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The contribution of young-of-year fishes to aquatic food web dynamics in an arid-land river system (Rio Grande, New Mexico)

Corey Krabbenhoft

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**THE CONTRIBUTION OF YOUNG-OF-YEAR FISHES TO
AQUATIC FOOD WEB DYNAMICS IN AN ARID-LAND
RIVER SYSTEM (RIO GRANDE, NEW MEXICO)**

by

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B.S., BIOLOGY, UNIVERSITY OF NEW MEXICO, 2009

THESIS

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ABSTRACT

1. Larval fishes have a rich history in ichthyological research. However, relatively little attention has been given to the role of young-of-year (YOY) fishes in ecosystem processes. Despite difficulties of sampling and identifying these small fishes, YOY may serve an important role in the dynamics of some aquatic communities. The specific role of YOY fishes in aquatic, desert food webs remains largely uncharacterized.
2. We hypothesize that YOY fishes may control abundance and community composition of lower trophic levels (i.e., aquatic invertebrates) because they are numerically dominant predators during the growing season. The goal of this study is to determine the role of YOY fishes in aquatic food webs and the impact they have on trophic dynamics of dryland river food webs using the Rio Grande as an example.

3. A mesocosm experiment was designed to assess the effect of YOY fish predators on meio- and micro- faunal invertebrate prey density and diversity. We manipulated presence and absence of YOY fishes and leaf litter, and compared invertebrate diversity and abundance across an array of 24 stock tanks.
4. Data showed that YOY fishes significantly influence the composition of invertebrate communities, as does allochthonous carbon. Community composition varied among treatments both because fishes preferred some taxa over others and because of instances of avoidance by invertebrates. Stable isotope analyses (carbon and nitrogen) suggest important indirect effects on the behavior of invertebrates in fish-treated mesocosms.
5. Results suggest that YOY fishes play an important role in aquatic food web dynamics and that community composition of aquatic invertebrates is, in part, subject to direct and indirect changes induced by the presence of YOY fishes.

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Overview

The availability of freshwater is a critical resource for most ecosystems. In arid environments (<500 mm rainfall per year), freshwater is a limiting resource which governs the distribution of life in a landscape (Noy-Meir, 1973). As human populations grow, standards of living rise and climate change accelerates, freshwater resources will continue to increase in value. In a world where availability of water is intimately associated with human development, ecosystem function and the homologous dependence on water of non-human organisms is easily overshadowed. Once natural landscapes now include dams, reservoirs and other impoundments which represent the importance of maintaining this resource. While such innovations have increased the ability of humans to harness, store and utilize freshwater, these implements are largely detrimental to native, non-human populations (Baxter, 1977). Disregard for ecosystem function and natural processes has created a need for restoration efforts which have cost the United States over \$15 billion in the last twenty years alone (Bernhardt *et al.*, 2005). Such costly practices are not only unsustainable economically, but biologically as well. With looming climate change scenarios, those ecosystems that are water limited will be the most vulnerable.

With major interests in water allocation for human needs, the uniqueness of desert river ecosystems often goes unrecognized. With respect to hydrologic regimes and species composition, desert rivers exhibit extremes in both cases. Desert hydrographs are often punctuated with immensely high, short-lived flows, in addition to sustained dry periods. Levels of endemism are often higher in desert rivers, although overall diversity is typically lower than temperate or tropical counterparts (Minckley & Marsh, 2009).

Species adapted to extreme local conditions are susceptible to changes in flow regime which remove natural flashiness (Bunn *et al.*, 2006b). Impoundments, withdrawal for municipal or agricultural purposes and climate change can all have detrimental effects on natural flow regimes, potentially at the expense of native species. Nonnatives are consequently an increasing problem in freshwater ecosystems, as they may be more suited to artificial flow regimes that are historically uncharacteristic (Meffe & Minckley, 1987; Marchetti & Moyle, 2001). Given the various threats to freshwater resources and the coincident human interest, desert river ecosystems are increasingly the subject of research. While this area of scientific inquiry is on the rise, there is still much to learn. The southwestern United States, the most arid region of the country, has played host to fewer restorative projects per river kilometer than any other region in the country (Bernhardt *et al.*, 2005). As such, the more research applied to these highly endangered systems, the better.

While conditions in desert ecosystems may be deteriorating, the field of desert ecology is on the rise. The general scientific community has realized that understanding these unique ecosystems is imperative for the future of conservation, water management and population development. Additionally, deserts are among the few landscapes that are predicted to become more widespread as the full impact of climate change is realized. Desertification, although a process more intimately tied to the terrestrial landscape (Le Houérou, 1996), will impose serious alterations to ecosystem function, both in terrestrial and aquatic ecosystems (Puigdefábregas, 1998). As desertification increases, so does the likelihood of increased variability in climatic components. O’Gorman & Schneider (2008) suggested that increased temperature associated with climate change will cause

major shifts in the hydrologic cycle, including rates of evaporative loss, atmospheric retention times and local precipitation regimes. Naturally, this shift implies severe consequences for terrestrial and aquatic systems alike. A potential problem is that changes in climate extremes do not necessarily imply increased frequency of extreme ecological responses; thus, building a baseline framework for the ecology of imperiled systems is integral to determining how these ecosystems will fare under future climate scenarios (Smith, 2011). The inquiry into the inherent components of ecosystem function is necessary for long-term projection of ecosystem stability.

My study addresses some of the unique components of desert ecosystems in New Mexico. The Rio Grande is one of the longest rivers in the United States and it completely bisects the state of New Mexico. It offers many of the characteristics uniquely attributed to desert rivers including endemic fauna, endangered species, highly variable flow, altered flow regimes and is an important source of freshwater for human needs. Specifically, this study examines the bottom-up and top-down controls of food web structure in a harsh system supporting a large biomass of larval and juvenile fishes. Previous studies on top adult and intermediate predators have suggested that the impact of fishes on trophic structure and productivity can be great (e.g., Carpenter *et al.*, 1987; Power 1990). Conversely, other research has concluded that top-down regulation exists, but relatively infrequently (Polis & Strong, 1996). Many previous studies addressing the roles of top-down and bottom-up processes have focused on adult stages and/or lacustrine fishes. This study is designed to address larval and juvenile stages in a relatively unstudied riverine system. Similar to work by Power (1990), flow is reduced in the Rio Grande for notable portions of the year, creating lentic habitats. The questions examined

herein regard the specific role of larval and juvenile fishes in determining composition and function of aquatic communities in drying, harsh river ecosystems.

Introduction

The success of a fish species is intimately tied to its ability to forage for resources. As such, understanding the main components of fish diet (Larimore, 1957; Davis, 1970), instances of prey selection (Landström, 1955; Brooks, 1968) and the conditions under which growth and survivorship are maximized (Crawford, 1923) is essential to the conservation of fishes. However, early approaches to diet studies were often done from the perspective of fisheries management and aquaculture as opposed to the ecological function of fishes in their environment (Crawford, 1923). With the development of new technology, this idea translated to marine environments in an attempt to maximize output in artificial settings (Davis, 1970). As a result, the focus of the literature on fish diet has largely been derived in marine habitats (Cushing, 1983; Frank, 1988; Fukami *et al.*, 1999; Fiksen & MacKenzie, 2002; Cocheret de la Morinière *et al.*, 2003) and on adult fishes (e.g., Mathur, 1977).

While valuable, knowledge gained solely with respect to adult fishes, fails to address the vulnerable, and ecologically distinctive early stages of ontogeny. Particularly from a conservation perspective, young-of-year (YOY) fishes and their roles in the environment are critical areas of research. The number of studies has grown in both marine and freshwater environments. Studies like Cushing (1983), Miller (1988) and Wieser & Medgyesy (1990) illuminated the differences in the function of larvae in the environment

from that of their adult counterparts from a dietary perspective. More recently, Cocheret de la Morinière *et al.* (2003) looked at the differences between adult and early life stages in terms of functional feeding groups (i.e., herbivorous and predatory feeding styles). Increasingly, there has been recognition among the scientific community of how larval and juvenile fishes play different functional roles than adults in their respective ecosystems. YOY fishes may serve not only as important prey items, but as potential competitors in predation on lower trophic levels.

Similarly, YOY fishes may be an important link in the carbon budget between primary producers and higher trophic levels. Markle & Clauson (2006) characterized feeding habits of two sucker species (Catostomidae) in Upper Klamath Lake, Oregon.

Ontogenetic shifts from the use of terrestrially-derived diet items to autochthonous resources were shown in both species. Additionally, as fishes grew, the proportion of identifiable gut content items decreased, suggesting an increase in the use of algal, detrital and small, readily digested items. Mérioux & Ponton (1998) produced contrasting results in a French Guiana river where there was an overall increase in utilization of allochthonous items over time as terrestrial insects replaced microcrustaceans in the diet. While the conclusions drawn in each study differed, each considers the ontogenetic changes in larval fish diet and the potential importance of terrestrial carbon.

Regardless of the impacts demonstrated in individual systems or species, the makeup of fish and invertebrate communities and the nature of their interactions are integral to understanding aquatic food web dynamics. Moreover, the differences in function and importance of larval and adult fishes need to be accounted for. For example, in

recruitment driven systems, the success of larval fishes is directly proportional to the abundance of adult fishes in the future. Recruitment driven systems are typically host to short-lived species with communities that overturn frequently. Consequently, environmental factors impacting the growth and reproduction of larval individuals determines the relative abundances of species in the future community (Daskalov, 1999). This type of system is relatively rare among freshwater ecosystems and is not well studied in arid-land systems (Balcombe *et al.*, 2006; Pease *et al.* 2006).

Most larval fishes have rapid growth and energy uptake rates (Wieser & Medgyesy, 1990; Pedersen, 1997). Given this initial need for nourishment, young fishes have the potential to have severe negative impacts on primary consumer prey (usually small-bodied (< 250 μm in diameter) invertebrates called meiofauna) (Carpenter *et al.*, 1985). While previous studies have shown the top-down control of meiofaunal food items (e.g., Copepoda) by larval fishes (Dineen & Robertson, 2010), harsh environments (e.g., desert rivers) may allow for little fine-scale partitioning of resources. Accordingly, simple trophic interactions may fail to explain the eccentricities of these systems. One hypothesis is that fishes will converge on the most abundant diet item and any nutritive heterogeneity will be lost (Balcombe *et al.*, 2005). Should this be the case, it would explain temporary effects on trophic structure, but trophic interactions could change with seasonal succession, ontogeny (as the fishes grow) and increasing competition in harsh environments.

However, incorporation of YOY fishes into aquatic food web studies is complicated. Species identification at the larval and juvenile stages is sometimes not possible and small size and great numbers associated with bony fish larvae makes diversity difficult to

accurately sample; both factors have contributed greatly to the debate of whether or not larval and juvenile fishes can affect abundances in lower trophic levels (Frank, 1988). In the arid southwestern US, there are fewer naturally occurring species (Minckley & Marsh, 2009). Without the complex nature of high diversity, identification is made a more realistic endeavor. Our study area, the middle Rio Grande, New Mexico, is characterized by ten common taxa which are reproductively active from year to year (Pease *et al.*, 2006). Given the relative lack of diversity, confident species identification of larval and juvenile fishes is feasible.

In addition to the unique ability to identify YOY taxa, the Rio Grande is a recruitment driven system, subject to variable conditions both seasonally and from year to year (Turner *et al.*, 2010). In some reaches, the river dries down to a series of disconnected pools during the summer months. Obligately aquatic organisms like fishes and aquatic invertebrates are thus limited in the opportunity to seek refugia and are constrained in their ability to escape competition and forage for resources. Interaction strength of fish and invertebrate taxa, whether positive (i.e., facilitation) or negative, has the potential to be exacerbated in these harsh circumstances. Further, due to severe and persistent drought and increasing water extraction for human use, river drying occurs on a much more regular basis at present than historically (Ward & Booker, 2006). Harsh conditions have the potential to illicit major changes in food web structure and function. Indeed, Yonekura *et al.* (2009) observed this in an artificial pond study in Japan where there was a switch of the basal source of carbon transmitted to higher trophic levels from autochthonous to allochthonous inputs in a highly competitive environment because in-

stream resources were depleted. Likewise, Pease *et al.* (2006) demonstrated a similar effect in the Rio Grande during summer dry down.

In order to investigate the role of YOY fishes in river food webs, we set up a mesocosm experiment which addressed two issues related to the aquatic food web in the Rio Grande: (i) the role of YOY fishes as predators for shaping invertebrate community structure (i.e., top-down effects), and (ii) the role of terrestrially derived carbon for fueling the river food web (i.e., bottom-up effects). While bottom-up processes can help shape trophic level characteristics, the elevated metabolic requirement associated with growth (Wieser & Medgyesy, 1990) and the high numerical abundance and biomass of larval fishes (Platt *et al.*, 2003) are likely to enhance the effect of YOY fishes. We thus anticipated YOY fishes would be important in shaping community structure and behavior of aquatic invertebrates.

From biweekly sampling of each trophic level present in the mesocosm experiment, we assessed the role of YOY fishes as secondary consumers in a highly variable system. Gut content and stable isotope analyses were employed to test the hypothesis that YOY fishes are integral to the function of the aquatic food web, and answer some basic questions regarding that role. Specifically, we address the following questions:

- (1) Do YOY fishes have an impact on invertebrate density? If so, under what conditions?
- (2) Do YOY fishes have preferential diet items, and if so which diet items are preferred by YOY fishes?
- (3) Are there non-lethal or otherwise indirect effects of YOY predators on prey?

Methods

Experimental Setup

A quasi-natural mesocosm experiment was conducted at the Sevilleta National Wildlife Refuge during the summer of 2009, at a site immediately adjacent to the Rio Grande mainstem, a short distance upstream of the confluence with the Rio Salado (13S, 328968 E, 3794181 N – UTM). Twenty-four round stock tanks (diameter ~1.5 m, depth ~0.5 m) were set up in a six-by-four array along the main channel of the Rio Grande. After each tank was filled with ~10 cm sediment from the surrounding floodplain soils, river water was pumped to fill the tank (depth of ~40 cm) on 26 May 2009. Using sediment and water directly from the floodplain and river provided the least biased method for introducing aquatic invertebrates; thus the initial mesocosm invertebrate community was a product of whichever taxa occurred in the river and the floodplain soils (resting stages) at the time. Additionally, allowing mesocosms to be naturally colonized produces the best replicability of individual tanks (Harris *et al.*, 2007). Tanks were allowed to equilibrate for three days before being stocked with fishes (29 May 2009). YOY fishes were collected with a fine-mesh seine from a nearby backwater (13S, 325958 E, 3777695 N – UTM) and immediately transported to the mesocosms. Fishes (roughly 5 mm to 10 mm standard length (SL)) were transferred to treatment tanks with fine-mesh aquarium nets while attempting to equalize density (approximate to natural conditions) and minimize mortality. Fishes could not be identified to species prior to introduction without substantial mortality; thus, we could not control the species stocked.

In order to mimic different levels of association with the riparian environment, a leaf litter treatment was cross-factored with the fish treatment (Fig. 1). The treatment allowed for a comparison between high and low interactions with the riparian area, which are indicative of the location of pool formation relative to the main channel during dry down. This treatment also addressed the importance of allochthonous carbon in fish diets and invertebrate community shifts. In the middle Rio Grande, the majority of allochthonous carbon is provided by leaf litter of cottonwood trees (*Populus* sp.). Thus, the terrestrial carbon treatment consisted of dried cottonwood leaves (300 g per mesocosm) taken from the leaf litter in a riparian area. Leaves were introduced to the appropriate tanks after filling them with water. Once settled, the leaves provided a thin cover over the entire surface of the benthos.

Weekly sampling began on 2 June 2009 (four days after stocking fishes), and continued for six consecutive weeks thereafter. At each sampling period, water quality and physical parameters (i.e., dissolved oxygen, temperature, salinity, conductivity, pH, turbidity and depth) were measured using a YSI Model 85 Multiparameter Meter and a LaMotte 1970-ISO 2020wi Kit portable turbidity meter. Three fish from each treatment tank were collected with fine mesh aquarium nets and preserved. Invertebrates were collected using a randomly placed stovepipe sampler (14.75 cm in diameter) and hand operated bilge pump, which enabled us to sample both the water column and the benthos. One stovepipe sample per mesocosm was sieved using a 45 μ m stainless mesh sieve and preserved. Algae and macrophytes were also preserved where sufficient material (four dry mg) for stable isotope analysis was present. During the last week of sampling, each mesocosm was entirely emptied of its contents following regular sampling (data in Appendix B). All

macroinvertebrates and fishes were collected and preserved to gain an idea of the total contents of each tank. All tissue types were preserved in 70% ethanol (EtOH).

Sample Processing: Invertebrates

Invertebrate samples were washed and sorted by hand using dissecting microscopes with up to 75x magnification. All invertebrates in each sample were removed, separated according to taxon and enumerated. Identification was to the lowest practical taxonomic level, typically to genus or family for all those except microcrustaceans, which were generally identified to the ordinal level. Identifications are according to Merritt *et al.* (2010) and Smith (2001). Those specimens which were not whole were only counted if the head of the organism was present to avoid counting any individual twice.

Fishes

Once in the laboratory, all fishes were identified to the species level, measured for standard length and the life stage was recorded according to Snyder (1976 & 1981). Gut contents were removed and analyzed for the fishes taken during sample weeks two, four and six. Although the treatment design incorporates six replicates of each treatment, only three replicates were fully analyzed for each, due to time constraints associated with sample processing. As such, six fish mesocosms were processed per week; three from each of two fish treatments (YOY fishes and leaf litter, YOY fishes without leaf litter). There was only one instance of scarcity (during week two) in fishes such that we were not able to take a full sample (three fish). As three fishes were removed at each sampling period per mesocosm, the YOY fishes sample size is 53 (3 fish x 2 fish treatments x 3

replicate tanks x 3 sampling periods, minus 1 - the instance in which only two fish were sampled).

For gut content analysis, the gut tube, from esophagus to anus, was completely removed from each fish. Forceps were used to open the tube and remove its contents. Diet items were then spread out in a petri dish. Invertebrate items were identified to the lowest practical taxonomic level (typically to family; order for microcrustaceans). Each taxonomically distinct group was enumerated and quantified using surface area (mm^2). Individuals that were not identifiable were grouped as “unidentified” (and are hereafter referred to as such). Where only a fragment of an organism was found, it was counted as one individual unless it could be paired with other fragments (Bowen, 1996). If a fragment was unidentifiable, it was grouped with other such invertebrate fragments and referred to as “invertebrate fragments” (and so called from here forward). Diet items of substances other than invertebrates (e.g., detritus) were quantified only by surface area (mm^2). The only exception is for a specific type of detritus for which a count is also reported. Attempts to identify the seed-like, detrital component (via plant, algal and fungal experts) produced no conclusive identification.

Stable Isotopes

While gut content (i.e., diet) data are informative, they capture only a snapshot of overall diet and do not consider whether ingested items are incorporated into tissues. To gain a perspective on item integration and to understand trophic structure, we used stable isotopes (nitrogen and carbon) (Larimore, 1957; Fry, 1991). In our mesocosm experiment, each trophic level (i.e., primary producers, macrophytes, invertebrates and

fishes) was sampled, where possible, to characterize the food web in terms of carbon and nitrogen, allowing a comparison across time steps and treatments.

For fishes, muscle tissue from the right caudal peduncle was extracted. Skin and scales were removed before further processing. Where this did not yield enough tissue, both caudal peduncles were taken, and where necessary, tissue from the anterior portion of the fish was removed. Where possible, only muscle tissue was used, but on the smallest individuals, bone and skin were sometimes needed to produce enough dry weight (one dry mg) to analyze (Minagawa & Wada, 1984; Hesslein *et al.*, 1991). While there is concern surrounding the issue of the incorporation and fractionation rates of different tissues, multiple authors (Kelly *et al.*, 2006; Andvik *et al.*, 2010) have found a strong correlation between fin (bone and skin) and muscle tissues in juvenile pallid sturgeon (*Scaphirhynchus albus*). Similarly, Pinnegar & Plunin (1999) found that variance in carbon isotope values of rainbow trout juveniles (*Oncorhynchus mykiss*) was due largely to lipid content rather than differences between muscle, bone and skin tissues. In this study, no further measures were taken to account for lipid content beyond preservation. Regardless, only the smallest (i.e., youngest) individuals required multiple tissue types, so the period of exogenous feeding prior to sampling was minimal. Invertebrates required no additional preparation beyond identification and enumeration, except for taxa occurring in shells (e.g., *Physa* sp.). In these instances, soft tissue was removed from the shell prior to isotopic analysis. Algal, macrophyte and detrital tissue samples were manually cleansed of invertebrates prior to analysis.

Tissues were freeze-dried and ground to a fine powder. For fishes and invertebrates, approximately one dry mg of tissue was extracted and encapsulated in a 3.5 x 5 mm tin

capsule prior to being analyzed. Algae, macrophytes and detritus were dried and ground in a similar manner, but measured to approximately four dry mg and encased in a 5 x 9 mm tin capsule.

