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SECONDARY PRODUCTION RATES, CONSUMPTION RATES, AND TROPHIC BASIS OF PRODUCTION OF FISHES IN THE COLORADO RIVER, GRAND CANYON, AZ: AN ASSESSMENT OF POTENTIAL COMPETITION FOR FOOD

A THESIS SUBMITTED TO

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PROGRAM IN BIOLOGY

BY

KEVIN CHRISTOPHER DONNER

POCATELLO, IDAHO

APRIL 2011

To the Graduate Faculty:

The members of the committee appointed to examine the dissertation of Kevin C. Donner find it satisfactory and recommend that it be accepted.

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Major Advisor, Colden V. Baxter

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Graduate Faculty Representative: Mark Shapely

DEDICATION

I dedicate this thesis to my wife and parents whose love and support continues to be critical to all of my endeavors

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The components of this thesis incorporate data from an array of contributors and the analyses presented here would not be possible without such contributions. Raw catch rate data and capture efficiencies used to estimate abundance for large fishes were provided by Scott Rogers, Andy Makinster, and the Arizona Game and Fish Dept. Capture efficiencies for small fishes were provided by Dr. Bill Pine (University of Florida). Humpback chub population estimates were provided by Dr. Carl Walters (University of British Columbia) and their diets were quantified and summarized by Dr. Emma Rosi-Marshall and Dustin Kincaid (Cary Institute of Ecosystem Science). The diets of some 800+ small fish were quantified and summarized by Sarah Zahn-Seegert (Loyola University) and Emma Rosi-Marshall (Cary Institute of Ecosystem Studies). I would also like to thank the legion of people who assisted in field and laboratory work including: Dustin Kincaid, Kate Behn, Adam Copp, Amber Gaul, Carina Hall, Maria Pacioretty, Nichelle Heyrand, and Nate Tillotson. I would not have been able to complete this work without the outstanding support of my advisor, Colden Baxter and the members of the Stream Ecology Center at Idaho State University. Lastly, I thank the Grand Canyon Monitoring and Research Center, the U.S. Bureau of Reclamation and the U.S. Geological Survey for much appreciated logistical and financial support.

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GENERAL INTRODUCTION

The native fish assemblage of the Colorado River between Glen Canyon and what is now Lake Mead (hereafter, the Grand Canyon reach) have exhibited dramatic and alarming changes over the last 60 years. Four of eight native fish species have been extirpated from the reach, one species, the Humpback chub (*Gila cypha*), has been listed as a federally endangered species, and the remaining three species, flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*C. discobolus*), and speckled dace (*Rhinichthys osculus*) have exhibited dramatic shifts in their distribution and abundance (Minckley 2003). Managers and researchers have gone to great lengths to understand and address the causes of native fish decline in the Grand Canyon reach and have often focused on changes in physical habitat (e.g. temperature, sediment), particularly those associated with the closure of Glen Canyon dam in 1963. Changes in physical habitat have certainly played a role, however, biological factors in the context of physical habitat alteration (e.g. altered food resource availability, competition for food) may also be significant drivers of change in native fish assemblages. This thesis explores the potential for altered food resources and competition with non-native fishes to drive changes and contribute to losses in the native fish assemblage. In an attempt to provide an ecological context for the content of this thesis, I present a brief natural history of the Colorado River in Grand Canyon which emphasizes the physical and biological changes associated with the construction and operation of Glen Canyon Dam and their implications for fish fauna.

The physical habitat

The un-impounded Colorado River in Grand Canyon was characterized by highly turbid, sediment-laden waters, a snowmelt-driven hydrograph (3,000-85,000cms), and

broad annual variation in temperature (0-29°C; Topping et al.2003). After construction of Glen Canyon dam, sediment load decreased by 90%, clear water flows from the base of GCD and 90% of sediment inputs originate from tributaries. Natural flow dynamics of the seasons were lost, daily fluctuations in discharge were introduced due to hydro-peaking for power demand, and hypolimnetic releases constrained annual thermal regimes (Carothers and Brown 1991, Gloss et al.2005). Sediment and temperature characteristics begin to recover with increasing distance from the dam, but they do not approach pre-impoundment conditions before the river enters Lake Mead, the next reservoir.

Primary producers

Relatively little information exists regarding algal communities of the Colorado River before the construction of GCD making pre/post impoundment comparisons difficult. The pre-impoundment Colorado River was highly turbid during winter flows and restricted light availability during this timeframe may have suppressed primary productivity relative to post impoundment conditions. Flows during late summer ($113 m^2/s$) were reportedly clear and may have allowed for relatively brief periods of high primary productivity (Minckley 1991). Some evidence suggests that the abundance of certain algal species may have changed dramatically in the Colorado River, post-impoundment. In a 1962 survey, Williams and Scott reported algal cell densities of *Diatoma vulgare, Gomphonema olivaceum, Navicula viridula, Synedra ulna* and *Surirella sp*. in the mainstem of the Colorado river to be 400-1600 cells/ml. Crayton and Sommerfeld (1978) surveyed the same algal species and found their density to be 1600x lower than reported by Williams and Scott (Minckley 1991). This single comparison

suggests significant changes with regard to species composition, however, it is unclear what impact the dam has had on total primary productivity throughout the Grand Canyon reach. Since approximately 1966, the clear, nutrient rich waters of the Glen Canyon Dam tailwater have fueled high rates of primary productivity which has been dominated by the filamentous algae, *Cladophora glomerata* (McKinney 2001). Primary productivity and the relative abundance of *C. glomerata* decreases with distance downstream of the dam and is negatively correlated with turbidity (Stevens 1997, Hall et al. 2009).

Invertebrates

Data that describe the historic (pre-impoundment) abundance or composition of aquatic macro-invertebrates in the Grand Canyon are scarce, making pre- and post-impoundment comparisons difficult. However there is some evidence that aquatic invertebrate communities in Grand Canyon exhibited dramatic changes coincident with the closure of Glen Canyon dam. Musser (1959) documented a greater diversity of macroinvertebrates in Glen Canyon than what is present today. Several studies suggest that the pre-impoundment invertebrate assemblage in Grand Canyon may have resembled historic assemblages found near Flaming Gorge (Blinn 1991, Rosi-Marshall et al. 2010). An analysis of invertebrate assemblages in Flaming Gorge by Vinson (2002) documented the dramatic loss of invertebrate diversity as a result of the construction of Flaming Gorge dam. It is likely that similar changes may have occurred in Glen and Grand Canyons as a result of the construction of Glen Canyon dam.

Since the closure of Glen Canyon dam several invertebrates have been introduced in Grand Canyon, including *Gammarus lacustris* which was intentionally stocked in the

late 1960's as a food resource for rainbow trout in Glen Canyon, and the New Zealand mud snail, *Potamopyrgus antipodarum*, which was first detected in the Grand Canyon in 1995 and has since become a dominant member of the invertebrate assemblage in Glen Canyon (Cross et al. 2010). The current aquatic invertebrate assemblages in the Grand Canyon of the Colorado River are dominated by the nearctic Diptera families Simuliidae and Chironomidae, *Gammarus lacustris* and *Potamopyrgus antipodarum* (Blinn and Cole 1991, Stevens et al.1997, Rosi-Marshall et al. 2010). The introduction and establishment of these non-native invertebrates likely has implications for the quantity and quality of food available to native fishes, however, the potential for altered invertebrate assemblages to contribute to native fish declines is unknown.

Fish Fauna

The native fish assemblage of the Grand Canyon reach consisted of eight species including; Colorado pikeminnow (*Ptychocheilus lucius*), humpback chub (*Gila cypha*) bonytail chub (*G. elegans*), roundtail chub (*G. robusta*), razorback sucker (*Xyrauchen texanus*), flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*C. discobolus*), and speckled dace (*Rhinichthys osculus*). Bonytail chub and roundtail chub were likely extirpated from the reach before the closure of Glen Canyon dam and the Colorado pikeminnow and razorback sucker were last detected in the canyon in 1968 and 1984, respectively. The humpback chub (*Gila cypha*) was listed as a federally endangered species in 1967 and the population is largely restricted to a suite of aggregations along the reach, with the largest of these in the vicinity of the confluence with the Little Colorado River. The remaining three species, flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*C. discobolus*), and speckled dace (*Rhinichthys osculus*)

have declined in abundance overall, with their distribution characterized by virtual absence in the Glen Canyon segment and higher numbers downstream of the confluence of the Little Colorado River (Makinster et al. 2011). Concurrent with the decline and loss of native fishes, an array of non-native fishes have been established throughout the reach. Currently, more than 12 non-native fish species occur in the Grand Canyon including, but not limited to; rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), yellow bullhead (*Ameiurus natalis*), fathead minnow (*Pimephales promelas*), plains killifish (*Fundulus zebrinus*), and red shiner (*Cyprinella lutrensis*) (Webb et al. 2002, Makinster et al. 2011). These non-native fishes potentially predate upon or compete with native fishes and though several studies have investigated predatory interactions (Yard et al. 2011), none have specifically evaluated the potential for non-native fishes to compete with natives. Competition for food may be particularly important to native fishes in the context of the altered food resources (e.g. invertebrates) which are now typical of the Grand Canyon reach.

Here I present a thesis which examines the potential for trophic interactions to contribute to native fish decline in regulated rivers. The first chapter constitutes the focus of my graduate research and attempts to 1) quantify linkages between food resources and rates of production for the fish assemblage, 2) evaluate longitudinal, seasonal, and annual variability of trophic dynamics, 3) investigate overlap in use of food resources between different fish species and the assemblage as a whole, and 4) assess the potential strength of competition for food between fishes. The second chapter compares two model approaches estimating rates of consumption by fish, the Wisconsin bioenergetics model

and the Benke-Wallace model. Using data from a well characterized population of rainbow trout, I document divergences in the estimates of consumption rate by fish generated by each model. I develop and present a modified version of the Benke-Wallace model that incorporates, yet does not require, extensive parameterization for application with understudied fish species and reconcile its estimates of consumption with those of the Wisconsin model.

This thesis has been conducted as part of a large, multi-investigator research project aimed at characterizing food webs and carbon cycling and evaluating effects of adaptive management of Glen Canyon Dam on the fish populations and ecosystem of the in the Colorado River in Glen and Grand Canyons. Thus, I was fortunate to be able to draw on efforts by others in conducting my thesis project (see also Acknowledgments). That said, the scope of my own contribution included key components of fieldwork, research, and analysis. I participated in the collection of fish diet samples and population data and was principally responsible for processing and summarizing approximately 1000 diet samples from large adult fishes (>150mm) including; flannelmouth sucker, bluehead sucker, rainbow trout, brown trout, common carp, channel catfish, and yellow bullhead. I also contributed to processing and summarization of small (<150mm) fish diets including; red shiner, plains killifish, juvenile rainbow trout. Finally, I personally completed estimates and analyses of species abundance, rates of secondary production, trophic basis of fish production, consumption rates, and coefficients of competition for all fish species as reported in Chapter 1, and I carried out all analyses used to complete the comparison of the estimates of fish consumption via the Wisconsin bioenergetics model versus the Benke-Wallace model reported in Chapter 2.

CHAPTER 1

TROPHIC BASIS OF PRODUCTION OF FISHES IN THE COLORADO RIVER, GRAND CANYON, AZ: AN ASSESSMENT OF POTENTIAL COMPETITION FOR FOOD

Abstract

Regulation of the flows of large rivers has contributed to the decline and extirpation of native fishes worldwide. River regulation typically coincides with shifts in food availability and introduction of non-native fishes which may compete with natives, however, the role that these factors play in native fish decline is not well understood. To examine the potential impact of altered food resources and competition with non-natives, I quantified secondary production, rates of consumption, trophic basis of production, and coefficients of competition for the assemblage of native and non-native fishes of the Colorado River in Grand Canyon. Secondary production of the fish assemblage ranged from 0.05±0.01 g AFDM m^{-2} yr^{-1} to 0.47±0.12 g AFDM m^{-2} yr^{-1}, and was dominated by non-native rainbow trout in the tailwater of Glen Canyon dam and by flannelmouth sucker at sites > ca. 100 km downstream of Glen Canyon dam. Simuliidae and Chironomidae fueled 41-57% of secondary production by the entire fish assemblage at all sites. Estimates of a coefficient of competition between non-native and native fishes exceeded 1 (indicating strong potential for competition for food) at sites where rainbow trout were most abundant. Moreover, competition coefficients between individual species and the rest of the assemblage exceeded 1 for all but the most abundant and trophically divergent species. Simplified trophic basis of production and competition for depauperate food resources may be common in large, regulated rivers, potentially resulting in unstable food web structure and erratic shifts in abundance or extirpation of native fishes. Management that increases food resource diversity, and prevents introductions or constrains the success of non-native fishes in these systems may benefit

current native fish assemblages and help prevent future extirpation. Results of this study highlight the importance of food web perspectives in understanding and managing fishes in regulated rivers.

INTRODUCTION

Over half of the world's large rivers have had their flows regulated for human purposes (Wu et al. 2004, Nilsson et al. 2005) often resulting, directly or indirectly, in the decline and extirpation of native fishes (Edwards 1978, Martinez et al. 1994, Quinn and Kwak 2003, Dudley and Platania 2007). In the past, mechanistic explanation of native fish decline in these rivers has focused on the direct effects of alterations in physical habitat such as changes in flow, temperature, and sediment regimes, and lost migratory connectivity (Robinson and Childs 2001, Marchetti and Moyle 2001, Poff and Zimmerman 2010). Though these changes are undoubtedly important, they may not be entirely responsible for native fish declines. Altered food resources and competition with non-native fishes have also been implicated; however, their potential impact on native fishes in regulated rivers has rarely been assessed and is not well understood.

The source, quantity, and quality of food resources available to fishes can be dramatically affected by altered habitat regimes of regulated rivers. In many cases, river regulation reduces sediment load and associated allochthonous sources of organic matter. These conditions can facilitate increases in autochthonous resources, particularly in the tailwaters below dams (Ward and Stanford 1983). Aquatic macroinvertebrates, the predominant food of many riverine fishes, often exhibit low diversity in regulated rivers (e.g., Vinson 2001, Cortes et al. 2002, Poff and Zimmermann 2010) and these conditions may be exacerbated by the introduction and establishment of non-native invertebrates (e.g., Cross et al. 2010, Poff and Zimmerman 2010). Such changes may affect the quantity and quality of food available to fishes with implications for the dynamics of fish

populations and the communities within which they interact (Poff and Allen 1995, Cross et al. 2011), including the potential for competitive interactions among fishes. For example, if invertebrate composition shifts to taxa more resistant to predation, native fishes may experience decreased forage quality, increased potential for limitation by food, and possible population decline (Power et al. 1995, Wooton et al. 1996). In regulated rivers, altered food resources and diminished invertebrate diversity may recover with distance downstream of a dam (Ward and Stanford 1983), however these patterns are highly variable among large rivers. Evaluating the pathways that support production of fishes in regulated rivers could provide insight into the factors contributing to decline and/or limiting the recovery of native fishes. Although many studies have investigated the diets of individual fish species in regulated rivers (e.g., McKinney and Speas 2001, Mitsak et al. 2003), only a small number have specifically attempted to link their trophic ecology to rates of population production (e.g., Godby et al. 2007, Cross et al. 2011) and none have attempted to do so along the longitudinal profile of a river. Thus, there is a distinct need for analyses of the trophic basis of fish production along the length of large regulated rivers.

In combination with altered food resources, non-native fishes, which are thought to compete with natives, may be an additional threat to native fish persistence in regulated rivers. Establishment of non-native fishes is often facilitated in these systems through accidental introduction, intentional establishment of non-native sport fisheries, and creation of habitats to which are they are well suited (Moyle and Light 1996, Taylor et al. 2001, Bunn and Arthington 2002, Havel et al. 2005). Competition between native and non-native fishes may be particularly likely due to a lack of coevolved mechanisms

for niche partitioning, and thus non-native species may be more likely to overlap with other fishes in their use of important food resources. The low diversity of food resources typically found in regulated rivers (Poff and Zimmerman 2010) may also contribute to increased potential for trophic overlap among fishes. Conceivably, physical habitat and food resource availability may be so altered that river conditions are better suited for some non-native fishes than for natives. This may provide a competitive advantage for non-natives and underscores the importance of understanding their potential role in limiting native fishes in regulated rivers. Most studies of competition have focused on a single native-non-native species pair (Weigelt et al. 2007), but when fishes occur in more diverse assemblages, approaches that address the entire assemblage are required. Multiple species may compete for shared food resources, and the cumulative effect of competition between a given species and an assemblage may be greater than that of individual species pairs. Therefore, studies of competition among fishes, such as may occur in regulated rivers, may benefit from approaches that address interactions within entire fish assemblages.

The Grand Canyon reach of the Colorado River epitomizes many of the physical and biological changes observed in large regulated rivers throughout the world, including declines and losses of native fishes (Minckley 2003). Since the completion of Glen Canyon dam, primary productivity has increased in the dam's tailwater reach, macroinvertebrate diversity has decreased and assemblages have become dominated by non-native taxa (Gloss et al. 2005). Four of the eight original native fishes are extirpated from the reach, one species, the humpback chub (*Gila cypha*), has been listed as a federally endangered species, and the remaining three species, flannelmouth sucker

(*Catostomus latipinnis*), bluehead sucker (*C. discobolus*), and speckled dace (*Rhinichthys osculus*) have declined in abundance (Minckley 2003). Concurrent with the decline and loss of native fishes, an array of non-native fishes have become established throughout the reach. Currently, more than 12 non-native fish species occur in the Grand Canyon including, but not limited to; rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), yellow bullhead (*Ameiurus natalis*), fathead minnow (*Pimephales promelas*), plains killifish (*Fundulus zebrinus*), and red shiner (*Cyprinella lutrensis*) (Webb et al. 2002). Past research has documented that non-native fishes dominate areas nearest Glen Canyon dam and that natives become more abundant further downstream (Makinster et al. 2011). Invertebrate abundance and biomass decline with distance from the dam, paralleling patterns of primary productivity (Stevens et al. 1997, Hall et al. 2009). Given that patterns of physical and biological alteration in the Grand Canyon reach are generally representative of those seen in large regulated rivers, patterns in trophic basis of fish production and potential competition for food may also be representative of other systems. Thus, such analyses could provide insight into the factors causing declines or constraining recovery of native fishes in regulated rivers.

Here I present a two year investigation of fish assemblage secondary production rates, consumption rates, trophic basis of production, and coefficients of potential competition for food along the longitudinal profile of the Colorado River in Grand Canyon. This approach allowed me to 1) quantify linkages between food resources and rates of production for the fish assemblage, 2) evaluate longitudinal, seasonal, and annual variability of trophic dynamics, 3) investigate overlap in use of food resources between

different fish species and the assemblage as a whole, and 4) assess the potential strength of competition for food between fishes. Because organic matter resources and invertebrate diversity is low and non-native fishes are common in the Colorado River, I expected few prey resources would support the bulk of fish production and trophic overlap among species would be strong, trophic basis of fish production would be relatively homogenous over the time frame of the study, and strong potential competition for food would occur among fishes, including non-native and native species. My approach allowed me to evaluate these predictions and to examine the general hypothesis that, in regulated rivers, altered food resources and competition for food may be threats to the persistence of native fishes.

METHODS

Study site

The Grand Canyon reach of the Colorado River encompasses approximately 450 linear kilometers of river, from the tailwater of a hypolimnetic, hydro-electric dam in Glen Canyon, AZ to the eastern end of Lake Mead, AZ (Figure 1). Historically, this reach was characterized by highly turbid, sediment-laden waters, a snowmelt-driven hydrograph (3,000-85,000cms), and broad annual variation in temperature (0-29°C; Topping et al. 2003). Presently, clear, nutrient rich water flows from Glen Canyon dam and 90% of sediment inputs originate from tributaries. Natural flow dynamics of the seasons have been lost, daily fluctuations in discharge have increased due to hydro-peaking for power demand, and hypolimnetic releases constrain annual thermal regimes (Carothers and Brown 1991, Gloss et al. 2005). Sediment and temperature characteristics

begin to recover with increasing distance from the dam, but they do not approach pre-impoundment conditions before the river enters Lake Mead, the next reservoir. Primary productivity and aquatic macro-invertebrate biomass is high in the dam's tailwater relative to pre-impoundment conditions and declines exponentially with increasing distance downstream (Stevens et al. 1997, Gloss et al. 2005, Hall et al. 2009). Invertebrate diversity is greatly diminished throughout the Grand Canyon and current assemblages are dominated by non-native nearctic Simuliidae and Chironomidae and *Gammarus lacustris* (Blinn and Cole 1991, Stevens et al. 1997, Cross et al. 2011) In addition the New Zealand mud snail, *Potamopyrgus antipodarum*, first detected in the Grand Canyon in 1995, has since become a dominant member of the assemblage, especially in the reach immediately downstream of the dam (Cross et al. 2010; 2011).

