	$6.67x10^{-3}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
64	Diaptomidae family	P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$2.96x10^{1}$	$2.96x10^{1}$	Banse and Mosher 1980
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
65	Temoridae family	Biomass DW	$1.65x10^{-3}$	$6.49x10^{-4}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$2.96x10^{1}$	$2.96x10^{1}$	Banse and Mosher 1980
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
66	Calanoida copepodites	Biomass DW	$5.98x10^{-3}$	$4.76x10^{-3}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$2.96x10^{1}$	$2.96x10^{1}$	Banse and Mosher 1980
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
67	Harpacticoida	Biomass DW	$9.80x10^{-6}$	$6.05x10^{-5}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	$2.96x10^{1}$	$2.96x10^{1}$	Banse and Mosher 1980
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004
68	Nauplii	Biomass DW	$1.16x10^{-2}$	$2.62x10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.36x10^{-1}$	$4.36x10^{-1}$	Jørgensen 1979
		P/B	$4.40x10^{1}$	$4.40x10^{1}$	BQ-OL CMP Workgroup
		C/B	$1.44x10^{2}$	$1.44x10^{2}$	BQ-OL CMP Workgroup
		R/B	1.16	1.16	Makarewicz and Likens 1979
		Diet	.	.	BQ-OL CMP Workgroup Krause 2004

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
69	Rotifers	Biomass DW	$1.60\text{x}10^{-2}$	$1.60\text{x}10^{-2}$	BQ-OL CMP Workgroup
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$5.20\text{x}10^{1}$	$5.20\text{x}10^{1}$	BQ-OL CMP Workgroup
		C/B	$2.08\text{x}10^{2}$	$2.08\text{x}10^{2}$	BQ-OL CMP Workgroup
		R/B	1.16	1.16	Makarewicz and Likens 1979
		Diet	.	.	BQ-OL CMP Workgroup Pennak 1978
70	Blue-green Algae	Biomass WW	4.64	1.66	BQ-OL CMP Workgroup
		WW : DW	$3.60\text{x}10^{-1}$	$3.60\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.60\text{x}10^{-1}$	$4.60\text{x}10^{-1}$	Jørgensen 1979
		P/B	$1.76\text{x}10^{2}$	$2.46\text{x}10^{2}$	BQ-OL CMP Workgroup
		R/B	$7.28\text{x}10^{1}$	$7.28\text{x}10^{1}$	Biddanda and Cotner 2002
71	Diatoms	Biomass WW	8.45	7.29	BQ-OL CMP Workgroup
		WW : DW	$3.30\text{x}10^{-1}$	$3.30\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$5.17\text{x}10^{-1}$	$5.17\text{x}10^{-1}$	Jørgensen 1979
		P/B	$1.76\text{x}10^{2}$	$2.46\text{x}10^{2}$	BQ-OL CMP Workgroup
		R/B	$7.28\text{x}10^{1}$	$7.28\text{x}10^{1}$	Biddanda and Cotner 2002
72	Flagellates	Biomass WW	$8.45\text{x}10^{-1}$	$5.31\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$4.00\text{x}10^{-1}$	$4.00\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$1.76\text{x}10^{2}$	$2.46\text{x}10^{2}$	BQ-OL CMP Workgroup
		C/B	None	None	None
		R/B	$7.28\text{x}10^{1}$	$7.28\text{x}10^{1}$	Biddanda and Cotner 2002
73	Golden Algae	Biomass WW	$1.93\text{x}10^{-1}$	$1.50\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$4.00\text{x}10^{-1}$	$4.00\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$1.76\text{x}10^{2}$	$2.46\text{x}10^{2}$	BQ-OL CMP Workgroup
		R/B	$7.28\text{x}10^{1}$	$7.28\text{x}10^{1}$	Biddanda and Cotner 2002
74	Green Algae	Biomass WW	$5.60\text{x}10^{-1}$	$3.28\text{x}10^{-1}$	BQ-OL CMP Workgroup
		WW : DW	$4.30\text{x}10^{-1}$	$4.30\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$5.05\text{x}10^{-1}$	$5.05\text{x}10^{-1}$	Jørgensen 1979
		P/B	$1.76\text{x}10^{2}$	$2.46\text{x}10^{2}$	BQ-OL CMP Workgroup
		R/B	$7.28\text{x}10^{1}$	$7.28\text{x}10^{1}$	Biddanda and Cotner 2002

Appendix 3.1 (con't)

No.	Taxa	Parameter	Pre Value	Post Value	Reference(s)
75	Epiphytes	Biomass WW	$6.70\text{x}10^{-1}$	6.26	BQ-OL CMP Workgroup
		WW : DW	$1.20\text{x}10^{-1}$	$1.20\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$1.20\text{x}10^{2}$	$1.20\text{x}10^{2}$	BQ-OL CMP Workgroup
		R/B	$4.95\text{x}10^{1}$	$3.54\text{x}10^{1}$	Biddanda and Cotner 2002
76	Macrophytes	Biomass WW	7.55	$8.09\text{x}10^{1}$	BQ-OL CMP Workgroup
		WW : DW	$1.20\text{x}10^{-1}$	$1.20\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	8.8	8.8	BQ-OL CMP Workgroup
		R/B	3.64	2.6	Biddanda and Cotner 2002
77	Periphytes	Biomass WW	3.24	2.05	BQ-OL CMP Workgroup
		WW : DW	$1.20\text{x}10^{-1}$	$1.20\text{x}10^{-1}$	Jørgensen 1979
		DW : Carbon	$4.50\text{x}10^{-1}$	$4.50\text{x}10^{-1}$	Jørgensen 1979
		P/B	$2.65\text{x}10^{1}$	$2.65\text{x}10^{1}$	BQ-OL CMP Workgroup
		R/B	$1.10\text{x}10^{1}$	7.85	Biddanda and Cotner 2002

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Appendix 3.2

Balanced exchange matrices for the pre- and post-zebra mussel invasion networks. For clarity, the matrix was changed to list format. Flows units are gC m^{-2} yr^{-1} and all zero flows were removed from the list. N.P., Prod., Cons., Resp., Imp., and Exp. stand for not present, production, consumption, respiration, imports, and exports, respectively.