Carbon and nitrogen stable isotopes were analyzed at the Earth and Planetary Sciences Stable Isotope Laboratory at the University of New Mexico, Albuquerque, NM. Evolved CO₂ and N₂ gases were analyzed on a Finnigan Mat Delta Plus isotope ratio mass spectrometer. Ratios of stable isotopes are reported in parts per thousand (‰, or per mil) in delta (δ) notation. Delta values are computed using the following equation:

$$\delta^{13}\text{C} \text{ or } \delta^{15}\text{N} = [(R_{\text{sample}}/R_{\text{standard}}) - 1] \times 1000 \quad (\text{Eq. 1})$$

where R is equal to ¹³C/¹²C or ¹⁵N/¹⁴N (Fry, 2006; Sharp, 2006). Delta values are reported relative to standards of Vienna Pee Dee belemnite limestone (VPDB) for carbon and air for nitrogen. Reproducibility of carbon and nitrogen delta values was within 0.3‰ based on concurrent runs of samples of known isotopic composition.

Data Analysis

Abundances derived from stovepipe samples represent invertebrate communities and correspondingly depict prey availability to YOY fishes. Using these data, invertebrate density (number of individuals per cubic centimeter) and diversity were estimated for each sample. Diversity was calculated using the Shannon-Weaver Diversity Index (Shannon & Weaver, 1963):

$$H' = - \sum_{i=1}^R p_i \ln p_i \quad (\text{Eq. 2})$$

where p_i is the proportion of individuals belonging to the i^{th} taxon, of a total of R taxa.

Diversity and density were compared across time steps and between fish and leaf treatments using analysis of variance (ANOVA). Abundances were further compared between tanks with “Fish” and “No fish” treatments as a surrogate for shifts in invertebrate community behavior in the presence of fishes.

To evaluate treatment effects on invertebrate assemblage composition, we first used non-metric multi-dimensional scaling (NMDS) plots to visualize differences in invertebrate communities in individual mesocosms. The purpose of NMDS is to reduce dimensionality of data to allow revelation of factors important in determining trends related to environmental variables (Dale, 1975; Kenkel & Orłóci, 1986). Stress values are reported to indicate the fit of these multi-dimensional datasets in two dimensions.

Permutational multivariate analysis of variance (PERMANOVA) procedures were used to test statistical differences between factors influencing these communities.

PERMANOVA is designed to test the relative effect each treatment (fishes, leaves and time) has on community composition. PERMANOVA is similar to multivariate analysis of variance (MANOVA), but includes a permutation procedure which eliminates the need for normal distributions of dependent variables. The response of these variables to each factor are then determined (per traditional MANOVA procedures).

Ontogenetic changes in diet were accounted for by grouping YOY fishes according to standard length (SL) in two mm intervals. Standard length provided the best way to categorize fishes while providing roughly equal sample sizes. Life stages are reported for each fish, but the majority of fishes were in the juvenile life stage. Sampling week, or time, also provided biases given the differential growth rates observed in individual

mesocosms. The proportions of the five most important diet items were given for each size class based on surface area (SA) and raw numbers.

To analyze stable isotopes, the metrics outlined in Turner *et al.* (2010) were used. These methods evaluate position of isotope ratios in bivariate space (carbon and nitrogen biplots) to make statistical inferences about changes in trophic structure based on metrics of Layman *et al.* (2007). For invertebrate stable isotopes, Example 1 from Turner *et al.* (2010) was used. These metrics use a residual permutation procedure (RPP; 999 permutations) and nested linear models to calculate differences in centroid location and dispersion between functional groups. Specifically, three metrics were calculated: the Euclidean distance in isotope space between group centroids (CD), the mean distance between nearest neighbors (NND) compared across treatments and the mean distance to centroid from surrounding points (MDC). Statistics reflect whether differences between treatments differed significantly from zero. This method was used to test niche breadth of invertebrate points in isotope space between those derived from fish and fishless tanks (Bearhop *et al.*, 2004; Layman *et al.*, 2007; Martínez del Río *et al.*, 2009).

To analyze overall trends in fish diet, the amount of change in carbon and nitrogen isotopic composition of fish tissues was tracked. Some variance observed in isotopes of fishes (largely carbon) is due to the relative composition of autochthonous and allochthonous resources in individual tanks. Correspondingly, the values for the isotopes of fishes were compared between leaf treatments to assess how well changes in carbon resources were transmitted to higher levels of the food web.

Results

Physical Parameters

Water quality parameters varied greatly over time (Fig. 2 & Fig. 3) (data in Appendix E). As expected, temperature increased and depth decreased with each successive sampling period. The two are likely correlated as greater surface area to volume ratios will gain heat more efficiently. The amount of change in depth was fairly constant across all mesocosms from week to week, although the between tank depth showed some variation. Generally, the mesocosms which were farthest away from the main river channel and the associated riparian vegetation had lower values for depth at each sampling period. This is illustrated in Figure 2 by the decrease in depth (within a single sample week) over groups of four mesocosms (e.g., mesocosm one is closest to the main channel, mesocosms two, three and four are increasingly farther from the main channel). Only one mesocosm dried completely by the last sampling period (mesocosm 24).

Similarly, there were changes over time in each of the physical parameters measured. The leaf treatment was associated with variation in physical characteristics and is shown in Figure 3. On average, dissolved oxygen, pH and turbidity were greatly reduced in leaf treated tanks, while salinity and specific conductivity were generally higher. In both treatments, there was an increase in all parameters over time. Again, this is likely due to an interaction with decreasing depth. Oxygen saturation will increase as volume depletes, and there will be concentration of particulate and dissolved mater (i.e., turbidity), hydrogen ions (i.e., pH) and salts (i.e., salinity and conductivity) as evaporative processes lower water level.

Invertebrates

Density of invertebrates (cm^{-3}) was calculated for each mesocosm across treatments and sample weeks (Fig. 4) (data in Appendix A). In all treatments, there is a general increase in density over time. This is likely due to the concentration effect of dry down of the tanks. The ANOVA for the effect of time on density was significant only for the leaf treatment (p-value 0.015 for leaves, 0.097 for bare ground), suggesting significant increase in density over time in leaf treatments. Water levels in the mesocosms decreased 21 cm on average over the six week sampling period. Invertebrate density was not influenced by the presence of fishes (p-value 0.474 in the bare ground treatment, 0.981 in the leaf treatment). There are a few instances of abnormally high density in individual tanks (i.e., tanks three and four from the bare ground/fish treatments, tank five in the leaf litter/fish treatment). In each of these instances, the invertebrate fauna is dominated by an anomalously large number of meiofauna – 1.61 copepods (Copepoda), 1.28 cladocerans (Cladocera) and 2.57 copepods per cubic centimeter respectively (per sample). These numbers can be compared to the 0.059 copepods and 0.049 cladocerans per cubic centimeter seen in a given sample on average.

To further investigate this phenomenon, diversity was calculated for each mesocosm using the Shannon-Weaver Diversity Index (Fig. 5). Diversity was stable across time (p-values 0.362 and 0.874 in bare ground and leaf treated tanks, respectively) and fish treatment (p-values 0.087 and 0.517 for bare ground and leaf treated tanks, respectively), with the differences between treatments not differing significantly from zero. The stability of diversity over time is likely due to the turnover of taxa within a tank; as one taxon decreases in abundance, another propagates to take its place. Additionally, the

tanks with unusually high densities, while containing large densities of copepods and cladocerans, also contain relatively large numbers of other meiofauna to bolster diversity (e.g., copepod nauplii and nematodes (Nematoda)).

Based on density and diversity figures alone, it would appear that fishes have little to no impact on general invertebrate abundance. However, the impact on specific invertebrate taxa needs to be addressed. We compared the total abundance of each invertebrate taxon in tanks with fishes against abundances in tanks with no fish treatment (Fig. 6). This relationship generally fell along a 1:1 ratio line, although deviations occur largely according to invertebrate size. Larger-bodied and less abundant items ($< 10^2$ individuals) appear too infrequently to evaluate deviation from a 1:1 ratio. These taxa include beetles (Coleoptera), fly larvae (Diptera), and assorted true bugs (Hemiptera). Those larger taxa which were slightly more abundant tend to fall above the 1:1 line suggesting they were found more frequently in tanks without fishes than with. A few smaller-bodied meiofauna (abundances $> 10^3$ but $< 10^4$ individuals) fell above the 1:1 line and exhibited lower abundance in mesocosms with fishes. Other, more abundant meiofauna ($\geq 10^4$ individuals) were small-bodied microcrustaceans that fell along or just below the 1:1 line and thus were proportional across treatments or slightly less abundant in tanks without fishes.

NMDS plots (Fig. 7) produced a stress value of 0.14, a relatively good approximation of the data. The differences between invertebrate communities across leaf treatment and time are the most pronounced. Fish treatment also exhibits partitioning, but to a lesser degree. Invertebrate communities are more variable (occupy more NMDS area) under the leaf treatment than the bare ground treatment, suggesting a change in resources can

impact the community structure. Many of these divergent tanks are also those treated with fish, suggesting an interaction between the two treatments. With respect to time, the invertebrate community is more similar (clustered) in the sixth (late) sampling period than in the second (early) sampling period, with the fourth sample week being intermediate in variation.

PERMANOVA revealed each treatment (leaves, fishes and time) had a highly significant effect on the observed community structure of invertebrates (Fig. 5), although total model r^2 was only 0.44. This low explanatory power is likely due to the inherent variability of individual mesocosms (Caquet *et al.*, 2001; Wong *et al.*, 2004; Matthews & Marsh-Matthews, 2006). Similar to the conclusions from the NMDS plots, the presence of leaves and sampling week had the largest effect on invertebrate community composition (p-values = 0.001; r^2 = 0.111 and 0.133, respectively). However, the fish treatment is also highly significant with a p-value of 0.005 and r^2 of 0.031. The interaction of treatments also played a significant role in shaping the invertebrate community. For example, the change in influence of leaves over time is significant (p-value: 0.001; r^2 : 0.086). The interaction of leaves and fishes approaches significance with a p-value of 0.061 (r^2 = 0.019). Additionally, the interaction of all three treatments, fish presence, leaves and time is significant (p-value: 0.02; r^2 : 0.037). Interaction of fish presence and time was found to be non-significant (p-value: 0.33, r^2 : 0.021) suggesting that although there is a significant impact of YOY fishes on the invertebrate community, the degree of influence does not change over time.

Fishes

Species composition of fishes used for gut content analysis was determined in the laboratory after preservation (data in Appendix C). Identification revealed one river carpsucker (*Carpionodes carpio*), two common carp (*Cyprinus carpio*), six western mosquitofish (*Gambusia affinis*), 38 Rio Grande silvery minnow (*Hybognathus amarus*), five fathead minnows (*Pimephales promelas*) and one flathead chub (*Platygobio gracilis*) in our samples. Table 1 illustrates the growth of the fishes over time, except in the case of *G. affinis*, which reproduced in two of the tanks used in gut content analysis before the last week of sampling (thus the low SL numbers in week six). For all other species, an increase in growth is seen between sample periods and represents a different stage in ontogeny at each interval. Differences in behavior and feeding of fish species are not addressed here as the sample size for each species differs greatly and approximately 75% of fishes in the gut content analysis were Rio Grande silvery minnow.

The contents of fish guts are presented in Table 2. Prey items were examined by raw number and by surface area. Some taxa (e.g., Copepoda) differed greatly in their contribution to diet according to which metric was used (likely due to small body size coupled with great abundances). While rank importance differed slightly for these taxa, the most abundant taxa were generally the same for both metrics. The deviation between surface area and raw number observed in some taxa (e.g., Chironomidae) is largely due to the large proportion of gut contents which were unidentifiable digested materials. Non-biting midges (Chironomidae) and copepods are the two most important prey items regardless of the measure used. Together, chironomids and copepods compose 70% of total diet items by number and 35.3% of the identifiable material measured for surface area (only 30.6% surface area was identifiable material). Other abundant items such as

spring-tails (Collembola), segmented worms (Oligochaeta) and water boatmen (Corixidae) also fell out among the more abundant diet items in both categories. Interestingly, terrestrial and semi-terrestrial invertebrates (e.g., thrips (Thysanoptera), spring-tails and adult flies) are among the more abundant items in the gut contents. Additionally, white plant matter resembling seeds was also one of the more abundant items.

Changes observed in diet based on standard length of fishes were minimal (Fig. 8). Cladocerans were more prominent in gut contents in the smallest individuals and almost absent in all other size categories. Conversely, terrestrial items were not as abundant in the smallest SL category, but were approximately equal in all larger SL categories. There was little change in consumption of chironomids and copepods, although each taxon has a peak in the smallest and largest categories, respectively. In the case of chironomids, this may be due to the overall larger size of the prey item in small fishes when examined by surface area. Terrestrial and semi-terrestrial diet items peak in importance in the mid-sized fishes (SL = 16-17.99), and diminish in abundance in the smallest and largest fishes.

The differences in abundance of invertebrate items in gut contents (by number) and in the mesocosms were generally more distinct in mesocosms treated with leaf litter (Table 3). Chironomids, thrips, oligochaetes, mosquitoes (Culicidae), adult flies and spring-tails were preferential diet items, each making up a larger percentage of the gut content than the mesocosm community. Chironomids were the most preferred food item, making up 21.2% of the gut content of the fishes, but only 4.9% of the invertebrate community derived from leaf-treated mesocosms. Feeding preference patterns diminish in tanks

which received no leaf litter, as invertebrate taxa are found in the gut contents in numbers that are roughly proportional to the community in the mesocosms. Terrestrially derived diet items such as thrips and spring-tails appear to be proportionally more important in fish diets than predicted based on their abundance in tanks. Additionally, the white plant matter resembling seeds is nearly as large a component of the diet as chironomids, but abundance data in the tanks is lacking as detrital matter was not necessarily kept in the invertebrate stovepipe samples. This component is also thought to have been terrestrially-derived. In some instances, the gut contents (by number) were more diverse than the pool of existing invertebrates in the tank from which the fishes were removed, due to the large proportion of terrestrial items in the gut contents.

Stable Isotopes

To assess indirect effects YOY fishes may have had on invertebrate community and behavior, we used stable isotope analyses to track the movement of nutrients through the food web (data in Appendix D). Differences in trophic structure and utilized niche space between mesocosms were then found. Dispersion of isotope ratios in bivariate space for invertebrates was larger in mesocosms without YOY fishes than in those with fishes (Fig. 9). The difference between treatments in each metric outlined by Turner *et al.* (2010) was highly statistically different from zero: Euclidean distance between centroids was 2.12 (p-value 0.002), NND was 1.26 (p-value 0.001) and CD was 0.42 (p-value 0.005). The difference applies to the invertebrate community as a whole, but a taxon-specific analysis is needed to draw further conclusions.

Changes in isotope values for specific invertebrate taxa were analyzed to see if there were taxon-specific effects induced by fishes (Fig. 10). Data was not available for every taxon so this analysis was limited to those which were in great enough abundance to have produced at least one dry mg of tissue from both fish and fishless tanks. Each taxon was then averaged over all points to develop a centroid to represent the taxon (see error bars). There is a general depletion in both the carbon and nitrogen ratios from the “No fish” treatment to the “Fish” treatment. There are a few instances of enrichment in carbon and nitrogen, although to a relatively smaller degree. When delineated by functional feeding group, this change is similar between groups. Collectors exploit a different suite of dietary sources than do YOY fishes, and may not be constrained by fishes as competitors. While we might have expected enrichment to occur in collectors, or those taxa not in direct competition with fishes, the trend does not differ from that of the predators. It is also worth noting that the taxa examined here are largely coleopterans, of which only three individual larvae were found in gut contents. However, the taxa that were found in gut contents (Copepoda; Ephemeroptera – represented here by Baetidae and *Centroptilum*), do not differ substantially from other taxa in the stable isotope response to the presence or absence of fishes.

Because we are only addressing shifts in the invertebrate community with respect to fish treatment, it is helpful to examine the community at a finer scale to determine how much of this variation is due to the leaf treatment and its interactions with the fish treatment, as opposed to the fish treatment alone (Fig. 11). When fish are not present (Fig. 11 B & D), the carbon values of our data tend to follow the expected decrease associated with a change from autochthonous to allochthonous resources (p-value 0.001, MD). When

leaves are not present (Fig. 11 C & D), carbon values are more enriched in the absence of fish (p-value 0.001, MD). Invertebrate carbon values are also more dispersed under these treatments (p-value 0.004, MDC). In the case where fish are present (Fig. 11 A & C), the community does not show the expected shift in carbon values associated with autochthonous and allochthonous resources, but remains depleted regardless of whether leaves are present. This suggests some kind of constraint (in the tanks stocked with fishes) that requires invertebrates to rely on allochthonous resources even when detritus is relatively scarce.

The question is then whether or not this constraint is due to the presence of YOY fishes in these mesocosms. Figure 12 shows the isotope values of the fishes, divided amongst leaf treatments. The fish isotopes also are subject to change in the carbon dimension based on the available carbon in the tank. In the leaf treatment, fishes exhibit more depleted values than they do in the bare ground treatment (p-value 0.001, MD). Those from the bare ground treatment also have a much narrower range of carbon values, although a larger range in nitrogen values (p-value 0.074, MDC; p-value 0.055, MNN). The bare ground treatment fishes have a slightly higher nitrogen value than those in the leaf treatment, suggesting they may be feeding at higher trophic levels. These changes, particularly those in the nitrogen dimension, may also be due to ontogenetic changes in diet as the fishes grow.

Ontogenetic changes in resource use in fishes were mapped by plotting fish isotope values according to sample week (Fig. 13). There is substantial overlap between sample weeks (p-values 0.124, 0.069 and 0.261, MDC for comparisons of weeks two to four, two to six and four to six, respectively). Fishes are more clustered (largely in the carbon

dimension) in week two (early sample period) and in week six (late sample period) than in week four (p-value 0.001 and 0.023, MDC for comparisons of weeks two to four and four to six, respectively). Fishes are utilizing the most isotopic niche space in week four rather than weeks two or six. This suggests that there is not a significant shift in diet overall, but that there are slight differences in diet from week to week.

Discussion

In the mesocosm experiment, our predictions that young-of-year fishes would have an impact on the invertebrate community were generally supported. While some invertebrate taxa were consumed preferentially, the indirect response of invertebrate taxa was similar across the community. Preferential diet items were identified, but only in the leaf-treated mesocosms. Additionally, invertebrate resource use was altered in the presence of YOY fishes, even in taxa that are not necessarily predated upon. While community composition was affected by the presence of YOY fishes, density and diversity were generally not.

Physical Parameters

A convergence was observed in the physical environment of the mesocosms over time (Figs. 2 & 3). Abiotic factors likely played a role in the convergence of invertebrate community. Increased temperatures and decreased depth may provide conditions for which certain species are better adapted. The increases in salinity and turbidity over time may have a similar effect. Although there were slight differences in initial conditions, convergence was seen in tanks that received different leaf treatments. A potential explanation for similarities across leaf treatments is the decomposition of leaf matter and

subsequent release of nutrients. Prior to decomposition of leaf matter, in-stream production is limited because the substrate is largely covered and all available nutrients are being utilized by fungi associated with the decomposition of leaves (Suberkropp & Chauvet, 1995). As leaves break down, nutrients are released and in-stream production increases. Once nutrients are no longer bound in the decomposition of leaves, nutrient and turbidity levels may converge between treatments, and invertebrate community structure may follow. This relationship has been previously well documented (Webster & Patten, 1979; Newbold *et al.*, 1980). This may also be a factor in the lower turbidity observed in leaf-treated mesocosms (i.e., limitation of phytoplankton growth due to immobilization of nutrients).

Invertebrate Density

Our analysis of invertebrate density illustrates the tendency for individual mesocosms to vary greatly in terms of invertebrate communities (Matthews & Marsh-Matthews, 2006). In a few cases, density was several orders of magnitude higher than other tanks at the same sampling period (Fig. 4). In these instances, invertebrates were dominated largely by one or a few meiofaunal taxa (e.g., Copepoda). With higher reproductive rates and shorter generation time, meiofauna, under the appropriate conditions, are able to greatly outnumber the majority of other invertebrate taxa (Morin & Nadon, 1991). This concept also corresponds with our comparison of abundances in tanks with and without YOY fishes (Fig. 6) where copepods are roughly proportional across treatments. Abundances of microcrustaceans may thus be regulated by other factors (i.e., density-independent factors). Additionally, early instars are small-bodied and may be occupying a “size-refuge” that allows them to be relatively invulnerable to predation (Bechara *et al.*, 1993).

In other words, the relatively small size of prey items contributes to a lack of predation by fish predators due to the tendency of fish, as visual predators, to predate larger-bodied prey items where possible (Brooks & Dodson, 1965; Dineen & Robertson, 2010).

YOY Feeding Preferences & Invertebrate Community Structure

Hypothesis testing via PERMANOVA indicated that fish presence alone accounts for a significant proportion of variation in invertebrate community structure. Although densities were not significantly impacted by the presence of fishes, species compositions were. This likely corresponds with the preferential feeding observed in leaf-treated mesocosms (Table 3). Previous work has suggested that lower turbidity (as seen in leaf-treated tanks) may afford fishes the opportunity to be selective, visual predators (Hayes & Rutledge, 1991). Because turbidity was lower in leaf-treated mesocosms and fishes had the opportunity to be selective (Nurminen & Horppila, 2006), certain items were selected for under these conditions. This pattern has been shown in headwater rainbow trout (*Oncorhynchus mykiss*) (Nakano *et al.*, 1999), but is not well demonstrated among other taxa or larger-order streams.