Site selection

Six sites were included in this study, which I refer to as RM0 (rkm -20 to 1), RM30 (rkm 47 to 55), RM60 (rkm 98 to 111), RM125 (rkm 201 to 208), RM165 (rkm 264 to 274), and RM225 (rkm 354 to 364). By convention, RM0 (also known as Lee's Ferry) represents the starting point of this particular segment of the Colorado River. Sites were selected to encompass the longitudinal profile the Colorado River from Glen Canyon dam through Grand Canyon, including the spectrum of sediment and temperature conditions and the major geomorphic reach types (as defined by Schmidt and Graf 1990). Site length ranged from 6.8 km to 20.9 km and was constrained by large rapids. Mean river width for each site ranged from 60.8 m to 131.4 m. I studied fish assemblages at these sites seasonally over the course of two years. The study period included a high flow release from the dam as well as other flow manipulations. Evaluating the effects of

individual management experiments was not the focus of this study (see Rosi-Marshall et al. 2010, Cross et al. 2011); rather the aim was to encompass seasonal and annual variability that are now typical of the river, including the ongoing adaptive management of river flows.

Fish abundance, biomass, and secondary production

I estimated fish size structure and abundance on 3-4 dates per year during 2007 and 2008. Adults and juveniles of large-bodied species (>150 mm adult length) were sampled using methods of the long-term fish monitoring program in Grand Canyon (see McKinney 1999 for details). Briefly, fishes were captured using single-pass electro-fishing in 15 to 45, 0.1 mile segments. Abundance was estimated by dividing the number of fish caught in a monitoring segment by species-specific capture efficiencies (flannelmouth and bluehead sucker-0.021, rainbow trout-0.095, brown trout-0.09, common carp-0.06). Capture efficiencies for large-bodied fishes were derived by comparing catch estimates obtained between 2000 and 2004 with mark-recapture abundance estimates for whole-populations from the same period (R.S. Rogers, Arizona Game and Fish Department, *unpublished*). I assumed that capture efficiency was the main source of error in estimates of fish abundance and therefore used variability in capture efficiency reported by Speas et al. (2004) to estimate 95% confidence intervals for abundance. For small-bodied fishes (e.g., speckled dace, fathead minnow), I estimated abundance by conducting three-pass removal electro-fishing and single-pass electro-fishing seasonally on 4 dates during 2007 and 3 dates during 2008. Abundance estimates were derived from single-pass electro-fishing efforts by dividing total catch by species-specific capture efficiencies (W. Pine, University of Florida, *unpublished*).

Biomass was estimated for each species by applying a length-weight regression to size structure data and abundance estimates. Length-weight regressions were derived from biometric data collected during electro-fishing efforts. Annual secondary production rates for each species were estimated by multiplying size-structured biomass estimates and size-specific instantaneous growth rates (Busacker et al. 1990). Size-specific instantaneous growth rates for each species were determined using Von Bertalanffy curves and length-weight regressions (R.S. Rogers, Arizona Game and Fish Department, *unpublished*). Instantaneous growth rates were not available for common carp, thus their production was estimated by applying a relatively conservative net production efficiency of 0.1 to estimated consumption rates for the entire population (see methods below). Due to low capture efficiency, I was unable to quantify abundance of channel catfish and yellow bullhead, thus these species are excluded from analyses that required estimates of fish production. During the timeframe of the study, yellow bullhead were present but rare at RM60 and channel catfish were commonly captured via hook-and-line at RM165 and RM225.

Gut content sampling and analysis

The gut contents of 1855 fish were collected and analyzed over a period of two years, including; 436 flannelmouth suckers, 197 bluehead suckers, 232 speckled dace, 77 humpback chub, 444 rainbow trout, 214 fathead minnows, 156 common carp, 24 plains killifish, 30 channel catfish, 18 yellow bullhead, 14 red shiners, and 13 brown trout (Table 1). In general, 10-15 individuals of each of the dominant species present at a site were collected each season from April 2007-January 2009. Sample sizes of 1-10 were typical for species uncommon to a given site or season (e.g., plains killifish, yellow

bullhead). Fish were typically collected after dusk via single-pass electro-fishing (DC pulse current, 250-400w,13-25a) in near-shore areas; however, the collection of small-bodied species was often supplemented via seining during daytime. Capture location, fork length (mm), weight (g), and sex were recorded for each individual before removal and preservation of the entire gut tract in 95% ethanol. Whenever possible, gut contents from a range of fish sizes were collected to account for possible shifts in diet with ontogeny. To sample the gut contents of endangered humpback chub, a non-lethal gastric lavage technique (Stone 2004) was used. This method constrained sampling to chub larger than 150 mm total length. For most fishes, I determined dietary composition by manually removing, separating, and identifying materials contained in the foregut of each fish. For the purposes of this study, the foregut was defined as the area anterior to the pyloric sphincter for species with a "true stomach" (e.g., trout, catfish), and the anterior 20% of the stomach for species without a "true stomach" (e.g., carp, suckers, dace). This approach avoided compositional bias that may have arisen from differential digestion of diet items (Hyslop 1980).

Gut contents were separated into diet item categories (detrital aggregate, terrestrial plant material, *Cladophora*, macroinvertebrate family and, for select taxa, species) using a dissecting microscope (Bausch and Lamb, 0.7x-3x). Materials in each category were dried at 60°C for 24hrs, weighed to the nearest microgram (µg), and the proportion of each category to the total dry weight of the gut content sample was calculated. Gut content composition for smaller fish (<150 mm) and those of humpback chub were determined using an area-based analysis of digital images taken under magnification of a stereo microscope (100-400x) and analyzed with image analysis

software (ImagePro Plus ® Media Cybernetics, Bethesda, Maryland and Leica Application Suite © Leica Microsystems Ltd., Heerbrugg, Switzerland). This method yields dietary composition that is statistically indistinguishable from gravimetric analysis (Zahn-Seegert 2010). Seasonal and annual dietary composition was determined for all species at each site by averaging the diet proportions of each individual at a site-season-year combination and averaging the seasonal diet at each site-year combination, respectively.

Consumption

As a step toward assessing the potential competition for food, I estimated annual rates of consumption for each species at each site as well as for the entire assemblage at a site. Annual consumption rate of each diet item *i* by the population of consumer *j* (C) was estimated as;

$$1)\quad C_{ij} = \frac{(P_j * B_i)}{(NPE_a * AE_i)}$$

Where P_j is the annual secondary production rate of the consumer population, B_i is the proportional contribution of the prey item to the consumer's production, AE_i is a species-specific assimilation efficiency for the food type, and NPE_a is the net production efficiency of the consumer at age *a*. For each species, NPE was assumed to be a function of age (*a*) where;

$$2)\quad NPE_a = 0.25(\pm 0.05) - e^{(-0.16(\pm 0.05) * a)}$$

I applied this function to all species when estimating age specific NPE (see chapter 2). Estimated NPE derived from the Wisconsin bioenergetics model (Hanson et al. 1997) for

rainbow trout at RM0 and modeled estimates of NPE for lake trout reported in Jackson (1996) fell within the range of error of this function. As mentioned above, production estimates were not available for common carp, thus, consumption rate for this species was estimated using the gastric evacuation method outlined by Elliot and Persson (1978) and the gastric evacuation rate for carp of 2.7% hr^{-1} which was derived from fish inhabiting a comparable temperature range (Kevern 1966). I used bootstrap analysis to generate 95% confidence intervals around consumption estimates by randomizing net production efficiency and production estimates between upper and lower bounds.

Trophic basis of production

I estimated the proportional contribution of diet items to annual secondary production of fish following the "trophic basis of production" (TBP) method (Benke and Wallace 1980). The relative proportion of fish production attributable to a food type (B_i) was calculated as:

$$3)\quad B_i = \frac{(G_i * AE_i)}{\sum_{i=1}^{n}(G_i * AE_i)}$$

where G_i is the annual average fraction of a food type in the diet, AE_i is a species-specific assimilation efficiency for the food type, and P_j is the annual secondary production rate of the consumer population measured in g AFDM m^{-2} yr^{-1}. Consumer-prey AE values derived from the literature were used when available (Table 2). When AE values specific to consumer-prey pairs were not available, I used those from the most closely related consumer-prey combination possible. Estimates of TBP for the entire fish assemblage were derived by summing TBP averages for each fish species, weighted by the production of each. I bootstrapped 95% confidence intervals around TBP by

randomizing individual diets within a site-season-year combination. Estimates of TBP were considered significantly different if confidence intervals did not overlap.

Competition coefficient analysis

In order to quantify the potential strength of competition for food, I modified an approach presented by Schoener (1974,) and Spiller (1986) to calculate coefficients of competition. In its original form, the competition coefficient, α, describes the number of individuals of competitor *i* that are equivalent to that of competitor *j* with regard to use of food resources, and is expressed as;

$$4)\quad \alpha_{ij} = \left(\frac{c_j}{c_i}\right) * \left[\frac{\sum_{k=1}^{m}(d_{ik}/f_k)\,(d_{jk}/f_k)\,b_{jk}}{\sum_{k=1}^{m}(d_{ik}/f_k)^2\,b_{ik}}\right]$$

where $\frac{cj}{ci}$ is the ratio of material consumed by an individual of competitor *j* to that consumed by competitor *i*, d is the proportion of resource *k* in the diet of competitor *i* (similarly for d_{jk}), f is the proportional availability of resource *k* in the environment, and b is assimilation efficiency of resource *k*. I modified this equation where α is expressed as;

$$5)\quad \alpha_{ij} = \left(\frac{c_{pj}}{c_{pi}}\right) * \left[\frac{\sum_{k=1}^{m}(d_{ik}/pC_k)\,(d_{jk}/pC_k)\,b_{jk}}{\sum_{k=1}^{m}(d_{ik}/pC_k)^2\,b_{ik}}\right]$$

Where $\frac{c_{pj}}{c_{pi}}$ is the ratio of material consumed by the population of competitor *j* to that consumed by the population of competitor *i* and pC_k is the proportional contribution of resource *k* to total consumption by the entire assemblage of fishes. By replacing $\frac{cj}{ci}$ with consumption by the entire population of each competitor, $\frac{c_{pj}}{c_{pi}}$, I was able to analyze competition coefficients at each site from the perspective of a) the assemblage of fishes

(*j*) *vs* each fish species (*i*) and b) assemblage of non-native fishes (*j*) *vs* assemblage of native fishes (*i*). This approach allowed me to assess the potential competition for food within an entire assemblage of fishes. I replaced f_k with pC_k for several reasons; 1) reliable estimates of detrital aggregate and terrestrial plant material availability were not available, 2) estimates of consumption of some invertebrates by the fish assemblage were similar to or exceeded secondary production of those invertebrates (W. Cross, Montana State University, *unpublished*), and 3) there is considerable evidence that standing crop biomass, often used as a surrogate for availability, is not a good indicator of food available to fishes (Rader 1997, Cross et al. 2011). Given this modification, fish preference for invertebrate prey could inflate the invertebrate availability term in these calculations relative to those for other resources, thus I expected the magnitude of competition coefficients to be conservative. Based on the equation above, then, the competition coefficient, α, represents a multiplier whereby the species or assemblage *i* times α is equivalent to the assemblage *j* with regard to food resource use. Values greater than 1 suggest that competition between groups is stronger than competition within each group. I bootstrapped 95% confidence intervals around competition coefficients for groups by randomizing consumption rate of each and coefficients were considered significantly different if confidence intervals did not overlap.

RESULTS

Fish production

Estimates of the annual production of the entire fish assemblage across the 6 sites in 2007 and 2008 ranged from 0.05±0.01 g AFDM m^{-2} yr^{-1} to 0.47±0.12 g AFDM m^{-2} yr^{-}

^{1}, representing a 10 fold range across sites (Figure 2, Appendix A). Production by the assemblage was highest at RM125 and 165 during 2007 (0.35 and 0.33 g AFDM m^{-2} yr^{-1} respectively) and RM0, 125, and 165 during 2008 (0.47, 0.36, and 0.38 g AFDM m^{-2} yr^{-1}, respectively) and lowest at RM30, RM60, and RM225 during both years of study (0.07, 0.18, and 0.05 g AFDM m^{-2} yr^{-1} respectively during 2007 and 0.19, 0.15, and 0.29 g AFDM m^{-2} yr^{-1} respectively during 2008). Production by non-native rainbow trout was dominant at the two sites closest to the dam (RM0 and 30; 100% and 86% total annual production, respectively) whereas native flannelmouth sucker dominated production at sites further downstream (RM60, RM125, RM165, and RM225; 53-94% total production) during both years of study. Native humpback chub production comprised 15.4% and 15.9% of total production at RM60 during 2007 and 2008, respectively. Juvenile (<150 mm) large-bodied fishes (rainbow trout, flannelmouth sucker and bluehead sucker) contributed 5-25% of total annual fish production at sites. Small-bodied species (speckled dace and nonnative fathead minnow, plains killifish, red shiner) constituted relatively small proportions (<5%) of total annual production at site, however, at some sites their production (especially that of fathead minnow and speckled dace) was comparable to or greater than that of less common, large-bodies species (e.g., common carp, brown trout) and juveniles of large-bodied species (e.g, humpback chub).

In terms of production, overlap between native and non-native fishes occurred at all sites during both years, but the extent of overlap was highest at RM60 where non-natives contributed 7.2% and 27.1% to total annual fish production during 2007 and 2008 respectively. The extent of overlap was lowest at RM0, RM165, and RM225 where

>95% to total annual fish production was attributable to either non-native rainbow trout (RM0) or native flannelmouth sucker (RM165, RM225) during both years of study.

Fish production exhibited some changes over the duration of this investigation. Total fish production increased significantly at RM0, RM30 and RM225 from 0.14, 0.08, and 0.05 g AFDM m^{-2} yr^{-1} during 2007 to 0.47, 0.19, and 0.29 g AFDM m^{-2} yr^{-1}, respectively in 2008. Rainbow trout were responsible for 100% and 88% of the 2-4 fold increases at RM0 and RM30, respectively, and flannelmouth suckers were responsible for 100% of the nearly 6 fold increase in estimated production at RM225. Production by the assemblage decreased slightly between the two years at RM125 and RM165, but these differences were not statistically significant.

Food consumption by fish

Fish consumed an array of resources including detrital aggregate, *Cladophora*, terrestrial seeds and leaves, aquatic invertebrates, terrestrial invertebrates, fish, and even the occasional terrestrial vertebrate and scraps of human food presumably derived from camps along the river (Figure 3). Longitudinal patterns in total consumption for the entire fish assemblage were similar to fish production. For example, the highest and lowest rates of consumption by the fish assemblage were measured at sites with the highest and lowest rates of production by the assemblage during both years. Total consumption by the fish assemblages ranged from 0.92 to 7.60 g AFDM m^{-2} yr^{-1} at a given site during 2007 and 2008 and 32-75% of consumed materials consisted of *Cladophora*, detrital aggregate, and terrestrial plant. Assemblages consumed 0.21-3.23 g AFDM m^{-2} $yr^{-1}$of aquatic invertebrate prey at a given site-year combination, 77-97% of

which consisted of Simuliidae, Chironomidae, and *G. lacustris*. Significant increases in total consumption between years occurred at RM0, RM30, RM165 and RM225 and coincided with increases in production (e.g. RM0) and shifts in age structure of dominant fish species at those sites.

Trophic basis of fish production

When evaluated at the level of the entire fish assemblage, fish production at a given site-year combination was primarily fueled by Simuliidae, Chironomidae, detrital aggregate, and *Cladophora*. Simuliidae and Chironomidae supported, on average, 41-57% of total fish production across sites throughout the 2 year duration of study (Figure 4). Absolute rates of total fish production attributable to Chironomidae and Simuliidae were greatest at RM165 (0.21 g AFDM m^{-2} yr^{-1}) and RM0 (0.24 g AFDM m^{-2} yr^{-1}) during 2007 and 2008 respectively (Figure 5). Average annual site-specific fish production attributable to Simuliidae and Chironomidae increased from 0.11 g AFDM m^{-2} yr^{-1} during 2007 to 0.14 g AFDM m^{-2} yr^{-1} in 2008. Materials with relatively low assimilation efficiencies (detrital aggregate, *Cladophora*, and terrestrial plant material) contributed 5-62% of total fish production at a given site, fueling the lowest proportions of fish assemblage production at RM0 and increasing with distance downstream. Rates of fish production attributable to these resources were highest at RM125 (0.12 and 0.19 g AFDM m^{-2} yr^{-1}, 2007 and 2008 respectively) and RM165 (0.13 and 0.16 g AFDM m^{-2} yr^{-1}, 2007and 2008 respectively) during both years of study.

Production of native fish species was principally fueled by Simuliidae, Chironomidae and detrital aggregate, though the proportion contributed by each varied

among natives (Figure 6). Trophic basis of production (TBP) of humpback chub and speckled dace was dominated by Simuliidae and Chironomidae (65% of humpback chub production and 70-76% of speckled dace production) whereas flannelmouth sucker TBP was fueled to a lesser extent by these items (38%-62%) and bluehead sucker TBP was dominated by detrital aggregate (58-82%).

Production of non-native species was fueled by a wider array of food items and was more variable among sites and between species than that of native fishes (Figure 6). From 9 to 51% of rainbow trout (the dominant large-bodied, non-native species) production and 27-43% of fathead minnow (the dominant small-bodied, non-native species) production was fueled by Simuliidae and Chironomidae. The proportional contribution of Simuliidae and Chironomidae to non-native fish production was particularly high at sites where each of these species exhibited the highest rates of secondary production. *Gammarus* also fueled large proportions of rainbow trout, yellow bullhead, and common carp production at certain sites. Detrital aggregate, *Cladophora*, and terrestrial plant material fueled 12-37% of rainbow trout production, 21-66% of common carp production, 22-64% of fathead minnow production at a given site, averaged over both years of study. These food items contributed to less than 9% of production for the remaining non-native species with the exception of channel catfish (31% of channel catfish production was fueled by *Cladophora*).

Potential competition for food resources

Coefficients of competition between the assemblage of native fishes and the assemblage of non-native fishes exceeded 1 at RM30 and were less than 1 at RM60,

RM125, RM165, and RM225 during both years of study (Figure 7). Coefficients of competition at RM0 would have far exceeded 1 however, the scarcity of native fishes at RM0 precluded the such analysis. Competition coefficients increased significantly between 2007 and 2008 at RM60, RM125, RM165, and RM225, corresponding with significant increases in production and associated rates of consumption by rainbow trout that occurred at those sites. The scarcity of native fishes at RM0 precluded reliable estimates of their population, thus, I was unable to provide quantitative estimates of competition coefficients for that site. Had estimates been available, the sheer dominance of non-native rainbow trout at this site would have resulted in competition coefficients far surpassing those at all other sites (see Figure 7).

Coefficients of competition between the assemblage of fishes and individual species exceeded 1 in 76% of cases during 2007 and 70% of cases during 2008, indicating that interspecific competition with the rest of the assemblage may be more important that intraspecific competition for most species (Table 3). Coefficients exceeded 1 in 63% of cases for non-native species and 81% of cases for native fishes during both years of study. All native fishes, except adult flannelmouth sucker, had coefficients greater than 1 owing to extensive dietary overlap with the rest of the fish assemblage and, in some cases, resulting from relatively low consumption rates. Three of the 7 non-native fishes had coefficients less than 1, correspondent with their relatively high rates of consumption (e.g., rainbow trout) or trophic divergence from the rest of the assemblage (e.g. common carp, brown trout). Small bodied fishes also exhibited coefficients greater than 1 and, in many cases, many orders of magnitude greater than 1 owing to their relatively low production rates relative to large bodied adults which

dominate total consumption by the assemblage. The direction and magnitude of changes in fish competition coefficients were variable between years and among species. For example, competition coefficients for juvenile flannelmouth sucker generally increased in 2008 whereas coefficient of adult flannelmouth sucker remained relatively constant. Coefficients for the dominant non-native species, rainbow trout, remained relatively static between years at all sites with the exception of a dramatic decline at RM165. Competition coefficients for humpback chub, on the other hand, doubled from 2007 to 2008.