Appendix 3.2

Pred	Prey	Pre Exchange	Post Exchange
1	3	$2.32x10^{-3}$	$1.26x10^{-2}$
1	5	$1.42x10^{-2}$	$4.31x10^{-2}$
1	7	$1.59x10^{-4}$	$8.40x10^{-4}$
1	9	$1.68x10^{-4}$	$4.80x10^{-3}$
1	10	$1.68x10^{-6}$	$4.79x10^{-3}$
1	11	$1.68x10^{-6}$	$4.79x10^{-4}$
1	12	$1.68x10^{-4}$	$4.79x10^{-3}$
1	13	$1.68x10^{-4}$	$4.79x10^{-4}$
1	14	$1.68x10^{-6}$	$4.79x10^{-4}$
1	16	$1.19x10^{-4}$	$6.52x10^{-4}$
1	17	$2.26x10^{-5}$	$1.20x10^{-4}$
1	18	N.P.	$6.22x10^{-6}$
1	19	$2.26x10^{-5}$	$1.20x10^{-4}$
1	20	$2.26x10^{-5}$	$1.20x10^{-5}$
1	23	$2.97x10^{-4}$	$1.49x10^{-3}$
1	24	$3.57x10^{-5}$	$1.87x10^{-3}$
1	25	0	$1.20x10^{-5}$
1	27	0	$1.20x10^{-5}$
1	28	$2.64x10^{-5}$	$1.56x10^{-4}$
1	29	$2.64x10^{-5}$	$1.56x10^{-4}$
1	30	N.P.	$9.35x10^{-5}$
1	31	$7.12x10^{-4}$	$6.53x10^{-4}$
1	32	$1.19x10^{-4}$	$6.22x10^{-4}$
1	34	$2.26x10^{-5}$	$1.20x10^{-5}$
1	35	$2.26x10^{-5}$	$1.20x10^{-4}$
2	3	$7.52x10^{-3}$	$1.14x10^{-3}$
2	4	$3.92x10^{-2}$	$5.99x10^{-3}$
2	5	$2.44x10^{-2}$	$4.16x10^{-2}$
2	6	$9.54x10^{-3}$	$2.71x10^{-2}$
2	7	$1.96x10^{-1}$	$2.72x10^{-2}$
2	8	$9.55x10^{-2}$	$2.71x10^{-2}$
2	9	$3.26x10^{-4}$	$6.25x10^{-4}$
2	10	$3.27x10^{-6}$	$6.24x10^{-4}$
2	11	$3.26x10^{-6}$	$6.24x10^{-5}$
2	12	$3.26x10^{-4}$	$6.24x10^{-4}$
2	13	$3.27x10^{-4}$	$6.23x10^{-5}$
2	14	$3.26x10^{-6}$	$6.24x10^{-5}$
2	15	$8.29x10^{-4}$	$1.14x10^{-1}$
2	16	$1.61x10^{-1}$	$1.33x10^{-2}$
2	17	$1.08x10^{-3}$	$1.64x10^{-4}$
2	18	N.P.	$9.59x10^{-6}$
2	19	$1.08x10^{-3}$	$1.64x10^{-4}$
2	20	$1.08x10^{-3}$	$1.64x10^{-5}$
2	24	$1.77x10^{-2}$	$2.73x10^{-2}$
2	25	$1.08x10^{-6}$	$1.64x10^{-5}$
2	26	N.P.	$7.85x10^{-4}$
2	27	$1.08x10^{-5}$	$1.64x10^{-5}$
2	28	$5.52x10^{-3}$	$7.85x10^{-4}$
2	29	$5.53x10^{-3}$	$7.86x10^{-4}$
2	30	N.P.	$4.62x10^{-4}$
2	31	$1.96x10^{-3}$	$7.52x10^{-4}$
2	32	$3.26x10^{-3}$	$9.60x10^{-4}$
2	33	$9.02x10^{-3}$	$1.73x10^{-4}$
2	34	$1.08x10^{-3}$	$1.64x10^{-5}$
2	35	$1.08x10^{-3}$	$1.64x10^{-4}$
2	37	$1.17x10^{-1}$	$1.62x10^{-2}$
2	39	$2.20x10^{-3}$	$2.45x10^{-4}$
2	40	$2.21x10^{-1}$	$2.45x10^{-2}$
2	42	$2.21x10^{-1}$	$2.45x10^{-2}$
2	43	$1.17x10^{-1}$	$1.62x10^{-2}$
3	4	$1.88x10^{-2}$	$4.57x10^{-3}$
3	5	$4.44x10^{-3}$	$2.66x10^{-2}$
3	6	$3.61x10^{-3}$	$4.61x10^{-2}$
3	7	$1.70x10^{-2}$	$1.37x10^{-2}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
3	8	$6.59\text{x}10^{-2}$	$3.58\text{x}10^{-2}$
3	9	$6.90\text{x}10^{-5}$	$3.41\text{x}10^{-4}$
3	10	0	$3.41\text{x}10^{-4}$
3	11	0	$3.41\text{x}10^{-5}$
3	12	$6.89\text{x}10^{-5}$	$3.41\text{x}10^{-4}$
3	13	$6.90\text{x}10^{-5}$	$3.40\text{x}10^{-5}$
3	14	0	$3.41\text{x}10^{-5}$
3	16	$3.00\text{x}10^{-2}$	$1.72\text{x}10^{-3}$
3	18	N.P.	$5.71\text{x}10^{-6}$
3	24	$3.08\text{x}10^{-3}$	$1.14\text{x}10^{-2}$
3	26	N.P.	$3.07\text{x}10^{-4}$
3	28	$1.03\text{x}10^{-3}$	$3.07\text{x}10^{-4}$
3	29	$1.03\text{x}10^{-3}$	$3.08\text{x}10^{-4}$
3	30	N.P.	$1.72\text{x}10^{-4}$
3	31	$4.13\text{x}10^{-4}$	$1.64\text{x}10^{-4}$
3	32	$2.36\text{x}10^{-4}$	$5.72\text{x}10^{-4}$
3	33	$3.13\text{x}10^{-3}$	$1.72\text{x}10^{-4}$
3	37	$4.19\text{x}10^{-2}$	$6.07\text{x}10^{-3}$
3	39	$3.01\text{x}10^{-4}$	$4.42\text{x}10^{-5}$
3	40	$3.01\text{x}10^{-2}$	$4.41\text{x}10^{-3}$
3	42	$3.01\text{x}10^{-2}$	$4.42\text{x}10^{-3}$
3	43	$4.19\text{x}10^{-2}$	$6.07\text{x}10^{-3}$
3	46	$1.38\text{x}10^{-4}$	0
3	47	$1.38\text{x}10^{-3}$	0
3	48	$1.38\text{x}10^{-3}$	0
3	49	$1.38\text{x}10^{-2}$	0
3	50	$1.38\text{x}10^{-1}$	0
3	51	$1.38\text{x}10^{-3}$	0
3	52	$1.38\text{x}10^{-1}$	0
3	53	$1.38\text{x}10^{-1}$	0
3	54	$1.38\text{x}10^{-3}$	0
3	55	$1.38\text{x}10^{-5}$	0
3	57	$6.93\text{x}10^{-3}$	$8.76\text{x}10^{-4}$
3	58	$6.29\text{x}10^{-4}$	0
3	59	$6.29\text{x}10^{-4}$	0
3	60	$6.29\text{x}10^{-6}$	0
3	61	$6.30\text{x}10^{-4}$	0
3	62	$6.29\text{x}10^{-4}$	0
3	63	$6.30\text{x}10^{-4}$	0
3	64	$6.29\text{x}10^{-5}$	0
3	65	$6.30\text{x}10^{-4}$	0
3	66	$6.29\text{x}10^{-4}$	0
3	68	$6.29\text{x}10^{-4}$	0
4	4	$9.65\text{x}10^{-4}$	$2.18\text{x}10^{-4}$
4	6	$9.88\text{x}10^{-5}$	$5.44\text{x}10^{-4}$
4	8	$1.23\text{x}10^{-3}$	$5.44\text{x}10^{-4}$
4	9	$4.01\text{x}10^{-6}$	$1.00\text{x}10^{-5}$
4	10	0	$9.99\text{x}10^{-6}$
4	12	$4.01\text{x}10^{-6}$	$9.98\text{x}10^{-6}$
4	13	$4.02\text{x}10^{-6}$	0
4	15	$1.45\text{x}10^{-4}$	$1.09\text{x}10^{-2}$
4	16	$1.01\text{x}10^{-3}$	$5.98\text{x}10^{-5}$
4	17	$1.10\text{x}10^{-4}$	$2.33\text{x}10^{-5}$
4	19	$1.10\text{x}10^{-4}$	$2.33\text{x}10^{-5}$
4	20	$1.10\text{x}10^{-4}$	$2.33\text{x}10^{-6}$
4	24	$9.89\text{x}10^{-5}$	$3.10\text{x}10^{-4}$
4	25	0	$2.33\text{x}10^{-6}$
4	26	N.P.	$1.82\text{x}10^{-6}$
4	27	$1.10\text{x}10^{-6}$	$2.33\text{x}10^{-6}$
4	28	$3.22\text{x}10^{-5}$	$1.82\text{x}10^{-6}$
4	29	$3.22\text{x}10^{-5}$	$1.82\text{x}10^{-6}$
4	30	N.P.	$5.46\text{x}10^{-6}$
4	31	$2.29\text{x}10^{-5}$	$5.28\text{x}10^{-6}$
4	32	$8.04\text{x}10^{-5}$	$2.00\text{x}10^{-5}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
4	34	$1.10x10^{-4}$	$2.33x10^{-6}$
4	35	$1.10x10^{-4}$	$2.33x10^{-5}$
4	36	0	$1.47x10^{-4}$
4	37	$2.32x10^{-3}$	$3.08x10^{-4}$
4	39	$1.21x10^{-5}$	$1.03x10^{-6}$
4	40	$1.21x10^{-3}$	$1.03x10^{-4}$
4	41	0	$1.47x10^{-4}$
4	42	$1.21x10^{-3}$	$1.03x10^{-4}$
4	43	$2.32x10^{-3}$	$3.08x10^{-4}$
4	46	$6.27x10^{-5}$	$9.25x10^{-6}$
4	47	$6.28x10^{-4}$	$9.24x10^{-5}$
4	48	$6.28x10^{-4}$	$9.26x10^{-5}$
4	49	$6.27x10^{-3}$	$9.26x10^{-5}$
4	50	$6.27x10^{-2}$	$9.25x10^{-3}$
4	51	$6.27x10^{-4}$	$9.27x10^{-6}$
4	52	$6.27x10^{-2}$	$9.26x10^{-3}$
4	53	$6.28x10^{-2}$	$9.26x10^{-3}$
4	54	$6.27x10^{-4}$	$9.26x10^{-5}$
4	55	$6.28x10^{-6}$	$9.26x10^{-6}$
4	57	$6.27x10^{-4}$	$2.94x10^{-4}$
4	58	$2.26x10^{-4}$	$8.42x10^{-5}$
4	59	$2.26x10^{-4}$	$8.43x10^{-6}$
4	60	$2.26x10^{-6}$	0
4	61	$2.26x10^{-4}$	$8.43x10^{-5}$
4	62	$2.26x10^{-4}$	$8.41x10^{-6}$
4	63	$2.26x10^{-4}$	$8.42x10^{-5}$
4	64	$2.26x10^{-5}$	$8.41x10^{-6}$
4	65	$2.26x10^{-4}$	$8.41x10^{-6}$
4	66	$2.26x10^{-4}$	$8.42x10^{-6}$
4	68	$2.26x10^{-4}$	$8.41x10^{-5}$
5	4	$1.26x10^{-3}$	$8.19x10^{-5}$
5	6	$1.26x10^{-4}$	$8.18x10^{-5}$
5	7	$1.26x10^{-3}$	$8.20x10^{-5}$
5	8	$1.05x10^{-3}$	$8.19x10^{-5}$
5	9	$1.75x10^{-5}$	$1.37x10^{-5}$
5	10	0	$1.37x10^{-5}$
5	11	0	$1.37x10^{-6}$
5	12	$1.75x10^{-5}$	$1.37x10^{-5}$
5	13	$1.75x10^{-5}$	$1.37x10^{-6}$
5	14	0	$1.37x10^{-6}$
5	15	$5.26x10^{-4}$	$8.20x10^{-3}$
5	16	$1.26x10^{-3}$	$8.18x10^{-5}$
5	17	$6.31x10^{-4}$	$5.97x10^{-5}$
5	19	$6.32x10^{-4}$	$5.97x10^{-5}$
5	20	$6.31x10^{-4}$	$5.98x10^{-6}$
5	24	$1.26x10^{-4}$	$8.19x10^{-5}$
5	25	0	$5.97x10^{-6}$
5	27	$6.31x10^{-6}$	$5.97x10^{-6}$
5	30	N.P.	$4.27x10^{-6}$
5	32	$3.51x10^{-5}$	$2.73x10^{-6}$
5	34	$6.32x10^{-4}$	$5.97x10^{-6}$
5	35	$6.31x10^{-4}$	$5.97x10^{-5}$
5	36	$6.58x10^{-3}$	$4.35x10^{-4}$
5	37	$2.61x10^{-2}$	$1.75x10^{-3}$
5	38	$1.26x10^{-3}$	$8.21x10^{-5}$
5	39	$3.02x10^{-5}$	$2.08x10^{-6}$
5	40	$3.02x10^{-3}$	$2.08x10^{-4}$
5	41	$6.58x10^{-3}$	$4.34x10^{-4}$
5	42	$3.02x10^{-3}$	$2.08x10^{-4}$
5	43	$2.61x10^{-2}$	$1.75x10^{-3}$
5	44	$1.26x10^{-3}$	$8.20x10^{-5}$
5	45	N.P.	$8.69x10^{-1}$
5	46	$6.42x10^{-5}$	$4.34x10^{-6}$
5	47	$6.43x10^{-4}$	$4.33x10^{-5}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
5	48	$6.43\text{x}10^{-4}$	$4.34\text{x}10^{-5}$
5	49	$6.42\text{x}10^{-3}$	$4.34\text{x}10^{-5}$
5	50	$6.42\text{x}10^{-2}$	$4.34\text{x}10^{-3}$
5	51	$6.42\text{x}10^{-4}$	$4.34\text{x}10^{-6}$
5	52	$6.42\text{x}10^{-2}$	$4.34\text{x}10^{-3}$
5	53	$6.43\text{x}10^{-2}$	$4.34\text{x}10^{-3}$
5	54	$6.42\text{x}10^{-4}$	$4.34\text{x}10^{-5}$
5	55	$6.43\text{x}10^{-6}$	$4.34\text{x}10^{-6}$
5	56	N.P.	$8.21\text{x}10^{-6}$
5	57	$2.63\text{x}10^{-3}$	$8.19\text{x}10^{-5}$
5	58	$5.83\text{x}10^{-4}$	$3.95\text{x}10^{-5}$
5	59	$5.83\text{x}10^{-4}$	$3.95\text{x}10^{-6}$
5	60	$5.83\text{x}10^{-6}$	0
5	61	$5.83\text{x}10^{-4}$	$3.95\text{x}10^{-5}$
5	62	$5.83\text{x}10^{-4}$	$3.95\text{x}10^{-6}$
5	63	$5.84\text{x}10^{-4}$	$3.95\text{x}10^{-5}$
5	64	$5.83\text{x}10^{-5}$	$3.94\text{x}10^{-6}$
5	65	$5.84\text{x}10^{-4}$	$3.94\text{x}10^{-6}$
5	66	$5.83\text{x}10^{-4}$	$3.95\text{x}10^{-6}$
5	68	$5.83\text{x}10^{-4}$	$3.94\text{x}10^{-5}$
6	37	$5.42\text{x}10^{-4}$	$1.87\text{x}10^{-3}$
6	43	$5.42\text{x}10^{-4}$	$1.87\text{x}10^{-3}$
6	46	$1.80\text{x}10^{-5}$	$6.23\text{x}10^{-5}$
6	47	$1.80\text{x}10^{-4}$	$6.22\text{x}10^{-4}$
6	48	$1.80\text{x}10^{-4}$	$6.23\text{x}10^{-4}$