Chironomids, copepods, cladocera, and oligochaetes, along with a suite of terrestrial items, were the most preferred diet items for YOY fishes. Allochthonous inputs are generally thought to be less important to aquatic food webs than autochthonous sources in desert rivers (Bunn *et al.*, 2006a) because terrestrial plant matter represents a less labile resource than does autochthonous carbon. However, Yonekura *et al.* (2009) suggests that subsidies of terrestrial resources (i.e., invertebrates) may also represent a higher growth benefit than autochthonous sources alone. We surmise that this deviation from traditional

arid-land river dynamics is due to the close association with riparian areas in our experimental design and the relative ease for fish to catch large, immobile prey items (Stephens & Krebs, 1986; Wright & O'Brien, 1982). The utilization of both in-stream and riparian food sources may ultimately be beneficial to a community under density-related stressors (Faria & Costa, 1999).

The impact of YOY fishes over time may be influenced by natural changes (i.e., succession) of invertebrate communities. Invertebrate communities are the most variable among tanks in the earliest sampling week and become more similar over time (Fig. 7). Drying of individual tanks naturally coincides with increase in temperature (increase of 6.63 °C from week two to week six on average), increased invertebrate density (due to concentration effects) and a decrease in available resources (e.g., pelagic habitat). Changes in community composition over time also coincided with emergence, and thus loss of representation, of those invertebrates which exhibit a terrestrial life stage (e.g., Odonata). All of these elements may contribute to convergence of invertebrate communities in replicate tanks over time and our data suggest these processes occur indiscriminately with respect to fish or leaf treatments.

There is an interaction term for fishes and leaf litter which likely highlights the tendency of YOY to become more selective under leaf treatment conditions. Again, this ability may be tied to the abiotic conditions associated with the leaf treatment. The interaction of fish presence and time is insignificant suggesting the impact of YOY fishes does not change over time. Additionally, the stability observed in the most important diet items relative to standard length (Fig. 8) suggests there was no significant change in diet. This is contrary to the findings of Cushing (1983), where it was demonstrated that the marine

larvae of haddock (*Melanogrammus aeglefinus*) became more effective predators over time (despite a decrease in population size due to mortality) and a subsequent change in prey items was observed. This deviation may be due to the relatively longer period of development of haddock and the extended period of observation by Cushing (1983). Cushing (1983) describes a sharp increase in predation by larvae when fins are developed. This particular feature coincides with the earliest samples of our own mesocosm fishes. Additionally, diet may be less variable throughout ontogeny in harsh environmental conditions typical of the Rio Grande during summer dry down.

Indirect effects: Stable Isotopes

Variation in the invertebrate stable isotopes was due to both fish and leaf treatments. While some invertebrate shifts were due to change in carbon resource (leaf treatment vs. no leaf treatment), the expected change in carbon value for invertebrate tissues was not seen in tanks stocked with fishes (Fig. 11). Carbon values of fish tissues did exhibit the expected change, suggesting that they are feeding on resources with autochthonous carbon integrated into tissues. This decreased dispersion of invertebrate isotope values in the presence of YOY fishes (Fig. 9) suggests a decrease in the utilized niche space. This could be due to fish predation on these outlying invertebrates or differences in resource use by invertebrates in the presence of fishes. Predator avoidance and the ability of indirect responses to affect food web structure have been well documented (Carpenter *et al.*, 1985; Turner & Mittelbach, 1990; Turner 1996). A change in resource use could indicate predation evasion or competition with fishes for food resources. In either scenario, the differences in centroid, dispersion and nearest neighbor indicate an increase in resource overlap between invertebrates in the presence of YOY fishes. Increased

resource overlap by the invertebrate community likely means greater pressure on resources (e.g., food) in an increasingly harsh environment.

This idea that trophic niche space of invertebrates is greater in the absence of fish predators is further supported when we address the stable isotope analysis of YOY fish tissues with respect to leaf treatment. The same shift from enriched to depleted carbon values is seen when leaves are added as a treatment (Fig. 12). However, the range of carbon values is much higher for the fish community than the invertebrate community under this condition. While fishes' isotope values expand to include the more depleted values associated with terrestrial carbon, in-stream resources are still being used, as is illustrated by those fishes occupying the more enriched carbon isotope space. This suggests the ability to utilize either resource when given the opportunity, a beneficial strategy as demonstrated by Faria & Costa (1999) and Yonekura *et al.* (2009).

Invertebrates do not follow this pattern, either because they are exhibiting predator avoidance, or the majority of those which do utilize in-stream resources when leaves are present are quickly consumed by fishes. In either case, invertebrates are constrained to less biologically available resources (terrestrial carbon) in the presence of fishes.

Clustering of invertebrates in isotope space indicates overlap of isotopic and presumably dietary niches. However, taxon specific changes in invertebrate values did not differentiate according to functional feeding group. If competition were an important factor, one would expect to see the greatest change in predatory invertebrates. It appears that depletion in both nitrogen and carbon in invertebrates occurs indiscriminately and across the entire community in the presence of YOY fishes (Fig. 10). In increasingly

harsh systems, limited resources may not be able to sustain increased competition for long.

In addition to the composition of invertebrate communities, patterns in the stable isotopes of fish tissues may be related to the convergence seen over time in invertebrate communities. The carbon values of fishes in week two exhibit a narrow range (Fig. 13). This could be due to the morphological limitations of fishes (e.g., gape limited food intake) (Wainwright & Richard, 1995) as well as the beginning of succession for invertebrates. As invertebrate communities develop (week four), fishes are able to utilize additional food sources that have become more abundant in the succession of the tank (e.g., meiofauna). At the last sampling period (week six), abiotic conditions were harsh, invertebrate communities converged (Fig. 7) and YOY isotopes were again somewhat constrained. Similar invertebrate successional dynamics were seen by Hill *et al.* (2004) in subtidal communities following disturbances. The eccentricities of changes observed in fish isotope values follow the successional dynamics of the invertebrate community well. Sampling of the invertebrate community for stable isotopes over time, which was not feasible in this study, would greatly benefit further investigation of this idea.

Based on the combined data sets for invertebrate community, fish gut content and stable isotopes of the various trophic levels of our mesocosm experiment, we have shown that young-of-year fishes do play a role in the food webs of drying, arid rivers. Although the structure of the invertebrate community appears to be impacted by both bottom-up and top-down processes, there is an individual influence from each and an interaction of the two. Little impact was observed from either in terms of density or diversity, but community structure differed greatly in terms of invertebrate taxa present, and those taxa

which were dominant. Preferential feeding patterns were seen for YOY fishes, something that was enhanced in situations with excess terrestrial carbon inputs associated with low turbidity. In these instances, chironomids and copepods proved to be the most preferential diet items, closely followed by a suite of terrestrially-derived diet items. This illustrates the tendency for YOY fishes to make metabolically efficient diet choices, given their increased need for energy in early life stages and in harsh environmental conditions. Additionally, we have illustrated the indirect effects on invertebrate community imposed by the presence of YOY fishes in drying pools with limited resources. While instances of predation were observed, so were instances of predator avoidance and/or competition by co-occurring invertebrates.

Future Research

Future developments in this field would be greatly advanced by species-specific examinations of invertebrate behaviors in similar systems. While identification of invertebrate diet items (removed from fish gut content) can rarely be done to the species level, stable isotope analyses of invertebrates in the presence of YOY fishes needs to be developed to a greater extent. Additionally, this study did not address the role of adult fishes, which may act as predators and/or competitors to YOY fishes. How the interactions illustrated here are changed by the presence of a top predator needs to be examined in order to fully understand trophic interactions in drying, arid rivers.

APPENDIX A. Invertebrate community data.

Week	Mesocosm	Leaves	Fishes	<i>Aedes</i> larva	<i>Aedes</i> pupa	Baetidae nymph	<i>Berosus</i> adult	<i>Berosus</i> larva	Calanoida	<i>Callibaetis</i> nymph	Carabidae adult	<i>Centroptilum</i> larva
2	1	no	fish			1						
2	2	yes	none			1						
2	3	no	fish									
2	4	no	none			1						
2	5	no	none			1						
2	6	no	fish			3						
2	7	yes	none			1						
2	8	yes	fish									
2	9	yes	fish									
2	10	no	none			6						
2	11	no	fish									
2	12	yes	none			8						
2	13	yes	none		2							
2	14	yes	fish	2								
2	15	no	none			22						
2	16	no	fish									
2	17	no	fish									
2	18	yes	none			4						
2	19	yes	fish									
2	20	no	none			1						
2	21	no	none			3						
2	22	no	fish			2						
2	23	yes	none			4						
2	24	yes	fish									
4	1	no	fish			1						
4	2	yes	none			7						
4	3	no	fish		4	1						
4	4	no	none			2						
4	5	no	none									
4	6	no	fish									
4	7	yes	none									
4	8	yes	fish									
4	9	yes	fish			4						
4	10	no	none			3		1				
4	11	no	fish			4						
4	12	yes	none			1						

APPENDIX A. Continued.

Week	Mesocosm	Ceratopogonidae larva	Ceratopogonidae pupa	<i>Chaoborus</i> larva	Chironomidae larva	Chironomidae pupa	Cladocera	Collembola	Copepoda	Copepoda nauplii	Corixidae nymph	<i>Culex</i> larva
2	1				67		1		34		5	
2	2				2							
2	3				15							
2	4	1			618		24		42			
2	5				123		287		73			
2	6				18		11					
2	7				1					1		48
2	8				3							
2	9				9							
2	10				527		79			1665	1	
2	11				108		5			87		
2	12				20				18	1		
2	13											85
2	14				1				1		1	1
2	15				684		108			182		
2	16				390		1		19		3	
2	17				215	1			1			
2	18				4				3			
2	19				4			1				
2	20				185		6		85			
2	21				531	4	24			95	1	
2	22				373		2			4		
2	23				11	1			1			
2	24				8							
4	1	1			33	1	104		911			
4	2				14							
4	3				28	2	1			58		10
4	4				174	2	1		30			
4	5				106		1		147			
4	6	1			67		183			113	9	
4	7				56		80					
4	8											
4	9				23			1	14	3		
4	10		1		413		301					
4	11				152		92			672		
4	12				14				8			

APPENDIX A. Continued.

Week	Mesocosm	<i>Culex</i> pupa	Culicidae pupa	Culicidae larva	<i>Culistea</i> larva	Curculionidae larva	Cyclopoida	Dytiscidae adult	Dytiscidae larva	<i>Dytiscus</i> larva	Entomobryidae adult	Ephemeroptera adult
2	1										2	
2	2		1	13		1						
2	3			16								
2	4			3								
2	5			1								
2	6											
2	7						18					
2	8			1			1					
2	9			53								
2	10			11			761					
2	11						170					
2	12		4	75								
2	13						2		2			
2	14		1		1							
2	15			2			618					
2	16											
2	17			17								
2	18		3	79								
2	19			1								
2	20			2								
2	21						126					
2	22						42					
2	23		4	129								
2	24						1					
4	1											
4	2			19			120			2		
4	3						110					
4	4			1								
4	5			1								
4	6						585					
4	7			4			2004					
4	8						19					
4	9			1								
4	10						45					
4	11						7188					
4	12		14	47								

APPENDIX A. Continued.

Week	Mesocosm	Ephemeroptera	Ephydriidae pupa	<i>Fallceon</i> nymph	Gastropoda	Gerridae adult	Gomphidae	Harpacticoida	Hemiptera adult	<i>Heterocloeon</i> nymph	<i>Hydraticus</i> larva	Hydracarina
2	1											
2	2											
2	3							1				
2	4											
2	5											
2	6							15				
2	7											
2	8	1										
2	9		2									
2	10									13		
2	11											
2	12		1									
2	13	1										
2	14											
2	15		2									
2	16							1				
2	17		1									
2	18											
2	19											
2	20											
2	21											
2	22											
2	23							7			4	
2	24											
4	1											
4	2	4										
4	3											
4	4							4				
4	5			7			1					
4	6									9		
4	7	12										
4	8											
4	9	4						4				
4	10											
4	11									16		
4	12											

APPENDIX A. Continued.

Week	Mesocosm	Hydrachnidae	<i>Hydrochus</i> adult	<i>Hydrophilus</i> larva	<i>Hydroporus</i> larva	Hydropsychidae nymph	Isotomidae	<i>Laccodytes</i> adult	<i>Laccophilus</i> larva	Nematoda	Notonectidae nymph	Oligochaeta
2	1									2		
2	2											
2	3											
2	4											
2	5											
2	6											
2	7											
2	8											
2	9											
2	10						1			1		
2	11											
2	12									2		
2	13			2								
2	14											
2	15											
2	16									1		
2	17						1					
2	18											
2	19											
2	20											
2	21											
2	22									1		
2	23	1										
2	24											
4	1									12		
4	2											
4	3									2		
4	4											
4	5											
4	6									7		
4	7											
4	8											
4	9									1		41
4	10									3		
4	11											12
4	12				1							

APPENDIX A. Continued.

Week	Mesocosm	Ostracoda	<i>Physa</i>	Rotifera	Syrphidae larva	Syrphidae pupa	Tabanidae pupa	Thysanoptera	Trichoptera	<i>Tropisternus</i> larva	unidentified larva	Velidae adult
2	1							1				
2	2											
2	3											
2	4	2										
2	5							1				
2	6											
2	7											
2	8							0				
2	9				1							
2	10						1					
2	11			1								
2	12					3						
2	13											
2	14											
2	15			112								
2	16											
2	17											
2	18											
2	19											
2	20											
2	21											
2	22	1										
2	23							1				
2	24											
4	1	1	4									
4	2											
4	3		2	148								
4	4											
4	5	1										
4	6	12										
4	7											
4	8											
4	9											
4	10	3						1				
4	11	4		120								
4	12											

APPENDIX A. Continued.

Week	Mesocosm	Leaves	Fishes	<i>Aedes</i> larva	<i>Aedes</i> pupa	Baetidae nymph	<i>Berosus</i> adult	<i>Berosus</i> larva	Calanoida	<i>Callibaetis</i> nymph	Carabidae adult	<i>Centroptilum</i> larva
4	13	yes	none			28						
4	14	yes	fish			4						
4	15	no	none			20						
4	16	no	fish									
4	17	no	fish			3						
4	18	yes	none			1						
4	19	yes	fish			1						
4	20	no	none						1			
4	21	no	none									
4	22	no	fish			3						
4	23	yes	none			3						
4	24	yes	fish									
6	1	no	fish									
6	2	yes	none			9						
6	3	no	fish			7		3				
6	4	no	none			2						
6	5	no	none									
6	6	no	fish				2					
6	7	yes	none			4					1	
6	8	yes	fish					3				
6	9	yes	fish									
6	10	no	none			4						
6	11	no	fish			2						
6	12	yes	none			22	1				1	
6	13	yes	none									
6	14	yes	fish			4		1				
6	15	no	none						5			7
6	16	no	fish									
6	17	no	fish			1						
6	18	yes	none							10		
6	19	yes	fish									
6	20	no	none			3						
6	21	no	none									
6	22	no	fish									
6	23	yes	none			1		2				

APPENDIX A. Continued.

Week	Mesocosm	Ceratopogonidae larva	Ceratopogonidae pupa	<i>Chaoborus</i> larva	Chironomidae larva	Chironomidae pupa	Cladocera	Collembola	Copepoda	Copepoda nauplii	Corixidae nymph	<i>Culex</i> larva
4	13				24		8			2692		
4	14	1			14	1	2		60	12		
4	15				56		500			976		
4	16				353		110		689			
4	17				19				24		1	
4	18				4				150			
4	19				20	1			4			
4	20				370		80		8			
4	21				239		259			355		
4	22				382		117			3	1	
4	23				17		145		109			
4	24				3							
6	1				28		51		416		1	
6	2	18			72	1	9			24		
6	3				79		7			231		
6	4				39		333		643			
6	5	3			108		52		82			
6	6				20		1230			8		
6	7				4	3	12			40		
6	8	5			114						3	
6	9	2			96	2	9			60	1	
6	10				44	1	610				1	5
6	11	1			22		109			20		
6	12				262	18	5					
6	13				31		1			3		
6	14				63		3		964			
6	15	6			89		689		1253		1	
6	16				64		1426			4		
6	17	2			41	4	74				1	
6	18			1	43		258			1131		
6	19				44		4	4	6372		8	
6	20	5			73	6	463					
6	21				128	2	260			244		
6	22						696			16		
6	23	1			27		5					

APPENDIX A. Continued.

Week	Mesocosm	<i>Culex</i> pupa	Culicidae pupa	Culicidae larva	<i>Culistea</i> larva	Curculionidae larva	Cyclopoida	Dytiscidae adult	Dytiscidae larva	<i>Dytiscus</i> larva	Entomobryidae adult	Ephemeroptera adult
4	13			28			932					
4	14											
4	15						1356					
4	16											
4	17											
4	18			4								
4	19											
4	20						109					
4	21			1			296					
4	22						316					
4	23			10								
4	24											
6	1											
6	2		1	9			669					
6	3						877					
6	4											
6	5											
6	6						30					
6	7						263					
6	8						100					
6	9						578		1			
6	10	1					454					
6	11						1577					
6	12		3	9			231	1	2			
6	13			3			227			1		2
6	14											
6	15							1				
6	16						744					
6	17		1				125					
6	18						1557					
6	19											
6	20			1			174					
6	21						922		1			
6	22						1284		4			
6	23		1	1			136					

APPENDIX A. Continued.

Week	Mesocosm	Ephemeroptera	Ephydriidae pupa	<i>Fallceon</i> nymph	Gastropoda	Gerridae adult	Gomphidae	Harpacticoida	Hemiptera adult	<i>Heterocloeon</i> nymph	<i>Hydraticus</i> larva	Hydracarina
4	13									64		
4	14							18				
4	15											
4	16							5				
4	17											
4	18											
4	19							3				
4	20									1		
4	21											
4	22									1		
4	23								1			
4	24											
6	1											
6	2									6		
6	3									5		1
6	4											
6	5											
6	6				1	1				7		
6	7											
6	8	3										
6	9	19						37		25		
6	10											
6	11				1							1
6	12											
6	13							1				
6	14											
6	15											
6	16							34				
6	17											
6	18									6		
6	19	8										
6	20											
6	21											
6	22							4				
6	23											

APPENDIX A. Continued.

Week	Mesocosm	Hydrachnidae	<i>Hydrochus</i> adult	<i>Hydrophilus</i> larva	<i>Hydroporus</i> larva	Hydropsychidae nymph	Isotomidae	<i>Laccodytes</i> adult	<i>Laccophilus</i> larva	Nematoda	Notonectidae nymph	Oligochaeta
4	13											28
4	14									1		13
4	15											
4	16											
4	17											
4	18											
4	19											
4	20									4		
4	21									4		
4	22		1						1	3		1
4	23								2			
4	24						1					
6	1											
6	2					5				2		
6	3		1							12		
6	4											
6	5									2		
6	6									54		4
6	7											
6	8									4		30
6	9		1	1						2		58
6	10						2					
6	11									9		4
6	12		1									
6	13											
6	14									1		
6	15									7		6
6	16									174		32
6	17	1										
6	18									6		
6	19							4				
6	20											
6	21		1							4	1	
6	22									4		
6	23				1				1	1		

APPENDIX A. Continued.

Week	Mesocosm	Ostracoda	<i>Physa</i>	Rotifera	Syrphidae larva	Syrphidae pupa	Tabanidae pupa	Thysanoptera	Trichoptera	<i>Tropisternus</i> larva	unidentified larva	Velidae adult
4	13											
4	14											
4	15			2024								
4	16							1			5	
4	17											
4	18											
4	19											
4	20	5										
4	21	7										
4	22	9		1					1			
4	23											
4	24											
6	1	26										
6	2											
6	3	4										
6	4	24										
6	5	82										
6	6	21										
6	7			2109								
6	8											
6	9	1	2									
6	10	28								2		1
6	11	211		4								
6	12	3								1		
6	13			7								1
6	14											
6	15	509		14								
6	16	42		4								
6	17	122										
6	18	7										
6	19											
6	20	56										
6	21	40										
6	22	176		8								
6	23	1										

APPENDIX B. Mesocosm clear-out invertebrate abundances.

Mesocosm	Baetidae	Ceratopogonidae pupa	Chironomidae	Chironomidae pupa	Cladocera	Coleoptera adult	Copepoda	Corixidae adult	Corixidae nymph	Culicidae	Culicidae pupa
1											
2	360		2			7		5	1	141	13
3						1					
4						2					
5						1					
6			1					1			
7	52		1							1	1
8	16			1		1		3			
9	113		2			1		1			
10								2			
11	23		1			2	2	32	2		
12	35		3			1	1	2		47	4
13	304		2	1		1	14	3	8	100	225
14	104		1			4			3		
15	459		9	1	187		32	12		26	23
16											
17						2				1	
18	3		3								
19			14	1		2	8	1			
20	1										
21	114		6		91	1	9	33	1	1	
22	21	1	3			2		2	5		
23	123		7			1		3		51	8
24	4		7	2					1		

APPENDIX B. Continued.