DISCUSSION

Results of this study demonstrate that the production of fishes in the regulated Colorado River in Glen and Grand Canyons is fueled by a small array of food resources of potentially limited availability, and that this may lead to strong competition for food among fishes, including competition with non-native species, that may constrain production of the remaining native fishes in this river. For example, more than half of the trophic basis of production for the assemblage of fishes was derived from two insect taxa, black flies (Simuiliidae) and midges (Chironomidae). Similar cases of food web simplification may occur in other large regulated rivers, particularly those where dams have wrought the most dramatic alteration of habitat and fauna (Vinson 2001, Johnson et al. 2007, Takoa et al. 2008). Continued damming of large rivers around the world promises to further this process of biotic and food web homogenization (Nillson et al. 2005, Poff et al. 2007). Food web homogenization may facilitate competition for food in regulated rivers whose degraded habitat conditions already challenge the physiological tolerance of many native fishes (Minckley 2003), and strong competition may further

exacerbate the impacts from nonnative fishes in those systems (Minckley 1991, Moyle and Light 1996).

Patterns in fish production

The majority of secondary production by the fish assemblage was fueled by invertebrate resources, thus one might expect spatial patterns in fish production to mirror the relative production of invertebrate prey. However, longitudinal patterns in total fish production did not reflect previously reported longitudinal patterns of invertebrate density and biomass. Stevens et al. (1997) reported that invertebrate abundance and biomass decreased with distance downstream of Glen Canyon Dam, a pattern that has been documented for invertebrate production during the time frame of this study as well (W. Cross, Montana State University, *unpublished*), yet the highest rates of fish production were found at sites far downstream of Glen Canyon Dam (e.g. RM165). Of invertebrates, Simuliidae and Chironomidae fueled the greatest proportion of fish production, and patterns of fish production may track those taxa specifically, however, analyses that evaluate prey demand and availability for individual prey taxa, and particularly these insects, will be necessary to investigate this possibility.

If disconnects between fish production and invertebrate availability exist in the Grand Canyon, two factors may help to explain high estimates of fish production at downstream sites. First, movement of fishes into study sites may have inflated estimates of fish production, particularly if significant proportions of that production originate from tributary environments. Native humpback chub and flannelmouth and bluehead suckers are known to use tributaries for spawning (Weiss et al. 1998, Gorman and Stone 1999,

Douglas and Douglas 2000) and extensive mainstem movements (>100 km) have been documented in Grand Canyon for flannelmouth suckers in particular (Theime 1997), but the proportion of populations using tributaries, the duration of that use and the production derived therein is unknown. Though fishes certainly move, major seasonal changes in abundance at sites that would have been indicative of synchronous migrations involving large segments of populations were not evident in the data used to estimate fish production. A second mechanism potentially responsible for patterns in fish production may be that native fishes that dominate the assemblage at downstream sites may exhibit greater trophic efficiency than the non-native rainbow trout that dominate production closer to Glen Canyon Dam. Ecological efficiencies of native fishes in the Colorado River have not been investigated, however, a study of white sucker by Ahlgren (1990) is supportive of relatively high ecological efficiencies by fishes in the Catostomidae family and may partly explain why Catostomids dominate secondary production in downstream sections of the Grand Canyon where high quality prey are scarce relative to resources of low quality (Stevens et al. 1997). Future efforts should investigate fish movement and ecological efficiencies to better understand patterns of their production.

Simplified trophic basis of fish production

The simplified trophic basis of fish production observed in this study may be, in large part, attributable to low food resource diversity common of many regulated rivers (Bunn and Arthington 2002, Poff et al. 2010) and documented in other flow regulated segments of the Colorado River basin. For example, below Flaming Gorge Dam on the Green River, a major tributary of the Colorado, Vinson (2001) described the loss of one of the world's most diverse (> 20 species) assemblages of mayflies. Similar diminished

aquatic plant diversity (Rørslett et al. 1989) and overall homogenization of food resources for fishes have been documented in regulated rivers throughout the world (Brittain et al. 1989, Bunn and Arthington 2002). Simplifying the trophic basis of production for fishes is of particular concern because it may impart a food web structure that is highly unstable, owing to the dominance of a few strong links between predators and their prey as opposed to many weak, stabilizing interactions (McCann et al. 1998). Under this condition, oscillations of any one food resource could potentially drive chaotic dynamics in the populations of consumers, like fishes, linked to that resource (McCann 2000). If simplified foodweb structure is common in regulated rivers, it may help to explain the relatively erratic dynamics of fish populations commonly documented in these ecosystems. Furthermore, under circumstances like those in the Colorado River in Grand Canyon, it is perhaps to be expected that those native fishes able to persist may tend to be relatively flexible in their foraging and/or those whose feeding habits match the limited resources that remain.

Importance of food quality

Studies that link the diets of fishes to their production and rates of consumption often assume uniform assimilation efficiency of ingested materials (Ney 1993) despite considerable evidence that food quality can moderate fish growth to a large extent (Benke et al. 1988, Bowen 1995, Bukovinszky et al. 2008). Results of my analysis provide further evidence that accounting for food quality is important in studies evaluating the trophic basis of fish production. For example, *Cladophora*, detrital aggregate, and terrestrial plant material constituted the majority of organic matter consumed by fish assemblages at all sites, however, these materials are assimilated by fish with relatively

low efficiency and therefore fueled smaller proportions of fish production relative to invertebrates. Moreover, failing to account for variation in the quality of diet items would have resulted in significantly lower estimates of consumption by fish species and assemblages. That said, in many cases assimilation efficiencies were not available for specific consumer-prey combinations (e.g., catostomid-*Cladophora*, common carp-terrestrial plant material) and coarse approximations had to be made using other values from the literature. Future research aimed at quantifying key consumer-prey specific assimilation efficiencies would greatly improve confidence in my estimates of trophic basis of production and consumption rates for fishes in the Colorado River.

Accounting for quality has highlighted a potential mechanism by which species in Grand Canyon may moderate the strength of competitive interactions. Though *Cladophora*, detrital aggregate, and terrestrial plant material are likely assimilated with relatively low efficiency by fishes of the Colorado River, they are among the most abundant and available food resources in the study reach (Stevens et al. 1997), fueling as much as 62% of production by the fish assemblage at a given site, and are less likely to become limiting to fishes relative to invertebrate prey. These materials may allow fishes to meet metabolic requirements during periods of scarcity and could potentially moderate competition for higher quality forage (e.g., invertebrates). Low quality forage, particularly filamentous algae, is often abundant in the tailwater of dams throughout the world (Liu and Yu 1992, Bergey et al. 2010) and may allow fishes with flexible foraging strategies to persist in regulated rivers with depauperate food resources. On the other hand, fishes that require relatively high quality food resources may have difficulty

persisting in regulated rivers where such resources are rare and low quality resources are relatively abundant (Bunn and Arthington 2002).

Potential competition for food

Reduced invertebrate diversity in regulated rivers may amplify diet overlap among fishes, setting the stage for competitive interactions that contribute to native fish decline. In the Colorado, fishes exhibit such extensive and consistent overlap in their use of food resources that the strength of potential competition between native and non-native fishes appears to be driven, to a large extent, by the production rate of the dominant native or non-native species. For instance, during the second year of this study increases in the production of rainbow trout coincided with a near doubling of competition coefficients for native fish assemblages at downstream sites. Moreover, as of 2010 a nearly eight fold increase in rainbow trout had occurred in these reaches (A. Bunch, Arizona Game and Fish Department, *unpublished data*) as large numbers of trout from the tailwater emigrate downstream following a dramatic spike in their recruitment that accompanied a 2008 high flow release from Glen Canyon dam (Cross et al. 2011, Korman et al. 2011). Thus, the potential for competition from this nonnative species has likely increased substantially since the time of my study..

The actual occurrence of competition for food requires that shared resources are limited in their availability to fishes, or set of consumers (Schoener 1983). Although this study did not explicitly evaluate the potential for food limitation, parallel studies to this one suggest such limitation is likely. For example, comparison of fish demand to invertebrate production in the tailwater of Glen Canyon dam showed that despite an

apparent surplus of total invertebrate production rainbow trout appeared to track the availability of insect taxa with a propensity to drift, namely Simuliidae and Chironomidae whose production increased dramatically following the 2008 high flow release and was a likely mechanism driving the burst in rainbow trout productivity there (Cross et al. 2011, Korman et al. 2011). I found that these two insect taxa fueled more than half of fish assemblage production at sites throughout the Grand Canyon reach, and estimates of their secondary production in these reaches (W. Cross, Montana State University, *unpublished data*) suggest they may be limited in their availability to fish in reaches downstream of Glen Canyon as well. These patterns lend support to the hypothesis that food may limit fishes in the Grand Canyon, and similar conditions might be expected to occur in other large regulated rivers, however, additional research is needed to evaluate this possibility.

Implications for theory

Patterns in secondary production of fishes and the trophic basis of that production in Grand Canyon are generally supportive of the Serial Discontinuity Concept (Ward and Stanford 1983) in that production by the fish assemblage was dominated by non-native, cold-water species near Glen Canyon dam's tailwater and was dominated by native, warm-water fishes at sites far downstream of the dam. It is important to note, however, that four native species (Colorado pikeminnow, razorback sucker, bonytail chub, and roundtail chub) have been extirpated from Grand Canyon. Therefore, native fish assemblages do not fully recover between Glen Canyon dam the next reservoir, Lake Mead. Further, my analysis of secondary production does not include channel catfish which are distributed in downstream reaches and may represent a significant source of non-native fish production. In addition, our results would have been less supportive of

the Serial Discontinuity Concept had we utilized biomass as our criteria for evaluation. Common carp contribute less than 5% to total fish assemblage production at downstream sites (RM125, RM165, and RM225), yet they compose up to one third of total biomass at these sites. Such low estimates of production by carp are attributable to population size-frequencies which are skewed toward large individuals, and are further evidenced by mark-recapture data that indicates carp exhibit little growth in the study reaches (Arizona Game and Fish Dept., *unpublished data*), as well as my observation that two out of every three carp gut tracts examined in this study were empty. As a caveat, there is a great deal of uncertainty in estimating fish abundance and the production rate of fishes in large rivers, and the Colorado River in Grand Canyon is no exception. Improved field and analytical techniques aimed at increasing confidence and reducing error associated with abundance estimates in large rivers would greatly improve our ability to carry out studies of this type.

Implications for management

Results of my study illustrate the need to account for food resources and trophic interactions in addition to physical habitat alteration when studying and managing mechanisms contributing to native fish declines or losses in regulated rivers. The current paradigm emphasizes restoration of natural flow regimes (Poff et al. 1997) and other physical habitat based restoration efforts in order to restore native fish populations. These approaches have shown promise in many rivers; however, may not always achieve native fish restoration goals (Rosi-Marshall et al. 2010). Accounting for food availability and trophic interactions experienced by native fishes may help explain non-linear responses to flow or thermal restoration efforts and better guide future efforts. For

example, preceding the second year of this study, a high flow release from Glen Canyon dam was conducted which, in part, was intended to benefit native fishes by rebuilding critical habitat. It appears, however, to have indirectly subsidized a 2 fold increase in non-native trout production Glen Canyon principally via improved recruitment associated with increases in insect production (Cross et al. 2011, Korman et al. 2011). This has led to dramatic increases in trout numbers and production throughout Grand Canyon, which, in turn, drove 2-4 fold increases in competition coefficients at downstream sites between 2007 and 2008. Management strategies that enhance the diversity and productivity of food available to fishes, in combination with restoring natural flow regimes, may provide benefit for native fishes by increasing food web stability and reducing the magnitude of shifts in fish abundance, native or nonnative. Investigations of macroinvertebrate diversity and production, trophic basis of fish production, and fish population dynamism under such management strategies would further illuminate the relationship between food webs and fish population dynamics in this and other large regulated rivers.

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Figure 1. The Grand Canyon of the Colorado River and sites selected for this study.

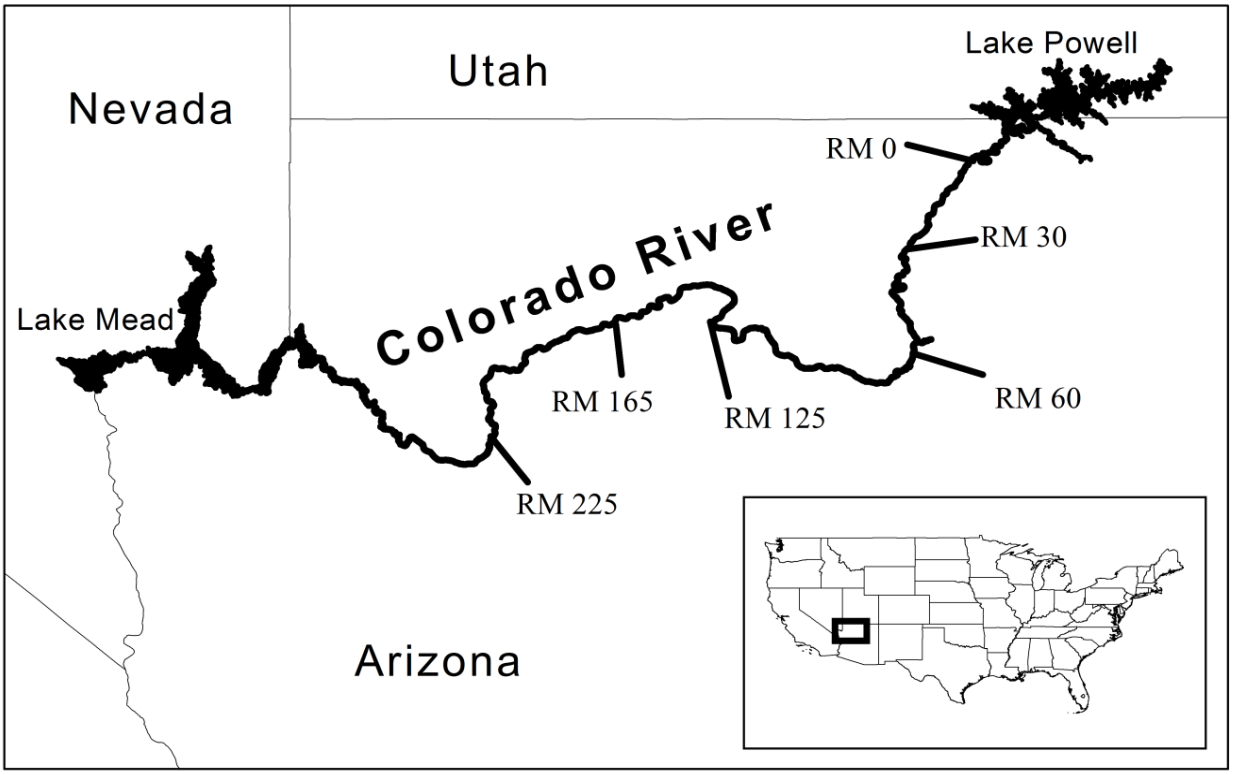

Figure 2. Total annual secondary production by the assemblage of fishes at 6 sites along the Colorado River, Grand Canyon, AZ. Colored sections represent the absolute contribution of each fish species to total production by the fish assemblage. Error bars represent 95% confidence intervals and are generated from variability in capture efficiency.

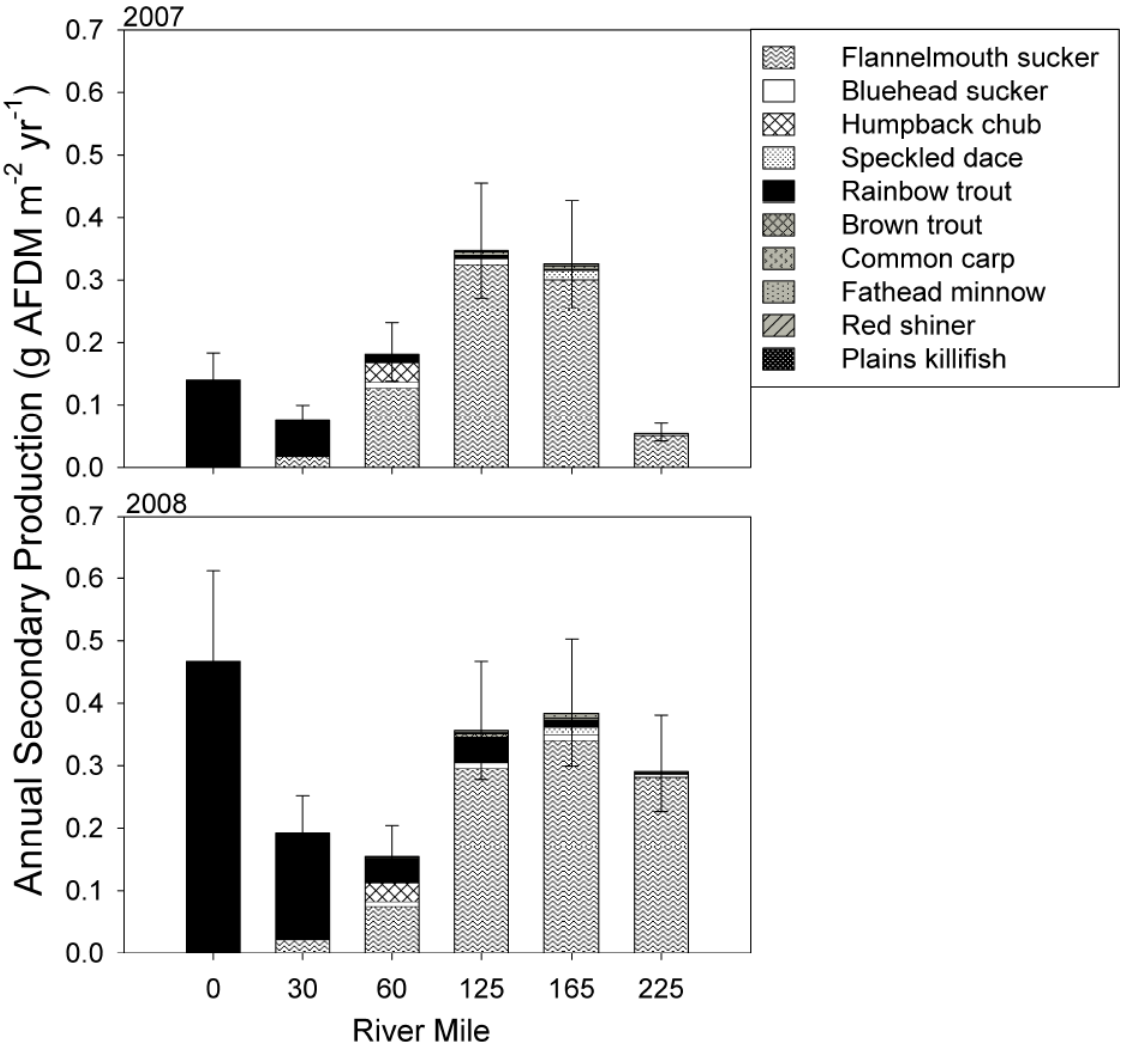

Figure 3. Total consumption by the assemblage of fishes at each of 6 sites during 2007 and 2008 in the Colorado River, Grand Canyon, AZ. Colored sections represent the absolute contribution of selected diet categories to total consumption by the fish assemblage. Error bars represent boot-strapped 95% confidence intervals for total consumption by the fish assemblage.