6	49	$1.80\text{x}10^{-3}$	$6.24\text{x}10^{-4}$
6	50	$1.80\text{x}10^{-2}$	$6.23\text{x}10^{-2}$
6	51	$1.80\text{x}10^{-4}$	$6.24\text{x}10^{-5}$
6	52	$1.80\text{x}10^{-2}$	$6.23\text{x}10^{-2}$
6	53	$1.80\text{x}10^{-2}$	$6.23\text{x}10^{-2}$
6	54	$1.80\text{x}10^{-4}$	$6.23\text{x}10^{-4}$
6	55	$1.80\text{x}10^{-6}$	$6.23\text{x}10^{-5}$
6	57	$8.67\text{x}10^{-5}$	$1.13\text{x}10^{-4}$
6	58	$3.27\text{x}10^{-5}$	$1.13\text{x}10^{-4}$
6	59	$3.27\text{x}10^{-5}$	$1.13\text{x}10^{-5}$
6	60	0	$1.13\text{x}10^{-6}$
6	61	$3.27\text{x}10^{-5}$	$1.13\text{x}10^{-4}$
6	62	$3.27\text{x}10^{-5}$	$1.13\text{x}10^{-5}$
6	63	$3.27\text{x}10^{-5}$	$1.13\text{x}10^{-4}$
6	64	$3.27\text{x}10^{-6}$	$1.13\text{x}10^{-5}$
6	65	$3.28\text{x}10^{-5}$	$1.13\text{x}10^{-5}$
6	66	$3.27\text{x}10^{-5}$	$1.13\text{x}10^{-5}$
6	68	$3.27\text{x}10^{-5}$	$1.13\text{x}10^{-4}$
7	36	$1.06\text{x}10^{-2}$	$1.24\text{x}10^{-2}$
7	37	$7.36\text{x}10^{-2}$	$8.67\text{x}10^{-2}$
7	39	$2.77\text{x}10^{-5}$	$3.33\text{x}10^{-5}$
7	40	$2.77\text{x}10^{-3}$	$3.33\text{x}10^{-3}$
7	41	$1.06\text{x}10^{-2}$	$1.24\text{x}10^{-2}$
7	42	$2.77\text{x}10^{-3}$	$3.33\text{x}10^{-3}$
7	43	$7.36\text{x}10^{-2}$	$8.67\text{x}10^{-2}$
7	46	$1.06\text{x}10^{-4}$	$1.24\text{x}10^{-4}$
7	47	$1.06\text{x}10^{-3}$	$1.24\text{x}10^{-3}$
7	48	$1.06\text{x}10^{-3}$	$1.24\text{x}10^{-3}$
7	49	$1.06\text{x}10^{-2}$	$1.24\text{x}10^{-3}$
7	50	$1.06\text{x}10^{-1}$	$1.24\text{x}10^{-1}$
7	51	$1.06\text{x}10^{-3}$	$1.24\text{x}10^{-4}$
7	52	$1.06\text{x}10^{-1}$	$1.24\text{x}10^{-1}$
7	53	$1.06\text{x}10^{-1}$	$1.24\text{x}10^{-1}$
7	54	$1.06\text{x}10^{-3}$	$1.24\text{x}10^{-3}$
7	55	$1.06\text{x}10^{-5}$	$1.24\text{x}10^{-4}$
7	56	N.P.	$2.38\text{x}10^{-4}$
7	57	$5.28\text{x}10^{-3}$	$2.38\text{x}10^{-3}$
7	58	$9.59\text{x}10^{-4}$	$1.13\text{x}10^{-3}$
7	59	$9.59\text{x}10^{-4}$	$1.13\text{x}10^{-4}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
7	60	$9.59x10^{-6}$	$1.13x10^{-5}$
7	61	$9.59x10^{-4}$	$1.13x10^{-3}$
7	62	$9.59x10^{-4}$	$1.13x10^{-4}$
7	63	$9.60x10^{-4}$	$1.13x10^{-3}$
7	64	$9.59x10^{-5}$	$1.13x10^{-4}$
7	65	$9.61x10^{-4}$	$1.13x10^{-4}$
7	66	$9.59x10^{-4}$	$1.13x10^{-4}$
7	67	0	$1.13x10^{-6}$
7	68	$9.59x10^{-4}$	$1.13x10^{-3}$
8	37	$3.93x10^{-3}$	$3.82x10^{-3}$
8	43	$3.93x10^{-3}$	$3.82x10^{-3}$
8	46	$7.85x10^{-5}$	$7.63x10^{-5}$
8	47	$7.86x10^{-4}$	$7.62x10^{-4}$
8	48	$7.86x10^{-4}$	$7.63x10^{-4}$
8	49	$7.85x10^{-3}$	$7.64x10^{-4}$
8	50	$7.85x10^{-2}$	$7.63x10^{-2}$
8	51	$7.86x10^{-4}$	$7.64x10^{-5}$
8	52	$7.86x10^{-2}$	$7.63x10^{-2}$
8	53	$7.86x10^{-2}$	$7.63x10^{-2}$
8	54	$7.85x10^{-4}$	$7.63x10^{-4}$
8	55	$7.86x10^{-6}$	$7.63x10^{-5}$
8	56	N.P.	$2.07x10^{-5}$
8	57	$5.60x10^{-4}$	$2.07x10^{-4}$
8	58	$4.77x10^{-4}$	$4.61x10^{-4}$
8	59	$4.78x10^{-4}$	$4.61x10^{-5}$
8	60	$4.78x10^{-6}$	$4.60x10^{-6}$
8	61	$4.78x10^{-4}$	$4.61x10^{-4}$
8	62	$4.77x10^{-4}$	$4.60x10^{-5}$
8	63	$4.78x10^{-4}$	$4.60x10^{-4}$
8	64	$4.77x10^{-5}$	$4.60x10^{-5}$
8	65	$4.78x10^{-4}$	$4.60x10^{-5}$
8	66	$4.77x10^{-4}$	$4.60x10^{-5}$
8	68	$4.78x10^{-4}$	$4.60x10^{-4}$
9	4	$1.89x10^{-6}$	0
9	8	$1.89x10^{-6}$	0
9	15	$1.89x10^{-6}$	$1.84x10^{-5}$
9	36	$7.37x10^{-5}$	$8.36x10^{-6}$
9	37	$3.10x10^{-5}$	$3.51x10^{-6}$
9	40	$2.24x10^{-5}$	$2.53x10^{-6}$
9	41	$7.37x10^{-5}$	$8.36x10^{-6}$
9	42	$2.24x10^{-5}$	$2.53x10^{-6}$
9	43	$3.10x10^{-5}$	$3.52x10^{-6}$
9	44	$7.36x10^{-5}$	$8.38x10^{-6}$
9	45	N.P.	$1.16x10^{-2}$
9	47	$5.81x10^{-6}$	0
9	48	$5.81x10^{-6}$	0
9	49	$5.81x10^{-5}$	0
9	50	$5.81x10^{-4}$	$6.55x10^{-5}$
9	51	$5.81x10^{-6}$	0
9	52	$5.81x10^{-4}$	$6.55x10^{-5}$
9	53	$5.81x10^{-4}$	$6.55x10^{-5}$
9	54	$5.81x10^{-6}$	0
9	57	$4.49x10^{-5}$	0
9	58	$1.07x10^{-6}$	0
9	59	$1.07x10^{-6}$	0
9	61	$1.07x10^{-6}$	0
9	62	$1.07x10^{-6}$	0
9	63	$1.07x10^{-6}$	0
9	65	$1.07x10^{-6}$	0
9	66	$1.07x10^{-6}$	0
9	68	$1.07x10^{-6}$	0
10	4	0	$1.02x10^{-6}$
10	6	0	$1.02x10^{-6}$
10	8	0	$1.02x10^{-6}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
10	15	0	$1.02x10^{-4}$
10	36	0	$4.65x10^{-5}$
10	37	0	$1.96x10^{-5}$
10	40	0	$1.41x10^{-5}$
10	41	0	$4.64x10^{-5}$
10	42	0	$1.41x10^{-5}$
10	43	0	$1.96x10^{-5}$
10	44	0	$4.66x10^{-5}$
10	45	N.P.	$6.43x10^{-2}$
10	47	0	$3.63x10^{-6}$
10	48	0	$3.64x10^{-6}$
10	49	0	$3.64x10^{-6}$
10	50	$5.37x10^{-6}$	$3.64x10^{-4}$
10	52	$5.37x10^{-6}$	$3.64x10^{-4}$
10	53	$5.37x10^{-6}$	$3.64x10^{-4}$
10	54	0	$3.64x10^{-6}$
10	57	0	$3.40x10^{-6}$
11	15	0	$1.15x10^{-6}$
11	45	N.P.	$7.23x10^{-4}$
11	50	$2.33x10^{-6}$	$4.09x10^{-6}$
11	52	$2.33x10^{-6}$	$4.09x10^{-6}$
11	53	$2.33x10^{-6}$	$4.09x10^{-6}$
12	4	$9.59x10^{-6}$	$4.43x10^{-6}$
12	6	0	$4.43x10^{-6}$
12	8	$9.58x10^{-6}$	$4.43x10^{-6}$
12	15	$9.57x10^{-6}$	$4.43x10^{-4}$
12	36	$3.73x10^{-4}$	$2.02x10^{-4}$
12	37	$1.57x10^{-4}$	$8.49x10^{-5}$
12	39	$1.13x10^{-6}$	0
12	40	$1.13x10^{-4}$	$6.10x10^{-5}$
12	41	$3.73x10^{-4}$	$2.02x10^{-4}$
12	42	$1.13x10^{-4}$	$6.11x10^{-5}$
12	43	$1.57x10^{-4}$	$8.50x10^{-5}$
12	44	$3.73x10^{-4}$	$2.02x10^{-4}$
12	45	N.P.	$2.79x10^{-1}$
12	46	$2.94x10^{-6}$	$1.58x10^{-6}$
12	47	$2.94x10^{-5}$	$1.58x10^{-5}$
12	48	$2.94x10^{-5}$	$1.58x10^{-5}$
12	49	$2.94x10^{-4}$	$1.58x10^{-5}$
12	50	$2.94x10^{-3}$	$1.58x10^{-3}$
12	51	$2.94x10^{-5}$	$1.58x10^{-6}$
12	52	$2.94x10^{-3}$	$1.58x10^{-3}$
12	53	$2.94x10^{-3}$	$1.58x10^{-3}$
12	54	$2.94x10^{-5}$	$1.58x10^{-5}$
12	55	0	$1.58x10^{-6}$
12	56	N.P.	$1.48x10^{-6}$
12	57	$2.27x10^{-4}$	$1.48x10^{-5}$
12	58	$5.44x10^{-6}$	$2.95x10^{-6}$
12	59	$5.44x10^{-6}$	0
12	61	$5.44x10^{-6}$	$2.95x10^{-6}$
12	62	$5.44x10^{-6}$	0
12	63	$5.45x10^{-6}$	$2.95x10^{-6}$
12	65	$5.45x10^{-6}$	0
12	66	$5.44x10^{-6}$	0
12	68	$5.44x10^{-6}$	$2.95x10^{-6}$
13	15	0	$2.29x10^{-6}$
13	36	$2.85x10^{-5}$	$1.04x10^{-6}$
13	37	$1.20x10^{-5}$	0
13	40	$8.63x10^{-6}$	0
13	41	$2.85x10^{-5}$	$1.04x10^{-6}$
13	42	$8.63x10^{-6}$	0
13	43	$1.20x10^{-5}$	0
13	44	$2.84x10^{-5}$	$1.05x10^{-6}$
13	45	N.P.	$1.44x10^{-3}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
13	47	$2.25x10^{-6}$	0
13	48	$2.25x10^{-6}$	0
13	49	$2.25x10^{-5}$	0
13	50	$2.25x10^{-4}$	$8.17x10^{-6}$
13	51	$2.25x10^{-6}$	0
13	52	$2.25x10^{-4}$	$8.18x10^{-6}$
13	53	$2.25x10^{-4}$	$8.18x10^{-6}$
13	54	$2.25x10^{-6}$	0
13	57	$1.73x10^{-5}$	0
14	15	0	$1.83x10^{-6}$
14	45	N.P.	$1.15x10^{-3}$
14	50	$6.90x10^{-6}$	$6.53x10^{-6}$
14	52	$6.90x10^{-6}$	$6.54x10^{-6}$
14	53	$6.90x10^{-6}$	$6.53x10^{-6}$
15	37	$2.24x10^{-5}$	$2.64x10^{-3}$
15	43	$2.24x10^{-5}$	$2.64x10^{-3}$
15	46	$1.99x10^{-6}$	$2.35x10^{-4}$
15	47	$1.99x10^{-5}$	$2.34x10^{-3}$
15	48	$1.99x10^{-5}$	$2.35x10^{-3}$
15	49	$1.99x10^{-4}$	$2.35x10^{-3}$
15	50	$1.99x10^{-3}$	$2.35x10^{-1}$
15	51	$1.99x10^{-5}$	$2.35x10^{-4}$
15	52	$1.99x10^{-3}$	$2.35x10^{-1}$
15	53	$1.99x10^{-3}$	$2.35x10^{-1}$
15	54	$1.99x10^{-5}$	$2.35x10^{-3}$
15	55	0	$2.35x10^{-4}$
15	56	N.P.	$5.87x10^{-5}$
15	57	$4.98x10^{-5}$	$5.32x10^{-4}$
15	58	$1.81x10^{-5}$	$2.13x10^{-3}$
15	59	$1.81x10^{-5}$	$2.13x10^{-4}$
15	60	0	$2.13x10^{-5}$
15	61	$1.81x10^{-5}$	$2.13x10^{-3}$
15	62	$1.81x10^{-5}$	$2.13x10^{-4}$
15	63	$1.81x10^{-5}$	$2.13x10^{-3}$
15	64	$1.81x10^{-6}$	$2.13x10^{-4}$
15	65	$1.81x10^{-5}$	$2.13x10^{-4}$
15	66	$1.81x10^{-5}$	$2.13x10^{-4}$
15	67	0	$2.13x10^{-6}$
15	68	$1.81x10^{-5}$	$2.13x10^{-3}$
16	36	$1.59x10^{-4}$	$4.15x10^{-5}$
16	37	$1.59x10^{-4}$	$4.14x10^{-5}$
16	41	$1.59x10^{-4}$	$4.15x10^{-5}$
16	43	$1.59x10^{-4}$	$4.14x10^{-5}$
16	46	$2.09x10^{-4}$	$5.38x10^{-5}$
16	47	$2.09x10^{-3}$	$5.37x10^{-4}$
16	48	$2.09x10^{-3}$	$5.38x10^{-4}$
16	49	$2.09x10^{-2}$	$5.39x10^{-4}$
16	50	$2.09x10^{-1}$	$5.38x10^{-2}$
16	51	$2.09x10^{-3}$	$5.39x10^{-5}$
16	52	$2.09x10^{-1}$	$5.39x10^{-2}$
16	53	$2.09x10^{-1}$	$5.38x10^{-2}$
16	54	$2.09x10^{-3}$	$5.38x10^{-4}$
16	55	$2.09x10^{-5}$	$5.38x10^{-5}$
16	56	N.P.	$8.30x10^{-6}$
16	57	$3.18x10^{-4}$	$8.28x10^{-5}$
16	58	$9.04x10^{-4}$	$2.33x10^{-4}$
16	59	$9.04x10^{-4}$	$2.33x10^{-5}$
16	60	$9.04x10^{-6}$	$2.33x10^{-6}$
16	61	$9.05x10^{-4}$	$2.33x10^{-4}$
16	62	$9.04x10^{-4}$	$2.33x10^{-5}$
16	63	$9.05x10^{-4}$	$2.33x10^{-4}$
16	64	$9.04x10^{-5}$	$2.33x10^{-5}$
16	65	$9.06x10^{-4}$	$2.33x10^{-5}$
16	66	$9.04x10^{-4}$	$2.33x10^{-5}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
16	68	$9.04x10^{-4}$	$2.33x10^{-4}$