Mesocosm	Dytiscidae adult	Dytiscidae larva	Gerridae adult	Gomphidae	Hemiptera adult	Hydrachnidae	Hydraenidae adult	Hydrophilidae adult	Hydrophilidae larva	Leptohyphidae	Mesovelinae adult
1			2								
2	6	12						16			3
3								3			
4			1					2			
5								1			
6											
7	1							3	1	6	
8	3		1					9			
9											
10	2		1					7			
11							2	2			1
12	1						1	17	1		1
13	1	14	1						7		
14		1						9			
15		1	1				2	2	3	1	
16											
17	1										
18	1							6	3		1
19					1			6	2	3	
20								1			
21	3	3					1	6	2		
22	3	4		8		1	1				1
23	13	12						19	5		6
24					1				1		

APPENDIX B. Continued.

Mesocosm	Mesovelidae nymph	Notonectidae adult	Notonectidae nymph	Odonata	Ostracoda	Physidae	Plecoptera	<i>Somatochlora</i>	Terrestrial Velidae adult	Velidae nymph
1						1				
2	5	1							1	1
3		1								
4		1				1		13	2	
5		1						18	1	
6		1				3				
7			7	1						
8		3							6	
9						1			1	1
10								2		
11						2				
12									2	5
13							1		1	2
14									2	4
15	7				1			1	3	3
16						15		14	1	
17										
18		3							1	1
19			1						3	5
20		1						26	1	1
21	1	16	34							2
22		1							2	1
23										
24										

APPENDIX C. Mesocosm fishes data.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
2	1	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	12.00
2	1	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	14.00
2	1	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
2	3	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	15.24
2	3	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	14.50
2	3	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	16.19
2	6	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	14.60
2	6	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	15.40
2	6	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	13.09
2	8	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	17.14
2	8	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	13.02
2	8	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	14.13
2	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	13.20
2	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
2	9	weekly	no	<i>Rhi</i>	<i>cat</i>	juvenile	15.00
2	11	weekly	yes	<i>Car</i>	<i>car</i>	mesolarva	12.70
2	11	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	14.00
2	11	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	12.30
2	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.40
2	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.20
2	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	13.40
2	16	weekly	no	<i>Gam</i>	<i>aff</i>	juvenile	20.00
2	16	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.50
2	16	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
2	17	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
2	17	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	14.00
2	17	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00
2	19	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	13.50
2	19	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
2	19	weekly	no	<i>Rhi</i>	<i>cat</i>	juvenile	16.00
2	22	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	15.71
2	22	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	18.09
2	22	weekly	yes	<i>Pim</i>	<i>pro</i>	juvenile	16.19
2	24	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	14.00
2	24	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	12.00
2	24	weekly	yes	<i>Pim</i>	<i>pro</i>	juvenile	12.54
3	1	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
3	1	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	20.00
3	1	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	21.00

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
3	3	weekly	no	<i>Cyp</i>	<i>car</i>	juvenile	26.00
3	3	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	14.30
3	3	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.60
3	6	weekly	no	<i>Gam</i>	<i>aff</i>	juvenile	16.25
3	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	13.52
3	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.34
3	8	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
3	8	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.50
3	8	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.00
3	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
3	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.50
3	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.50
3	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
3	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
3	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.50
3	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.00
3	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.00
3	16	weekly	no	<i>Gam</i>	<i>aff</i>	adult	17.00
3	16	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	18.00
3	16	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	21.00
3	17	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	20.00
3	19	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.94
3	19	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.73
3	19	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.86
3	24	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.00
3	24	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00
3	24	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.00
4	1	weekly	no	<i>Gam</i>	<i>aff</i>	adult	26.00
4	1	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.00
4	1	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	23.00
4	3	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	15.40
4	3	weekly	yes	<i>Pim</i>	<i>pro</i>	juvenile	22.00
4	3	weekly	yes	<i>Pim</i>	<i>pro</i>	juvenile	22.00
4	6	weekly	yes	<i>Cyp</i>	<i>car</i>	juvenile	39.00
4	6	weekly	yes	<i>Gam</i>	<i>aff</i>	adult	24.12
4	6	weekly	yes	<i>Gam</i>	<i>aff</i>	adult	19.20
4	8	weekly	yes	<i>Cyp</i>	<i>car</i>	juvenile	21.43
4	8	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
4	8	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	13.17

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
4	9	weekly	no	<i>Cyp</i>	<i>car</i>	juvenile	22.23
4	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.50
4	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.50
4	11	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	19.50
4	11	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	20.47
4	11	weekly	yes	<i>Pim</i>	<i>pro</i>	juvenile	21.00
4	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.00
4	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.50
4	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.50
4	16	weekly	no	<i>Gam</i>	<i>aff</i>	adult	35.00
4	16	weekly	no	<i>Gam</i>	<i>aff</i>	adult	18.50
4	16	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	28.00
4	17	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.00
4	17	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
4	17	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
4	19	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.00
4	19	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
4	19	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	23.00
4	22	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	18.73
4	22	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	15.08
4	22	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	13.65
4	24	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	15.08
4	24	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	13.39
4	24	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.34
4	24	weekly	yes	<i>Hyb</i>	<i>ama</i>	juvenile	13.30
4	24	weekly	yes	<i>Pla</i>	<i>gra</i>	metalarva	13.78
4	24	weekly	no	<i>Pla</i>	<i>gra</i>	metalarva	13.78
5	1	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	22.00
5	1	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	20.00
5	1	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	22.00
5	3	weekly	no	<i>Cyp</i>	<i>car</i>	juvenile	40.00
5	3	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
5	3	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	21.50
5	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.00
5	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.00
5	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.50
5	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
5	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
5	6	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
5	8	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
5	8	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.50
5	8	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
5	8	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.50
5	8	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	20.00
5	8	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	20.00
5	9	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
5	9	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	23.80
5	9	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	20.00
5	11	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.50
5	11	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	26.00
5	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
5	14	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
5	14	weekly	no	<i>Pla</i>	<i>gra</i>	juvenile	21.00
5	16	weekly	no	<i>Gam</i>	<i>aff</i>	adult	29.00
5	16	weekly	no	<i>Gam</i>	<i>aff</i>	adult	22.00
5	16	weekly	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.03
5	17	weekly	no	<i>Gam</i>	<i>aff</i>	juvenile	11.96
5	17	weekly	no	<i>Gam</i>	<i>aff</i>	juvenile	11.18
5	17	weekly	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
5	22	weekly	no	<i>Car</i>	<i>car</i>	juvenile	29.50
5	22	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	18.46
5	22	weekly	no	<i>Pim</i>	<i>pro</i>	juvenile	18.85
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.05
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.87
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.19
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	13.49
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.14
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.40
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.93
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.94
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	14.45
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.98
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.98
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.73
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.59
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	13.17
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.82
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	14.45
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.94

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.19
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.46
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	14.92
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.66
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.98
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.94
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	12.54
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.78
5	24	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.82
5	24	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	18.46
5	24	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	18.85
5	24	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	16.03
6	1	clearout	no	<i>Cat</i>	<i>com</i>	juvenile	35.00
6	1	clearout	no	<i>Cyp</i>	<i>car</i>	juvenile	80.00
6	1	clearout	no	<i>Cyp</i>	<i>lut</i>	juvenile	22.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	36.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	22.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	24.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	18.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	19.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	21.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	21.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	21.00
6	1	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	33.00
6	3	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	3	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	22.10
6	3	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.50
6	3	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
6	3	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	17.78
6	6	clearout	no	<i>Cyp</i>	<i>car</i>	juvenile	52.00
6	6	clearout	no	<i>Cyp</i>	<i>car</i>	juvenile	64.00
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	yes	<i>Gam</i>	<i>aff</i>	juvenile	10.63
6	6	clearout	yes	<i>Gam</i>	<i>aff</i>	juvenile	11.27
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.92
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.13
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.44
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.53
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.48
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.01
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	yes	<i>Gam</i>	<i>aff</i>	juvenile	10.16
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.88
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.18
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.23
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.40
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.23
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.87
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.18
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.01
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.14
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.14
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.23
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.14
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.44
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.70
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.97
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.35
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.53
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.49
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.84
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.62
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.97
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.22
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.01
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.14
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.92
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.49
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.40
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.31
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.91
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.18
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.14
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.49
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.87
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.10
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.27
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.49
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.22
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.40
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.97
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.88
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.53
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.44
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.57
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.23
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.01
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.14
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.53
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.18
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.14
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.53
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.35
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.71

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.92
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.48
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.01
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.05
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.40
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.35
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.88
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.79
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.36
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.53
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.23
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.10
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.88
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.97
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.32
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.70
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.80
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.10
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.79
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.92
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.45
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.84
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	8.45
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.61
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	11.31
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.92
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.66
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.13
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.01
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	10.79
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	41.00
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.75
6	6	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	9.23
6	6	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.50

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	6	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.90
6	6	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.00
6	6	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00
6	6	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	21.50
6	6	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	22.00
6	8	clearout	yes	<i>Gam</i>	<i>aff</i>	juvenile	15.00
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.45
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.54
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.81
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.65
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.13
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.13
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.81
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.29
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.50
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.81
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.49
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	38.50
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.61
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.33
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.29
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.54
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.81
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.77
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.81
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.93
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.12
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.18
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.65
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.70
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.02
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.72
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.65
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.81
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.18
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	12.38
6	8	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.97
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	16.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	8	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	14.92
6	8	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	19.80
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	8	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	8	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	22.00
6	8	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	20.00
6	9	clearout	no	<i>Gam</i>	<i>aff</i>	adult	37.00
6	9	clearout	no	<i>Gam</i>	<i>aff</i>	adult	26.50
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.71
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	26.00
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.81
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.93
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.75
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.32
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.58
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.03
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.11
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.49
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.41
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.67
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.97
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.84

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.49
6	9	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.72
6	9	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	26.00
6	9	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	18.59
6	9	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	26.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00
6	11	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.60
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.50
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	27.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	11	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	13.65
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	27.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	26.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	26.00
6	11	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	23.10
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	15.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	11	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.60
6	11	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	24.00
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	17.50
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.50
6	14	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	14	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	19.00
6	14	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	22.00
6	16	clearout	no	<i>Gam</i>	<i>aff</i>	adult	34.00
6	16	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	16	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
6	16	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	27.50
6	16	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	37.00
6	16	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	31.00
6	16	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	30.00
6	16	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	28.00
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.77
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.99
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.16
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.77
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.25
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.81
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.38
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	18.33
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.81
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.70
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.86
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.90
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.55
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	13.26
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.73
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.90
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.21
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.77
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.03
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.81
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.21
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.30
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.95
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.03
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.64
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.34

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.34
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.60
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.51
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.34
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.51
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.47
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.03
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.30
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.51
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.00
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.50
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	adult	41.00
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.34
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.03
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.90
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.29
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.34
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.56
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	14.95
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.60
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	17.42
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.21
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	16.51
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	15.34
6	17	clearout	no	<i>Gam</i>	<i>aff</i>	juvenile	18.07
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.76
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.60
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.58
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.71
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.40
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.41
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.27
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
6	17	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	17	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	26.00
6	17	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	28.50
6	17	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	36.00
6	17	clearout	no	<i>Pla</i>	<i>gra</i>	juvenile	34.50
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.50
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	18.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.50
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	26.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.50
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	20.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	23.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	19	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.50
6	19	clearout	no	<i>Pim</i>	<i>pro</i>	juvenile	25.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	28.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	27.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	19.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.50
6	22	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	21.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.50

APPENDIX C. Continued.

Week	Mesocosm	Weekly sample or clearout	Gut contents taken	Genus	Species	Life Stage	SL
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	28.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	28.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	28.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	27.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.50
6	22	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	23.20
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.50
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	24.00
6	22	clearout	yes	<i>Hyb</i>	<i>ama</i>	juvenile	20.80
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	25.00
6	22	clearout	no	<i>Hyb</i>	<i>ama</i>	juvenile	22.00

APPENDIX D. Stable isotope data.

Week	Meso.	Leaves	Fishes	Descriptor	Life	d15N	d13C	C:N
					Stage			
2	1	none	fish	Chironomidae	larva	7.97	-22.02	3.6
2	15	none	none	Chironomidae	larva	8.71	-23.57	3.8
2	16	none	fish	Chironomidae	larva	9.34	-21.66	3.5
2	17	none	fish	Chironomidae	larva	7.96	-22.40	4.3
2	9	yes	fish	Culicidae	larva	3.33	-27.45	3.6
2	12	yes	none	Culicidae	larva	3.96	-27.14	3.8
2	17	none	fish	Culicidae	larva	6.74	-26.58	3.7
2	6	none	fish	Physidae		10.23	-24.45	3.7
2	2	yes	none	Detritus		1.21	-25.47	43.4
2	8	yes	fish	Detritus		1.15	-25.80	26.0
2	15	none	none	Detritus		1.10	-23.50	36.4
2	16	none	fish	<i>Gam aff</i>		10.54	-22.25	3.9
2	1	none	fish	<i>Hyb ama</i>		11.67	-23.04	3.4
2	1	none	fish	<i>Hyb ama</i>		11.35	-22.76	3.3
2	1	none	fish	<i>Hyb ama</i>		11.43	-24.08	3.4
2	9	yes	fish	<i>Hyb ama</i>		8.53	-24.13	3.3
2	9	yes	fish	<i>Hyb ama</i>		8.51	-23.56	3.2
2	14	yes	fish	<i>Hyb ama</i>		7.81	-24.40	3.4
2	14	yes	fish	<i>Hyb ama</i>		7.24	-23.71	3.4
2	16	none	fish	<i>Hyb ama</i>		9.89	-22.55	3.2
2	16	none	fish	<i>Hyb ama</i>		9.97	-22.21	3.5
2	17	none	fish	<i>Hyb ama</i>		10.57	-22.41	3.5
2	17	none	fish	<i>Hyb ama</i>		10.63	-22.78	3.7
2	17	none	fish	<i>Hyb ama</i>		10.85	-22.07	3.5
2	19	yes	fish	<i>Hyb ama</i>		7.58	-24.00	3.5
2	19	yes	fish	<i>Hyb ama</i>		6.52	-26.96	3.5
2	19	yes	fish	<i>Hyb ama</i>		6.22	-26.56	3.4
2	19	yes	fish	<i>Pim pro</i>		10.14	-23.28	3.5
2	14	yes	fish	<i>Pla gra</i>		7.94	-22.71	3.5
2	19	yes	fish	<i>Pla gra</i>		8.54	-23.85	3.4
2	9	yes	fish	<i>Rhi cat</i>		8.82	-23.22	3.5
2	19	yes	fish	<i>Rhi cat</i>		9.66	-23.25	3.8
4	4	none	none	Chironomidae	larva	6.83	-21.13	3.7
4	9	yes	fish	Chironomidae	larva	3.83	-27.20	3.1
4	16	none	fish	Chironomidae	larva	5.67	-23.99	3.9
4	1	none	fish	Copepoda		5.84	-25.34	3.6
4	12	yes	none	Culicidae	larva	3.65	-29.16	3.7
4	12	yes	none	Culicidae	larva	3.74	-29.31	3.8
4	12	yes	none	Culicidae	larva	3.68	-29.55	3.7
4	12	yes	none	Culicidae	pupa	4.07	-28.22	3.5
4	1	none	fish	Detritus		2.30	-22.46	33.9

APPENDIX D. Continued.

Week	Meso.	Leaves	Fishes	Descriptor	Life	d15N	d13C	C:N
					Stage			
4	3	yes	fish	Detritus		1.84	-29.14	29.7
4	7	yes	none	Detritus		-0.25	-27.42	129.1
4	8	yes	fish	Detritus		2.74	-25.95	18.1
4	8	yes	fish	Detritus		1.40	-28.21	37.2
4	13	yes	none	Detritus		1.47	-27.94	24.5
4	15	none	none	Detritus		0.83	-25.52	27.5
4	18	yes	none	Detritus		-0.69	-27.88	64.8
4	20	none	none	Detritus		2.12	-25.54	19.3
4	23	yes	none	Detritus		1.34	-27.66	76.1
4	9	yes	fish	<i>Cyp car</i>		12.67	-22.46	3.3
4	1	none	fish	<i>Gam aff</i>		9.34	-25.06	4.1
4	16	none	fish	<i>Gam aff</i>		13.57	-20.97	3.4
4	16	none	fish	<i>Gam aff</i>		13.84	-19.87	3.4
4	17	none	fish	<i>Hyb ama</i>		12.59	-22.60	3.5
4	17	none	fish	<i>Hyb ama</i>		10.66	-22.60	3.8
4	17	none	fish	<i>Hyb ama</i>		10.23	-23.05	3.9
4	1	none	fish	<i>Pim pro</i>		9.64	-23.46	3.3
4	1	none	fish	<i>Pim pro</i>		13.39	-19.74	3.2
4	9	yes	fish	<i>Pim pro</i>		7.65	-26.39	3.7
4	9	yes	fish	<i>Pim pro</i>		9.73	-26.18	3.9
4	16	none	fish	<i>Pim pro</i>		10.38	-23.67	4.4
6	5	none	none	Fil. Algae		3.33	-25.95	26.3
6	4	none	none	<i>Nostoc</i>		0.51	-6.34	27.3
6	5	none	none	Macrophyte		7.24	-26.10	6.9
6	20	none	none	Macrophyte		8.94	-26.74	7.1
6	17	none	fish	Acanthosomatidae	adult	6.51	-25.86	4.3
6	1	none	fish	<i>Aquarius</i>	adult	9.47	-25.55	7.2
6	1	none	fish	<i>Aquarius</i>	adult	8.88	-25.69	9.1
6	1	none	fish	<i>Aquarius</i>	adult	9.44	-24.49	6.5
6	12	yes	none	Baetidae	nymph	4.59	-28.73	5.9
6	12	yes	none	Baetidae	nymph	3.19	-25.52	4.6
6	12	yes	none	Baetidae	nymph	4.76	-27.40	5.7
6	13	yes	none	Baetidae	nymph	6.94	-27.47	3.9
6	15	none	none	Baetidae	nymph	5.85	-24.30	4.2
6	15	none	none	Baetidae	nymph	5.27	-23.98	4.3
6	20	none	none	Baetidae	nymph	1.00	-18.55	4.8
6	21	none	none	Baetidae	nymph	4.08	-25.00	6.1
6	2	yes	none	Baetidae	nymph	4.65	-29.53	5.0
6	2	yes	none	<i>Berosus</i>	adult	8.37	-29.64	7.6
6	2	yes	none	<i>Berosus</i>	adult	12.04	-27.26	4.1
6	2	yes	none	<i>Berosus</i>	adult	10.20	-26.66	4.2

APPENDIX D. Continued.

Week	Meso.	Leaves	Fishes	Descriptor	Life	d15N	d13C	C:N
					Stage			
6	8	yes	fish	<i>Berosus</i>	adult	9.65	-27.78	5.8
6	8	yes	fish	<i>Berosus</i>	adult	7.91	-28.61	7.4
6	14	yes	fish	<i>Berosus</i>	adult	4.06	-26.05	4.0
6	14	yes	fish	<i>Berosus</i>	adult	4.43	-32.44	9.3
6	14	yes	fish	<i>Berosus</i>	adult	3.83	-27.55	4.0
6	15	none	none	<i>Berosus</i>	adult	11.28	-16.49	3.9
6	16	none	fish	<i>Berosus</i>	adult	4.19	-30.45	4.4
6	17	none	fish	<i>Berosus</i>	adult	4.69	-25.46	3.9
6	9	yes	fish	<i>Berosus</i>	larva	5.37	-29.64	5.3
6	12	yes	none	<i>Berosus</i>	larva	14.39	-22.44	3.5
6	14	yes	fish	<i>Berosus</i>	larva	3.30	-28.20	4.9
6	14	yes	fish	<i>Berosus</i>	larva	3.21	-28.96	5.0
6	1	none	fish	<i>Buenoa</i>	adult	5.26		5.6
6	22	none	fish	<i>Callibaetis</i>	nymph	7.88	-22.50	3.8
6	24	yes	fish	<i>Callibaetis</i>	nymph	9.13	-27.73	4.1
6	24	yes	fish	<i>Callibaetis</i>	nymph	7.78	-28.25	4.6
6	12	yes	none	Carabidae	adult	8.25	-11.88	3.6
6	9	yes	fish	<i>Centroptilum</i>	nymph	3.99	-28.84	3.8
6	9	yes	fish	<i>Centroptilum</i>	nymph	3.97	-28.13	3.9
6	9	yes	fish	<i>Centroptilum</i>	nymph	2.29	-23.40	4.2
6	14	yes	fish	<i>Centroptilum</i>	nymph	2.47	-27.16	4.2
6	14	yes	fish	<i>Centroptilum</i>	nymph	9.06	-26.07	4.2
6	14	yes	fish	<i>Centroptilum</i>	nymph	2.84	-27.82	4.9
6	14	yes	fish	<i>Centroptilum</i>	nymph	9.04	-26.61	3.9
6	15	none	none	<i>Centroptilum</i>	nymph	5.63	-24.64	3.7
6	19	yes	fish	Chironomid	larva	5.40	-26.53	4.3
6	2	yes	none	Chironomidae	larva	4.61	-29.02	3.8
6	5	none	none	Chironomidae	larva	6.27	-20.25	3.8
6	8	yes	fish	Chironomidae	larva	4.39	-26.70	4.1
6	9	yes	fish	Chironomidae	larva	4.33	-28.69	3.6
6	17	none	fish	Chironomidae	larva	5.62	-23.99	3.7
6	20	none	none	Chironomidae	larva	4.68	-18.80	3.8
6	23	yes	none	Chironomidae	larva	5.44	-27.21	3.7
6	16	none	fish	Cladocera		2.35	-22.99	4.1
6	9	yes	fish	Coccinellidae	adult	7.28	-23.02	4.1
6	17	none	fish	Coccinellidae	adult	6.91	-22.57	3.9
6	17	none	fish	Coccinellidae	adult	3.48	-28.28	8.9
6	4	none	none	Copepoda		6.36	-22.95	4.1
6	9	yes	fish	Copepoda		5.31	-27.25	4.2
6	12	yes	none	Copepoda		5.29	-29.82	3.5
6	14	yes	fish	Copepoda		4.43	-29.16	3.9

APPENDIX D. Continued.