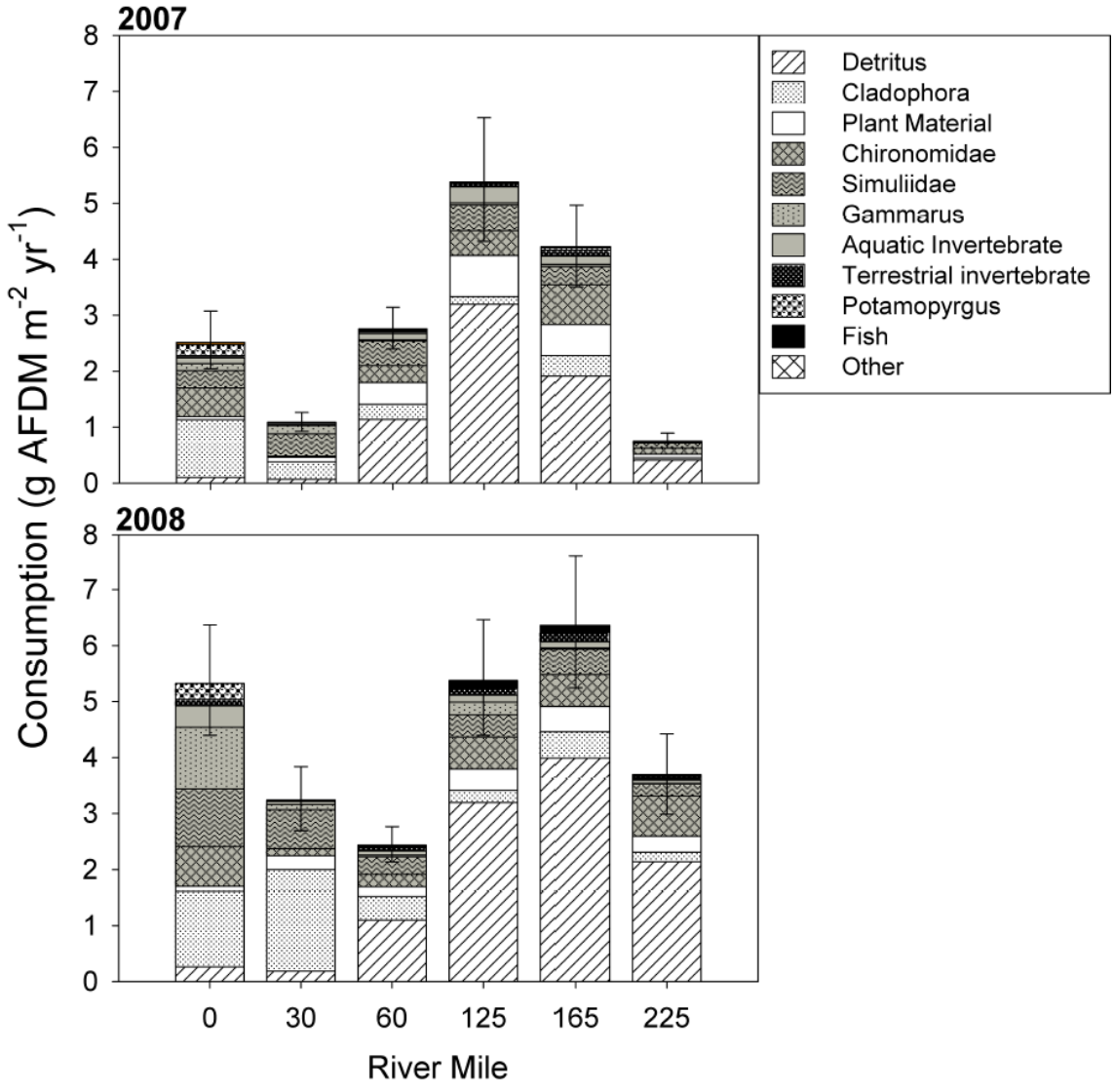

Figure 4. Proportional trophic basis of production for the assemblage of fishes at 6 sites during 2007 and 2008 in the Colorado River, Grand Canyon, AZ. Colored sections represent the proportional contribution of selected diet categories to total production.

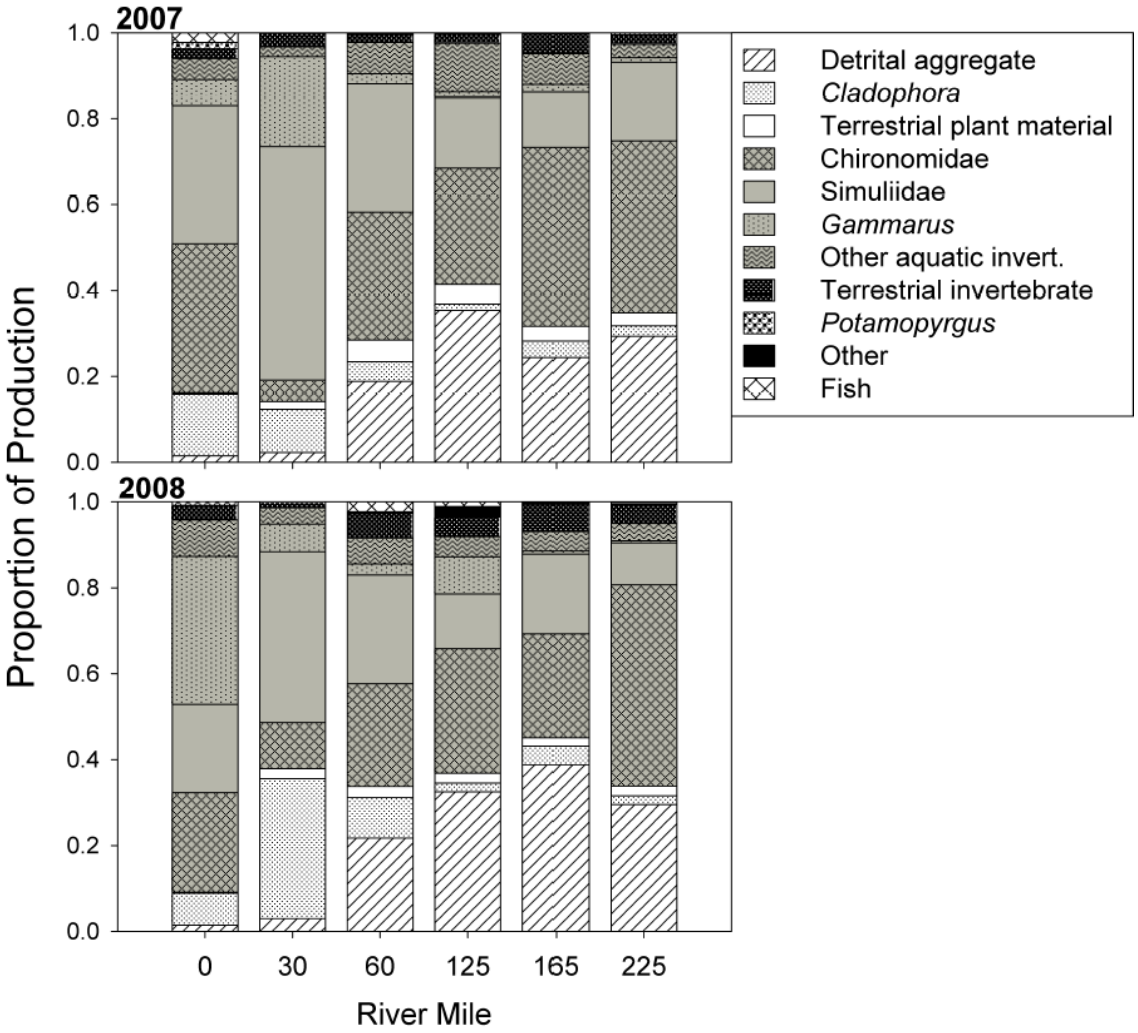

Figure 5. Trophic basis of production for the entire assemblage of fishes at each site during 2007 and 2008 in the Colorado River, Grand Canyon, AZ. Color coded bars represent each of the 6 study sites. Error bars represent bootstrapped 95% confidence intervals.

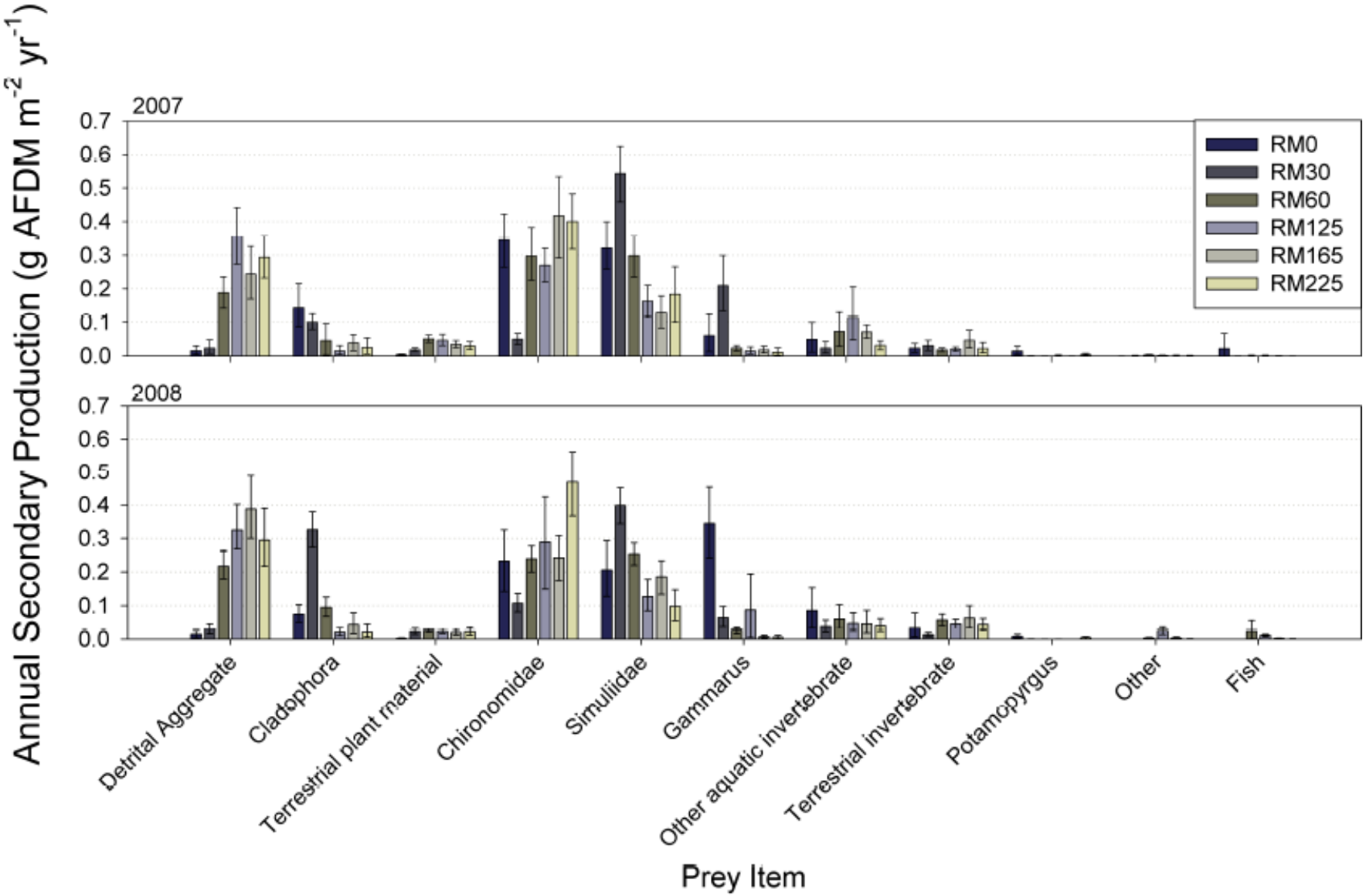

Figure 6. Proportional trophic basis of production (TBP) averaged over the years 2007 and 2008 for fish species in the Colorado River, Grand Canyon, AZ. Colored sections of each bar represent the proportional contribution of a given diet item to total production. The top, rightmost panel includes species for which analysis of TBP at multiple sites was not possible due to low sample size.

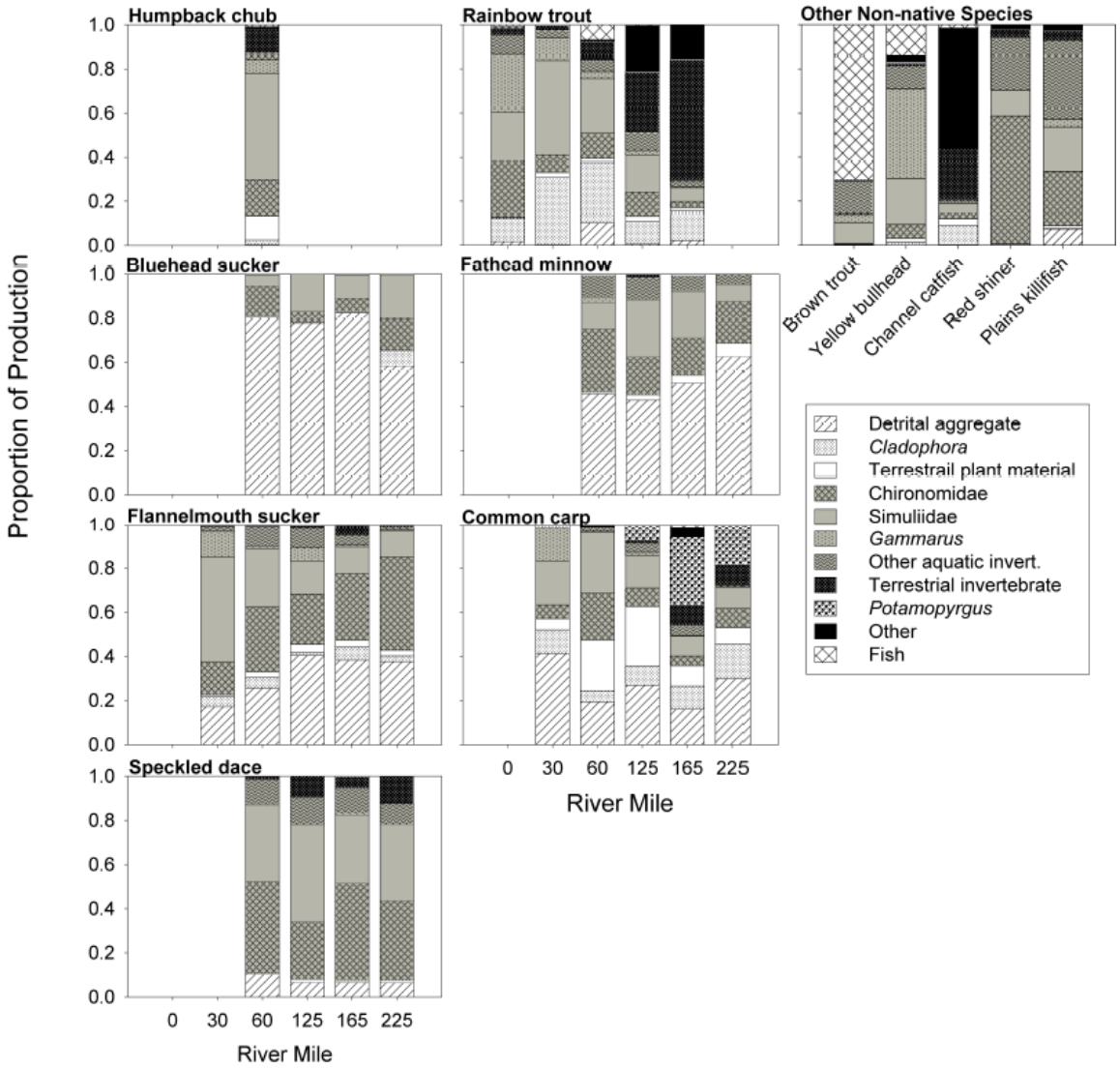

Figure 7. Coefficients of competition (Schoener 1974) between native and non-native fishes at each of 6 sites during 2007 and 2008 in the Colorado River, Grand Canyon, AZ. Error bars represent bootstrapped 95% confidence intervals. Coefficients greater than 1 suggest that potential competition between non-native and native fished was stronger than competition among native fishes. Calculation of coefficients at RM0 was not possible due to the scarcity of native fishes.

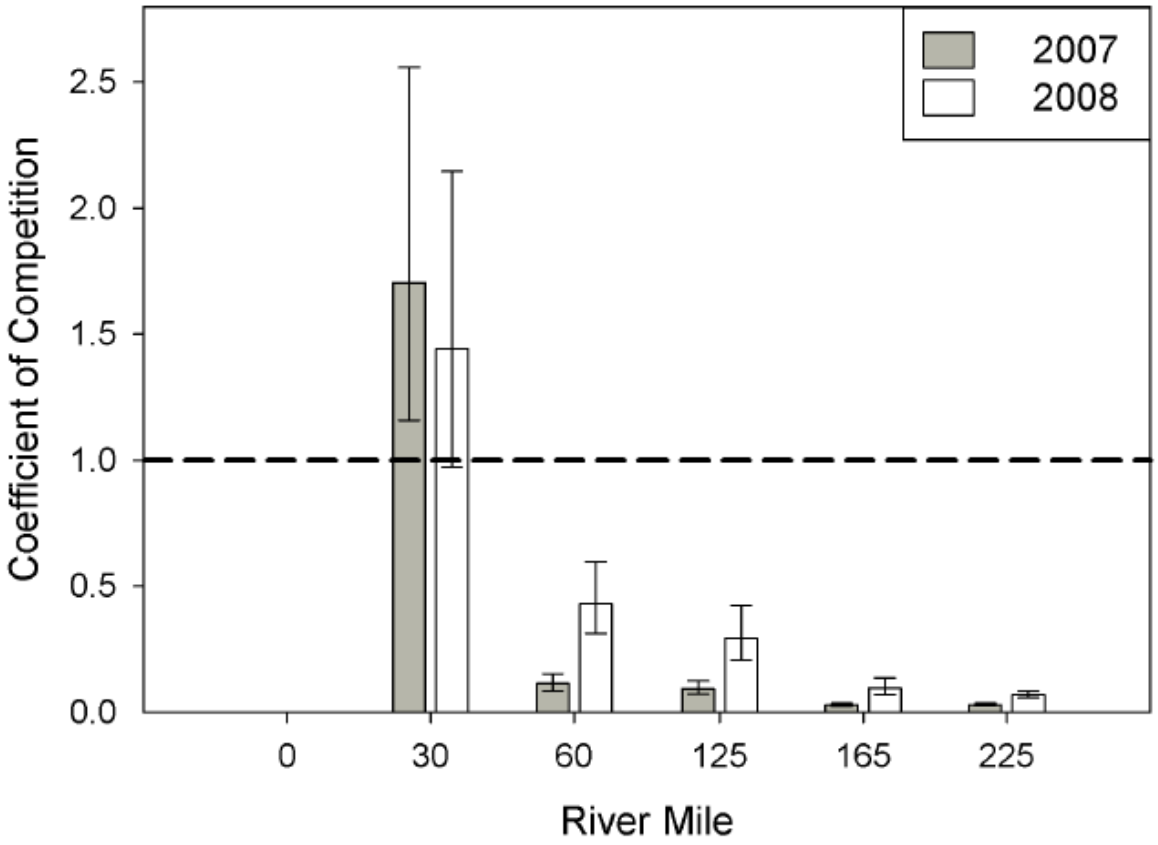

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Table 1. Number of diets analyzed for each eco-species at sites in the Colorado River, Grand Canyon, AZ during 2007 and 2008

	2007						2008					
	RM0	RM30	RM60	RM125	RM165	RM225	RM0	RM30	RM60	RM125	RM165	RM225
Native												
Flannelmouth sucker		8	32	36	31	22		6	43	31	34	28
Juv. Flannelmouth sucker			19	10	25	35			8	22	21	25
Bluhead sucker			21	8	9	7			26	12	12	17
Juv. Bluhead sucker			15	5	8	2			7	19	10	19
Humpback chub			26						51			
Speckled dace			32	26	36	39			25	24	25	25
Non-Native												
Rainbow trout	26	44	16	40	16		47	51	24	41	35	
Juv. Rainbow Trout	2	11	2	16	5		29	22	7	3	7	
Common carp		14	15	16	19	12		9	26	10	20	15
Fathead minnow			39	24	37	21			23	24	28	18
Brown trout[1]			1	2	1			2	2	4	1	
Plains killifish[1]			5		10				2	5	2	
Red shiner[1]			4						5	3	2	
Yellow bullhead[1,2]			8						10			
Channel catfish[1,2]					4	11						15

[1] Diet data lumped across sites for trophic basis of production analyses

[2] Species not incorporated into analyses which require estimates of secondary production

Table 2. Literature derived assimilation efficiencies for consumer-prey combinations

Consumer	Prey Item	Temp °C	Assimilation Efficiency	Source
Salmo Trutta	*Baetis*	7.1 & 15.1	0.69 & 0.70	Elliott 1976
	Chironomidae	7.1 & 15.1	0.7 & 0.72	Elliott 1976
	Gammarus	4.2-20.4	0.78-0.84	Elliott 1976
	Hydropsyche	7.1 & 15.1	0.71 & 0.72	Elliott 1976
	Mealworms	7.1 & 15.1	0.69 & 0.71	Elliott 1976
	Oligocheates	7.1 & 15.1	0.69 & 0.71	Elliott 1976
	Protonumera	7.1 & 15.1	0.69 & 0.71	Elliott 1976
	Gasterosteus aculeatus	13	0.95	Elliott and Hurley 2000
Oncorhychus mykiss	Chironomidae	17	0.869	Flinders et al (unpublished)
	Cladophora		0.1	Leibfried 1988
	Potamopyrgus		0.09	Vinson and Baker 2008
	Tubificidae	5-20	0.72-0.85	Brocksen and Bugge 1974
Cyprinus carpio	Chironomidae		0.74	Ivlev 1939
Ctenopharyngodon idella	Plant Material	16-26	0.29-0.37	Wiley et al 1986
	Plant Material	21	0.165	Fowler 1982
	Lemna		0.526	Van Dyke et al 1977
Catostomus commersoni	*Daphnia*		0.549	Ahlgren 1990
	Detrital Aggregate		0.196	Ahlgren 1990
	Mealworms		0.651	Ahlgren 1990
	Simuliidae		0.605	Ahlgren 1990
	Chironomidae		0.95	Eiriksdottir 1974
	Gammarus		0.71	Eiriksdottir 1974
	Tricorythodes		0.73	Eiriksdottir 1974
Fundulus notatus	Chironomidae	23	0.9	Atmar et al 1972
Fundulus heteroclitus	*Orchestria grillus*	5-20	0.73-0.86	Targett 1979

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Vinson, M. R. and M. A. Baker. 2008. Poor growth of rainbow trout fed New Zealand mud snails. North American Journal of Fisheries Management. 28:701-709

Table 3. Coefficient of competition (Schoener 1974) between a species population and the population of all other species in the assemblage during 2007 and 2008 in the Grand Canyon reach of the Colorado River. Coefficients less than 1 (in grey) indicate that the impact of competition between the species and the assemblage is weaker than that of intraspecific competition.