17	16	$1.70x10^{-3}$	$1.99x10^{-5}$
17	17	$1.52x10^{-4}$	$2.58x10^{-6}$
17	19	$1.52x10^{-4}$	$2.58x10^{-6}$
17	20	$1.52x10^{-4}$	0
17	27	$1.52x10^{-6}$	0
17	34	$1.52x10^{-4}$	0
17	35	$1.52x10^{-4}$	$2.58x10^{-6}$
17	36	$1.53x10^{-2}$	$2.58x10^{-4}$
17	37	$2.35x10^{-2}$	$3.97x10^{-4}$
17	38	$1.17x10^{-3}$	$1.99x10^{-5}$
17	39	$7.79x10^{-5}$	$1.32x10^{-6}$
17	40	$7.79x10^{-3}$	$1.32x10^{-4}$
17	41	$1.53x10^{-2}$	$2.58x10^{-4}$
17	42	$7.79x10^{-3}$	$1.32x10^{-4}$
17	43	$2.35x10^{-2}$	$3.97x10^{-4}$
17	44	$1.17x10^{-3}$	$1.99x10^{-5}$
17	45	N.P.	$1.99x10^{-2}$
18	50	N.P.	$1.36x10^{-5}$
18	52	N.P.	$1.36x10^{-5}$
18	53	N.P.	$1.36x10^{-5}$
19	36	$5.04x10^{-2}$	$3.00x10^{-3}$
19	37	$7.75x10^{-2}$	$4.60x10^{-3}$
19	38	$3.84x10^{-3}$	$2.31x10^{-4}$
19	39	$2.57x10^{-4}$	$1.53x10^{-5}$
19	40	$2.57x10^{-2}$	$1.53x10^{-3}$
19	41	$5.04x10^{-2}$	$3.00x10^{-3}$
19	42	$2.57x10^{-2}$	$1.53x10^{-3}$
19	43	$7.74x10^{-2}$	$4.61x10^{-3}$
19	44	$3.84x10^{-3}$	$2.31x10^{-4}$
19	45	N.P.	$2.31x10^{-1}$
20	16	$1.25x10^{-4}$	$1.75x10^{-6}$
20	19	$1.11x10^{-5}$	0
20	20	$1.11x10^{-5}$	0
20	34	$1.11x10^{-5}$	0
20	35	$1.11x10^{-5}$	0
20	36	$1.12x10^{-3}$	$2.27x10^{-5}$
20	37	$1.73x10^{-3}$	$3.48x10^{-5}$
20	38	$8.57x10^{-5}$	$1.75x10^{-6}$
20	39	$5.72x10^{-6}$	0
20	40	$5.72x10^{-4}$	$1.16x10^{-5}$
20	41	$1.12x10^{-3}$	$2.27x10^{-5}$
20	42	$5.72x10^{-4}$	$1.16x10^{-5}$
20	43	$1.73x10^{-3}$	$3.49x10^{-5}$
20	44	$8.57x10^{-5}$	$1.75x10^{-6}$
20	45	N.P.	$1.75x10^{-3}$
21	36	$1.03x10^{-2}$	$1.33x10^{-5}$
21	37	$1.03x10^{-2}$	$1.33x10^{-5}$
21	38	$1.44x10^{-2}$	$1.86x10^{-5}$
21	39	$7.16x10^{-6}$	0
21	40	$7.17x10^{-4}$	0
21	41	$1.03x10^{-2}$	$1.33x10^{-5}$
21	42	$7.17x10^{-4}$	0
21	43	$1.03x10^{-2}$	$1.33x10^{-5}$
21	44	$2.07x10^{-2}$	$2.66x10^{-5}$
21	45	N.P.	$5.31x10^{-2}$
21	75	$2.07x10^{-2}$	$2.66x10^{-2}$
21	76	$6.18x10^{-2}$	$7.97x10^{-4}$
21	77	$2.15x10^{-3}$	$2.66x10^{-6}$
21	79	$2.15x10^{-3}$	$2.66x10^{-6}$
22	50	N.P.	$1.31x10^{-6}$
22	52	N.P.	$1.31x10^{-6}$
22	53	N.P.	$1.31x10^{-6}$
23	16	$5.43x10^{-3}$	$2.99x10^{-6}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
23	24	$4.33x10^{-4}$	$2.33x10^{-5}$
23	32	$2.01x10^{-4}$	$1.10x10^{-6}$
23	36	$3.07x10^{-3}$	$1.66x10^{-5}$
23	37	$3.07x10^{-3}$	$1.66x10^{-5}$
23	38	$6.13x10^{-3}$	$3.33x10^{-5}$
23	39	$2.01x10^{-6}$	0
23	40	$2.01x10^{-4}$	$1.10x10^{-6}$
23	41	$3.07x10^{-3}$	$1.66x10^{-5}$
23	42	$2.01x10^{-4}$	$1.10x10^{-6}$
23	43	$3.07x10^{-3}$	$1.66x10^{-5}$
23	44	$6.14x10^{-3}$	$3.32x10^{-5}$
23	45	N.P.	$1.33x10^{-1}$
24	46	$5.02x10^{-5}$	$2.02x10^{-6}$
24	47	$5.02x10^{-4}$	$2.02x10^{-5}$
24	48	$5.02x10^{-4}$	$2.02x10^{-5}$
24	49	$5.02x10^{-3}$	$2.02x10^{-5}$
24	50	$5.02x10^{-2}$	$2.02x10^{-3}$
24	51	$5.02x10^{-4}$	$2.02x10^{-6}$
24	52	$5.02x10^{-2}$	$2.02x10^{-3}$
24	53	$5.02x10^{-2}$	$2.02x10^{-3}$
24	54	$5.02x10^{-4}$	$2.02x10^{-5}$
24	55	$5.02x10^{-6}$	$2.02x10^{-6}$
24	56	N.P.	0
24	57	$1.21x10^{-3}$	$1.02x10^{-4}$
24	58	$4.56x10^{-4}$	$1.84x10^{-5}$
24	59	$4.56x10^{-4}$	$1.84x10^{-6}$
24	60	$4.56x10^{-6}$	0
24	61	$4.56x10^{-4}$	$1.84x10^{-5}$
24	62	$4.56x10^{-4}$	$1.84x10^{-6}$
24	63	$4.56x10^{-4}$	$1.84x10^{-5}$
24	64	$4.56x10^{-5}$	$1.84x10^{-6}$
24	65	$4.56x10^{-4}$	$1.84x10^{-6}$
24	66	$4.56x10^{-4}$	$1.84x10^{-6}$
24	68	$4.56x10^{-4}$	$1.84x10^{-5}$
24	70	$5.04x10^{-3}$	$2.03x10^{-4}$
24	71	$5.04x10^{-3}$	$2.03x10^{-3}$
24	72	$5.03x10^{-3}$	$2.03x10^{-4}$
24	73	$5.04x10^{-4}$	$2.03x10^{-5}$
24	74	$5.05x10^{-3}$	$2.03x10^{-5}$
24	75	$5.02x10^{-3}$	$2.02x10^{-1}$
24	77	$5.02x10^{-3}$	$2.02x10^{-4}$
25	36	$2.17x10^{-6}$	$4.34x10^{-6}$
25	37	$3.34x10^{-6}$	$6.66x10^{-6}$
25	40	$1.11x10^{-6}$	$2.21x10^{-6}$
25	41	$2.17x10^{-6}$	$4.33x10^{-6}$
25	42	$1.11x10^{-6}$	$2.21x10^{-6}$
25	43	$3.34x10^{-6}$	$6.67x10^{-6}$
25	45	N.P.	$3.33x10^{-4}$
26	3	N.P.	$2.54x10^{-6}$
26	4	N.P.	$2.54x10^{-6}$
26	5	N.P.	$4.41x10^{-5}$
26	6	N.P.	$2.48x10^{-5}$
26	7	N.P.	$1.23x10^{-5}$
26	8	N.P.	$1.23x10^{-5}$
26	9	N.P.	$5.51x10^{-6}$
26	10	N.P.	$5.51x10^{-6}$
26	12	N.P.	$5.50x10^{-6}$
26	15	N.P.	$1.71x10^{-3}$
26	16	N.P.	$1.23x10^{-5}$
26	19	N.P.	$1.75x10^{-6}$
26	21	N.P.	$2.54x10^{-6}$
26	23	N.P.	$2.54x10^{-6}$
26	24	N.P.	$1.23x10^{-5}$
26	31	N.P.	$1.06x10^{-6}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
26	33	N.P.	$2.33x10^{-6}$
26	35	N.P.	$1.75x10^{-6}$
26	40	N.P.	$4.09x10^{-6}$
26	42	N.P.	$4.10x10^{-6}$
27	36	$7.34x10^{-6}$	$6.31x10^{-6}$
27	37	$1.13x10^{-5}$	$9.69x10^{-6}$
27	40	$3.74x10^{-6}$	$3.21x10^{-6}$
27	41	$7.33x10^{-6}$	$6.31x10^{-6}$
27	42	$3.74x10^{-6}$	$3.22x10^{-6}$
27	43	$1.13x10^{-5}$	$9.70x10^{-6}$
27	45	N.P.	$4.85x10^{-4}$
28	3	$4.15x10^{-3}$	$2.33x10^{-6}$
28	4	$2.08x10^{-3}$	$2.33x10^{-6}$
28	5	$5.39x10^{-3}$	$4.05x10^{-5}$
28	6	$1.99x10^{-3}$	$2.27x10^{-5}$
28	7	$6.24x10^{-3}$	$1.13x10^{-5}$
28	8	$4.57x10^{-3}$	$1.13x10^{-5}$
28	9	$1.38x10^{-5}$	$5.07x10^{-6}$
28	10	0	$5.07x10^{-6}$
28	12	$1.38x10^{-5}$	$5.06x10^{-6}$
28	13	$1.38x10^{-5}$	0
28	15	$1.25x10^{-3}$	$1.57x10^{-3}$
28	16	$7.89x10^{-3}$	$1.13x10^{-5}$
28	17	$1.31x10^{-3}$	$1.61x10^{-6}$
28	19	$1.31x10^{-3}$	$1.61x10^{-6}$
28	20	$1.31x10^{-3}$	0
28	21	$2.08x10^{-3}$	$2.33x10^{-6}$
28	23	$8.30x10^{-4}$	$2.33x10^{-6}$
28	24	$4.15x10^{-4}$	$1.13x10^{-5}$
28	25	$1.31x10^{-6}$	0
28	27	$1.31x10^{-5}$	0
28	28	$4.98x10^{-4}$	0
28	29	$4.98x10^{-4}$	0
28	31	$8.30x10^{-5}$	0
28	32	$2.77x10^{-4}$	0
28	33	$4.15x10^{-4}$	$2.14x10^{-6}$
28	34	$1.31x10^{-3}$	0
28	35	$1.31x10^{-3}$	$1.61x10^{-6}$
28	39	$4.15x10^{-5}$	0
28	40	$4.15x10^{-3}$	$3.76x10^{-6}$
28	42	$4.15x10^{-3}$	$3.77x10^{-6}$
29	3	$2.08x10^{-3}$	$8.24x10^{-6}$
29	4	$1.04x10^{-3}$	$8.24x10^{-6}$
29	5	$2.69x10^{-3}$	$1.43x10^{-4}$
29	6	$9.95x10^{-4}$	$8.03x10^{-5}$
29	7	$3.12x10^{-3}$	$3.98x10^{-5}$
29	8	$2.29x10^{-3}$	$3.97x10^{-5}$
29	9	$6.92x10^{-6}$	$1.79x10^{-5}$
29	10	0	$1.79x10^{-5}$
29	11	0	$1.79x10^{-6}$
29	12	$6.92x10^{-6}$	$1.79x10^{-5}$
29	13	$6.93x10^{-6}$	$1.79x10^{-6}$
29	14	0	$1.79x10^{-6}$
29	15	$6.22x10^{-4}$	$5.56x10^{-3}$
29	16	$3.95x10^{-3}$	$3.97x10^{-5}$
29	17	$6.52x10^{-4}$	$5.69x10^{-6}$
29	19	$6.52x10^{-4}$	$5.70x10^{-6}$
29	20	$6.52x10^{-4}$	0
29	21	$1.04x10^{-3}$	$8.24x10^{-6}$
29	23	$4.15x10^{-4}$	$8.24x10^{-6}$
29	24	$2.08x10^{-4}$	$3.98x10^{-5}$
29	26	N.P.	$2.75x10^{-6}$
29	27	$6.52x10^{-6}$	0
29	28	$2.49x10^{-4}$	$2.75x10^{-6}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
29	29	2.49x10^{-4}	2.75x10^{-6}
29	31	4.15x10^{-5}	3.43x10^{-6}
29	32	1.39x10^{-4}	2.75x10^{-6}
29	33	2.08x10^{-4}	7.56x10^{-6}
29	34	6.52x10^{-4}	0
29	35	6.52x10^{-4}	5.70x10^{-6}
29	39	2.08x10^{-5}	0
29	40	2.08x10^{-3}	1.33x10^{-5}
29	42	2.08x10^{-3}	1.33x10^{-5}
30	45	N.P.	3.68x10^{-3}
30	50	N.P.	3.05x10^{-6}
30	52	N.P.	3.06x10^{-6}
30	53	N.P.	3.06x10^{-6}
31	4	2.19x10^{-4}	1.68x10^{-5}
31	5	2.11x10^{-3}	1.54x10^{-4}
31	6	3.17x10^{-4}	2.50x10^{-4}
31	7	1.06x10^{-3}	8.40x10^{-5}
31	8	1.06x10^{-3}	8.39x10^{-5}
31	9	3.66x10^{-5}	2.55x10^{-6}
31	10	0	2.55x10^{-6}
31	12	3.66x10^{-5}	2.55x10^{-6}
31	13	3.66x10^{-5}	0
31	15	1.06x10^{-3}	8.40x10^{-3}
31	16	1.26x10^{-3}	7.63x10^{-5}
31	17	3.02x10^{-4}	2.36x10^{-5}
31	19	3.02x10^{-4}	2.36x10^{-5}
31	20	3.02x10^{-4}	2.36x10^{-6}
31	24	2.19x10^{-5}	1.68x10^{-5}
31	25	0	2.36x10^{-6}
31	27	3.02x10^{-6}	2.36x10^{-6}
31	30	N.P.	1.53x10^{-6}
31	31	9.97x10^{-5}	1.53x10^{-6}
31	32	7.31x10^{-5}	5.09x10^{-6}
31	33	2.19x10^{-4}	1.68x10^{-5}
31	34	3.02x10^{-4}	2.36x10^{-6}
31	35	3.02x10^{-4}	2.36x10^{-5}
31	37	5.29x10^{-4}	4.20x10^{-5}
31	39	1.96x10^{-5}	1.54x10^{-6}
31	40	1.96x10^{-3}	1.54x10^{-4}
31	42	1.96x10^{-3}	1.54x10^{-4}
31	43	5.29x10^{-4}	4.20x10^{-5}
32	37	1.46x10^{-4}	3.56x10^{-4}
32	43	1.46x10^{-4}	3.57x10^{-4}
32	46	4.87x10^{-6}	1.19x10^{-5}
32	47	4.87x10^{-5}	1.19x10^{-4}
32	48	4.87x10^{-5}	1.19x10^{-4}
32	49	4.87x10^{-4}	1.19x10^{-4}
32	50	4.87x10^{-3}	1.19x10^{-2}
32	51	4.87x10^{-5}	1.19x10^{-5}
32	52	4.87x10^{-3}	1.19x10^{-2}
32	53	4.87x10^{-3}	1.19x10^{-2}
32	54	4.87x10^{-5}	1.19x10^{-4}
32	55	0	1.19x10^{-5}
32	56	N.P.	2.38x10^{-6}
32	57	9.75x10^{-5}	2.38x10^{-4}
32	58	7.97x10^{-6}	1.95x10^{-5}
32	59	7.98x10^{-6}	1.95x10^{-6}
32	61	7.98x10^{-6}	1.95x10^{-5}
32	62	7.98x10^{-6}	1.95x10^{-6}
32	63	7.99x10^{-6}	1.95x10^{-5}
32	64	0	1.95x10^{-6}
32	65	7.99x10^{-6}	1.95x10^{-6}
32	66	7.97x10^{-6}	1.95x10^{-6}
32	68	7.98x10^{-6}	1.95x10^{-5}