Week	Meso.	Leaves	Fishes	Descriptor	Life		d15N	d13C	C:N
					Stage				
6	15	none	none	Copepoda			7.88	-25.88	4.3
6	16	none	fish	Copepoda			4.30	-23.64	4.0
6	23	yes	none	<i>Coptotomus</i>	adult		5.56	-25.80	11.7
6	9	yes	fish	Corixidae	adult		4.89	-26.36	3.7
6	19	yes	fish	Corixidae	adult		11.45	-25.57	4.2
6	1	none	fish	Corixidae	nymph		4.64	-23.15	3.5
6	9	yes	fish	Corixidae	nymph		7.35		6.5
6	9	yes	fish	Corixidae	nymph		3.70	-22.20	4.2
6	9	yes	fish	Corixidae	nymph		4.27	-28.96	3.8
6	14	yes	fish	Corixidae	nymph		11.21	-27.34	4.2
6	14	yes	fish	Corixidae	nymph		4.17	-28.76	3.9
6	14	yes	fish	Corixidae	nymph		4.25	-28.00	3.8
6	14	yes	fish	Corixidae	nymph		4.49	-27.59	3.6
6	14	yes	fish	Corixidae	nymph		3.79	-26.97	3.8
6	14	yes	fish	Corixidae	nymph		4.07	-27.02	3.7
6	15	none	none	<i>Culex</i>	larva		10.46	-25.88	3.8
6	23	yes	none	<i>Culex</i>	larva		9.93	-26.06	3.6
6	12	yes	none	Culicidae	larva		4.75	-28.43	3.5
6	14	yes	fish	Culicidae	larva		3.15	-27.74	3.5
6	12	yes	none	Culicidae	pupa		5.28	-29.59	3.4
6	2	yes	none	Cyclopoida			5.47	-28.70	4.3
6	18	yes	none	Cyclopoida			4.65	-28.36	4.2
6	9	yes	fish	Dytiscidae	adult		4.48	-26.48	6.5
6	9	yes	fish	Dytiscidae	adult		4.82	-23.33	5.4
6	14	yes	fish	Dytiscidae	larva		5.09	-28.33	4.0
6	17	none	fish	<i>Dytiscus</i>	adult		4.95	-29.26	4.7
6	14	yes	fish	<i>Dytiscus</i>	larva		5.28	-29.23	4.9
6	14	yes	fish	<i>Dytiscus</i>	larva		4.82	-27.75	3.8
6	14	yes	fish	<i>Dytiscus</i>	larva		9.82	-28.09	4.2
6	9	yes	fish	Gerridae	adult		4.11	-27.65	3.8
6	14	yes	fish	Gerridae	adult		8.99	-23.61	4.5
6	14	yes	fish	Gerridae	adult		6.65	-25.80	3.7
6	14	yes	fish	Gerridae	adult		7.25	-25.76	3.9
6	14	yes	fish	<i>Hydaticus</i>	adult		6.23	-27.30	5.8
6	19	yes	fish	<i>Hydrobiomorpha</i>	adult		3.74	-28.17	9.4
6	14	yes	fish	Hydrophilidae	adult		8.19	-25.86	8.8
6	14	yes	fish	Hydrophilidae	adult		7.15	-26.83	5.4
6	14	yes	fish	Hydrophilidae	adult		5.95	-25.73	5.8
6	14	yes	fish	<i>Hydrophilus</i>	adult		13.01	-23.59	4.3
6	18	yes	none	<i>Hydrophilus</i>	adult		9.80	-27.30	6.5
6	18	yes	none	<i>Hydrophilus</i>	adult		11.47	-23.56	4.8

APPENDIX D. Continued.

Week	Meso.	Leaves	Fishes	Descriptor	Life Stage	d15N	d13C	C:N
6	19	yes	fish	<i>Hydrophilus</i>	adult	8.79	-24.97	4.4
6	2	yes	none	<i>Laccophilus</i>	adult	11.74	-22.45	4.5
6	16	none	fish	<i>Laccophilus</i>	adult	6.76	-24.03	4.0
6	21	none	none	<i>Laccophilus</i>	adult	11.28	-25.15	4.6
6	21	none	none	<i>Laccophilus</i>	adult	12.59	-26.35	4.4
6	23	yes	none	<i>Laccophilus</i>	adult	9.85	-28.55	5.8
6	23	yes	none	<i>Laccophilus</i>	adult	10.90	-26.73	5.0
6	23	yes	none	<i>Laccophilus</i>	adult	10.10	-28.16	5.3
6	15	none	none	<i>Laccophilus</i>	larva	9.48	-25.48	4.7
6	9	yes	fish	<i>Linnaeus</i>	adult	8.09		5.5
6	9	yes	fish	<i>Linnaeus</i>	adult	8.31	-25.13	4.1
6	16	none	fish	<i>Linnaeus</i>	adult	8.97		6.4
6	1	none	fish	<i>Physa</i>		4.90	-24.39	3.7
6	1	none	fish	<i>Physa</i>		4.90	-24.71	3.9
6	9	yes	fish	<i>Physa</i>		4.56	-24.45	3.7
6	9	yes	fish	<i>Physa</i>		3.95	-25.39	4.0
6	16	none	fish	<i>Physa</i>		3.40	-23.18	4.3
6	16	none	fish	<i>Physa</i>		1.90	-17.81	5.3
6	16	none	fish	<i>Physa</i>		4.08	-25.63	9.0
6	8	yes	fish	<i>Rhantus</i>	adult	10.45	-22.36	5.5
6	8	yes	fish	<i>Rhantus</i>	adult	8.03	-27.76	7.8
6	4	none	none	<i>Somatochlora</i>	nymph	10.43	-22.23	5.1
6	4	none	none	<i>Somatochlora</i>	nymph	9.91	-23.87	6.1
6	4	none	none	<i>Somatochlora</i>	nymph	11.65	-22.07	4.0
6	5	none	none	<i>Somatochlora</i>	nymph	11.92	-24.75	4.4
6	5	none	none	<i>Somatochlora</i>	nymph	12.84	-24.56	3.9
6	20	none	none	<i>Somatochlora</i>	nymph	10.22	-18.98	4.8
6	20	none	none	<i>Somatochlora</i>	nymph	9.41	-20.47	5.9
6	20	none	none	<i>Somatochlora</i>	nymph	5.21	-20.87	7.1
6	16	none	fish	<i>Somatochlora</i>	nymph	6.81	-23.21	3.8
6	16	none	fish	<i>Somatochlora</i>	nymph	5.48	-23.48	3.8
6	16	none	fish	<i>Somatochlora</i>	nymph	7.05	-23.52	3.9
6	1	none	fish	<i>Stylurus</i>	nymph	6.81	-24.81	3.8
6	17	none	fish	<i>Stylurus</i>	nymph	6.75	-24.61	4.8
6	22	none	fish	<i>Stylurus</i>	nymph	9.88	-25.74	5.6
6	22	none	fish	<i>Stylurus</i>	nymph	10.35	-24.98	4.8
6	22	none	fish	<i>Stylurus</i>	nymph	8.13	-27.22	7.3
6	10	none	none	<i>Thermonectus</i>	adult	12.24	-24.72	4.3
6	3	yes	fish	<i>Tropisternus</i>	adult	3.33	-25.59	4.9
6	3	yes	fish	<i>Tropisternus</i>	adult	7.35	-27.28	4.3
6	4	none	none	<i>Tropisternus</i>	adult	4.29	-21.98	4.4

APPENDIX D. Continued.

Week	Meso.	Leaves	Fishes	Descriptor	Life	d15N	d13C	C:N
					Stage			
6	4	none	none	<i>Tropisternus</i>	adult	3.11	-20.85	4.6
6	7	yes	none	<i>Tropisternus</i>	adult	7.31	-24.43	5.5
6	7	yes	none	<i>Tropisternus</i>	adult	8.64	-25.25	5.3
6	11	none	fish	<i>Tropisternus</i>	adult	5.57	-23.58	4.3
6	14	yes	fish	<i>Tropisternus</i>	adult	4.58	-27.72	4.3
6	17	none	fish	<i>Tropisternus</i>	adult	3.67	-24.15	4.1
6	19	yes	fish	<i>Tropisternus</i>	adult	3.41	-26.55	9.3
6	19	yes	fish	<i>Tropisternus</i>	adult	8.90	-28.52	4.5
6	19	yes	fish	<i>Tropisternus</i>	adult	6.85	-23.35	7.7
6	20	none	none	<i>Tropisternus</i>	adult	12.95	-23.59	4.0
6	23	yes	none	<i>Tropisternus</i>	adult	10.80	-27.44	4.1
6	23	yes	none	<i>Tropisternus</i>	adult	11.61	-24.89	4.3
6	23	yes	none	<i>Tropisternus</i>	adult	6.07	-29.68	7.1
6	15	none	none	<i>Tropisternus</i>	larva	11.73	-25.15	4.5
6	15	none	none	<i>Tropisternus</i>	larva	9.45	-24.47	5.3
6	23	yes	none	<i>Tropisternus</i>	larva	7.76	-28.86	6.2
6	23	yes	none	<i>Tropisternus</i>	larva	12.42	-28.04	5.2
6	24	yes	fish	<i>Tropisternus</i>	larva	11.41	-26.43	4.4
6	14	yes	fish	<i>Uvarus</i>	adult	2.77	-27.54	4.6
6	2	yes	none	Detritus		1.70	-24.63	21.5
6	2	yes	none	Detritus		1.14	-25.64	23.4
6	2	yes	none	Detritus		2.43	-24.91	21.3
6	6	none	fish	Detritus		1.26	-25.44	24.1
6	15	none	none	Detritus		1.42	-26.18	29.9
6	19	yes	fish	Detritus		1.45	-27.61	43.7
6	20	none	none	Detritus		0.65	-27.22	23.9
6	23	yes	none	Detritus		2.02	-24.34	29.7
6	23	yes	none	Detritus		0.81	-27.60	33.9
6	1	none	fish	<i>Cat com</i>		10.34	-23.32	3.4
6	1	none	fish	<i>Cyp car</i>		8.14	-23.61	3.3
6	1	none	fish	<i>Cyp lut</i>		10.12	-22.59	3.5
6	9	yes	fish	<i>Gam aff</i>		10.13	-24.20	3.4
6	9	yes	fish	<i>Gam aff</i>		15.27	-21.60	3.8
6	16	none	fish	<i>Gam aff</i>		11.66	-21.71	3.5
6	17	none	fish	<i>Gam aff</i>		9.29	-23.17	3.6
6	17	none	fish	<i>Gam aff</i>		10.03	-22.96	3.6
6	9	yes	fish	<i>Hyb ama</i>		7.56	-26.81	3.6
6	14	yes	fish	<i>Hyb ama</i>		9.72	-26.51	3.2
6	14	yes	fish	<i>Hyb ama</i>		7.25	-25.52	3.2
6	14	yes	fish	<i>Hyb ama</i>		9.26	-24.43	3.3
6	19	yes	fish	<i>Hyb ama</i>		7.33	-26.08	3.4

APPENDIX D. Continued.

Week	Meso.	Leaves	Fishes	Descriptor	Life	d15N	d13C	C:N
					Stage			
6	19	yes	fish	<i>Hyb ama</i>		7.24	-25.65	3.4
6	19	yes	fish	<i>Hyb ama</i>		7.37	-25.90	3.3
6	1	none	fish	<i>Pim pro</i>		10.39	-22.66	3.6
6	16	none	fish	<i>Pla gra</i>		9.86	-22.82	3.7
6	16	none	fish	<i>Pla gra</i>		10.39	-21.96	3.6
6	17	none	fish	<i>Pla gra</i>		10.35	-23.62	4.5

APPENDIX E. Physical parameters.

Week	Mesocosm	Leaves	Fish	Depth (cm)	Water temp (°C)	DO (mg/L)	pH
1	1	none	fish	47	20.6	-	8.71
1	2	leaves	no fish	42	16.9	-	7.16
1	3	leaves	fish	36	16.1	-	7.22
1	4	none	no fish	31.5	17.4	-	8.75
1	5	none	no fish	45	18.3	-	8.75
1	6	none	fish	37	18.3	-	8.74
1	7	leaves	no fish	39.2	16.7	-	7.25
1	8	leaves	fish	38	15.6	-	7.25
1	9	leaves	fish	39.5	16.1	-	7.24
1	10	none	no fish	39.2	18.7	-	8.8
1	11	none	fish	40	19	-	8.81
1	12	leaves	no fish	36.1	17	-	7.34
1	13	leaves	no fish	41.4	17	-	7.23
1	14	leaves	fish	41.2	17.3	-	7.24
1	15	none	no fish	39.5	18.7	-	8.68
1	16	none	fish	32.6	18.8	-	8.84
1	17	none	fish	41	18.8	-	8.83
1	18	leaves	no fish	39	16.4	-	7.21
1	19	leaves	fish	33	17.4	-	7.27
1	20	none	no fish	35	20.2	-	8.87
1	21	none	no fish	44	23.7	-	8.7
1	22	none	fish	38	21.3	-	8.75
1	23	leaves	no fish	31	18.3	-	7.3
1	24	leaves	fish	39	20.6	-	7.31
2	1	none	fish	43	18.8	5.56	7.78
2	2	leaves	no fish	38	18.5	3.63	7.64
2	3	leaves	fish	32	18.5	4.02	7.81
2	4	none	no fish	29.5	18.6	4.46	8.18
2	5	none	no fish	41	19	4.37	8.04
2	6	none	fish	34	19.3	4.31	8.27
2	7	leaves	no fish	33	18.8	3.6	7.82
2	8	leaves	fish	33.5	18.3	2.91	7.63
2	9	leaves	fish	36	18.7	3.17	7.73
2	10	none	no fish	34	19.5	3.68	8.2
2	11	none	fish	36	19.6	3.91	8.28
2	12	leaves	no fish	30	18.7	3.31	7.81
2	13	leaves	no fish	36	18.9	3.09	7.7

APPENDIX E. Continued.

Week	Mesocosm	Leaves	Fish	Depth (cm)	Water temp (°C)	DO (mg/L)	pH
2	14	leaves	fish	36	19.2	2.67	7.68
2	15	none	no fish	36.5	19.6	3.48	8.16
2	16	none	fish	27.5	19.7	3.81	8.24
2	17	none	fish	37	20.3	3.68	8.16
2	18	leaves	no fish	34	19.5	2.81	7.7
2	19	leaves	fish	32	19.7	2.97	7.85
2	20	none	no fish	33	19.8	3.57	8.24
2	21	none	no fish	40.5	20.3	3.31	8.15
2	22	none	fish	34.5	20.4	3.5	8.12
2	23	leaves	no fish	28	19.8	3.08	7.78
2	24	leaves	fish	33.5	19	2.62	7.61
3	1	none	fish	38	18.5	4.36	8.44
3	2	leaves	no fish	33	17.3	3.27	7.89
3	3	leaves	fish	26	17.6	2.81	7.93
3	4	none	no fish	23	17.5	4.08	8.38
3	5	none	no fish	36	18.9	3.66	8.43
3	6	none	fish	28	18.9	4.09	8.58
3	7	leaves	no fish	30	18.8	3.06	8.04
3	8	leaves	fish	28	17.2	2.72	7.86
3	9	leaves	fish	30	18.3	2.11	7.85
3	10	none	no fish	33	19.3	3.66	8.44
3	11	none	fish	31	19	3.97	8.72
3	12	leaves	no fish	25	17.5	3.29	8.07
3	13	leaves	no fish	32	18.3	2.03	7.89
3	14	leaves	fish	32	17.9	2.35	7.96
3	15	none	no fish	31	18.6	3.72	8.44
3	16	none	fish	18	18.3	4.37	8.63
3	17	none	fish	32	19.2	3.55	8.41
3	18	leaves	no fish	30	17.3	2.21	7.9
3	19	leaves	fish	24	18.2	1.95	7.87
3	20	none	no fish	28	18.2	4.04	8.41
3	21	none	no fish	35	19.1	3.39	8.37
3	22	none	fish	29	18.9	4.15	8.52
3	23	leaves	no fish	22	19.5	3	8.06
3	24	leaves	fish	28	17.4	2.43	7.91
4	1	none	fish	35	23.92	6.03	8.49
4	2	leaves	no fish	28.3	23.74	4.67	8.33

APPENDIX E. Continued.

Week	Mesocosm	Leaves	Fish	Depth (cm)	Water temp (°C)	DO (mg/L)	pH
4	3	leaves	fish	23.4	23.64	3.59	8.21
4	4	none	no fish	18	23.44	6.53	8.58
4	5	none	no fish	31.2	24.05	5.73	8.47
4	6	none	fish	24	24.26	8.15	8.78
4	7	leaves	no fish	25.5	23.97	3.86	8.28
4	8	leaves	fish	22.8	23.95	3.08	8.09
4	9	leaves	fish	27.5	24.54	4.31	8.25
4	10	none	no fish	27.3	24.56	6.32	8.6
4	11	none	fish	26.1	24.42	6.45	8.67
4	12	leaves	no fish	18	24.47	4.53	8.35
4	13	leaves	no fish	26.4	24.84	3.94	8.25
4	14	leaves	fish	25.5	25.34	3.65	8.14
4	15	none	no fish	27.1	24.73	5.92	8.51
4	16	none	fish	16.5	24.83	7.09	8.64
4	17	none	fish	26.2	25.74	6.73	8.56
4	18	leaves	no fish	26.4	24.62	2.9	8.19
4	19	leaves	fish	22.4	25.05	3.8	8.17
4	20	none	no fish	23.7	25.11	7.78	8.55
4	21	none	no fish	29	25.54	6.65	8.43
4	22	none	fish	24	25.79	8.25	8.56
4	23	leaves	no fish	17	25.84	5.36	8.28
4	24	leaves	fish	16.9	26.27	4.39	8.27
5	1	none	fish	31.2	24.2	6.7	8.48
5	2	leaves	no fish	24.1	24.4	3.72	8.18
5	3	leaves	fish	16.8	24.7	5.03	8.3
5	4	none	no fish	13.8	24.35	6.76	8.57
5	5	none	no fish	27.5	24.95	6.41	8.39
5	6	none	fish	20	24.34	8.85	8.71
5	7	leaves	no fish	18.3	24.9	5.07	8.36
5	8	leaves	fish	18.2	24.74	4.35	8.29
5	9	leaves	fish	23.8	26.62	3.14	8.62
5	10	none	no fish	22.9	26.48	6.91	8.54
5	11	none	fish	22.6	26.41	7.05	8.68
5	12	leaves	no fish	15.5	27.48	5.04	8.31
5	13	leaves	no fish	24.5	27.09	4.29	8.22
5	14	leaves	fish	22.9	27.68	5.64	8.46
5	15	none	no fish	22.7	27.49	6.22	8.44

APPENDIX E. Continued.

Week	Mesocosm	Leaves	Fish	Depth (cm)	Water temp (°C)	DO (mg/L)	pH
5	16	none	fish	9.7	29.07	7.72	8.62
5	17	none	fish	25.5	28.85	9.18	8.55
5	18	leaves	no fish	22.1	28.07	4.17	8.26
5	19	leaves	fish	16.5	29.5	5.72	8.3
5	20	none	no fish	18.9	28.87	9.35	8.61
5	21	none	no fish	25.7	29.47	6.37	8.4
5	22	none	fish	20.4	30.62	6.09	8.49
5	23	leaves	no fish	13.2	31.95	4.91	8.28
5	24	leaves	fish	3.9	35.69	6.11	8.31
6	1	none	fish	28.5	24.36	9.75	8.68
6	2	leaves	no fish	20.5	25.14	4.76	8.21
6	3	leaves	fish	14.5	25.63	6.15	8.27
6	4	none	no fish	11.5	25.01	8.29	8.65
6	5	none	no fish	25	25.03	6.65	8.38
6	6	none	fish	17	24.85	8.55	8.78
6	7	leaves	no fish	16.5	25.27	5.76	8.45
6	8	leaves	fish	19	25.24	6.92	8.55
6	9	leaves	fish	24	24.99	6.26	8.28
6	10	none	no fish	21	25.75	7.97	8.8
6	11	none	fish	20	25.7	7.81	8.76
6	12	leaves	no fish	12	26.62	6.03	8.34
6	13	leaves	no fish	23	25.2	4.43	8.15
6	14	leaves	fish	21	25.89	5.55	8.49
6	15	none	no fish	21	25.85	6.4	8.45
6	16	none	fish	6.5	27.35	7.3	8.49
6	17	none	fish	22	26.55	8.06	8.64
6	18	leaves	no fish	19	25.96	4.82	8.32
6	19	leaves	fish	14.5	27.43	5.54	8.36
6	20	none	no fish	12.5	26.89	7.24	8.47
6	21	none	no fish	23	26.44	8.59	8.59
6	22	none	fish	19	26.7	6.45	8.46
6	23	leaves	no fish	7.5	28.03	6.23	8.29

APPENDIX E. Continued.