	2007						2008					
Species	RM0	RM30	RM60	RM125	RM165	RM225	RM0	RM30	RM60	RM125	RM165	RM225
Bluehead sucker			40.08	190.59	131.63	23.65			24.29	8.58	47.62	41.73
Juv. bluehead sucker			337.44	497.98	338.84	3351.37			446.98	1052.14	351.60	
Flannelmouth sucker		1.59	0.48	0.30	0.62	0.22		1.09	0.73	0.29	0.38	0.30
Juv. flannelmouth sucker			4.80	1.16	1.61	1.33			14.25	12.25	2.74	1.00
Humpback chub			1.82						2.80			
Speckled dace			959.04	202.63	14.71	5.34			523.30	167.65	24.13	34.24
Rainbow trout	0.05	0.31	0.38	1.13	32.24		0.27	0.41	0.65	1.31	4.86	
Juv. Rainbow trout	2.52	13.15	304.86	30.09	3712.67		0.90	3.67	441.71	883.57	2085.57	
Brown trout		0.16	8.89	1.22	0.04			0.00	40.59	0.04	0.02	0.01
Common carp		1.21	0.73	0.16	0.07	5.42		1.35	20.12	1.71	0.15	0.38
Fathead minnow			110.34	126.32	85.91				121.43	101.57	70.34	
Plains killifish			294.50						302.87			
Red shiner			164.11						178.96			

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CHAPTER 2

COMPARISON AND RECONCILIATION OF TWO MODELING APPROACHES FOR ESTIMATING RATES OF FOOD CONSUMPTION BY FISH

ABSTRACT

Bioenergetics models play a critical role in advancing understanding of how materials and energy flow through ecosystems. Increasingly, fisheries scientists are interested in assessing organic matter processing rates by entire assemblages or communities of fishes, thus, there is a need for models that are easily parameterized to estimate consumption for understudied fish species. Here, I compare estimated rates of food consumption for a well studied population of rainbow trout in the Glen Canyon reach of the Colorado River derived from the Wisconsin bioenergetics model (Hanson et al. 1997) and a constant conversion efficiency model (Benke and Wallace 1980). I develop and apply a modification of the Benke-Wallace model, which has principally been applied to assemblages of invertebrates, to account for allometric shifts in conversion efficiency that are required to realistically represent bioenergetics of vertebrates like fishes. After modification of the Benke-Wallace model, differences between estimated consumption rate by each model were reduced by 86% for the entire population of Glen Canyon rainbow trout. The model may therefore be applicable to understudied species without extensive species-specific parameterization and could be useful for generating coarse estimates of consumption for entire fish assemblages that include such understudied species.

INTRODUCTION

Models that estimate the rate at which an organism consumes its food play a critical role in our understanding of how materials and energy flow through individuals, populations, communities, and ecosystems. These tools have been widely used in aquatic and fisheries science where they have assisted in evaluating the impacts of environmental change, predation and competition, bioaccumulation of contaminants, ecosystem processing rates, and the factors that limit or promote the performance of biota at scales ranging from the individual to the ecosystem. Among these models, the so-called Wisconsin bioenergetics model (Hanson et al.1997) has become the most widely applied and is often considered to be a standard for modeling the bioenergetics of fishes. The Wisconsin model utilizes a mass-balance balance approach to modeling the bioenergetics of fish where consumption (C):

$$C = R + W + G$$

is equal to the sum of respiration (R), egestion (E) and growth (G) (Winberg 1956, Kitchell 1977). In turn, respiration, egestion and growth are dependent variables that vary with diet, temperature, body mass, and species-specific physiological parameters (see Hanson et al.1997). The Wisconsin model incorporates considerable complexity in its parameterization and can be a powerful tool for simulating bioenergetic balances and estimating consumption by fishes under scenarios of physiological and environmental change (e.g., climate change, shifts in land use, ontogenetic changes, etc.). However, the algebraic complexity of the Wisconsin model, the extent to which it must be parameterized for new species, and the potential for error propagation from incorrect

parameterization (Boisclair and Legget 1989, Ney 1993), particularly for activity rates (Rowan, D. J. and J. B. Rasmussen 1996) often prevents its use in studies of fish species for whom little empirical physiological data exists. On the other hand, fisheries scientists are increasingly interested in assessing the potential for food limitation and organic matter processing rates by entire assemblages or communities of fishes. Thus, there is a need for models which are easily parameterized to estimate consumption for understudied species.

The rate at which an organism consumes its food has also been estimated through the use of constant conversion efficiency models (Allen 1951, Benke and Wallace 1980, Huryn 1996). This approach was pioneered by Allen (1951), whose study of brown trout in a New Zealand stream led to description of what came to be known as "Allen's paradox," which refers to his observation, which was subsequently observed in numerous other trout streams (Waters 1988), that the rate of consumption of food resources by the trout population appeared to exceed that of the estimated secondary production of those prey resources. In general, constant conversion efficiency models have occasionally been used to estimate consumption rates by fish (Huryn 1996) and have primarily been used to estimate consumption rates by aquatic macroinvertebrates (Benke and Wallace 1980, Rosi-Marshall and Wallace 2002). The most common constant conversion efficiency model, developed by Benke and Wallace (1980) and hereafter referred to as the Benke-Wallace model, estimates consumption, C, of diet item *i* by consumer *j* as:

$$(2) \quad C_{ij} = (B_i * P_i)/(NPE * AE_i)$$

where B_i is the proportion of production attributable to the diet item *i*, P is the secondary production rate of the consumer, NPE is net production efficiency, and AE is the assimilation efficiency of the diet item *i* when consumed by *j*. Further, B_i is estimated as:

$$(3)\ B_i = (G_i * AE_i) / \sum_i^n (G_i * AE_i)$$

where G_j is the proportional contribution of a diet item to the diet of consumer *j*. Constant conversion efficiency models may be particularly useful in the context of understudied fish species as they require relatively little empirical physiological data for parameterization. However, these models have been heavily criticized for assuming constant and positive net production efficiencies, particularly when they are applied to multiple populations with variable age structures, old and slow-growing populations, or species with atypical growth histories (Jackson 1996). Additional parameterization of constant conversion efficiency models may be needed in order to provide more realistic estimates of consumption by fish populations. Comparison of consumption rate estimates from bioenergetics models like the Wisconsin model and constant conversion efficiency approaches like the Benke-Wallace model utilizing data from a well studied fish species and well characterized population could provide insight necessary to construct new models that incorporate appropriate degrees of realism, yet, are easily adapted to understudied fish species.

Rainbow trout are among the most studied species in the realm of fisheries, have been the subject of countless physiological investigations, and have been the specific focus of parameterization using the Wisconsin bioenergetics model (e.g., Rand et al. 1993). One rainbow trout population that has been the object of intensive study and

monitoring is that of the Colorado River in the tailwater of Glen Canyon dam. Rainbow trout were introduced to Glen Canyon in 1922 and an abundant and naturally-reproducing population now supports a prized recreational fishery, while also posing a potential threat to the assemblage of native fishes downstream in Grand Canyon (Gloss et al. 2005, Korman et al. 2011, Yard et al. 2011). The use of such detailed data from the Glen Canyon rainbow trout population and physiological parameters from the literature provide the basis for comparison of the Wisconsin and Benke-Wallace models. Such comparisons are not common in bioenergetics literature, particularly assessments of entire fish populations, and may yield new information about the strengths, weaknesses, and sensitivities of each model. Further, reconciliation of the two models may produce a new framework from which the consumption rates of understudied species may be modeled, particularly those found in the Colorado River.

I utilized two years of data from the monitored population of rainbow trout in Glen Canyon, AZ (Makinster et al. 2011) and estimated consumption rates via both the Wisconsin and Benke-Wallace model. I utilized differences between the estimates from each model to alter parameterization of the Benke-Wallace model, which has principally been applied to estimating consumption rates for assemblages of invertebrates, so as to account for allometric changes in conversion efficiency that are required to realistically represent bioenergetics of vertebrates like fishes. I reconciled estimated rates of consumption derived from the Wisconsin and Benke-Wallace models for this population of rainbow trout, with the aim of developing an approach that might apply well to understudied populations of fishes and/or to circumstances where coarse estimates of consumption are needed for entire assemblages of fishes rather than a single, well-studied

taxon. In addition, I hoped such comparison and reconciliation would provide additional insights into the strengths and weaknesses of each model.

METHODS

Study Site

The Glen Canyon reach of the Colorado River encompasses 25 linear kilometers of river, from Glen Canyon dam to Lee's Ferry near Page, AZ (Figure 1). The tailwater of Glen Canyon dam is characterized by clear, nutrient rich water and a constrained annual thermal regime (mean daily temperature 10.1°C, range 8-12°C during July 2006 – June 2009) relative to pre-impoundment conditions (Cross et al.2011). Diurnal, seasonal, and annual fluctuations in discharge are relatively high (Topping et al.2003) and respond to shifting demands for power production and water delivery (Carothers and Brown 1991, Gloss et al.2005). Primary producer and aquatic macroinvertebrate biomass is relatively high (15.5 g C $\cdot$ m^{-2} and 3.7 to 9.1 g AFDM $\cdot$ m^{-2}, respectively) (Stevens et al. 1997, Gloss et al. 2005, Cross et al. 2011) and annual secondary production of macroinvertebrates ranges from 12.9 to 29.9 g AFDM $\cdot$ m^{-2} $\cdot$ yr^{-1} (Cross et al. 2011). Macroinvertebrate diversity is relatively low throughout the reach and assemblages are dominated by non-native *Potamopyrgus antipodarum*, nearctic Simuliidae and Chironomidae and *Gammarus lacustris* (Blinn and Cole 1991, Stevens et al.1997, Cross et al. 2010).

Rainbow trout were first introduced to Glen Canyon in 1922 however, a stable, naturally reproducing population was not established until after the closure of Glen Canyon dam in 1963 (Minckley 1991, McKinney et al. 2001). Since that time, Glen Canyon has become an established coldwater fishery and was awarded blue ribbon status

in 1980. The rainbow trout population has been intensively studied and monitored by state and federal institutions, generating datasets (e.g., Makinster et al. 2011) necessary to conduct a comparison of the Wisconsin model and the constant conversion model.

Fish Abundance and Biomass

Estimates of fish abundance and size structure are necessary to scale estimates growth and food consumption derived from the Wisconsin model to the entire population of fishes. The Benke-Wallace model requires estimates of fish abundance and biomass in order to estimate annual rates of secondary production and, in turn, rates of consumption by the fish population. I estimated size-structured abundance, biomass, and secondary production of the rainbow trout population in Glen Canyon on 3 dates per year during 2007 and 2008. Fish were sampled by biologists from the Arizona Game and Fish Department using the methods of the long-term fish population monitoring effort in Grand Canyon described by McKinney et al. (1999). Briefly, individuals were captured using single-pass electro-fishing in 36, 0.1 mile segments. I used these data to estimate abundance by dividing the number of fish caught in a monitoring segment by a capture efficiency (0.095), which was derived by comparing catch estimates obtained between 2000 and 2004 with mark-recapture abundance estimates for whole-populations from the same period (R.S. Rogers, Arizona Game and Fish Department, *unpublished*). I assumed that capture efficiency was the main source of error in estimates of abundance and therefore used variability in capture efficiency reported by Speas et al.(2004) to generate 95% confidence intervals for abundance. Biomass was estimated by applying a length-weight regression to size structure data and abundance estimates. Length-weight regressions were derived from biometric data collected during electro-fishing efforts.

Gut content sampling and analysis

Diet composition is required by both the Wisconsin and Benke-Wallace model to generate estimates of consumption for individual food types. I analyzed a total of 104 rainbow trout gut content samples collected on 7 occasions seasonally, from April 2007-January 2009. During each season, I attempted to collect 10-15 individuals via single-pass electro-fishing (DC pulse current, 250-400w,13-25a) in near-shore areas. Collections were typically made after dusk and, for each individual, capture location, fork length (mm), weight (g), and sex were recorded before removal and preservation of the entire gut tract in 95% ethanol. Whenever possible, gut contents from a range of fish sizes were collected to account for previously reported shifts in diet with ontogeny (McKinney and Speas 2001). I determined dietary composition by manually removing, separating, and identifying materials contained in the foregut of each fish which I defined as the area anterior to the pyloric sphincter. This approach avoided compositional bias that may have arisen from differential digestion of diet items (Hyslop 1980).

Gut contents were separated into diet item categories (detrital aggregate, terrestrial plant material, *Cladophora*, macroinvertebrates by Family and, for select taxa, species) using a dissecting microscope (Bausch and Lamb, 0.7x-3x). All diet categories were dried at 60°C for 24hrs, weighed to the nearest microgram (µg), and composition by proportion was based on the contribution of each diet category to total dry weight of the gut content sample. I determined seasonal and annual dietary composition by averaging the proportional diet of each individual within a given season and averaging the seasonal diet for each year, respectively. To account for ontogenetic shifts, the diets of age 1 trout were analyzed separately from those of older trout.

Assimilation Efficiency

Estimates of diet item quality are also required by both the Wisconsin and Benke-Wallace models. Therefore, I conducted a literature search for assimilation efficiency values (AE) for prey items found in the diets of rainbow trout in Glen Canyon (Table 1). In the event that AE was unavailable for a given prey item, I utilized values from diet items as similar as possible. For example, AE was not available for terrestrial plant material which it has a relatively high cellulose and lignin content likely results in a low digestibility. *Cladophora* also has relatively high cellulose content, thus, I assumed that assimilation efficiency of plant material was similar to that of *Cladophora*. In the Wisconsin model, quality of a given diet item is determined by the "percent indigestible," which I assumed to be 1-AE. In addition, the Wisconsin model requires an estimate of the energy density of prey, which I obtained from Hanson et al. (1997).

Secondary Production and Consumption

Annual rates of secondary production are an output of the Wisconsin model and an input of the Benke-Wallace model. In the Benke-Wallace model, annual rates of secondary production were estimated by multiplying size-structured biomass estimates (see "abundance and biomass" section of methods) and size-specific instantaneous growth rates (as in Busacker et al.1990). Size-specific instantaneous growth rates were determined using Von Bertalanffy curves and length-weight regressions (R.S. Rogers, Arizona Game and Fish Department, *unpublished*).

I estimated the rate of food consumption by the population of rainbow trout in Glen Canyon using the Wisconsin and Benke-Wallace models. For the Wisconsin model, population data for rainbow trout were separated into seven age classes using a length-at-

age relationship (R.S. Rogers, Arizona Game and Fish Department, *unpublished*). All individuals over 350 mm total length were assumed to be age 7. I utilized physiological parameters reported by Rand et al. (1993) to parameterize the Wisconsin model. These parameters were originally developed for anadromous steelhead (*O. mykiss*) but are commonly used in the context of resident rainbow trout populations. To parameterize environmental variables in the Wisconsin model, I used average daily water temperature measured at Lee's Ferry and obtained via the National Water Information System (USGS gauge 09380000) for the time period encompassing Jan 1, 2007 through Dec 31, 2008. To estimate consumption rates in the Benke-Wallace model, I divided size-structured estimates of secondary production by a literature derived net production efficiency. I assumed an NPE of 0.25 based on the work of Brett and Groves (1979), as well as reports by others who have used similar approaches to estimate consumption (Huryn 1996). Rainbow trout are generally regarded as carnivores (consuming mainly invertebrates), which are assigned production efficiencies closer to 0.3, however, the trout in Glen Canyon are known to consume invertebrates in conjunction with large amounts of filamentous algae (McKinney and Speas 2001, Cross et al. 2011), which likely results in reduced production efficiency. In the case of the Wisconsin model estimates of net production efficiency are an output of the model itself, and these values ranged between 0.03 and 0.21 for each cohort.

Reconciliation of the two models

Differences between estimates of consumption from the Benke-Wallace and Wisconsin models and a comparison of parameters from both models indicated that the net production efficiency parameter was likely responsible for divergence of the two

models. This result echoes past criticisms of constant conversion efficiency models (Hewitt and Kraft 1993, Jackson 1996), however, no studies have attempted to modify a constant conversion model to account for variable NPE. In order to create a model which might be easily applied to understudied fish species yet incorporates an acceptable degree of realism, I modified the Benke-Wallace model to account for allometric changes in NPE by regressing NPE with fish age. I parameterized an NPE-age regression by solving for net production efficiency in the Benke-Wallace model utilizing estimates of consumption derived from the Wisconsin model. Error around regression variables was derived by solving for NPE for each of the 6 rainbow trout sampling events which occurred during 2007 and 2008 (see abundance methodology).

RESULTS

Secondary Production

Total annual secondary production by the rainbow trout population in Glen Canyon was estimated to be 0.172 and 0.479 g AFDM/m2/yr for input into the Benke-Wallace model and 0.198 and 0.460 g AFDM/m2/yr by the Wisconsin model for years 2007 and 2008, respectively. Differences in production between the two approaches were greatest for age classes 3, 6, and 7 during both years.

Consumption

Total annual consumption by the population of rainbow trout in Glen Canyon was estimated to be 1.38 and 2.71 g AFDM/m2/yr by the Benke Wallace model during 2007 and 2008, respectively, which was low relative to the Wisconsin model estimates of 4.32

and 4.86 g AFDM/m2/yr, respectively (Figure 1). Interestingly, output from the Benke-Wallace model described a near doubling of consumption rates between 2007 and 2008 whereas the Wisconsin model indicated little change in consumption rate between the two years. This discrepancy is explained by the fact that the Wisconsin model estimates of consumption incorporated a decrease between 2007 and 2008 in average net production efficiency that resulted from a dramatic shift in the size structure of the rainbow trout population toward young, small fish, whereas this change was not reflected in constant-conversion efficiency version of the Benke-Wallace model. Estimates of annual consumption for older cohorts of fish by the Benke-Wallace model were consistently lower than those from the Wisconsin model (Figure 2). Estimates of annual consumption derived from the Wisconsin model for a given age class were, on average, 3.0 ± 1.5 and 2.6 ± 1.0 times higher in 2007 and 2008, respectively and as much as 5.7 times (age-class 7, 2007) higher than those from the Benke-Wallace model.