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
33	36	$4.90x10^{-3}$	$1.64x10^{-3}$
33	37	$4.90x10^{-3}$	$1.64x10^{-3}$
33	39	$1.63x10^{-5}$	$5.49x10^{-6}$
33	40	$1.63x10^{-3}$	$5.48x10^{-4}$
33	41	$4.90x10^{-3}$	$1.64x10^{-3}$
33	42	$1.63x10^{-3}$	$5.49x10^{-4}$
33	43	$4.90x10^{-3}$	$1.64x10^{-3}$
34	16	$9.56x10^{-5}$	$1.31x10^{-6}$
34	19	$8.54x10^{-6}$	0
34	34	$8.54x10^{-6}$	0
34	35	$8.54x10^{-6}$	0
34	36	$8.60x10^{-4}$	$1.70x10^{-5}$
34	37	$1.33x10^{-3}$	$2.62x10^{-5}$
34	38	$6.56x10^{-5}$	$1.31x10^{-6}$
34	39	$4.38x10^{-6}$	0
34	40	$4.38x10^{-4}$	$8.67x10^{-6}$
34	41	$8.60x10^{-4}$	$1.70x10^{-5}$
34	42	$4.38x10^{-4}$	$8.68x10^{-6}$
34	43	$1.33x10^{-3}$	$2.62x10^{-5}$
34	44	$6.57x10^{-5}$	$1.31x10^{-6}$
34	45	N.P.	$1.31x10^{-3}$
35	36	$3.62x10^{-2}$	$2.54x10^{-3}$
35	37	$5.57x10^{-2}$	$3.90x10^{-3}$
35	38	$2.77x10^{-3}$	$1.96x10^{-4}$
35	39	$1.85x10^{-4}$	$1.30x10^{-5}$
35	40	$1.85x10^{-2}$	$1.30x10^{-3}$
35	41	$3.62x10^{-2}$	$2.54x10^{-3}$
35	42	$1.85x10^{-2}$	$1.30x10^{-3}$
35	43	$5.57x10^{-2}$	$3.91x10^{-3}$
35	44	$2.77x10^{-3}$	$1.96x10^{-4}$
35	45	N.P.	$1.96x10^{-1}$
36	36	$3.82x10^{-2}$	$9.35x10^{-3}$
36	76	$2.14x10^{-1}$	1.05
36	77	$1.45x10^{-1}$	$7.08x10^{-2}$
36	79	$2.99x10^{-1}$	$1.46x10^{-1}$
37	70	$6.43x10^{-1}$	$1.29x10^{-1}$
37	71	$6.43x10^{-1}$	1.29
37	72	$6.42x10^{-1}$	$1.29x10^{-1}$
37	73	$6.43x10^{-2}$	$1.29x10^{-2}$
37	74	$6.44x10^{-1}$	$1.29x10^{-2}$
37	77	$1.81x10^{-1}$	$3.63x10^{-2}$
37	79	$2.17x10^{-1}$	$4.35x10^{-2}$
38	70	$2.56x10^{-2}$	$1.45x10^{-2}$
38	71	$2.56x10^{-2}$	$1.45x10^{-1}$
38	72	$2.56x10^{-2}$	$1.45x10^{-2}$
38	73	$2.56x10^{-3}$	$1.45x10^{-3}$
38	74	$2.57x10^{-2}$	$1.45x10^{-3}$
38	79	$1.10x10^{-1}$	$6.21x10^{-2}$
38	80	$1.79x10^{-2}$	$1.01x10^{-2}$
39	37	$5.83x10^{-4}$	$3.57x10^{-4}$
39	38	$3.49x10^{-5}$	$2.15x10^{-5}$
39	39	$1.94x10^{-6}$	$1.19x10^{-6}$
39	40	$1.94x10^{-4}$	$1.19x10^{-4}$
39	42	$1.94x10^{-4}$	$1.19x10^{-4}$
39	44	$5.82x10^{-4}$	$3.58x10^{-4}$
39	70	$1.13x10^{-4}$	$6.91x10^{-5}$
39	71	$4.37x10^{-5}$	$2.69x10^{-4}$
39	74	$1.13x10^{-4}$	$6.92x10^{-6}$
39	76	$1.13x10^{-4}$	$6.92x10^{-4}$
39	77	$4.37x10^{-5}$	$2.69x10^{-5}$
39	79	$3.61x10^{-3}$	$2.22x10^{-3}$
40	36	$5.69x10^{-3}$	$1.06x10^{-3}$
40	37	$2.00x10^{-2}$	$3.74x10^{-3}$
40	40	$1.44x10^{-2}$	$2.69x10^{-3}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
40	42	$1.44x10^{-2}$	$2.69x10^{-3}$
40	43	$4.31x10^{-3}$	$8.06x10^{-4}$
40	46	$5.33x10^{-4}$	$9.96x10^{-5}$
40	47	$5.33x10^{-3}$	$9.94x10^{-4}$
40	48	$5.33x10^{-3}$	$9.96x10^{-4}$
40	49	$5.33x10^{-2}$	$9.97x10^{-4}$
40	50	$4.09x10^{-1}$	$7.64x10^{-2}$
40	51	$4.09x10^{-3}$	$7.65x10^{-5}$
40	52	$4.09x10^{-1}$	$7.64x10^{-2}$
40	53	$4.09x10^{-1}$	$7.64x10^{-2}$
40	54	$5.33x10^{-3}$	$9.96x10^{-4}$
40	55	$4.09x10^{-5}$	$7.64x10^{-5}$
40	58	$5.73x10^{-3}$	$1.07x10^{-3}$
40	59	$5.73x10^{-3}$	$1.07x10^{-4}$
40	60	$5.73x10^{-5}$	$1.07x10^{-5}$
40	61	$5.73x10^{-3}$	$1.07x10^{-3}$
40	62	$5.73x10^{-3}$	$1.07x10^{-4}$
40	63	$5.74x10^{-3}$	$1.07x10^{-3}$
40	64	$5.73x10^{-4}$	$1.07x10^{-4}$
40	65	$5.74x10^{-3}$	$1.07x10^{-4}$
40	66	$5.73x10^{-3}$	$1.07x10^{-4}$
40	67	0	$1.07x10^{-6}$
40	68	$5.73x10^{-3}$	$1.07x10^{-3}$
40	69	$1.96x10^{-3}$	$3.67x10^{-3}$
40	70	$6.96x10^{-2}$	$1.30x10^{-2}$
40	71	$4.17x10^{-2}$	$7.79x10^{-2}$
40	74	$6.97x10^{-2}$	$1.30x10^{-3}$
40	75	$9.85x10^{-3}$	1.84
40	76	$6.95x10^{-2}$	$1.30x10^{-1}$
40	77	$4.17x10^{-2}$	$7.80x10^{-3}$
40	79	$7.49x10^{-2}$	$1.40x10^{-2}$
41	36	$9.62x10^{-3}$	$3.14x10^{-3}$
41	41	$9.61x10^{-3}$	$3.14x10^{-3}$
41	76	$5.39x10^{-2}$	$3.52x10^{-1}$
41	77	$3.64x10^{-2}$	$2.38x10^{-2}$
41	79	$7.53x10^{-2}$	$4.91x10^{-2}$
42	37	$7.23x10^{-3}$	$7.57x10^{-4}$
42	38	$7.21x10^{-3}$	$7.59x10^{-4}$
42	40	$3.62x10^{-3}$	$3.79x10^{-4}$
42	42	$3.62x10^{-3}$	$3.80x10^{-4}$
42	43	$4.63x10^{-1}$	$4.85x10^{-2}$
42	44	$2.39x10^{-1}$	$2.51x10^{-2}$
43	77	$1.62x10^{-1}$	$6.88x10^{-2}$
43	79	$9.19x10^{-1}$	$3.90x10^{-1}$
44	75	$9.88x10^{-2}$	$3.20x10^{-1}$
44	76	$6.58x10^{-2}$	$2.14x10^{-3}$
44	77	$9.88x10^{-2}$	$3.20x10^{-4}$
44	79	$6.59x10^{-2}$	$2.14x10^{-4}$
45	70	N.P.	$2.55x10^{1}$
45	71	N.P.	$2.55x10^{2}$
45	72	N.P.	$2.55x10^{1}$
45	73	N.P.	2.54
45	74	N.P.	2.55
45	78	N.P.	$3.91x10^{1}$
45	80	N.P.	$2.94x10^{1}$
46	70	$4.00x10^{-3}$	$4.64x10^{-3}$
46	71	$4.00x10^{-3}$	$4.64x10^{-2}$
46	72	$4.00x10^{-3}$	$4.64x10^{-3}$
46	73	$4.00x10^{-4}$	$4.64x10^{-4}$
46	74	$4.01x10^{-3}$	$4.65x10^{-4}$
46	78	$2.22x10^{-3}$	$2.58x10^{-3}$
47	70	$4.63x10^{-1}$	$1.10x10^{-1}$
47	71	$4.64x10^{-1}$	1.1
47	72	$4.63x10^{-1}$	$1.10x10^{-1}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
47	73	$4.64x10^{-2}$	$1.10x10^{-2}$
47	74	$4.64x10^{-1}$	$1.10x10^{-2}$
47	78	$2.58x10^{-1}$	$6.14x10^{-2}$
48	70	$9.13x10^{-2}$	$3.65x10^{-2}$
48	71	$9.14x10^{-2}$	$3.65x10^{-1}$
48	72	$9.13x10^{-2}$	$3.66x10^{-2}$
48	73	$9.13x10^{-3}$	$3.65x10^{-3}$
48	74	$9.15x10^{-2}$	$3.66x10^{-3}$
48	78	$5.07x10^{-2}$	$2.03x10^{-2}$
49	70	$3.24x10^{-1}$	$2.89x10^{-2}$
49	71	$3.24x10^{-1}$	$2.89x10^{-1}$
49	72	$3.24x10^{-1}$	$2.89x10^{-2}$
49	73	$3.24x10^{-2}$	$2.89x10^{-3}$
49	74	$3.25x10^{-1}$	$2.89x10^{-3}$
49	78	$1.80x10^{-1}$	$1.60x10^{-2}$
50	70	$9.68x10^{-1}$	$7.10x10^{-1}$
50	71	$9.69x10^{-1}$	7.1
50	72	$9.67x10^{-1}$	$7.10x10^{-1}$
50	73	$9.68x10^{-2}$	$7.10x10^{-2}$
50	74	$9.70x10^{-1}$	$7.11x10^{-2}$
50	78	$5.38x10^{-1}$	$3.95x10^{-1}$
51	70	$1.95x10^{-2}$	$1.31x10^{-3}$
51	71	$1.95x10^{-2}$	$1.31x10^{-2}$
51	72	$1.95x10^{-2}$	$1.31x10^{-3}$
51	73	$1.95x10^{-3}$	$1.31x10^{-4}$
51	74	$1.95x10^{-2}$	$1.31x10^{-4}$
51	78	$1.08x10^{-2}$	$7.24x10^{-4}$
52	70	1.05	$3.73x10^{-1}$
52	71	1.05	3.73
52	72	1.05	$3.73x10^{-1}$
52	73	$1.05x10^{-1}$	$3.73x10^{-2}$
52	74	1.05	$3.73x10^{-2}$
52	78	$5.83x10^{-1}$	$2.07x10^{-1}$
53	70	1.7	$4.27x10^{-1}$
53	71	1.7	4.27
53	72	1.7	$4.27x10^{-1}$
53	73	$1.70x10^{-1}$	$4.27x10^{-2}$
53	74	1.7	$4.27x10^{-2}$
53	78	$9.43x10^{-1}$	$2.37x10^{-1}$
54	70	$1.44x10^{-1}$	$7.65x10^{-2}$
54	71	$1.44x10^{-1}$	$7.65x10^{-1}$
54	72	$1.44x10^{-1}$	$7.65x10^{-2}$
54	73	$1.44x10^{-2}$	$7.65x10^{-3}$
54	74	$1.44x10^{-1}$	$7.66x10^{-3}$
54	78	$8.01x10^{-2}$	$4.25x10^{-2}$
55	70	$1.49x10^{-3}$	$5.06x10^{-3}$
55	71	$1.49x10^{-3}$	$5.06x10^{-2}$
55	72	$1.49x10^{-3}$	$5.06x10^{-3}$
55	73	$1.49x10^{-4}$	$5.05x10^{-4}$
55	74	$1.49x10^{-3}$	$5.06x10^{-4}$
55	78	$8.25x10^{-4}$	$2.81x10^{-3}$
56	58	N.P.	$1.25x10^{-3}$
56	59	N.P.	$1.25x10^{-4}$
56	60	N.P.	$1.25x10^{-5}$
56	61	N.P.	$1.25x10^{-3}$
56	62	N.P.	$1.25x10^{-4}$
56	63	N.P.	$1.25x10^{-3}$
56	64	N.P.	$1.25x10^{-4}$
56	65	N.P.	$1.25x10^{-4}$
56	66	N.P.	$1.25x10^{-4}$
56	67	N.P.	$1.25x10^{-6}$
56	68	N.P.	$1.25x10^{-3}$
57	46	$3.32x10^{-5}$	$4.80x10^{-5}$
57	47	$3.32x10^{-4}$	$4.79x10^{-4}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
57	48	$3.32x10^{-4}$	$4.80x10^{-4}$
57	49	$3.32x10^{-3}$	$4.80x10^{-4}$
57	50	$3.32x10^{-2}$	$4.80x10^{-2}$
57	51	$3.32x10^{-4}$	$4.80x10^{-5}$
57	52	$3.32x10^{-2}$	$4.80x10^{-2}$
57	53	$3.32x10^{-2}$	$4.80x10^{-2}$
57	54	$3.32x10^{-4}$	$4.80x10^{-4}$
57	55	$3.32x10^{-6}$	$4.80x10^{-5}$
57	58	$7.55x10^{-5}$	$1.09x10^{-4}$
57	59	$7.55x10^{-5}$	$1.09x10^{-5}$
57	60	0	$1.09x10^{-6}$
57	61	$7.55x10^{-5}$	$1.09x10^{-4}$
57	62	$7.55x10^{-5}$	$1.09x10^{-5}$
57	63	$7.56x10^{-5}$	$1.09x10^{-4}$
57	64	$7.55x10^{-6}$	$1.09x10^{-5}$
57	65	$7.56x10^{-5}$	$1.09x10^{-5}$
57	66	$7.55x10^{-5}$	$1.09x10^{-5}$
57	68	$7.55x10^{-5}$	$1.09x10^{-4}$
58	47	$3.35x10^{-2}$	$3.79x10^{-2}$
58	48	$3.35x10^{-2}$	$3.79x10^{-2}$
58	54	$3.34x10^{-2}$	$3.79x10^{-2}$
58	60	$1.52x10^{-4}$	$1.73x10^{-4}$
58	61	$1.52x10^{-2}$	$1.73x10^{-2}$
58	62	$1.52x10^{-2}$	$1.73x10^{-3}$
58	63	$1.52x10^{-2}$	$1.73x10^{-2}$
58	64	$1.52x10^{-3}$	$1.73x10^{-3}$
58	66	$1.52x10^{-2}$	$1.73x10^{-3}$
58	67	$1.52x10^{-6}$	$1.73x10^{-5}$
58	68	$1.52x10^{-2}$	$1.73x10^{-2}$
58	69	$5.01x10^{-3}$	$6.31x10^{-3}$
58	72	$1.33x10^{-1}$	$1.27x10^{-1}$
58	73	$1.33x10^{-2}$	$1.27x10^{-2}$
58	74	$1.33x10^{-1}$	$1.27x10^{-2}$
59	47	$4.41x10^{-3}$	$5.10x10^{-3}$
59	48	$4.41x10^{-3}$	$5.11x10^{-3}$
59	54	$4.40x10^{-3}$	$5.11x10^{-3}$
59	60	$2.00x10^{-5}$	$2.33x10^{-5}$
59	61	$2.00x10^{-3}$	$2.33x10^{-3}$
59	62	$2.00x10^{-3}$	$2.32x10^{-4}$
59	63	$2.00x10^{-3}$	$2.33x10^{-3}$
59	64	$2.00x10^{-4}$	$2.32x10^{-4}$
59	66	$2.00x10^{-3}$	$2.33x10^{-4}$
59	67	0	$2.33x10^{-6}$
59	68	$2.00x10^{-3}$	$2.32x10^{-3}$
59	69	$6.61x10^{-4}$	$8.51x10^{-4}$
59	72	$1.76x10^{-2}$	$1.71x10^{-2}$
59	73	$1.76x10^{-3}$	$1.71x10^{-3}$
59	74	$1.76x10^{-2}$	$1.71x10^{-3}$
60	47	$9.59x10^{-4}$	$2.41x10^{-3}$
60	48	$9.59x10^{-4}$	$2.42x10^{-3}$
60	54	$9.58x10^{-4}$	$2.42x10^{-3}$
60	60	$4.35x10^{-6}$	$1.10x10^{-5}$
60	61	$4.35x10^{-4}$	$1.10x10^{-3}$
60	62	$4.35x10^{-4}$	$1.10x10^{-4}$
60	63	$4.36x10^{-4}$	$1.10x10^{-3}$
60	64	$4.35x10^{-5}$	$1.10x10^{-4}$
60	66	$4.35x10^{-4}$	$1.10x10^{-4}$
60	67	0	$1.10x10^{-6}$
60	68	$4.35x10^{-4}$	$1.10x10^{-3}$
60	69	$1.44x10^{-4}$	$4.02x10^{-4}$
60	72	$3.83x10^{-3}$	$8.05x10^{-3}$
60	73	$3.83x10^{-4}$	$8.05x10^{-4}$
60	74	$3.84x10^{-3}$	$8.06x10^{-4}$
61	47	$4.25x10^{-2}$	$1.12x10^{-1}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
61	48	4.25×10^{-2}	1.12×10^{-1}
61	54	4.25×10^{-2}	1.12×10^{-1}
61	60	1.93×10^{-4}	5.06×10^{-4}
61	62	1.93×10^{-2}	5.06×10^{-3}
61	63	1.93×10^{-2}	5.06×10^{-2}
61	64	1.93×10^{-3}	5.06×10^{-3}
61	66	1.93×10^{-2}	5.06×10^{-3}
61	67	1.93×10^{-6}	5.06×10^{-5}
61	68	1.93×10^{-2}	5.06×10^{-2}
61	69	6.38×10^{-3}	1.85×10^{-2}
61	72	1.70×10^{-1}	3.71×10^{-1}
61	73	1.70×10^{-2}	3.71×10^{-2}
61	74	1.70×10^{-1}	3.72×10^{-2}
62	47	1.90×10^{-2}	1.68×10^{-2}
62	48	1.90×10^{-2}	1.68×10^{-2}
62	54	1.90×10^{-2}	1.68×10^{-2}
62	60	8.65×10^{-5}	7.64×10^{-5}
62	61	8.66×10^{-3}	7.65×10^{-3}
62	63	8.66×10^{-3}	7.64×10^{-3}
62	64	8.65×10^{-4}	7.63×10^{-4}
62	66	8.65×10^{-3}	7.64×10^{-4}
62	67	0	7.64×10^{-6}
62	68	8.65×10^{-3}	7.63×10^{-3}
62	69	2.86×10^{-3}	2.80×10^{-3}
62	72	7.61×10^{-2}	5.60×10^{-2}
62	73	7.61×10^{-3}	5.60×10^{-3}
62	74	7.63×10^{-2}	5.61×10^{-3}
63	47	2.96×10^{-1}	2.70×10^{-1}
63	48	2.96×10^{-1}	2.71×10^{-1}
63	54	2.96×10^{-1}	2.71×10^{-1}
63	60	1.35×10^{-3}	1.23×10^{-3}
63	61	1.35×10^{-1}	1.23×10^{-1}
63	62	1.35×10^{-1}	1.23×10^{-2}
63	63	1.35×10^{-1}	1.23×10^{-1}
63	64	1.35×10^{-2}	1.23×10^{-2}
63	66	1.35×10^{-1}	1.23×10^{-2}
63	67	1.35×10^{-5}	1.23×10^{-4}
63	68	1.35×10^{-1}	1.23×10^{-1}
63	69	4.45×10^{-2}	4.51×10^{-2}
63	72	1.19	9.02×10^{-1}
63	73	1.19×10^{-1}	9.02×10^{-2}
63	74	1.19	9.03×10^{-2}
64	68	1.91×10^{-3}	1.93×10^{-3}
64	69	6.31×10^{-4}	7.05×10^{-4}
64	70	1.68×10^{-2}	1.41×10^{-2}
64	71	1.68×10^{-2}	1.41×10^{-1}
64	72	1.68×10^{-2}	1.41×10^{-2}
64	73	1.68×10^{-3}	1.41×10^{-3}
64	74	1.68×10^{-2}	1.41×10^{-3}
65	68	1.70×10^{-3}	2.40×10^{-4}
65	69	5.60×10^{-4}	8.78×10^{-5}
65	71	1.50×10^{-2}	1.76×10^{-2}
65	72	1.50×10^{-2}	1.76×10^{-3}
65	73	1.50×10^{-3}	1.76×10^{-4}
65	74	1.50×10^{-2}	1.76×10^{-4}
66	68	7.15×10^{-3}	1.27×10^{-3}
66	69	2.36×10^{-3}	4.64×10^{-4}
66	70	6.29×10^{-2}	9.29×10^{-3}
66	71	6.30×10^{-2}	9.29×10^{-2}
66	72	6.29×10^{-2}	9.29×10^{-3}
66	73	6.29×10^{-3}	9.29×10^{-4}
66	74	6.30×10^{-2}	9.31×10^{-4}
67	70	5.55×10^{-5}	1.18×10^{-4}
67	71	5.56×10^{-5}	1.18×10^{-3}