Week	Mesocosm	Leaves	Fish	Sp. Cond. ($\mu\text{S}/\text{cm}$)	Salinity (ppt)	Turbidity (NTU)
1	1	none	fish	381.1	0.2	5.28
1	2	leaves	no fish	497.8	0.2	2.42
1	3	leaves	fish	497.4	0.2	2.73
1	4	none	no fish	378.3	0.2	7.5
1	5	none	no fish	411	0.2	5.35
1	6	none	fish	356	0.2	6.07
1	7	leaves	no fish	446.7	0.2	3.8
1	8	leaves	fish	463.5	0.2	2.22
1	9	leaves	fish	486.9	0.2	2.83
1	10	none	no fish	362.1	0.2	5.64
1	11	none	fish	357.7	0.2	6
1	12	leaves	no fish	548	0.3	1.77
1	13	leaves	no fish	512	0.2	2.71
1	14	leaves	fish	453.3	0.2	2.44
1	15	none	no fish	442.3	0.2	6.73
1	16	none	fish	385.5	0.2	6.85
1	17	none	fish	368.5	0.2	4.76
1	18	leaves	no fish	513	0.3	2.32
1	19	leaves	fish	490.3	0.2	1.56
1	20	none	no fish	430	0.2	6.84
1	21	none	no fish	392.9	0.2	6.44
1	22	none	fish	505	0.2	5.38
1	23	leaves	no fish	494.2	0.2	1.95
1	24	leaves	fish	529	0.3	2.12
2	1	none	fish	498.1	0.2	9.06
2	2	leaves	no fish	631	0.3	0.12
2	3	leaves	fish	674	0.3	0.82
2	4	none	no fish	509	0.2	12.8
2	5	none	no fish	547	0.3	23.6
2	6	none	fish	460.8	0.2	9.44
2	7	leaves	no fish	545	0.3	3.36
2	8	leaves	fish	642	0.3	2.82
2	9	leaves	fish	638	0.3	1.52
2	10	none	no fish	477	0.2	7.85
2	11	none	fish	444	0.2	10.2
2	12	leaves	no fish	698	0.4	0.76
2	13	leaves	no fish	710	0.3	0.94

APPENDIX E. Continued.

Week	Mesocosm	Leaves	Fish	Sp. Cond. ($\mu\text{S}/\text{cm}$)	Salinity (ppt)	Turbidity (NTU)
2	14	leaves	fish	539	0.3	0.67
2	15	none	no fish	601	0.3	7.37
2	16	none	fish	534	0.2	6.19
2	17	none	fish	500	0.2	7.51
2	18	leaves	no fish	663	0.3	1.44
2	19	leaves	fish	651	0.3	1.44
2	20	none	no fish	562	0.3	5.49
2	21	none	no fish	515	0.3	10.55
2	22	none	fish	794	0.4	5.71
2	23	leaves	no fish	660	0.3	1.28
2	24	leaves	fish	714	0.3	2
3	1	none	fish	564	0.3	20.7
3	2	leaves	no fish	765	0.4	5.52
3	3	leaves	fish	864	0.4	6.26
3	4	none	no fish	647	0.3	22.3
3	5	none	no fish	674	0.3	16.3
3	6	none	fish	542	0.3	14.8
3	7	leaves	no fish	664	0.3	11
3	8	leaves	fish	782	0.4	1.3
3	9	leaves	fish	778	0.4	4.24
3	10	none	no fish	587	0.3	5.89
3	11	none	fish	510	0.2	10.88
3	12	leaves	no fish	986	0.5	7.96
3	13	leaves	no fish	888	0.4	2.53
3	14	leaves	fish	626	0.3	3.31
3	15	none	no fish	692	0.4	10.15
3	16	none	fish	684	0.3	19.2
3	17	none	fish	634	0.3	13.1
3	18	leaves	no fish	802	0.4	2.14
3	19	leaves	fish	812	0.4	3.07
3	20	none	no fish	770	0.4	5.98
3	21	none	no fish	629	0.3	13.2
3	22	none	fish	1046	0.5	12.1
3	23	leaves	no fish	830	0.4	4.12
3	24	leaves	fish	906	0.4	1.56
4	1	none	fish	599	0.29	21
4	2	leaves	no fish	835	0.41	8.42

APPENDIX E. Continued.

Week	Mesocosm	Leaves	Fish	Sp. Cond. ($\mu\text{S}/\text{cm}$)	Salinity (ppt)	Turbidity (NTU)
4	3	leaves	fish	1017	0.5	7.9
4	4	none	no fish	747	0.36	9.53
4	5	none	no fish	726	0.35	17.1
4	6	none	fish	538	0.26	23.6
4	7	leaves	no fish	727	0.35	15
4	8	leaves	fish	876	0.43	2.92
4	9	leaves	fish	848	0.42	1.82
4	10	none	no fish	618	0.3	4.16
4	11	none	fish	517	0.25	6.1
4	12	leaves	no fish	1211	0.6	7.76
4	13	leaves	no fish	993	0.49	2.38
4	14	leaves	fish	675	0.33	2.38
4	15	none	no fish	832	0.41	9.81
4	16	none	fish	786	0.38	23.8
4	17	none	fish	702	0.34	5.53
4	18	leaves	no fish	891	0.44	3.03
4	19	leaves	fish	926	0.45	4.9
4	20	none	no fish	865	0.42	0
4	21	none	no fish	634	0.31	3.29
4	22	none	fish	1169	0.58	17.7
4	23	leaves	no fish	981	0.48	3.76
4	24	leaves	fish	1103	0.54	0.47
5	1	none	fish	627	0.31	42.2
5	2	leaves	no fish	909	0.45	6.62
5	3	leaves	fish	1120	0.56	4.91
5	4	none	no fish	888	0.44	15.2
5	5	none	no fish	777	0.38	11.6
5	6	none	fish	572	0.28	62.9
5	7	leaves	no fish	804	0.39	16.2
5	8	leaves	fish	1035	0.51	4.64
5	9	leaves	fish	992	0.47	5.39
5	10	none	no fish	682	0.32	4.54
5	11	none	fish	569	0.27	24.3
5	12	leaves	no fish	1486	0.71	11.6
5	13	leaves	no fish	1177	0.56	9.16
5	14	leaves	fish	772	0.36	4.18
5	15	none	no fish	979	0.46	18.9

APPENDIX E. Continued.

Week	Mesocosm	Leaves	Fish	Sp. Cond. ($\mu\text{S}/\text{cm}$)	Salinity (ppt)	Turbidity (NTU)
5	16	none	fish	1028	0.47	26.8
5	17	none	fish	823	0.37	15.9
5	18	leaves	no fish	1100	0.51	6.83
5	19	leaves	fish	1120	0.5	5.46
5	20	none	no fish	1048	0.48	10.45
5	21	none	no fish	722	0.32	17.4
5	22	none	fish	1560	0.7	27.5
5	23	leaves	no fish	1309	0.57	11.8
5	24	leaves	fish	1983	0.81	16.6
6	1	none	fish	628	0.3	53.1
6	2	leaves	no fish	940	0.46	6.28
6	3	leaves	fish	1198	0.59	9.97
6	4	none	no fish	958	0.47	8.86
6	5	none	no fish	763	0.37	13.1
6	6	none	fish	633	0.31	44.8
6	7	leaves	no fish	827	0.4	24
6	8	leaves	fish	1070	0.53	3.78
6	9	leaves	fish	971	0.48	25
6	10	none	no fish	641	0.31	5.97
6	11	none	fish	573	0.28	15.8
6	12	leaves	no fish	1529	0.77	8.5
6	13	leaves	no fish	1194	0.59	18.5
6	14	leaves	fish	750	0.36	10.78
6	15	none	no fish	963	0.47	27.8
6	16	none	fish	1144	0.56	45.3
6	17	none	fish	836	0.41	15.7
6	18	leaves	no fish	1104	0.54	12.3
6	19	leaves	fish	1081	0.53	9.77
6	20	none	no fish	1131	0.56	11.9
6	21	none	no fish	640	0.31	1.62
6	22	none	fish	1562	0.78	30.2
6	23	leaves	no fish	1266	0.63	3.08

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Fig. 1 The treatment design for the mesocosm experiment. All four treatments are shown: YOY fishes, cottonwood leaves, YOY fishes and cottonwood leaves and no addition. Based on the layout shown below, the main channel of the Rio Grande would be to the left of the diagram in the actual setup. Direction of flow would be from bottom to top.

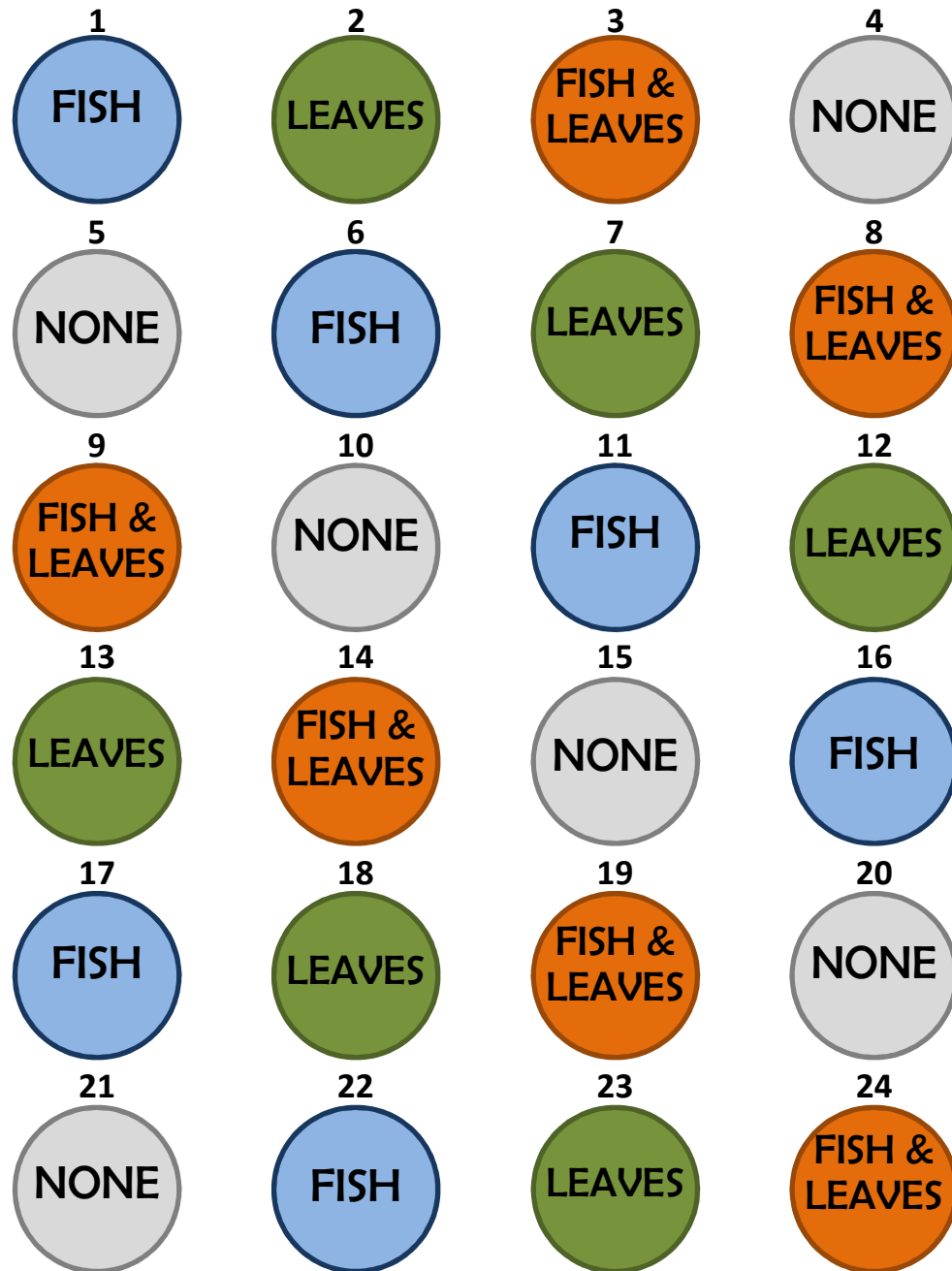


Fig. 2 (A) Temperature and (B) depth for each mesocosm during six sampling weeks. There is an increase in temperature and a decrease in depth over time in each mesocosm. The amount of change is fairly constant across mesocosms.

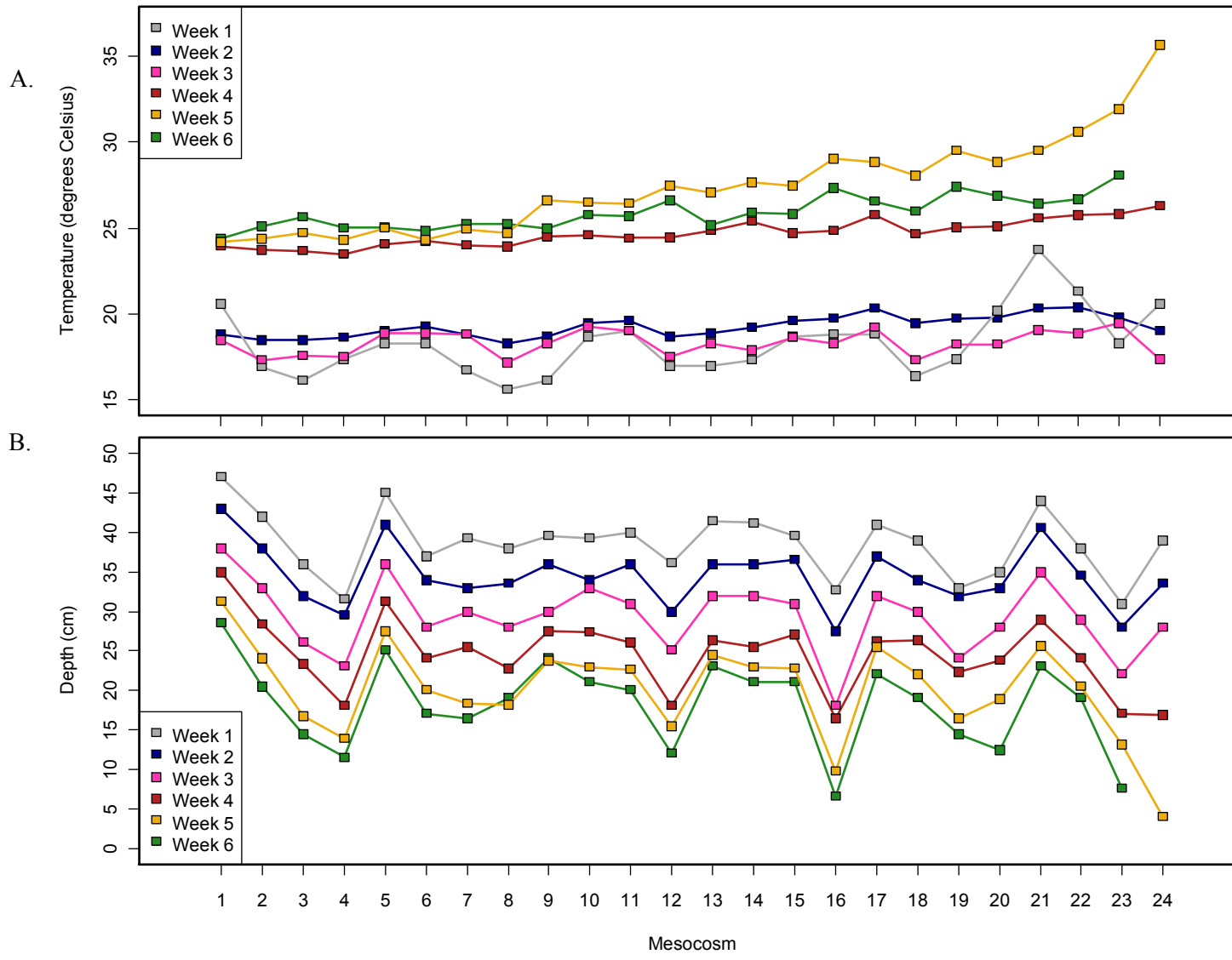


Fig. 3 Physical characteristics of water quality in each mesocosm over six sampling weeks. Depicted are (A) dissolved oxygen, (B) pH, (C) turbidity, (D) salinity and (E) specific conductivity. Bare ground tanks are on the left, leaf-treated on the right.

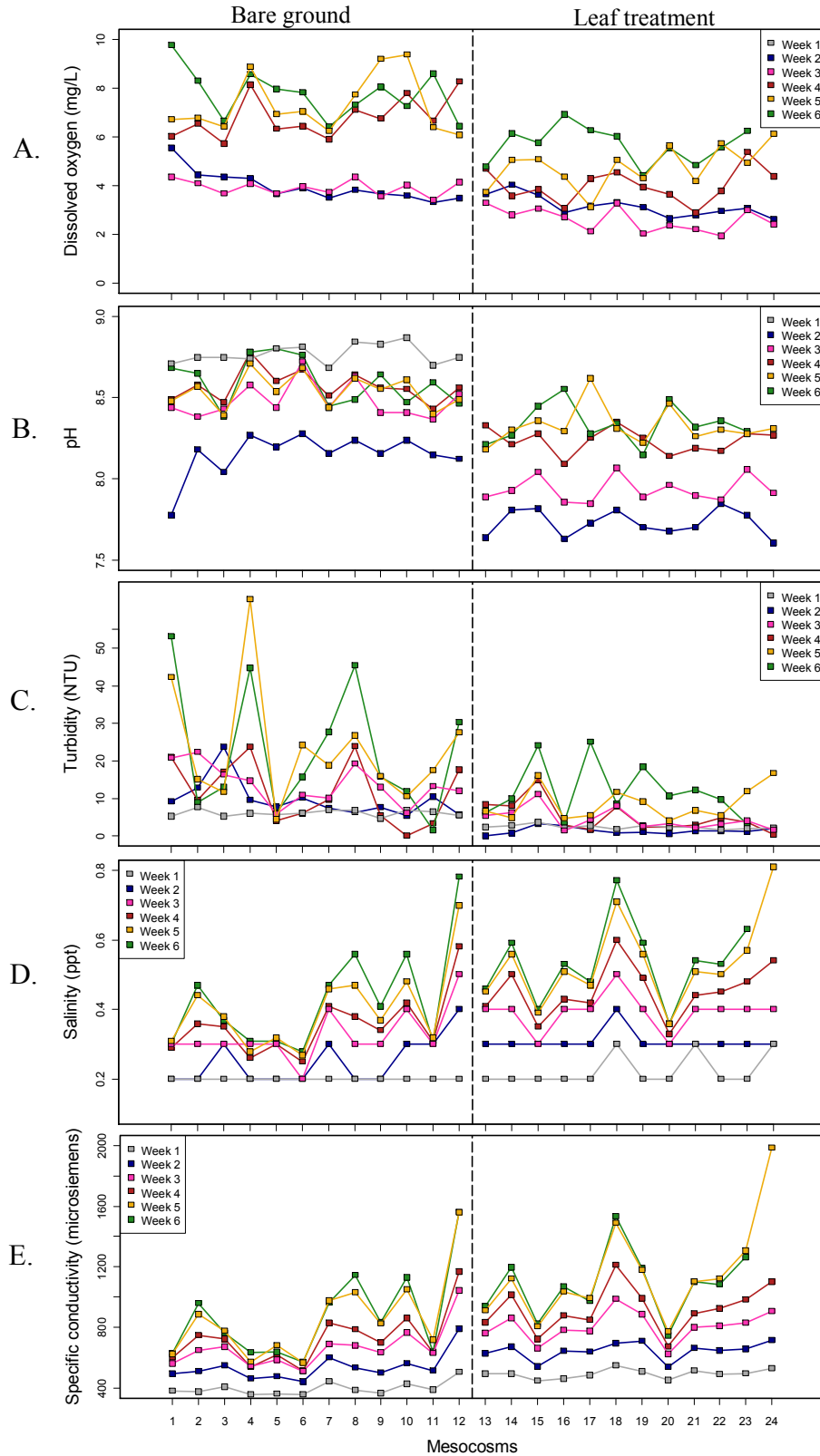


Fig. 4 Invertebrate density in the (A) bare ground tanks and the (B) leaf litter tanks with respect to fish treatment, over time. The blue line represents the second sampling week, the red the fourth and green the sixth. Density increases over time, likely due to the drying of the mesocosms. The peaks in tanks 11 and 16 in the bare ground/fish treatment and tank 19 in the leaf litter/fish treatment represent anomalies in tank development where one taxon is favored over others.