Reconciliation of models

In order to reconcile the Wisconsin and Benke-Wallace models, I modified the Benke-Wallace model to account for changes in NPE with fish age where NPE of a fish at age, *a*, is;

$$(4)\quad \sum_{i}^{n} C_{ij} = (B_i * P_{jn})/(NPE_a * AE_i)$$

The relationship between NPE and age of Glen Canyon rainbow trout was best described by an exponential decay function ($p<0.0001$, $F=121.1$; Figure 3). This is consistent with modeled estimates of NPE for lake trout, *Salvelinus namaycush*, (Jackson

1996) and of NPE for yellow perch, *Perca flavescens* (Hewitt and Kraft 1993). NPE of rainbow trout in Glen Canyon at age, *a*, can be expressed as:

$$(5)\quad NPE_a = 0.2804 * e^{(-0.2839 * a)}$$

After incorporation of this regression into the Benke-Wallace model, differences between estimated consumption rate by each model were reduced by 86% for the entire population of rainbow trout (Figure 4).

DISCUSSION

Constant conversion efficiency and mass-balance bioenergetics models both have utility in estimating the rate of food consumption by fish and have played a critical role in evaluating the flow of materials and energy through ecosystems. In this study, a comparison of the Wisconsin model (Hanson et al. 1997) and the Benke-Wallace model (Benke and Wallace 1980) using data from a well characterized population of rainbow trout documented divergence in the estimates of consumption rate by fish generated by each. Modifying the Benke-Wallace model, such that NPE declined exponentially with fish age, reconciled differences in estimated consumption rate between the two models. The modification of the Benke-Wallace model I present incorporates an additional layer of realism for modeling consumption rate by fishes, while avoiding the extensive species-specific parameterization characteristic of the Wisconsin model. Future efforts which describe the relationship between NPE and fish age in wild populations of other fish species will aide in the assessment and development of the modified Benke-Wallace

model and may provide a tool useful for generating coarse estimates of consumption for entire fish assemblages that include understudied species.

Limitations of the modified Benke-Wallace model

The modification of the Benke-Wallace model I present here is capable of generating consumption rates of rainbow trout which are comparable to those from the Wisconsin model. Further, the model addresses a significant criticism of constant conversion efficiency models (Jackson 1996) by varying conversion efficiency with the age of an organism. It should be noted however, that the regression between NPE and age in this model is specific to rainbow trout in Glen Canyon and may not be representative of other fish species. Literature values of NPE for other species fall within the 95% confidence intervals of the regression, however, development of species-specific regressions would yield more accurate estimates of consumption by other species populations. Utilizing my modification of the Benke-Wallace model to estimate consumption rates of slow-growing populations may be appropriate if NPE has been carefully characterized, however, even small estimates of error for relatively low NPE values may propagate into large error values for consumption estimates and preclude the usefulness of the model. In addition, the modified Benke-Wallace model assumes positive growth rates, an assumption that may be violated during seasonal periods of food scarcity (e.g. winter) or during spawning periods. Until the Benke-Wallace model is modified to account for negative growth rates, bioenergetics models (e.g. Hanson et al.1997) or evacuation rate methods (e.g. Elliot and Persson 1978) may be better suited for studies which evaluate fishes during times of negative growth.

Insights into the Wisconsin Bioenergetics model

I observed differences in estimates of fish production arrived at via the Wisconsin model and Benke-Wallace approaches that can be explained by examining the resolution of the information that each approach uses to make these estimates. Secondary production is estimated in the Wisconsin model using an average mass of fish within a given age class. This method can be fairly coarse, particularly for young age-classes which can encompass a wide range of fish sizes. In contrast, studies that employ the Benke-Wallace model often use the instantaneous growth rate method (Busacker 1990) which estimates secondary production individually for user-defined size classes (25 mm increments in this study). Modifying the Wisconsin model to allow for finer resolution of population structure would likely yield more accurate estimates of population-level production from this heavily used tool.

Numerous sensitivity analyses of the Wisconsin model have been conducted in the context of individual fishes and often focus on model parameterization (Chipps and Wahl 2008); however, as researchers increasingly evaluate fish populations, there is a need for additional sensitivity analyses which incorporate population metrics. My study has illustrated the importance of accounting for population size-structure when evaluating rates of food consumption by a fish population. For example, between 2007 and 2008, a shift in the size-structure of the Glen Canyon rainbow trout population resulted in a dramatic increase in secondary production but did not result in dramatic increase in estimates of food consumption by the Wisconsin model. The Benke-Wallace model failed to account for shifts NPE with changes in population structure and, therefore, estimates of food consumption appeared to double between study years, concurrent with

increased secondary production. Population size-structure plays a significant role in estimates of its food consumption, however, the importance of population metrics relative to bioenergetics model parameterization is unclear and is in need of further investigation.

Summary and implications

The results of this study may have implications for interpreting the conclusions of past studies which have employed constant conversion efficiency models. This may also be true of several classic studies, particularly that of Allen (1951) from which "Allen's paradox" was derived, as well as similar studies that have revisited the paradox since (e.g., Waters 1988, Huryn 1996), . In these studies, investigators utilized a constant NPE to estimate total annual consumption by fishes. Such studies have repeatedly reported that the rate of annual consumption by fish was equal to or exceeded the annual rate at which prey was produced (hence Allen's paradox). The results of my analyses suggest that, because they did not account for allometric changes in NPE, these investigators may have underestimated consumption rates of older fishes and, potentially, the fish population as a whole. Had these studies accounted for reduced NPE in adult fish, estimates of invertebrate consumption by fish may have further exceeded estimates of invertebrate secondary production. While this would not refute Allen's paradox, it certainly would make the results of these studies even more puzzling. It is possible that each study accurately characterized the average NPE of the entire population, thus underestimated consumption rates of older fish were overshadowed by overestimated consumption rates of younger fish. This is particularly possible in Huryn's (1996) study which examined a population of trout that was relatively stunted. Still, past studies which utilized constant production efficiencies to calculate consumption by populations that

contain older individuals may need to be revisited. Future studies utilizing approaches similar to the Benke-Wallace model must account for reductions in NPE with size or age if consumption is to be accurately estimated.

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Table 1. Literature derived assimilation efficiencies for consumer-prey combinations

Consumer	Prey Item	Temp °C	Assimilation Efficiency	Source
Oncorhychus mykiss	Chironomidae	17	0.869	Flinders et al 2010 (unpublished)
	Simuliidae		0.81	Tillotson 2009 (unpublished)
	Cladophora		0.1	Leibfried 1988
	Potamopyrgus		0.09	Vinson and Baker 2008
	Tubificidae	5-20	0.72-0.85	Brocksen and Bugge 1974
Salmo Trutta	*Gammarus*	4.2-20.4	0.78-0.84	Elliott 1976
	Gasterosteus aculeatus	13	0.95	Elliott and Hurley 2000

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Figure 1. Estimates of annual consumption by the rainbow trout population in Glen Canyon during 2007 and 2008 via the Wisconsin bioenergetics model (Hanson et al.1997) and the Benke-Wallace model (Benke and Wallace 1980).

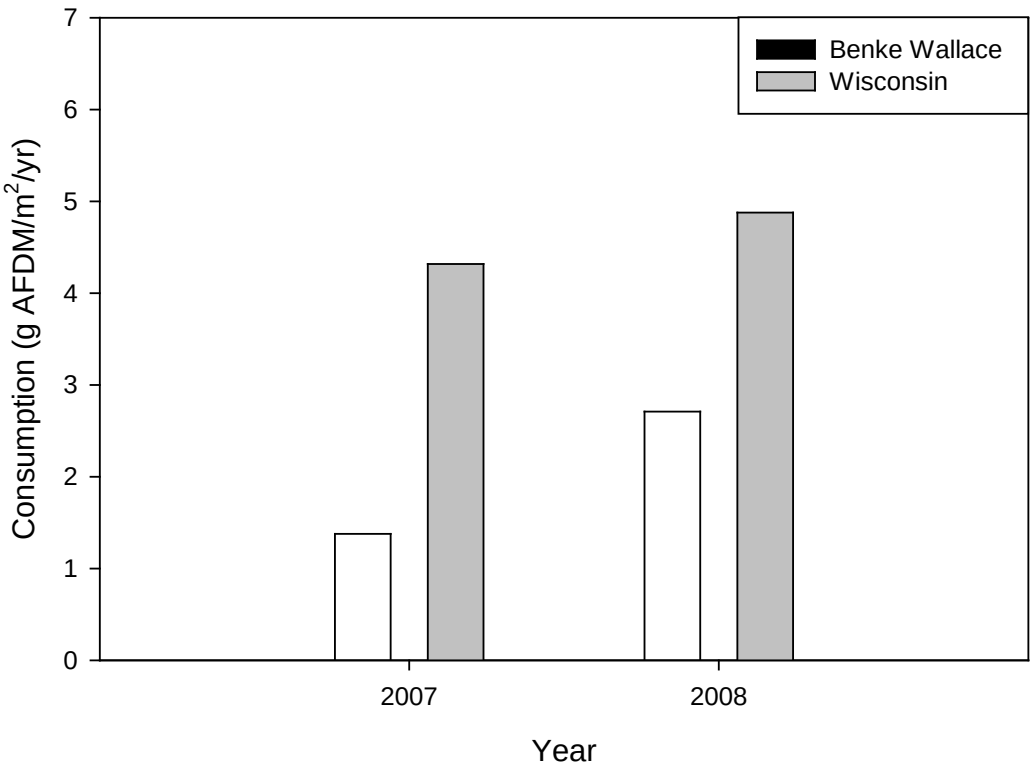


Figure 2. Annual consumption of food by each cohort of rainbow trout in Glen Canyon during 2007 and 2008, estimated by the Benke-Wallace and the Wisconsin bioenergetics models.

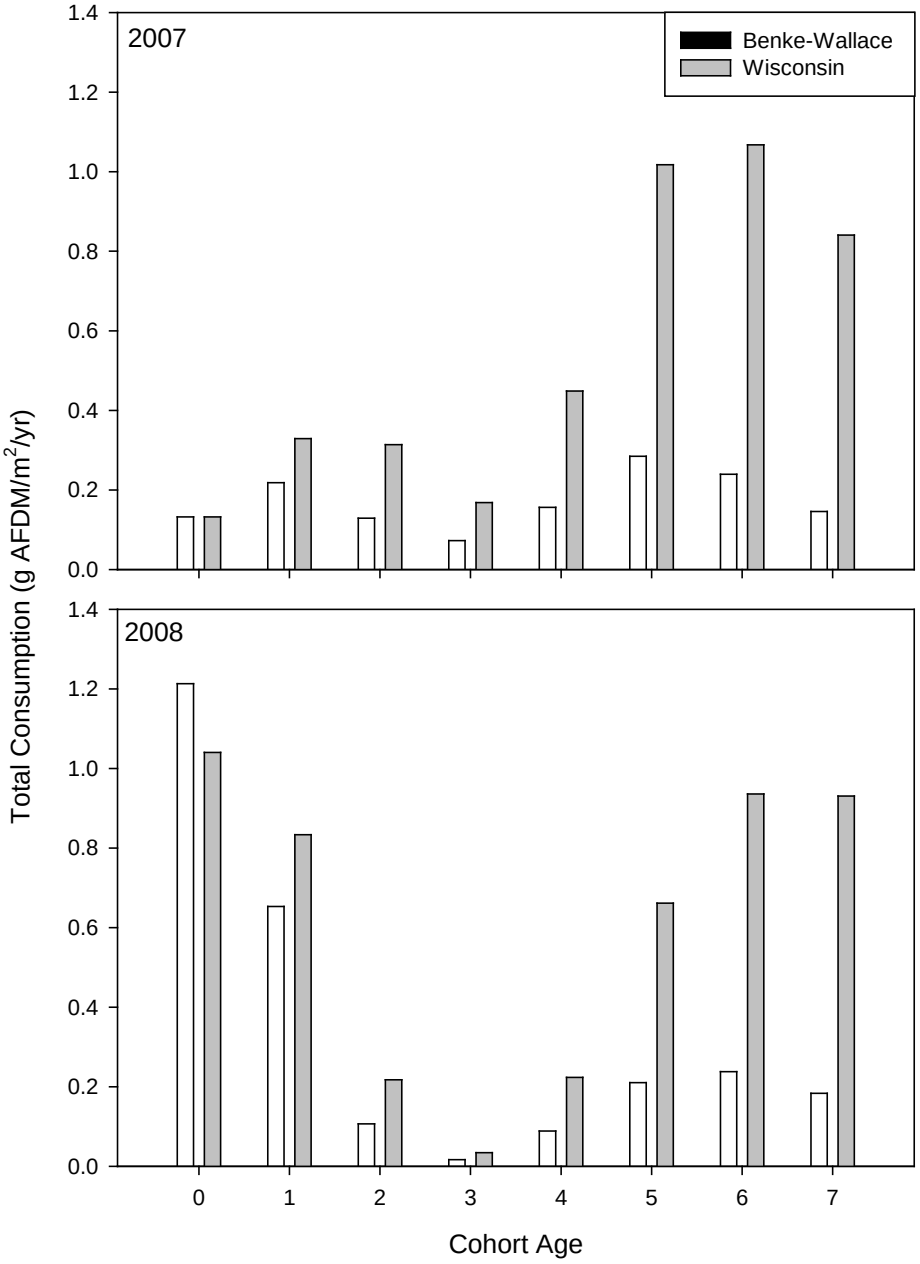


Figure 3. Relationship between net production efficiency and the age of rainbow trout in the Glen Canyon reach of the Colorado River during 2007-2008 derived from comparison of the Benke-Wallace and the Wisconsin bioenergetics models.

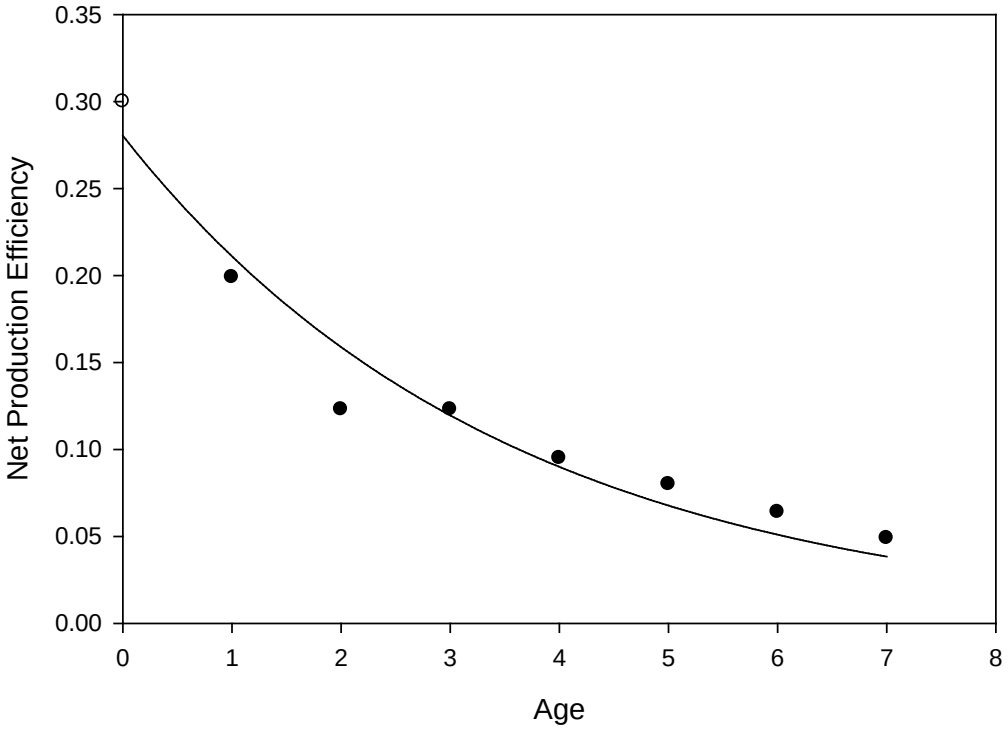
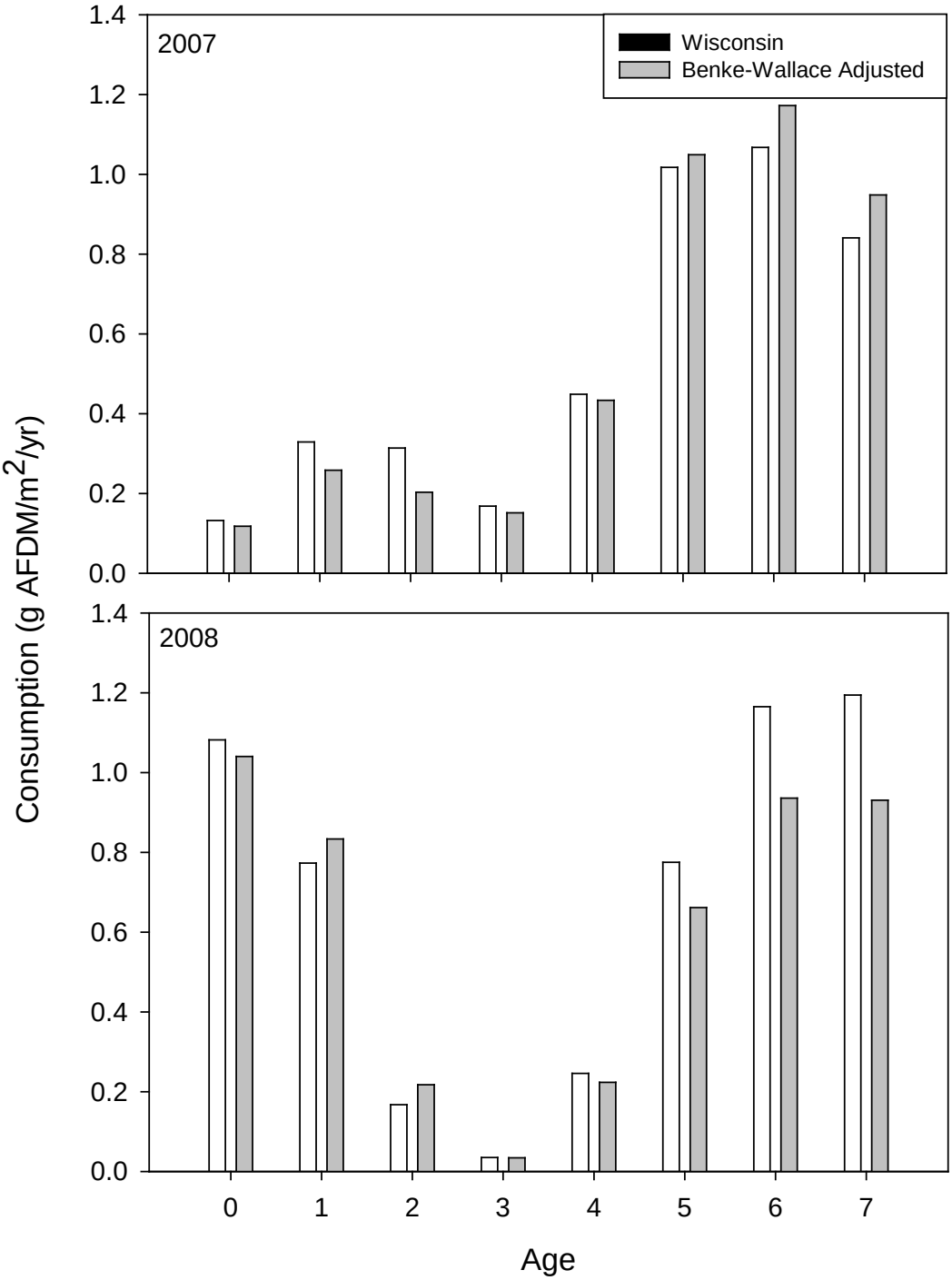


Figure 4. Total consumption by the rainbow trout population in the Glen Canyon reach of the Colorado River during 2007 and 2008 as estimated by the Wisconsin model and a modified version of the Benke-Wallace model that accounts for allometric changes in net production

efficiency.


2007
2008
Wisconsin
Benke-Wallace Adjusted
Consumption (g AFDM/m2/yr)
Age
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
1
2
3
4
5
6
7

Appendix A. Abundance (fish·m^{-2}), biomass (g AFDM·m^{-2}), secondary production (g AFDM·m^{-2}·yr^{-1}), and production/biomass ratios for fishes in the Grand Canyon, Colorado River, AZ during 2007 and 2008.