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
67	72	$5.55x10^{-5}$	$1.18x10^{-4}$
67	73	$5.56x10^{-6}$	$1.18x10^{-5}$
67	74	$5.56x10^{-5}$	$1.18x10^{-5}$
67	79	$5.55x10^{-5}$	$1.18x10^{-4}$
68	71	$6.69x10^{-2}$	$2.01x10^{-1}$
68	72	$6.68x10^{-2}$	$2.01x10^{-2}$
68	73	$6.68x10^{-3}$	$2.01x10^{-3}$
68	74	$6.69x10^{-2}$	$2.01x10^{-3}$
69	70	$5.28x10^{-2}$	$1.78x10^{-2}$
69	71	$5.28x10^{-2}$	$1.78x10^{-1}$
69	72	$5.28x10^{-2}$	$1.78x10^{-2}$
69	73	$5.28x10^{-3}$	$1.78x10^{-3}$
69	74	$5.29x10^{-2}$	$1.78x10^{-3}$
69	78	$6.60x10^{-2}$	$2.23x10^{-2}$
78	7	0	$7.16x10^{-3}$
78	8	0	$2.06x10^{-3}$
78	10	0	$3.44x10^{-4}$
78	12	$8.22x10^{-5}$	$3.21x10^{-3}$
78	15	0	$1.88x10^{-2}$
78	16	$3.70x10^{-3}$	$2.81x10^{-3}$
78	21	$5.89x10^{-4}$	0
78	32	$2.59x10^{-4}$	$1.01x10^{-3}$
78	45	N.P.	$2.57x10^{1}$
78	70	$6.93x10^{1}$	$1.19x10^{1}$
78	71	$1.39x10^{2}$	0
78	72	2.51	0
78	73	2.28	$8.86x10^{-1}$
78	74	0	6.97
78	75	3.29	$2.68x10^{1}$
78	76	1.96	$2.52x10^{1}$
78	77	$5.68x10^{-1}$	$3.90x10^{-1}$
79	1	$1.30x10^{-5}$	$5.48x10^{-5}$
79	2	$5.68x10^{-2}$	$1.36x10^{-2}$
79	3	$8.62x10^{-2}$	$9.09x10^{-3}$
79	7	0	$6.78x10^{-2}$
79	8	0	$1.96x10^{-2}$
79	10	0	$3.26x10^{-3}$
79	12	$7.35x10^{-4}$	$3.04x10^{-2}$
79	15	0	$1.78x10^{-1}$
79	16	$2.94x10^{-2}$	$2.36x10^{-2}$
79	17	$8.49x10^{-3}$	$1.82x10^{-3}$
79	19	$2.97x10^{-2}$	$2.52x10^{-2}$
79	20	0	$8.85x10^{-5}$
79	21	$5.26x10^{-3}$	$4.65x10^{-3}$
79	23	$1.01x10^{-3}$	$9.79x10^{-3}$
79	24	$4.51x10^{-2}$	$3.51x10^{-2}$
79	25	0	$1.11x10^{-5}$
79	27	0	$2.90x10^{-5}$
79	28	$1.03x10^{-3}$	0
79	30	N.P.	$5.46x10^{-4}$
79	32	$2.31x10^{-3}$	$9.59x10^{-3}$
79	33	0	$2.06x10^{-3}$
79	34	0	$1.27x10^{-4}$
79	35	$2.41x10^{-2}$	$1.70x10^{-2}$
79	36	$1.52x10^{-1}$	$6.77x10^{-1}$
79	37	1.85	1.12
79	38	$2.04x10^{-2}$	$6.51x10^{-2}$
79	39	0	$2.84x10^{-4}$
79	40	$2.86x10^{-1}$	$6.39x10^{-1}$
79	41	0	$2.17x10^{-1}$
79	43	0	$8.50x10^{-2}$
79	44	0	$1.87x10^{-1}$
79	45	N.P.	$6.33x10^{1}$
79	46	$1.50x10^{-2}$	$5.22x10^{-2}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
79	47	1.49	$8.16x10^{-1}$
79	49	1.19	$3.21x10^{-1}$
79	50	1.14	4.01
79	51	$3.31x10^{-2}$	$7.65x10^{-3}$
79	52	1.14	1.57
79	53	5.85	4.24
79	55	$3.83x10^{-3}$	$3.67x10^{-2}$
79	56	N.P.	$2.56x10^{-3}$
79	57	$3.86x10^{-2}$	$7.29x10^{-2}$
79	58	$2.82x10^{-1}$	$2.05x10^{-1}$
79	59	$2.84x10^{-2}$	$2.78x10^{-2}$
79	60	$5.92x10^{-3}$	$1.06x10^{-2}$
79	61	$1.43x10^{-1}$	$3.75x10^{-1}$
79	62	0	$6.55x10^{-2}$
79	63	2.35	1.22
79	64	$1.09x10^{-2}$	$6.27x10^{-2}$
79	65	$1.55x10^{-2}$	$1.02x10^{-2}$
79	66	0	$3.04x10^{-2}$
79	67	$1.24x10^{-4}$	$5.23x10^{-4}$
79	69	$1.88x10^{-1}$	$1.41x10^{-1}$
79	70	$2.29x10^{1}$	4.16
79	71	$4.61x10^{1}$	0
79	72	$8.32x10^{-1}$	0
79	73	$7.56x10^{-1}$	$3.11x10^{-1}$
79	74	0	2.44
79	75	$8.16x10^{-1}$	7.06
79	76	$4.86x10^{-1}$	6.64
79	77	2.26	1.64
80	46	$1.70x10^{-3}$	$4.25x10^{-3}$
80	47	$1.69x10^{-1}$	$6.65x10^{-2}$
80	49	$1.35x10^{-1}$	$2.62x10^{-2}$
80	50	$1.29x10^{-1}$	$3.27x10^{-1}$
80	51	$3.75x10^{-3}$	$6.23x10^{-4}$
80	52	$1.29x10^{-1}$	$1.28x10^{-1}$
80	53	$6.62x10^{-1}$	$3.46x10^{-1}$
80	55	$4.33x10^{-4}$	$2.99x10^{-3}$
80	56	N.P.	$2.09x10^{-4}$
80	57	$4.37x10^{-3}$	$5.94x10^{-3}$
80	58	$3.19x10^{-2}$	$1.67x10^{-2}$
80	59	$3.22x10^{-3}$	$2.27x10^{-3}$
80	60	$6.70x10^{-4}$	$8.64x10^{-4}$
80	61	$1.62x10^{-2}$	$3.06x10^{-2}$
80	62	0	$5.34x10^{-3}$
80	63	$2.66x10^{-1}$	$9.98x10^{-2}$
80	64	$1.24x10^{-3}$	$5.11x10^{-3}$
80	65	$1.76x10^{-3}$	$8.28x10^{-4}$
80	66	0	$2.48x10^{-3}$
80	67	$1.40x10^{-5}$	$4.27x10^{-5}$
80	69	$2.13x10^{-2}$	$1.15x10^{-2}$
80	70	$2.34x10^{1}$	3.05
80	71	$4.70x10^{1}$	0
80	72	$8.48x10^{-1}$	0
80	73	$7.71x10^{-1}$	$2.28x10^{-1}$
80	74	0	1.79
Prod.	1	$1.30x10^{-5}$	$5.48x10^{-5}$
Prod.	2	$5.68x10^{-2}$	$1.36x10^{-2}$
Prod.	3	$1.02x10^{-1}$	$2.29x10^{-2}$
Prod.	4	$6.36x10^{-2}$	$1.09x10^{-2}$
Prod.	5	$5.33x10^{-2}$	$1.12x10^{-1}$
Prod.	6	$1.67x10^{-2}$	$7.42x10^{-2}$
Prod.	7	$2.25x10^{-1}$	$1.17x10^{-1}$
Prod.	8	$1.72x10^{-1}$	$8.54x10^{-2}$
Prod.	9	$6.42x10^{-4}$	$5.82x10^{-3}$
Prod.	10	$6.43x10^{-6}$	$9.42x10^{-3}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
Prod.	11	$6.42x10^{-6}$	$5.81x10^{-4}$
Prod.	12	$1.46x10^{-3}$	$3.94x10^{-2}$
Prod.	13	$6.43x10^{-4}$	$5.81x10^{-4}$
Prod.	14	$6.42x10^{-6}$	$5.81x10^{-4}$
Prod.	15	$4.44x10^{-3}$	$3.48x10^{-1}$
Prod.	16	$2.47x10^{-1}$	$4.23x10^{-2}$
Prod.	17	$1.27x10^{-2}$	$2.22x10^{-3}$
Prod.	18	N.P.	$2.19x10^{-5}$
Prod.	19	$3.40x10^{-2}$	$2.56x10^{-2}$
Prod.	20	$4.27x10^{-3}$	$1.29x10^{-4}$
Prod.	21	$8.96x10^{-3}$	$4.66x10^{-3}$
Prod.	22	N.P.	$2.18x10^{-6}$
Prod.	23	$2.55x10^{-3}$	$1.13x10^{-2}$
Prod.	24	$6.72x10^{-2}$	$7.61x10^{-2}$
Prod.	25	$4.28x10^{-6}$	$5.14x10^{-5}$
Prod.	26	N.P.	$1.25x10^{-3}$
Prod.	27	$4.28x10^{-5}$	$6.92x10^{-5}$
Prod.	28	$8.39x10^{-3}$	$1.25x10^{-3}$
Prod.	29	$7.37x10^{-3}$	$1.25x10^{-3}$
Prod.	30	N.P.	$1.29x10^{-3}$
Prod.	31	$3.33x10^{-3}$	$1.58x10^{-3}$
Prod.	32	$6.99x10^{-3}$	$1.28x10^{-2}$
Prod.	33	$1.30x10^{-2}$	$2.43x10^{-3}$
Prod.	34	$4.28x10^{-3}$	$1.67x10^{-4}$
Prod.	35	$2.84x10^{-2}$	$1.74x10^{-2}$
Prod.	36	$3.46x10^{-1}$	$7.11x10^{-1}$
Prod.	37	2.32	1.25
Prod.	38	$5.73x10^{-2}$	$6.65x10^{-2}$
Prod.	39	$3.22x10^{-3}$	$6.49x10^{-4}$
Prod.	40	$6.26x10^{-1}$	$6.78x10^{-1}$
Prod.	41	$1.50x10^{-1}$	$2.41x10^{-1}$
Prod.	42	$3.40x10^{-1}$	$3.96x10^{-2}$
Prod.	43	$9.11x10^{-1}$	$2.65x10^{-1}$
Prod.	44	$2.76x10^{-1}$	$2.13x10^{-1}$
Prod.	45	N.P.	$9.08x10^{1}$
Prod.	46	$1.80x10^{-2}$	$5.71x10^{-2}$
Prod.	47	2.07	1.33
Prod.	48	$4.10x10^{-1}$	$4.52x10^{-1}$
Prod.	49	1.45	$3.55x10^{-1}$
Prod.	50	2.45	5.04
Prod.	51	$4.87x10^{-2}$	$8.98x10^{-3}$
Prod.	52	2.45	2.4
Prod.	53	7.69	5.29
Prod.	54	$4.09x10^{-1}$	$4.52x10^{-1}$
Prod.	55	$4.38x10^{-3}$	$4.04x10^{-2}$
Prod.	56	N.P.	$3.11x10^{-3}$
Prod.	57	$6.11x10^{-2}$	$8.37x10^{-2}$
Prod.	58	$3.24x10^{-1}$	$2.28x10^{-1}$
Prod.	59	$4.17x10^{-2}$	$3.08x10^{-2}$
Prod.	60	$8.50x10^{-3}$	$1.35x10^{-2}$
Prod.	61	$3.31x10^{-1}$	$5.64x10^{-1}$
Prod.	62	$1.82x10^{-1}$	$9.10x10^{-2}$
Prod.	63	2.81	1.53
Prod.	64	$3.12x10^{-2}$	$8.87x10^{-2}$
Prod.	65	$2.74x10^{-2}$	$1.17x10^{-2}$
Prod.	66	$1.91x10^{-1}$	$5.37x10^{-2}$
Prod.	67	$1.57x10^{-4}$	$7.74x10^{-4}$
Prod.	68	$2.01x10^{-1}$	$2.12x10^{-1}$
Prod.	69	$2.74x10^{-1}$	$2.31x10^{-1}$
Prod.	70	$1.21x10^{2}$	$4.65x10^{1}$
Prod.	71	$2.38x10^{2}$	$2.74x10^{2}$
Prod.	72	$1.14x10^{1}$	$2.89x10^{1}$
Prod.	73	4.53	4.31
Prod.	74	7.32	$1.41x10^{1}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
Prod.	75	4.24	$3.62x10^{1}$
Prod.	76	2.91	$3.34x10^{1}$
Prod.	77	3.5	2.24
Prod.	78	2.71	$4.01x10^{1}$
Prod.	79	1.77	$7.07x10^{-1}$
Prod.	80	$1.79x10^{-2}$	$2.94x10^{1}$
Cons.	1	$1.86x10^{-2}$	$7.87x10^{-2}$
Cons.	2	1.26	$3.74x10^{-1}$
Cons.	3	$7.39x10^{-1}$	$1.65x10^{-1}$
Cons.	4	$2.11x10^{-1}$	$4.27x10^{-2}$
Cons.	5	$2.92x10^{-1}$	$8.97x10^{-1}$
Cons.	6	$5.80x10^{-2}$	$1.94x10^{-1}$
Cons.	7	$5.19x10^{-1}$	$5.90x10^{-1}$
Cons.	8	$2.59x10^{-1}$	$2.42x10^{-1}$
Cons.	9	$2.21x10^{-3}$	$1.19x10^{-2}$
Cons.	10	$2.04x10^{-5}$	$6.58x10^{-2}$
Cons.	11	$8.87x10^{-6}$	$7.39x10^{-4}$
Cons.	12	$1.12x10^{-2}$	$2.86x10^{-1}$
Cons.	13	$8.55x10^{-4}$	$1.48x10^{-3}$
Cons.	14	$2.63x10^{-5}$	$1.18x10^{-3}$
Cons.	15	$6.49x10^{-3}$	$7.30x10^{-1}$
Cons.	16	$6.65x10^{-1}$	$1.65x10^{-1}$
Cons.	17	$9.81x10^{-2}$	$2.16x10^{-2}$
Cons.	18	N.P.	$4.25x10^{-5}$
Cons.	19	$3.15x10^{-1}$	$2.50x10^{-1}$
Cons.	20	$7.19x10^{-3}$	$1.89x10^{-3}$
Cons.	21	$1.65x10^{-1}$	$8.06x10^{-2}$
Cons.	22	N.P.	$4.10x10^{-6}$
Cons.	23	$3.10x10^{-2}$	$1.33x10^{-1}$
Cons.	24	$1.93x10^{-1}$	$2.11x10^{-1}$
Cons.	25	$1.36x10^{-5}$	$3.60x10^{-4}$
Cons.	26	N.P.	$1.87x10^{-3}$
Cons.	27	$4.59x10^{-5}$	$5.24x10^{-4}$
Cons.	28	$5.36x10^{-2}$	$1.73x10^{-3}$
Cons.	29	$2.68x10^{-2}$	$6.10x10^{-3}$
Cons.	30	N.P.	$3.69x10^{-3}$
Cons.	31	$1.41x10^{-2}$	$9.59x10^{-3}$
Cons.	32	$1.58x10^{-2}$	$3.72x10^{-2}$
Cons.	33	$2.29x10^{-2}$	$7.67x10^{-3}$
Cons.	34	$5.51x10^{-3}$	$1.42x10^{-3}$
Cons.	35	$2.27x10^{-1}$	$2.12x10^{-1}$
Cons.	36	$6.95x10^{-1}$	1.28
Cons.	37	3.03	1.65
Cons.	38	$2.33x10^{-1}$	$2.49x10^{-1}$
Cons.	39	$5.62x10^{-3}$	$4.26x10^{-3}$
Cons.	40	1.79	2.34
Cons.	41	$1.85x10^{-1}$	$4.31x10^{-1}$
Cons.	42	$7.23x10^{-1}$	$7.59x10^{-2}$
Cons.	43	1.08	$4.59x10^{-1}$
Cons.	44	$3.29x10^{-1}$	$3.22x10^{-1}$
Cons.	45	N.P.	$3.79x10^{2}$
Cons.	46	$1.86x10^{-2}$	$5.92x10^{-2}$
Cons.	47	2.16	1.4
Cons.	48	$4.25x10^{-1}$	$4.66x10^{-1}$
Cons.	49	1.51	$3.68x10^{-1}$
Cons.	50	4.51	9.05
Cons.	51	$9.08x10^{-2}$	$1.67x10^{-2}$
Cons.	52	4.89	4.75
Cons.	53	7.91	5.44
Cons.	54	$6.71x10^{-1}$	$9.76x10^{-1}$
Cons.	55	$6.93x10^{-3}$	$6.45x10^{-2}$
Cons.	56	N.P.	$5.63x10^{-3}$
Cons.	57	$1.05x10^{-1}$	$1.46x10^{-1}$
Cons.	58	$4.63x10^{-1}$	$3.30x10^{-1}$