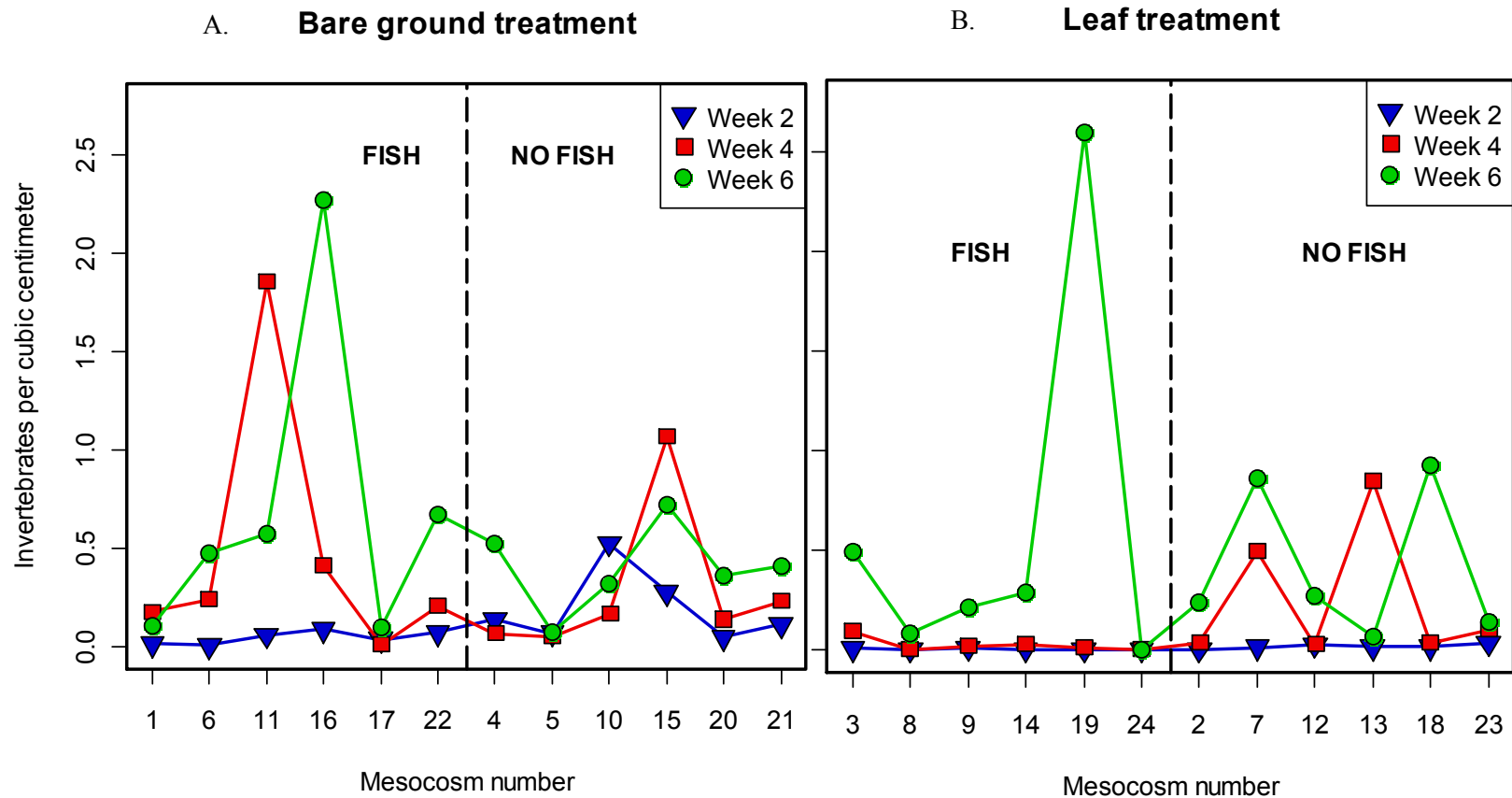


Fig. 5 Invertebrate diversity (Shannon-Weaver Diversity Index) in the (A) bare ground tanks and the (B) leaf litter tanks with respect to fish treatment, over time. The lack of a value in the leaf/fish treatment for tank eight in week four is due to only one taxon being present in that particular sample (resulting in a Shannon-Weaver Diversity Index of 0). The lack of a value in the leaf/fish treatment, tank 24, week six, is because the tank was completely dry at this sampling time and no data were collected.

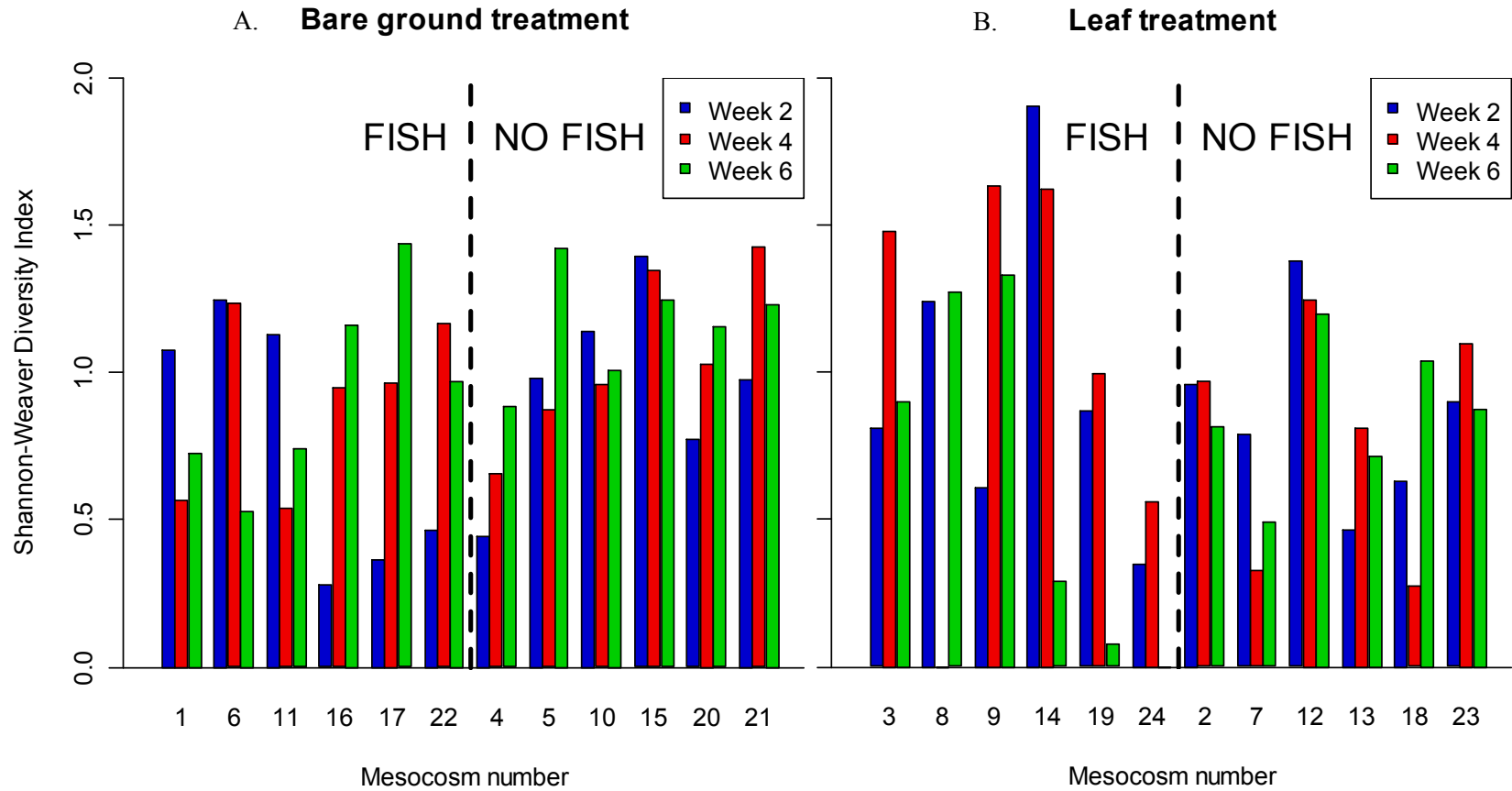


Fig. 6 The relationship of invertebrate taxa in mesocosms with fish and without fish on a log scale. For the most part, there is a one-to-one relationship but it was difficult to observe a pattern for those taxa with less than 100 individuals. More abundant taxa (>100 individuals) show a trend of having fewer individuals in tanks with fish. Small, but abundant diet items, like copepods, may be reproducing too fast for fish to have an effect.

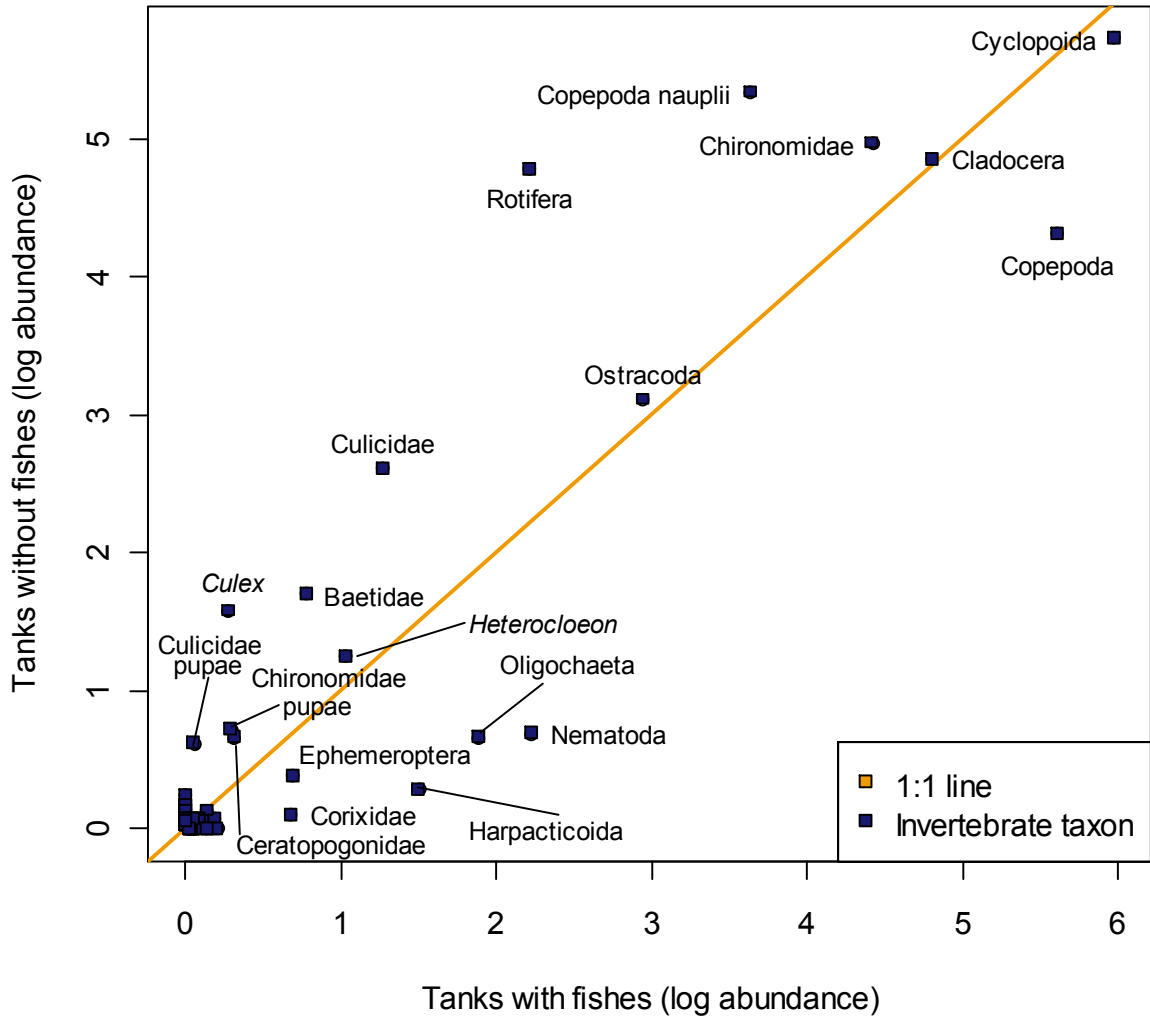


Fig. 7 Non-metric multi-dimensional scaling plots of each mesocosm according to invertebrate community composition. Points are delineated according to (A) leaf litter treatment, (B) presence and absence of YOY fishes, and (C) sampling week. Stress values for two-dimensional plots are reported. P-values and r^2 values are derived from PERMANOVA procedures.

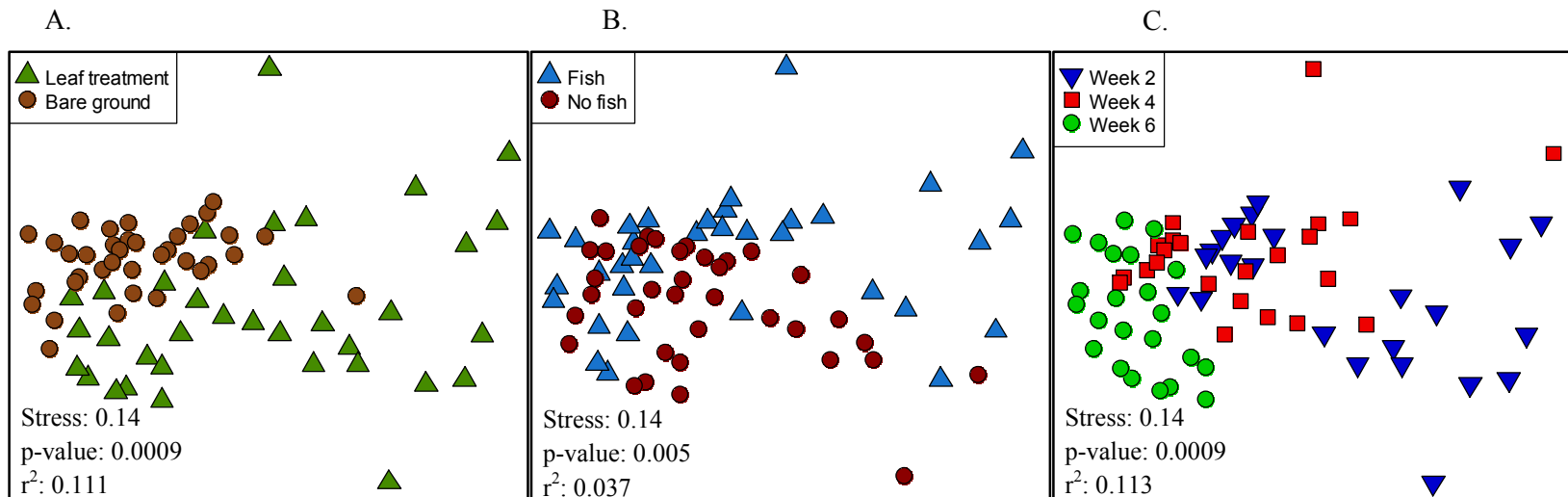


Fig. 8 The gut content proportion of (A) unidentifiable digested material, (B) copepods, (C) chironomids, (D) cladocerans, and (E) terrestrial and semi-terrestrial items, given according to raw numbers (yellow) and surface area (green). Surface area is given in a smaller scale because 70% of the overall surface area was unidentifiable digested material.

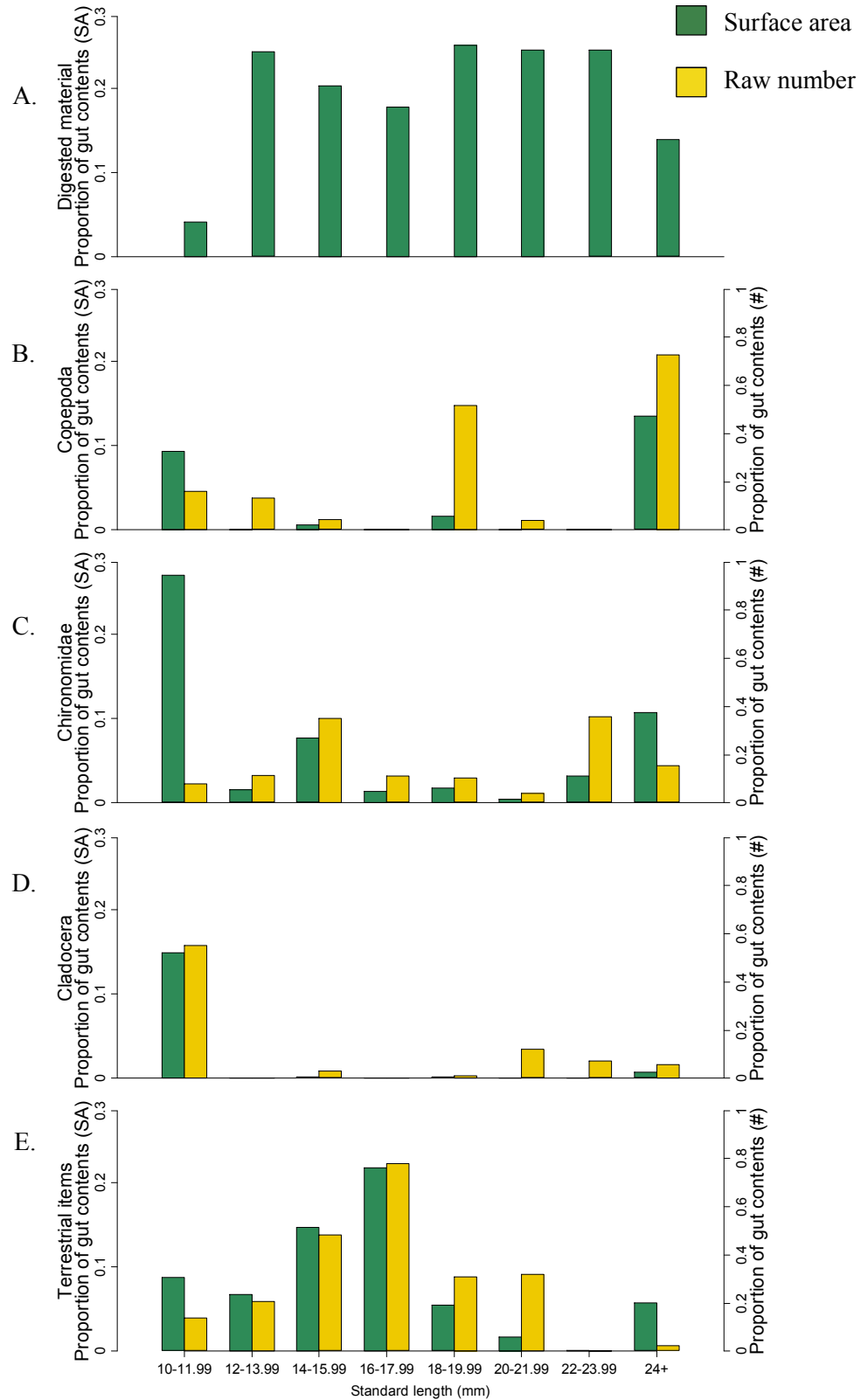


Fig. 9 Isotope biplots of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of the invertebrates removed from the mesocosms (A) with fish and (B) without fish. Dispersion of points is significantly greater in the absence of fish, particularly in the carbon dimension.