		2007				2008			
Species	Site	Abundance	Biomass	Production	P-B	Abundance	Biomass	Production	P-B
Native Fishes									
Flannelmouth Sucker									
	RM30	0.0035 (0.0027-0.0045)	0.0297 (0.0231-0.0389)	0.0176 (0.0137-0.023)	0.59	0.0043 (0.0034-0.0057)	0.0418 (0.0326-0.0547)	0.0215 (0.0168-0.0282)	0.52
	RM60	0.0053 (0.0041-0.007)	0.3678 (0.2869-0.4818)	0.1270 (0.0991-0.1664)	0.35	0.0032 (0.0025-0.0042)	0.2330 (0.1817-0.3052)	0.0751 (0.0586-0.0984)	0.32
	RM125	0.0486 (0.0379-0.0637)	0.3104 (0.2421-0.4067)	0.3248 (0.2534-0.4255)	1.05	0.0379 (0.0295-0.0496)	0.4411 (0.3441-0.5779)	0.2957 (0.2306-0.3873)	0.67
	RM165	0.0230 (0.0179-0.0301)	0.3327 (0.2595-0.4358)	0.2997 (0.2337-0.3926)	0.90	0.0258 (0.0201-0.0338)	0.4353 (0.3395-0.5702)	0.3401 (0.2653-0.4456)	0.78
	RM225	0.0016 (0.0013-0.0021)	0.0561 (0.0438-0.0735)	0.0512 (0.0399-0.0671)	0.91	0.0132 (0.0103-0.0173)	0.3491 (0.2723-0.4573)	0.2812 (0.2194-0.3684)	0.81
Bluehead Sucker									
	RM60	0.0018 (0.0014-0.0024)	0.0398 (0.0311-0.0522)	0.0097 (0.0076-0.0127)	0.24	0.0014 (0.0011-0.0018)	0.0341 (0.0266-0.0447)	0.0075 (0.0059-0.0099)	0.22
	RM125	0.0041 (0.0032-0.0054)	0.0244 (0.019-0.0319)	0.0062 (0.0048-0.0081)	0.25	0.0059 (0.0046-0.0078)	0.0422 (0.0329-0.0553)	0.0091 (0.0071-0.012)	0.22
	RM165	0.0011 (0.0009-0.0014)	0.0067 (0.0052-0.0088)	0.0017 (0.0013-0.0022)	0.25	0.0063 (0.0049-0.0082)	0.0446 (0.0348-0.0584)	0.0097 (0.0075-0.0126)	0.22
	RM225					0.0011 (0.0009-0.0015)	0.0082 (0.0064-0.0108)	0.0018 (0.0014-0.0023)	0.21
Humpback chub									
	RM60	0.0052 (0.0041-0.0068)	0.1767 (0.1378-0.2314)	0.0309 (0.0241-0.0404)	0.17	0.0049 (0.0038-0.0064)	0.1838 (0.1434-0.2408)	0.0298 (0.0233-0.0391)	0.16

		2007				2008			
Species	Site	Abundance	Biomass	Production	P-B	Abundance	Biomass	Production	P-B
Speckled Dace									
	RM60	0.0005 (0.0004-0.0006)	0.0004 (0.0003-0.0005)	0.0002 (0.0001-0.0003)	0.50	0.0005 (0.0004-0.0007)	0.0005 (0.0004-0.0006)	0.0002 (0.0002-0.0003)	0.49
	RM125	0.0026 (0.002-0.0034)	0.0030 (0.0023-0.0039)	0.0012 (0.0009-0.0015)	0.38	0.0026 (0.002-0.0034)	0.0018 (0.0014-0.0024)	0.0010 (0.0008-0.0014)	0.58
	RM165	0.0373 (0.0291-0.0489)	0.0202 (0.0158-0.0265)	0.0140 (0.0109-0.0184)	0.69	0.0323 (0.0252-0.0423)	0.0184 (0.0143-0.0241)	0.0119 (0.0093-0.0156)	0.65
	RM225	0.0053 (0.0042-0.007)	0.0061 (0.0048-0.008)	0.0023 (0.0018-0.0031)	0.38	0.0082 (0.0064-0.0107)	0.0047 (0.0036-0.0061)	0.0033 (0.0026-0.0043)	0.71
Non-native Fishes									
Rainbow Trout									
	RM0	0.0140 (0.0109-0.0183)	0.5150 (0.4017-0.6747)	0.1400 (0.1092-0.1834)	0.27	0.0560 (0.0437-0.0734)	0.8470 (0.6607-1.1096)	0.4670 (0.3643-0.6118)	0.55
	RM30	0.0334 (0.026-0.0437)	0.1930 (0.1505-0.2528)	0.0719 (0.0561-0.0942)	0.37	0.0883 (0.0689-0.1157)	0.3446 (0.2688-0.4515)	0.2165 (0.1689-0.2837)	0.63
	RM60	0.0010 (0.0008-0.0014)	0.0234 (0.0183-0.0307)	0.0129 (0.0101-0.0169)	0.55	0.0036 (0.0028-0.0047)	0.0912 (0.0712-0.1195)	0.0491 (0.0383-0.0644)	0.54
	RM125	0.0014 (0.0011-0.0018)	0.0093 (0.0073-0.0122)	0.0047 (0.0037-0.0062)	0.51	0.0128 (0.0099-0.0167)	0.0944 (0.0736-0.1236)	0.0504 (0.0393-0.0661)	0.53
	RM165	0.0002 (0.0002-0.0003)	0.0028 (0.0022-0.0037)	0.0016 (0.0013-0.0021)	0.57	0.0014 (0.0011-0.0019)	0.0227 (0.0177-0.0298)	0.0123 (0.0096-0.0161)	0.54
Brown Trout									
	RM30	0.0001 (0.0001-0.0002)	0.0008 (0.0006-0.0011)	0.0002 (0.0001-0.0002)	0.21	0.0001 (0.0005-0.0001)	0.0004 (0.0002-0.0003)	0.0002 (0-0.0001)	0.48
	RM60	0.0000 (0- 0)	0.0004 (0.0003-0.0005)	0.0001 (0.0001-0.0001)	0.30	0.0000 (0- 0)	0.0003 (0.0003-0.0004)	0.0001 (0.0001-0.0002)	0.38
	RM125	0.0002 (0.0001-0.0002)	0.0017 (0.0013-0.0022)	0.0004 (0.0003-0.0005)	0.21	0.0030 (0.0023-0.0039)	0.0150 (0.0117-0.0196)	0.0057 (0.0044-0.0074)	0.38

		2007				2008			
Species	Site	Abundance	Biomass	Production	P-B	Abundance	Biomass	Production	P-B
Brown Trout continued…									
	RM165	0.0001 (0.0001-0.0001)	0.0008 (0.0006-0.0011)	0.0004 (0.0003-0.0005)	0.48	0.0003 (0.0002-0.0004)	0.0039 (0.003-0.0051)	0.0013 (0.0011-0.0018)	0.35
	RM225					0.0000 (0-0.0001)	0.0009 (0.0007-0.0012)	0.0004 (0.0003-0.0006)	0.48
Common Carp									
	RM30	0.0000 (0-0.0001)	0.0150 (0.0117-0.0196)	0.0012 (0.0009-0.0015)	0.08	0.0001 (0-0.0001)	0.0230 (0.0179-0.0301)	0.0016 (0.0013-0.0021)	0.07
	RM60	0.0005 (0.0004-0.0007)	0.1783 (0.139-0.2335)	0.0014 (0.0011-0.0019)	0.01	0.0001 (0.0001-0.0001)	0.0256 (0.02-0.0335)	0.0003 (0.0003-0.0004)	0.01
	RM125	0.0004 (0.0003-0.0006)	0.1479 (0.1153-0.1937)	0.0041 (0.0032-0.0054)	0.03	0.0007 (0.0006-0.0009)	0.2443 (0.1906-0.32)	0.0028 (0.0022-0.0037)	0.01
	RM165	0.0004 (0.0003-0.0005)	0.1202 (0.0938-0.1575)	0.0046 (0.0036-0.006)	0.04	0.0004 (0.0003-0.0005)	0.1439 (0.1122-0.1885)	0.0046 (0.0036-0.006)	0.03
	RM225	0.0001 (0.0001-0.0002)	0.0465 (0.0362-0.0609)	0.0008 (0.0006-0.001)	0.02	0.0003 (0.0003-0.0004)	0.1196 (0.0933-0.1567)	0.0039 (0.003-0.0051)	0.03
Fathead Minnow									
	RM60	0.0041 (0.0032-0.0054)	0.0018 (0.0014-0.0023)	0.0012 (0.0009-0.0016)	0.68	0.0039 (0.0031-0.0051)	0.0017 (0.0013-0.0022)	0.0012 (0.0009-0.0016)	0.71
	RM125	0.0078 (0.0061-0.0103)	0.0035 (0.0027-0.0046)	0.0024 (0.0019-0.0031)	0.68	0.0095 (0.0074-0.0124)	0.0050 (0.0039-0.0066)	0.0030 (0.0023-0.0039)	0.59
	RM165	0.0090 (0.007-0.0118)	0.0039 (0.003-0.0051)	0.0027 (0.0021-0.0036)	0.70	0.0230 (0.0179-0.0301)	0.0122 (0.0095-0.016)	0.0072 (0.0056-0.0094)	0.59
	RM225					0.0004 (0.0003-0.0005)	0.0002 (0.0001-0.0002)	0.0001 (0.0001-0.0001)	0.74
Red Shiner									
	RM60	0.0004 (0.0003-0.0006)	0.0002 (0.0002-0.0003)	0.0001 (0.0001-0.0002)	0.67	0.0004 (0.0003-0.0006)	0.0002 (0.0002-0.0003)	0.0001 (0.0001-0.0002)	0.65
Plains Killifish									
	RM60	0.0004 (0.0003-0.0006)	0.0001 (0.0001-0.0001)	0.0001 (0.0001-0.0001)	0.91	0.0004 (0.0003-0.0006)	0.0001 (0.0001-0.0001)	0.0001 (0.0001-0.0001)	0.91

Appendix B. Proportional contribution of diet categories to the diets of fish species in the Grand Canyon reach of the Coloado River. 95% confidence intervals are reported in parantheses. Proportion of diet category is based on dry mass. For species with low sample size, proportions are based on the average of all individuals caught within a year.