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
Cons.	59	$6.11x10^{-2}$	$4.44x10^{-2}$
Cons.	60	$1.33x10^{-2}$	$2.10x10^{-2}$
Cons.	61	$5.71x10^{-1}$	$9.16x10^{-1}$
Cons.	62	$2.55x10^{-1}$	$1.45x10^{-1}$
Cons.	63	4.12	2.35
Cons.	64	$7.15x10^{-2}$	$1.75x10^{-1}$
Cons.	65	$4.87x10^{-2}$	$2.00x10^{-2}$
Cons.	66	$2.68x10^{-1}$	$1.15x10^{-1}$
Cons.	67	$2.83x10^{-4}$	$1.56x10^{-3}$
Cons.	68	$2.07x10^{-1}$	$2.25x10^{-1}$
Cons.	69	$2.83x10^{-1}$	$2.40x10^{-1}$
Cons.	78	$2.19x10^{2}$	$9.79x10^{1}$
Cons.	79	$9.07x10^{1}$	$1.02x10^{2}$
Cons.	80	$7.36x10^{1}$	6.15
Resp.	1	$1.85x10^{-2}$	$7.81x10^{-2}$
Resp.	2	1.14	$2.41x10^{-1}$
Resp.	3	$6.07x10^{-1}$	$1.32x10^{-1}$
Resp.	4	$1.47x10^{-1}$	$3.18x10^{-2}$
Resp.	5	$2.21x10^{-1}$	$7.41x10^{-1}$
Resp.	6	$3.84x10^{-2}$	$1.20x10^{-1}$
Resp.	7	$2.89x10^{-1}$	$4.71x10^{-1}$
Resp.	8	$8.75x10^{-2}$	$1.57x10^{-1}$
Resp.	9	$8.86x10^{-4}$	$3.80x10^{-3}$
Resp.	10	$7.90x10^{-6}$	$4.14x10^{-2}$
Resp.	11	0	$5.25x10^{-5}$
Resp.	12	$5.50x10^{-3}$	$1.81x10^{-1}$
Resp.	13	$2.85x10^{-5}$	$6.15x10^{-4}$
Resp.	14	$1.12x10^{-5}$	$3.76x10^{-4}$
Resp.	15	$2.05x10^{-3}$	$3.82x10^{-1}$
Resp.	16	$4.14x10^{-1}$	$1.20x10^{-1}$
Resp.	17	$8.53x10^{-2}$	$1.69x10^{-2}$
Resp.	18	N.P.	$2.07x10^{-5}$
Resp.	19	$2.37x10^{-1}$	$1.98x10^{-1}$
Resp.	20	$2.26x10^{-4}$	$1.59x10^{-3}$
Resp.	21	$1.51x10^{-1}$	$7.45x10^{-2}$
Resp.	22	N.P.	$1.92x10^{-6}$
Resp.	23	$2.75x10^{-2}$	$1.18x10^{-1}$
Resp.	24	$1.26x10^{-1}$	$1.35x10^{-1}$
Resp.	25	$9.30x10^{-6}$	$3.09x10^{-4}$
Resp.	26	N.P.	$6.20x10^{-4}$
Resp.	27	$3.13x10^{-6}$	$4.55x10^{-4}$
Resp.	28	$4.52x10^{-2}$	$4.72x10^{-4}$
Resp.	29	$1.94x10^{-2}$	$4.85x10^{-3}$
Resp.	30	N.P.	$2.40x10^{-3}$
Resp.	31	$1.08x10^{-2}$	$8.01x10^{-3}$
Resp.	32	$8.76x10^{-3}$	$2.44x10^{-2}$
Resp.	33	$9.88x10^{-3}$	$5.24x10^{-3}$
Resp.	34	$1.23x10^{-3}$	$1.25x10^{-3}$
Resp.	35	$1.97x10^{-1}$	$1.93x10^{-1}$
Resp.	36	$3.50x10^{-1}$	$5.64x10^{-1}$
Resp.	37	$7.11x10^{-1}$	$4.00x10^{-1}$
Resp.	38	$1.76x10^{-1}$	$1.82x10^{-1}$
Resp.	39	$2.41x10^{-3}$	$3.61x10^{-3}$
Resp.	40	1.16	1.66
Resp.	41	$3.53x10^{-2}$	$1.90x10^{-1}$
Resp.	42	$3.83x10^{-1}$	$3.63x10^{-2}$
Resp.	43	$1.70x10^{-1}$	$1.94x10^{-1}$
Resp.	44	$5.36x10^{-2}$	$1.09x10^{-1}$
Resp.	45	N.P.	$2.88x10^{2}$
Resp.	46	$6.32x10^{-4}$	$2.03x10^{-3}$
Resp.	47	$8.93x10^{-2}$	$7.09x10^{-2}$
Resp.	48	$1.56x10^{-2}$	$1.41x10^{-2}$
Resp.	49	$5.48x10^{-2}$	$1.35x10^{-2}$
Resp.	50	2.06	4.02