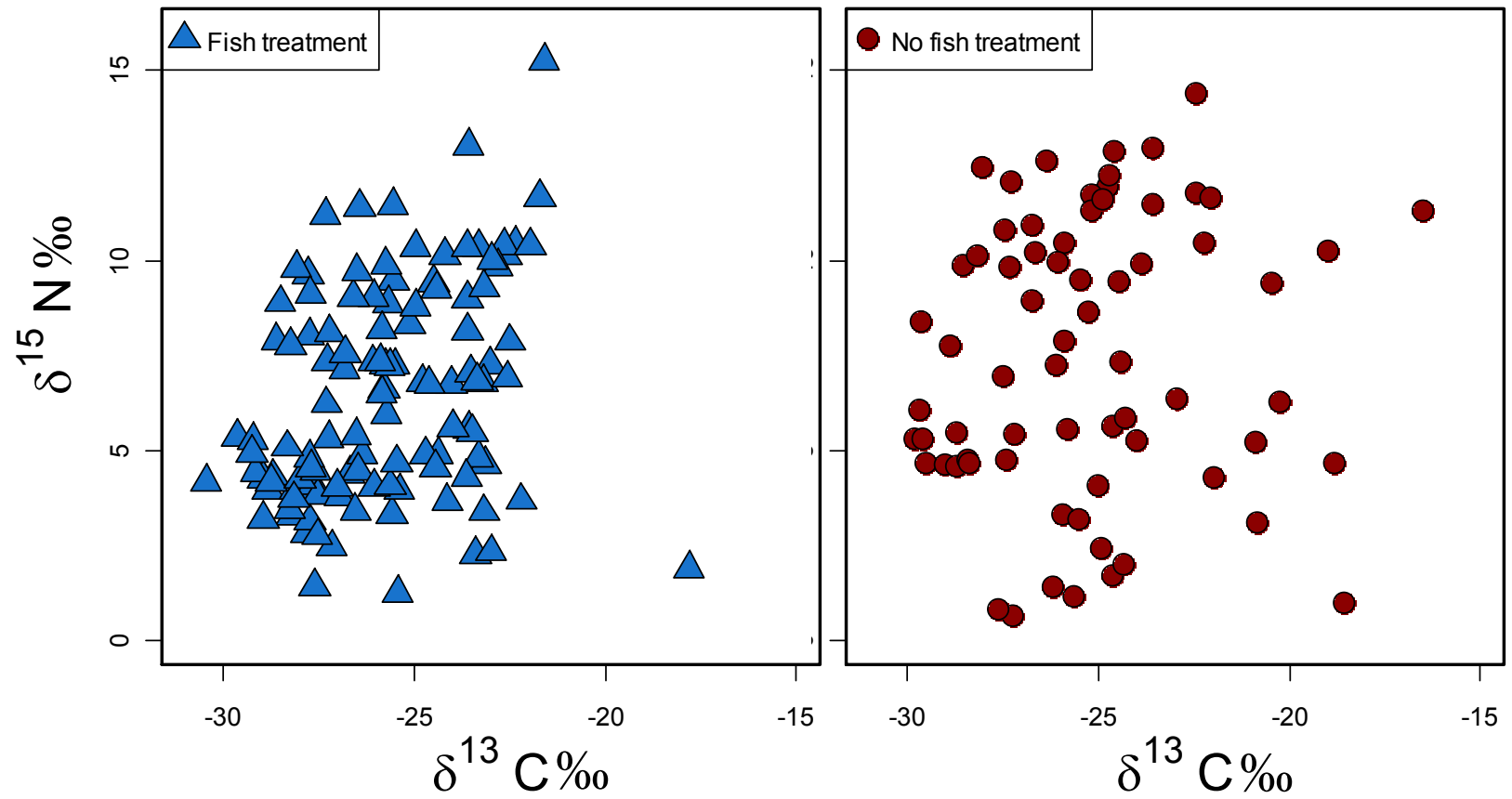


Fig. 10 Mean difference in (A) $\delta^{13}\text{C}$ and (B) $\delta^{15}\text{N}$ values between invertebrates from mesocosms without fishes and mesocosms with fishes for individual taxa. Bar colors correspond to functional feeding group. Coleopterans are adults unless otherwise specified. Dipterans, ephemeropterans and odonates are all larvae/nymphs. Taxa without error bars are represented by one stable isotope sample (although it may have included multiple individuals).

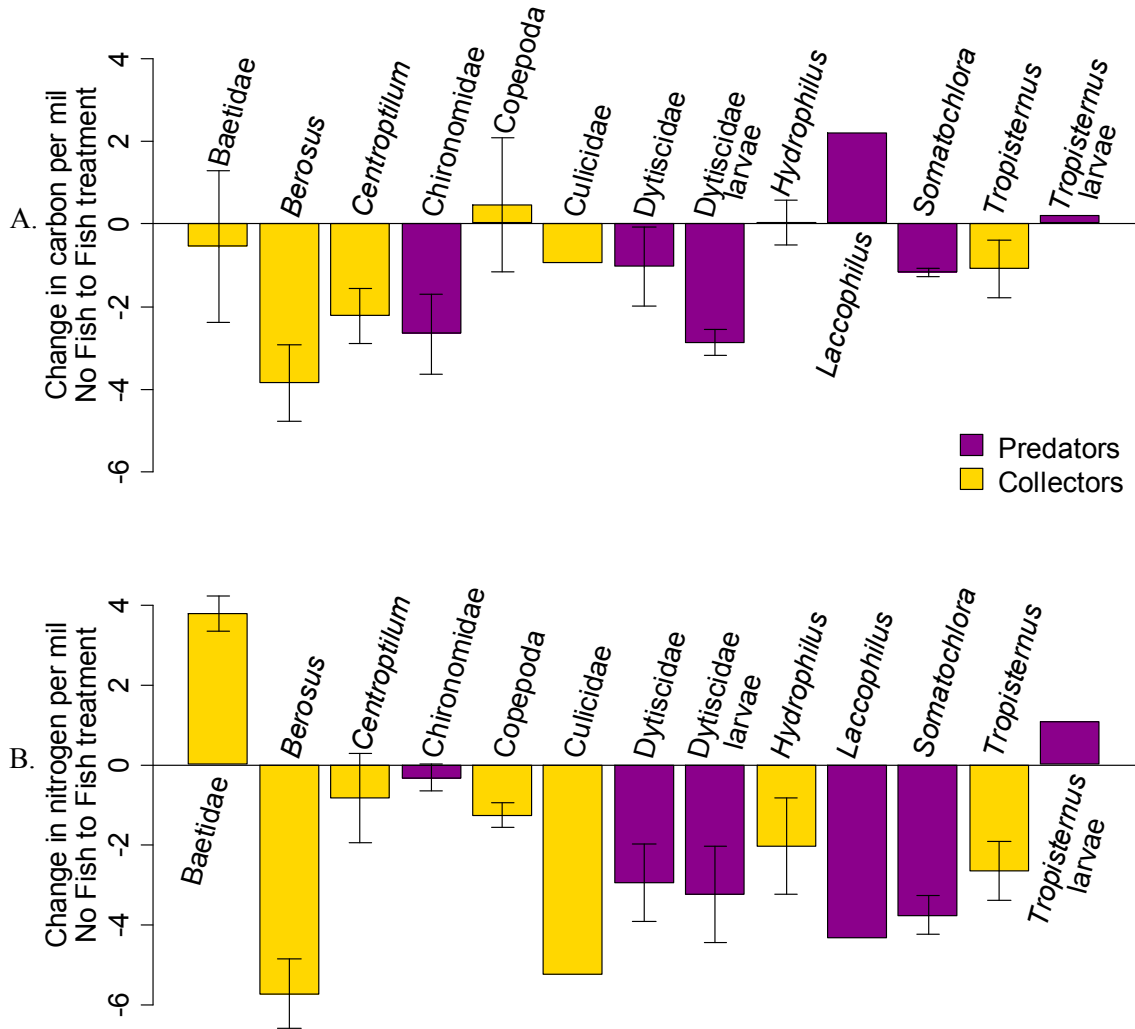


Fig. 11 Invertebrate isotope values from four treatments: (A) leaves and fishes, (B) leaves and no fishes, (C) no leaves with fishes and (D) no treatment. When fish are not present, leaves have a much bigger effect: $\delta^{13}\text{C}$ values drastically increase when leaves are not present. Isotopic signatures of invertebrates do not change much as a result of leaf treatment when fish are present. We see that they are still limited in the carbon dimension to the more depleted values (that which would coincide with algal, or autochthonous productivity).

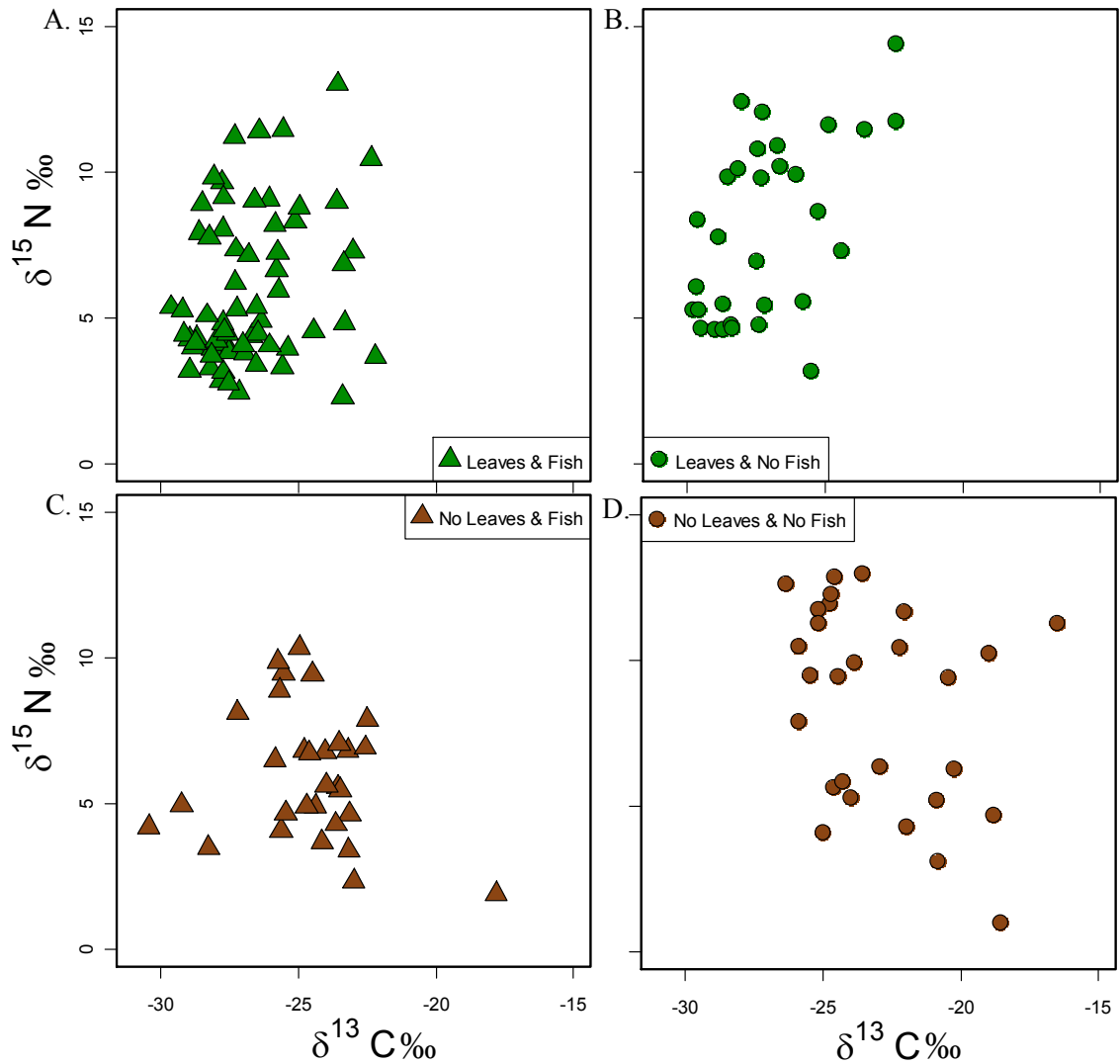


Fig. 12 Isotope signatures of fish tissues collected during sampling of the mesocosms. Fishes are separated according to the leaf treatment induced in their respective tanks. Those collected from tanks receiving no leaf treatment are more limited in the carbon dimension but exhibit a higher nitrogen value, on average.

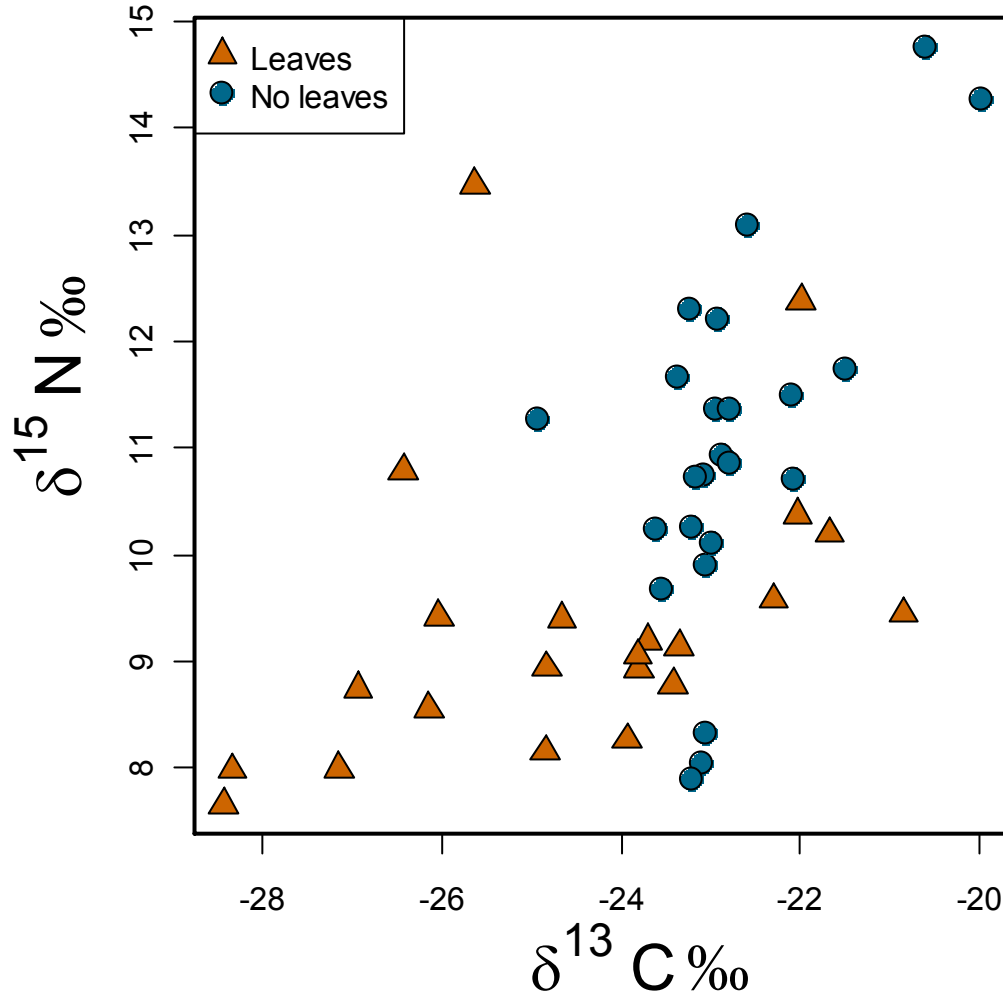


Fig. 13 Isotope biplot of the YOY fishes over time. Sample week two is the most constrained in both dimensions, while sample week four is the most spread out. There is overlap of all three sample weeks.

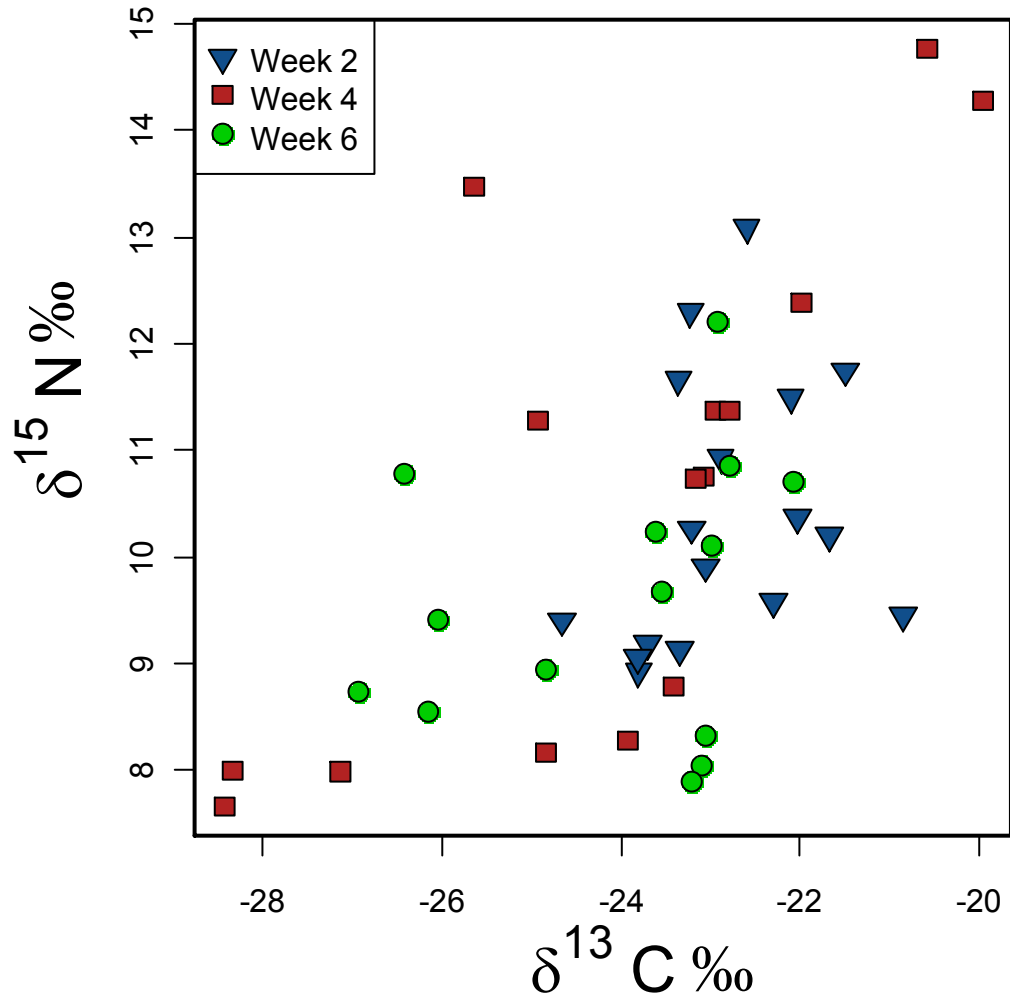


Table 1 The representation of species and standard lengths in the fishes removed for analysis over time. In the cases of *Ca. carpio* and *P. gracilis*, only one individual was collected. The small *G. affinis* in the sixth sampling period were newly-hatched young, due to a reproductive event before the sixth sampling week.

Sample week	Species	N =	Mean	Min	Max
2	<i>H. amarus</i>	14	14.61	11.43	18.09
	<i>P. promelas</i>	2	14.37	12.54	16.19
	<i>Ca. carpio</i>	1	-	12.70	-
4	<i>H. amarus</i>	13	16.34	13.17	20.47
	<i>P. promelas</i>	3	21.67	21.00	22.00
	<i>P. gracilis</i>	1	-	14.00	-
	<i>G. affinis</i>	2	21.66	19.20	24.12
	<i>Cy. carpio</i>	2	30.22	21.43	39.00
6	<i>H. amarus</i>	11	20.03	13.65	24.00
	<i>G. affinis</i>	4	11.77	10.16	15.00

Table 2 Contents of YOY guts by raw number (#) and by surface area (SA) in mm². Unidentifiable digested material made up the majority of the gut contents by surface area (69.4%), but was not part of the calculation by raw number. Generally, the most important taxa are in agreement between the two methods of measurement, although specific ranks differ.

YOY diet items	Percentage of gut contents	
	#	SA
Invertebrate items		
Rotifera	0.532	0.000*
Annelida		
Oligochaeta	1.595	4.457
Mollusca		
Gastropoda	<i>Physa</i> sp.	0.456
Crustacea		
Cladocera	7.973	0.540
Copepoda	52.999	4.925
Ostracoda	0.152	0.020
Collembola	2.658	1.826
Insecta		
Orthoptera	0.076	0.577
Ephemeroptera	0.456	0.271
Thysanoptera	2.809	0.524
Hemiptera	Corixidae	1.215
Coleoptera	Larvae	0.228
Diptera		
(<i>unidentified</i>)	Adults	1.139
(<i>unidentified</i>)	Pupae	0.228
(<i>unidentified</i>)	Larvae	0.076
Ceratopogonidae		0.228
Chironomidae		17.008
Culicidae		1.063
<u>Miscellaneous Items</u>		
Misc. terrestrial	0.152	0.485
Invertebrate eggs	0.304	0.359
Diatoms	1.822	0.026
White Seeds	6.302	1.149
Detritus	N/A	0.890
Invertebrate fragments	N/A	3.291
Sand (size >0.125 mm diameter)	N/A	0.280
Digested material	N/A	69.429

* negligible SA

Table 3 Comparison of percent total composition of diet items in invertebrate samples and gut contents (raw numbers). The relative proportions of these few diet items strongly suggest preferential feeding by YOY fishes, but only in leaf-treated tanks. Chironomidae, oligochaetes, and the terrestrially-derived thysanopterans, collembola and adult dipterans are preferential while copepods are relatively scarce in gut contents compared to mesocosm abundances. White plant matter (resembling seeds) was removed in great abundance from the gut contents of the YOY fishes. Data of the availability of this item in the mesocosm is not available.

		No leaves		Leaf treatment	
Taxon		% Invertebrate sample	% Gut content	% Invertebrate sample	% Gut content
<u>Aquatic</u>	Oligochaeta	0.23	0.26	1.30	12.30
	Copepoda	62.00	59.70	86.30	4.80
	Chironomidae larvae	10.30	16.60	4.90	21.20
	Culicidae larvae	0.07	0.00	0.81	8.90
<u>Terrestrial</u>	Collembola	0.01	1.60	0.06	6.20
	Thysanoptera	0.0*	1.60	0.00	12.30
	Diptera adults	0.00	0.78	0.00	4.10
	White plant matter	N/A	4.30	N/A	19.90

* Value less than 0.001 but greater than 0