Appendix 3.2 (con't)

Pred	Prey	Pre Exchange	Post Exchange
Resp.	51	4.21x10^{-2}	7.70x10^{-3}
Resp.	52	2.44	2.35
Resp.	53	2.21x10^{-1}	1.55x10^{-1}
Resp.	54	2.62x10^{-1}	5.24x10^{-1}
Resp.	55	2.55x10^{-3}	2.41x10^{-2}
Resp.	56	N.P.	2.52x10^{-3}
Resp.	57	4.39x10^{-2}	6.28x10^{-2}
Resp.	58	1.39x10^{-1}	1.01x10^{-1}
Resp.	59	1.94x10^{-2}	1.36x10^{-2}
Resp.	60	4.80x10^{-3}	7.41x10^{-3}
Resp.	61	2.40x10^{-1}	3.52x10^{-1}
Resp.	62	7.36x10^{-2}	5.39x10^{-2}
Resp.	63	1.31	8.18x10^{-1}
Resp.	64	4.03x10^{-2}	8.60x10^{-2}
Resp.	65	2.13x10^{-2}	8.36x10^{-3}
Resp.	66	7.70x10^{-2}	6.14x10^{-2}
Resp.	67	1.26x10^{-4}	7.81x10^{-4}
Resp.	68	5.87x10^{-3}	1.32x10^{-2}
Resp.	69	8.32x10^{-3}	8.31x10^{-3}
Resp.	70	5.60x10^{1}	2.00x10^{1}
Resp.	71	1.05x10^{2}	9.05x10^{1}
Resp.	72	1.11x10^{1}	6.96
Resp.	73	2.53	1.97
Resp.	74	8.85	5.18
Resp.	75	1.79	1.20x10^{1}
Resp.	76	1.49	1.14x10^{1}
Resp.	77	1.92	8.69x10^{-1}
Resp.	78	2.12x10^{2}	3.91x10^{1}
Resp.	79	4.65x10^{1}	1.58x10^{1}
Resp.	80	7.30x10^{1}	3.34
Imp.	70	1.77x10^{2}	6.65x10^{1}
Imp.	71	3.43x10^{2}	3.65x10^{2}
Imp.	72	2.25x10^{1}	3.59x10^{1}
Imp.	73	7.06	6.28
Imp.	74	1.62x10^{1}	1.93x10^{1}
Imp.	75	6.03	4.82x10^{1}
Imp.	76	4.4	4.48x10^{1}
Imp.	77	5.42	3.11
Imp.	78	2.48x10^{2}	2.49x10^{2}
Imp.	79	3.86x10^{1}	3.03x10^{1}
Imp.	80	7.08x10^{1}	7.21x10^{1}
Exp.	1	1.19x10^{-4}	5.02x10^{-4}
Exp.	2	6.13x10^{-2}	1.19x10^{-1}
Exp.	3	2.97x10^{-2}	9.99x10^{-3}
Exp.	5	1.80x10^{-2}	4.44x10^{-2}
Exp.	6	2.96x10^{-3}	0
Exp.	7	5.23x10^{-3}	1.62x10^{-3}
Exp.	9	6.84x10^{-4}	2.23x10^{-3}
Exp.	10	6.10x10^{-6}	1.49x10^{-2}
Exp.	11	2.12x10^{-6}	1.05x10^{-4}
Exp.	12	4.25x10^{-3}	6.52x10^{-2}
Exp.	13	1.84x10^{-4}	2.80x10^{-4}
Exp.	14	8.65x10^{-6}	2.21x10^{-4}
Exp.	16	3.75x10^{-3}	3.00x10^{-3}
Exp.	17	0	2.43x10^{-3}
Exp.	19	4.39x10^{-2}	2.60x10^{-2}
Exp.	20	2.70x10^{-3}	1.73x10^{-4}
Exp.	21	4.68x10^{-3}	1.44x10^{-3}
Exp.	23	9.89x10^{-4}	3.96x10^{-3}
Exp.	35	1.36x10^{-3}	1.40x10^{-3}
Exp.	78	2.53x10^{2}	2.68x10^{2}
Exp.	79	8.11x10^{1}	1.16x10^{2}
Exp.	80	7.13x10^{1}	4.55x10^{1}

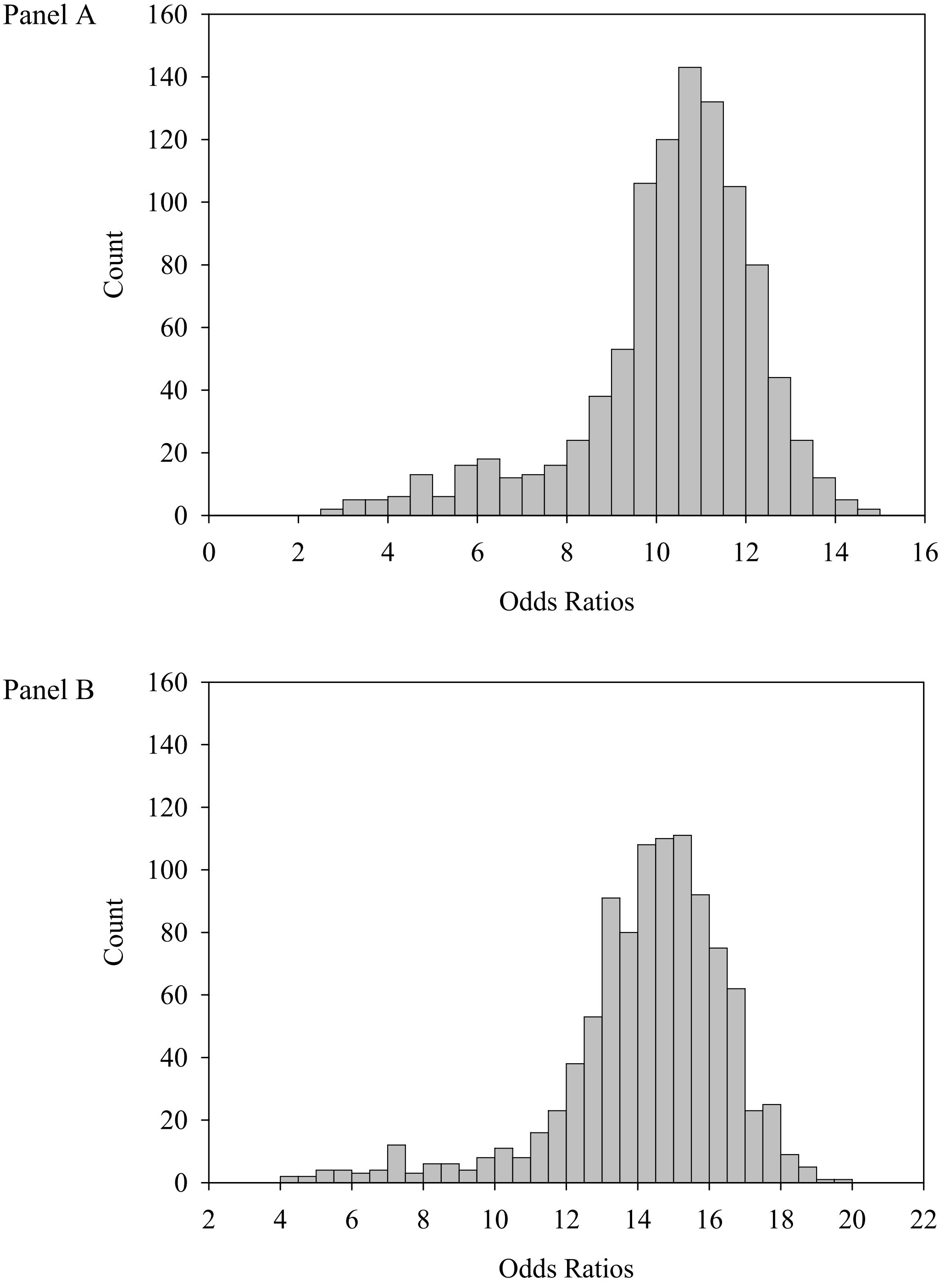
Appendix 3.3

Exploration of odds ratios from significance testing

In our cohesion analysis of the Bay of Quinte food web networks, we identified six borderline significant subgroups pre-zebra mussel invasion ($p = 0.07$; odds ratio = 12.7) and eight non-significant subgroups post-invasion ($p = 0.5$; odds ratio = 14.6). Generally, larger odds ratios correspond to greater statistical significance (i.e., smaller *p*-values), and therefore, we were initially surprised that the post-invasion subgroups were non-significant. To explore this result, we first plotted a histogram of the odds ratios generated during significance testing for the pre- (Panel A) and post-invasion (Panel B) networks to assess normality of the results (Table A3.1). Both distributions were slightly left-skewed; however, for the purposes of this analysis, the distributions were acceptable.

Next, we examined the flow topography. Flow was asymmetrically distributed after invasion, with zebra mussels garnering over 15% of the total system flow. Additionally, the greatest weights on flows were between zebra mussels and their prey (Appendix 3.2), which centralizes (or focuses) the network. Frank (1995) generates a predicted value of odds ratios from simulation data showing that highly centralized networks can yield large odds ratios. Frank demonstrates the process using networks with unweighted data, where particular actors engage in a large number of interactions; actors with many interactions (in an unweighted network) are analogous to actors engaging in interactions with large weights (in a weighted network). As such, the post-invasion Bay of Quinte network is highly centralized due to the dominance of zebra mussels. Because of this, high odds ratios can be sustained even in the absence of subgroups merely by locating zebra mussels and all their prey in a single subgroup. Therefore, we conclude that the concentration of exchanges within subgroups for the post-invasion network was not significantly different from what would be found by chance alone because of the extremely high centrality of zebra mussels.

Table A3.1. Distribution of odds ratios pre- (Panel A) and post-zebra mussel invasion (Panel B) used in significance testing.



References

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