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Native Fishes															
Bluehead Sucker															
Spring 2007															
	RM60	3	0.06 (0.11)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.92 (0.14)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)
	RM125	2	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.99 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	2	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.99 (0.02)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Spring 2007															
	RM60	9	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.97 (0.03)	0.00 (0)	0.00 (0)	0.00 (0)	0.03 (0.03)	0.00 (0)	0.00 (0)
	RM125	6	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	1.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	4	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.98 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.02 (0.04)	0.00 (0)	0.00 (0)
	RM225	3	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.03 (0.06)	0.00 (0)	0.00 (0)	0.00 (0)	0.96 (0.07)	0.00 (0)	0.00 (0)
Fall 2007															
	RM60	3	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.90 (0.14)	0.00 (0)	0.09 (0.13)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM125	3	0.01 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.82 (0.34)	0.00 (0)	0.00 (0)	0.00 (0)	0.16 (0.31)	0.00 (0)	0.00 (0)
	RM165	4	0.06 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.67 (0.22)	0.01 (0.02)	0.01 (0)	0.00 (0)	0.25 (0.17)	0.00 (0)	0.00 (0)
Winter 2008															
	RM60	6	0.04 (0.06)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.89 (0.14)	0.00 (0)	0.02 (0.01)	0.00 (0)	0.05 (0.07)	0.00 (0)	0.00 (0)
Spring 2008															
	RM60	9	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.97 (0.04)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Summer 2008															
	RM60	5	0.11 (0.08)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.86 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.02 (0.01)	0.00 (0)	0.00 (0)
	RM125	2	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.54 (0.87)	0.00 (0)	0.00 (0)	0.00 (0)	0.45 (0.86)	0.00 (0)	0.00 (0)
	RM225	5	0.02 (0.02)	0.10 (0.18)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.81 (0.33)	0.00 (0)	0.00 (0)	0.00 (0)	0.07 (0.13)	0.00 (0)	0.00 (0)
Fall 2008															
	RM60	5	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	1.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM125	6	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.90 (0.17)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.09 (0.16)	0.00 (0)	0.00 (0)
	RM165	6	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	1.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM225	5	0.01 (0.01)	0.19 (0.37)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.80 (0.39)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Winter 2009															
	RM60	7	0.03 (0.03)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.97 (0.03)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM125	4	0.02 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.97 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	6	0.03 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.89 (0.19)	0.00 (0)	0.00 (0)	0.00 (0)	0.08 (0.14)	0.00 (0)	0.00 (0)
	RM225	7	0.08 (0.13)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.71 (0.3)	0.00 (0)	0.00 (0)	0.00 (0)	0.20 (0.21)	0.00 (0)	0.00 (0)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Juv. Bluehead Sucker															
Spring 2007															
	RM60	2	0.25 (0.48)	0.00 (0.01)	0.00 (0.49)	0.00 (0)	0.00 (0)	0.00 (0)	0.75 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	2	0.49 (0.96)	0.00 (0)	0.00 (0.98)	0.00 (0.02)	0.00 (0)	0.00 (0)	0.50 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Summer 2007															
	RM60	2	0.50 (0.97)	0.00 (0)	0.00 (0.97)	0.00 (0)	0.00 (0)	0.00 (0)	0.50 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Fall 2007															
	RM60	9	0.00 (0)	0.00 (0)	0.00 (0.2)	0.00 (0.02)	0.00 (0.02)	0.00 (0)	0.87 (0)	0.01 (0)	0.11 (0)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)
	RM125	1	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	1.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)
	RM165	6	0.18 (0.14)	0.00 (0.02)	0.00 (0.3)	0.01 (0.07)	0.00 (0.05)	0.00 (0)	0.56 (0)	0.06 (0)	0.12 (0)	0.00 (0)	0.05 (0)	0.02 (0)	0.02 (0)
Winter 2008															
	RM60	2	0.08 (0.15)	0.00 (0)	0.00 (0.74)	0.00 (0)	0.00 (0.92)	0.00 (0)	0.38 (0)	0.00 (0)	0.01 (0)	0.00 (0)	0.53 (0)	0.00 (0)	0.00 (0)
	RM125	4	0.31 (0.41)	0.00 (0)	0.00 (0.42)	0.00 (0)	0.00 (0.05)	0.00 (0)	0.65 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0)	0.00 (0)	0.00 (0)
	RM225	2	0.34 (0.42)	0.00 (0)	0.00 (0.15)	0.00 (0)	0.00 (0.46)	0.00 (0)	0.36 (0)	0.00 (0)	0.07 (0)	0.00 (0)	0.24 (0)	0.00 (0)	0.00 (0)
Summer 2008															
	RM125	8	0.17 (0.22)	0.08 (0.08)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.63 (0.27)	0.00 (0)	0.09 (0.07)	0.00 (0)	0.00 (0)	0.03 (0.06)	0.00 (0)
	RM165	2	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.38 (0.19)	0.18 (0.35)	0.44 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM225	8	0.12 (0.2)	0.09 (0.11)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.61 (0.16)	0.00 (0)	0.13 (0.1)	0.00 (0)	0.05 (0.1)	0.00 (0)	0.00 (0)
Fall 2008															
	RM60	6	0.02 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.96 (0.07)	0.00 (0.01)	0.00 (0)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.00 (0)
	RM125	10	0.03 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.96 (0.03)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.00 (0)
	RM165	6	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.98 (0.02)	0.00 (0)	0.02 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM225	10	0.13 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.80 (0.2)	0.01 (0.02)	0.04 (0.06)	0.00 (0)	0.02 (0.03)	0.01 (0.02)	0.00 (0)
Flannelmouth Sucker															
Spring 2007															
	RM60	4	0.08 (0.11)	0.49 (0.55)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.27 (0.3)	0.11 (0.2)	0.02 (0.01)	0.00 (0)	0.03 (0.04)	0.01 (0)	0.00 (0)
	RM125	8	0.07 (0.05)	0.05 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.76 (0.15)	0.05 (0.05)	0.02 (0.02)	0.00 (0)	0.03 (0.03)	0.01 (0)	0.00 (0)
	RM165	7	0.20 (0.2)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.75 (0.25)	0.00 (0)	0.03 (0.02)	0.00 (0)	0.00 (0.05)	0.01 (0.01)	0.00 (0)
	RM225	8	0.09 (0.11)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.02 (0.03)	0.63 (0.24)	0.02 (0.03)	0.02 (0.02)	0.05 (0.06)	0.15 (0.11)	0.00 (0)	0.00 (0)
Summer 2007															
	RM30	4	0.09 (0.04)	0.01 (0.01)	0.00 (0)	0.08 (0.02)	0.00 (0)	0.00 (0)	0.09 (0.17)	0.00 (0)	0.04 (0.02)	0.00 (0)	0.68 (0.13)	0.00 (0)	0.00 (0)
	RM60	7	0.29 (0.23)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.01 (0.02)	0.17 (0.17)	0.01 (0)	0.10 (0.08)	0.00 (0)	0.39 (0.19)	0.01 (0)	0.01 (0.01)
	RM125	9	0.06 (0.05)	0.02 (0.03)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.73 (0.23)	0.01 (0)	0.05 (0.04)	0.00 (0)	0.12 (0.12)	0.01 (0.01)	0.00 (0)
	RM165	10	0.04 (0.04)	0.42 (0.27)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.43 (0.27)	0.00 (0)	0.04 (0.02)	0.00 (0)	0.05 (0.04)	0.02 (0.01)	0.00 (0)
	RM225	7	0.02 (0.01)	0.24 (0.25)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (0.3)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.28 (0.3)	0.01 (0.01)	0.00 (0)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Flannelmouth Sucker continued…															
Fall 2007															
	RM60	11	0.00 (0.01)	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.65 (0.23)	0.01 (0)	0.31 (0.09)	0.00 (0)	0.02 (0.16)	0.00 (0)	0.00 (0)
	RM125	12	0.03 (0)	0.00 (0.01)	0.00 (0)	0.01 (0)	0.00 (0)	0.02 (0.02)	0.48 (0.23)	0.07 (0)	0.32 (0.23)	0.00 (0)	0.02 (0.01)	0.05 (0)	0.00 (0)
	RM165	10	0.12 (0.02)	0.00 (0)	0.00 (0)	0.02 (0)	0.00 (0)	0.00 (0)	0.72 (0.09)	0.00 (0.03)	0.11 (0.13)	0.01 (0)	0.01 (0)	0.00 (0.03)	0.00 (0)
	RM225	5	0.02 (0.08)	0.00 (0)	0.00 (0)	0.00 (0.03)	0.00 (0)	0.00 (0)	0.55 (0.12)	0.00 (0)	0.17 (0.07)	0.00 (0.02)	0.24 (0)	0.01 (0)	0.00 (0)
Winter 2008															
	RM30	4	0.04 (0.05)	0.00 (0)	0.00 (0)	0.22 (0.41)	0.00 (0)	0.00 (0)	0.21 (0.32)	0.00 (0)	0.05 (0.05)	0.00 (0)	0.49 (0.46)	0.00 (0)	0.00 (0)
	RM60	10	0.08 (0.07)	0.00 (0)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.58 (0.25)	0.07 (0.07)	0.17 (0.14)	0.00 (0)	0.04 (0.03)	0.00 (0)	0.05 (0.09)
	RM125	7	0.05 (0.05)	0.02 (0.02)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.00 (0)	0.31 (0.24)	0.18 (0.23)	0.22 (0.12)	0.00 (0)	0.19 (0.09)	0.01 (0)	0.00 (0)
	RM165	5	0.37 (0.36)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.31 (0.31)	0.02 (0.02)	0.14 (0.08)	0.00 (0)	0.16 (0.15)	0.00 (0)	0.00 (0)
	RM225	2	0.18 (0.22)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.55 (0.29)	0.00 (0)	0.16 (0.31)	0.00 (0)	0.10 (0.18)	0.00 (0)	0.00 (0)
Spring 2008															
	RM30	3	0.02 (0.01)	0.27 (0.53)	0.00 (0)	0.06 (0.11)	0.00 (0)	0.00 (0)	0.38 (0.34)	0.01 (0.01)	0.02 (0.01)	0.00 (0)	0.23 (0.23)	0.00 (0)	0.00 (0)
	RM60	10	0.10 (0.08)	0.07 (0.14)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.34 (0.13)	0.00 (0)	0.05 (0.03)	0.00 (0)	0.41 (0.17)	0.01 (0)	0.00 (0)
	RM125	6	0.00 (0)	0.06 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.81 (0.09)	0.02 (0.03)	0.06 (0.05)	0.00 (0)	0.02 (0.02)	0.01 (0.01)	0.00 (0)
	RM165	7	0.12 (0.12)	0.04 (0.05)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.63 (0.25)	0.01 (0)	0.07 (0.05)	0.00 (0)	0.05 (0.04)	0.02 (0.02)	0.05 (0.08)
	RM225	3	0.11 (0.18)	0.03 (0.04)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.66 (0.33)	0.00 (0)	0.03 (0.02)	0.00 (0)	0.12 (0.16)	0.00 (0)	0.04 (0.04)
Summer 2008															
	RM30	6	0.12 (0.13)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.57 (0.35)	0.04 (0.04)	0.02 (0.02)	0.02 (0.04)	0.21 (0.33)	0.00 (0)	0.00 (0)
	RM60	7	0.19 (0.13)	0.02 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.69 (0.18)	0.01 (0)	0.01 (0.01)	0.00 (0)	0.07 (0.06)	0.00 (0)	0.00 (0)
	RM125	7	0.02 (0.01)	0.01 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.79 (0.13)	0.00 (0)	0.05 (0.04)	0.00 (0)	0.11 (0.09)	0.01 (0.01)	0.00 (0)
	RM165	8	0.07 (0.03)	0.16 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.49 (0.27)	0.05 (0.08)	0.03 (0.01)	0.00 (0)	0.16 (0.11)	0.05 (0.07)	0.00 (0)
	RM225	6	0.23 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.57 (0.25)	0.00 (0)	0.12 (0.2)	0.00 (0)	0.07 (0.06)	0.01 (0.01)	0.00 (0)
Fall 2008															
	RM60	9	0.03 (0.05)	0.03 (0.04)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.72 (0.19)	0.12 (0.19)	0.07 (0.06)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)
	RM125	10	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.89 (0.07)	0.03 (0.05)	0.05 (0.04)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)
	RM165	10	0.01 (0)	0.02 (0.02)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.73 (0.15)	0.01 (0)	0.17 (0.1)	0.00 (0)	0.04 (0.03)	0.01 (0.02)	0.00 (0)
	RM225	10	0.02 (0.01)	0.04 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.74 (0.17)	0.00 (0)	0.18 (0.14)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)
Winter 2009															
	RM60	17	0.12 (0.06)	0.01 (0.01)	0.00 (0)	0.03 (0.03)	0.00 (0)	0.00 (0)	0.65 (0.16)	0.05 (0.03)	0.07 (0.05)	0.00 (0)	0.07 (0.03)	0.00 (0)	0.00 (0)
	RM125	8	0.43 (0.32)	0.00 (0)	0.00 (0)	0.20 (0.26)	0.00 (0)	0.00 (0)	0.18 (0.22)	0.01 (0.01)	0.06 (0.06)	0.00 (0)	0.11 (0.09)	0.00 (0)	0.00 (0)
	RM165	9	0.06 (0.05)	0.12 (0.18)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.81 (0.18)	0.01 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM225	9	0.28 (0.23)	0.09 (0.17)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.58 (0.27)	0.02 (0.02)	0.01 (0)	0.00 (0)	0.02 (0.01)	0.00 (0)	0.00 (0)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Juv. Flannelmouth Sucker															
Spring 2007															
	RM60	4	0.01 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.99 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM125	3	0.05 (0.07)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.66 (0.64)	0.00 (0)	0.09 (0.19)	0.00 (0)	0.02 (0.05)	0.17 (0.34)	0.00 (0)
	RM165	6	0.35 (0.3)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.05)	0.47 (0.33)	0.03 (0.04)	0.00 (0)	0.00 (0)	0.02 (0.02)	0.09 (0.18)	0.00 (0)
	RM225	10	0.61 (0.23)	0.00 (0)	0.00 (0)	0.00 (0.01)	0.00 (0)	0.01 (0.02)	0.28 (0.25)	0.02 (0.02)	0.01 (0.01)	0.00 (0)	0.07 (0.1)	0.00 (0)	0.00 (0)
Summer 2007															
	RM60	3	0.45 (0.55)	0.00 (0)	0.00 (0)	0.02 (0.04)	0.00 (0)	0.00 (0)	0.35 (0.64)	0.01 (0.01)	0.02 (0.02)	0.00 (0)	0.17 (0.31)	0.00 (0)	0.00 (0)
	RM125	3	0.31 (0.27)	0.00 (0)	0.00 (0)	0.04 (0.05)	0.00 (0)	0.00 (0)	0.03 (0.06)	0.09 (0.11)	0.08 (0.06)	0.00 (0)	0.44 (0.11)	0.01 (0.01)	0.00 (0)
	RM225	9	0.52 (0.2)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.03 (0.06)	0.32 (0.22)	0.01 (0.01)	0.01 (0.01)	0.00 (0)	0.08 (0.06)	0.01 (0.01)	0.00 (0)
Fall 2007															
	RM60	7	0.39 (0.21)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.09 (0.1)	0.04 (0.04)	0.06 (0.07)	0.00 (0)	0.35 (0.27)	0.05 (0.05)	0.00 (0.01)
	RM125	1	0.00 (na)	0.00 (na)	0.00 (na)	0.17 (na)	0.00 (na)	0.00 (na)	0.72 (na)	0.00 (na)	0.10 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)
	RM165	10	0.23 (0.1)	0.01 (0.01)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.00 (0)	0.33 (0.2)	0.13 (0.07)	0.23 (0.07)	0.00 (0)	0.03 (0.03)	0.03 (0.02)	0.01 (0.01)
	RM225	8	0.23 (0.19)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.46 (0.19)	0.04 (0.04)	0.23 (0.17)	0.00 (0)	0.02 (0.02)	0.02 (0.03)	0.00 (0)
Winter 2008															
	RM60	3	0.07 (0.13)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.78 (0.22)	0.01 (0.01)	0.08 (0.12)	0.00 (0)	0.05 (0.05)	0.00 (0)	0.01 (0.03)
	RM125	3	0.13 (0.22)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.64 (0.63)	0.07 (0.13)	0.01 (0.01)	0.00 (0)	0.14 (0.27)	0.00 (0)	0.00 (0)
	RM165	9	0.40 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.41 (0.18)	0.02 (0.03)	0.08 (0.05)	0.00 (0)	0.09 (0.09)	0.00 (0)	0.00 (0)
	RM225	8	0.37 (0.27)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.38 (0.34)	0.01 (0.01)	0.18 (0.2)	0.00 (0)	0.07 (0.06)	0.00 (0)	0.00 (0)
Spring 2008															
	RM125	3	0.42 (0.27)	0.01 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.07 (0.14)	0.08 (0.08)	0.07 (0.05)	0.00 (0)	0.15 (0.16)	0.21 (0.16)	0.00 (0)
	RM165	1	0.00 (na)	0.00 (na)	0.00 (0)	0.00 (na)	0.00 (0)	0.00 (0)	0.75 (na)	0.00 (na)	0.25 (na)	0.00 (0)	0.00 (na)	0.00 (na)	0.00 (0)
	RM225	4	0.24 (0.28)	0.02 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.14 (0.27)	0.08 (0.07)	0.14 (0.17)	0.00 (0)	0.10 (0.17)	0.28 (0.22)	0.00 (0)
Summer 2008															
	RM125	1	0.03 (na)	0.03 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.22 (na)	0.32 (na)	0.08 (na)	0.00 (na)	0.06 (na)	0.26 (na)	0.00 (na)
	RM165	2	0.92 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.02 (0.04)	0.00 (0)	0.01 (0.03)	0.00 (0)	0.04 (0.06)	0.00 (0)	0.00 (0)
	RM225	4	0.64 (0.2)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.22 (0.25)	0.04 (0.05)	0.01 (0.02)	0.00 (0)	0.08 (0.15)	0.01 (0.02)	0.00 (0)
Fall 2008															
	RM60	3	0.25 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.68 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.05 (0)	0.00 (0)	0.00 (0)
	RM125	8	0.25 (0.1)	0.00 (0)	0.00 (0)	0.00 (0.01)	0.00 (0)	0.00 (0)	0.59 (0.28)	0.05 (0.05)	0.04 (0.14)	0.00 (0)	0.06 (0.1)	0.00 (0)	0.00 (0.01)
	RM165	10	0.14 (0.05)	0.00 (0)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.56 (0.19)	0.05 (0.05)	0.15 (0.16)	0.00 (0)	0.09 (0.03)	0.00 (0)	0.00 (0)
	RM225	10	0.07 (0.18)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.74 (0.16)	0.06 (0.01)	0.12 (0)	0.00 (0)	0.02 (0.05)	0.00 (0.01)	0.00 (0)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Juv. Flannelmouth Sucker continued…															
Winter 2009															
	RM60	4	0.90 (0.05)	0.01 (0.01)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.02 (0.04)	0.02 (0.03)	0.03 (0.04)	0.00 (0)	0.02 (0.02)	0.00 (0)	0.00 (0)
	RM125	5	0.84 (0.1)	0.00 (0)	0.00 (0)	0.02 (0.04)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.06)	0.00 (0)	0.00 (0)	0.08 (0.06)	0.01 (0.03)	0.00 (0)
	RM165	6	0.46 (0.1)	0.00 (0)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.06 (0.12)	0.08 (0.09)	0.07 (0.1)	0.00 (0)	0.31 (0.15)	0.00 (0)	0.00 (0)
	RM225	4	0.36 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.07 (0.09)	0.31 (0.27)	0.04 (0.04)	0.00 (0)	0.09 (0.1)	0.12 (0.19)	0.00 (0)
Humpback Chub															
Winter 2008															
	RM60	22	0.06 (0.02)	0.00 (0)	0.00 (0)	0.04 (0.01)	0.00 (0)	0.04 (0.02)	0.00 (0)	0.02 (0)	0.55 (0.07)	0.00 (0)	0.25 (0.04)	0.03 (0.01)	0.01 (0)
Spring 2008															
	RM60	1	0.22 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.20 (na)	0.00 (na)	0.36 (na)	0.21 (na)	0.00 (na)
Summer 2008															
	RM60	15	0.04 (0.02)	0.44 (0.13)	0.00 (0)	0.02 (0.02)	0.00 (0)	0.10 (0.02)	0.03 (0.02)	0.02 (0)	0.13 (0.06)	0.00 (0)	0.14 (0.07)	0.07 (0.02)	0.01 (0)
Fall 2008															
	RM60	21	0.08 (0.03)	0.19 (0.1)	0.03 (0.06)	0.00 (0)	0.00 (0)	0.07 (0.02)	0.00 (0)	0.02 (0.01)	0.35 (0.1)	0.00 (0)	0.20 (0.08)	0.05 (0.04)	0.00 (0)
Winter 2009															
	RM60	14	0.12 (0.02)	0.10 (0.08)	0.00 (0)	0.05 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.01)	0.36 (0.12)	0.00 (0)	0.31 (0.11)	0.01 (0.01)	0.01 (0.01)
Speckled Dace															
Spring 2007															
	RM60	5	0.42 (0.29)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.00 (0)	0.19 (0.27)	0.00 (0)	0 (0)	0.29 (0.38)	0.10 (0.2)	0.00 (0)
	RM125	6	0.34 (0.29)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.00 (0)	0.14 (0.26)	0.03 (0.05)	0 (0)	0.50 (0.3)	0.00 (0)	0.00 (0)
	RM165	13	0.51 (0.21)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.14 (0.16)	0.23 (0.18)	0.02 (0.01)	0 (0)	0.09 (0.08)	0.01 (0.01)	0.00 (0)
	RM225	11	0.32 (0.24)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.30 (0.25)	0.07 (0.08)	0.01 (0.01)	0 (0)	0.25 (0.2)	0.05 (0.1)	0.00 (0)
Summer 2007															
	RM60	9	0.36 (0.27)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.54 (0.27)	0.02 (0.03)	0.00 (0.01)	0 (0)	0.08 (0.08)	0.00 (0)	0.00 (0)
	RM125	9	0.40 (0.2)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.05 (0.09)	0.08 (0.13)	0.03 (0.02)	0 (0)	0.43 (0.2)	0.01 (0.01)	0.00 (0)
	RM165	8	0.48 (0.21)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.00 (0)	0.04 (0.05)	0.04 (0.07)	0 (0)	0.35 (0.16)	0.09 (0.07)	0.00 (0)
	RM225	10	0.20 (0.14)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.13 (0.2)	0.08 (0.14)	0.12 (0.15)	0 (0)	0.15 (0.13)	0.32 (0.25)	0.00 (0.01)
Fall 2007															
	RM60	10	0.01 (0.01)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.60 (0.26)	0.01 (0.01)	0.00 (0.01)	0 (0)	0.35 (0.27)	0.00 (0)	0.03 (0.02)
	RM125	10	0.00 (0.01)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.63 (0.23)	0.03 (0.02)	0.14 (0.15)	0 (0)	0.10 (0.06)	0.08 (0.12)	0.01 (0.02)
	RM165	5	0.20 (0.39)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.38 (0.34)	0.23 (0.3)	0.17 (0.14)	0 (0)	0.00 (0)	0.00 (0)	0.01 (0.01)
	RM225	8	0.11 (0.08)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.45 (0.22)	0.10 (0.09)	0.17 (0.1)	0 (0)	0.04 (0.04)	0.08 (0.1)	0.05 (0.09)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Speckled Dace continued…															
Winter 2008															
	RM60	8	0.48 (0.22)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.11 (0.21)	0.05 (0.07)	0.01 (0.01)	0 (0)	0.35 (0.21)	0.00 (0)	0.00 (0)
	RM125	1	0.26 (na)	0.00 (na)	0 (na)	0.00 (na)	0 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0 (na)	0.74 (na)	0.00 (na)	0.00 (na)
	RM165	10	0.45 (0.2)	0.00 (0)	0 (0)	0.08 (0.14)	0 (0)	0.00 (0)	0.04 (0.05)	0.06 (0.09)	0.00 (0.01)	0 (0)	0.36 (0.2)	0.00 (0)	0.00 (0)
	RM225	10	0.61 (0.24)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0.00 (0)	0.10 (0.19)	0.01 (0.03)	0.04 (0.05)	0 (0)	0.24 (0.2)	0.00 (0)	0.00 (0.01)
Spring 2008															
	RM60	5	0.02 (0.03)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.16 (0.3)	0.01 (0.02)	0.00 (0)	0 (0)	0.81 (0.29)	0.00 (0)	0 (0)
	RM125	6	0.03 (0.03)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.12 (0.15)	0.03 (0.03)	0.15 (0.17)	0 (0)	0.40 (0.36)	0.28 (0.26)	0 (0)
	RM165	5	0.35 (0.36)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.17 (0.33)	0.04 (0.03)	0.02 (0.03)	0 (0)	0.33 (0.27)	0.09 (0.13)	0 (0)
	RM225	4	0.07 (0.09)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.18 (0.23)	0.06 (0.08)	0.13 (0.18)	0 (0)	0.38 (0.43)	0.22 (0.29)	0 (0)
Summer 2008															
	RM60	1	0.10 (na)	0.00 (na)	0 (na)	0.00 (na)	0 (na)	0 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0 (na)	0.90 (na)	0.00 (na)	0 (na)
	RM125	3	0.25 (0.29)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.33 (0.65)	0.00 (0)	0.00 (0)	0 (0)	0.16 (0.32)	0.25 (0.49)	0 (0)
	RM165	3	0.09 (0.09)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.25 (0.49)	0.01 (0.01)	0.00 (0.01)	0 (0)	0.60 (0.57)	0.04 (0.05)	0 (0)
	RM225	2	0.38 (0.23)	0.01 (0.02)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.00 (0.01)	0.18 (0.3)	0.00 (0.01)	0 (0)	0.32 (0.11)	0.10 (0.19)	0 (0)
Fall 2008															
	RM60	10	0.27 (0.14)	0.00 (0)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.27 (0.2)	0.31 (0.17)	0.01 (0.01)	0.00 (0)	0.13 (0.12)	0.00 (0)	0.00 (0)
	RM125	10	0.15 (0.09)	0.00 (0)	0.00 (0)	0.03 (0.07)	0.00 (0)	0.00 (0)	0.24 (0.26)	0.15 (0.1)	0.10 (0.1)	0.00 (0)	0.21 (0.17)	0.11 (0.11)	0.00 (0)
	RM165	10	0.22 (0.18)	0.00 (0)	0.00 (0)	0.00 (0.01)	0.00 (0)	0.00 (0)	0.23 (0.24)	0.01 (0.01)	0.12 (0.11)	0.00 (0)	0.25 (0.14)	0.15 (0.19)	0.00 (0)
	RM225	10	0.23 (0.17)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.47 (0.26)	0.08 (0.07)	0.07 (0.04)	0.00 (0)	0.09 (0.09)	0.05 (0.06)	0.00 (0.01)
Winter 2009															
	RM60	4	0.60 (0.37)	0.00 (0)	0 (0)	0.03 (0.04)	0 (0)	0 (0)	0.23 (0.45)	0.12 (0.15)	0.00 (0)	0 (0)	0.02 (0.04)	0.00 (0)	0 (0)
	RM125	5	0.23 (0.34)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.17 (0.34)	0.32 (0.38)	0.21 (0.35)	0 (0)	0.06 (0.11)	0.00 (0)	0 (0)
	RM165	4	0.27 (0.36)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.28 (0.36)	0.00 (0)	0.02 (0.02)	0 (0)	0.07 (0.1)	0.00 (0)	0 (0)
	RM225	4	0.52 (0.32)	0.00 (0)	0 (0)	0.00 (0)	0 (0)	0 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0 (0)	0.37 (0.31)	0.12 (0.23)	0 (0)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Non-Native Fishes															
Brown Trout															
All Sites/Seasons		12	0.01 (0.01)	0.01 (0.03)	0.58 (0.29)	0.03 (0.05)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.17 (0.18)	0.01 (0.01)	0.06 (0.11)	0.10 (0.16)	0.01 (0.01)	0.00 (0)
Channel Catfish															
All Sites/Seasons		31	0.01 (0.02)	0.31 (0.14)	0.01 (0.01)	0.00 (0)	0.39 (0.14)	0.00 (0)	0.00 (0)	0.01 (0)	0.11 (0.07)	0.00 (0)	0.02 (0.02)	0.12 (0.09)	0.01 (0.02)
Common Carp															
Spring 2007															
	RM60	3	0.42 (0.44)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0.01)	0.27 (0.27)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.28 (0.14)	0.00 (0)	0.00 (0)
	RM125	3	0.12 (0.13)	0.03 (0.04)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.00 (0.01)	0.68 (0.31)	0.03 (0.05)	0.04 (0.04)	0.03 (0.05)	0.04 (0.04)	0.01 (0.01)	0.00 (0)
	RM165	6	0.04 (0.07)	0.30 (0.37)	0.00 (0)	0.00 (0.01)	0.00 (0)	0.00 (0)	0.24 (0.33)	0.00 (0)	0.22 (0.29)	0.17 (0.32)	0.02 (0.04)	0.01 (0.01)	0.00 (0)
	RM225	5	0.07 (0.07)	0.15 (0.21)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.44 (0.34)	0.01 (0.01)	0.10 (0.08)	0.16 (0.3)	0.04 (0.04)	0.01 (0.01)	0.00 (0)
Summer 2007															
	RM30	4	0.01 (0)	0.15 (0.27)	0.00 (0)	0.04 (0.05)	0.00 (0)	0.00 (0)	0.71 (0.28)	0.00 (0)	0.05 (0.03)	0.00 (0)	0.04 (0.03)	0.00 (0)	0.00 (0)
	RM60	3	0.05 (0.05)	0.00 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0.03)	0.55 (0.52)	0.04 (0.09)	0.06 (0.06)	0.00 (0)	0.30 (0.48)	0.00 (0.07)	0.00 (0)
	RM125	6	0.04 (0.03)	0.01 (0.01)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.52 (0.35)	0.01 (0.01)	0.18 (0.23)	0.17 (0.31)	0.05 (0.07)	0.00 (0.01)	0.00 (0.01)
	RM165	4	0.00 (0)	0.52 (0.54)	0.00 (0)	0.00 (0)	0.05 (0.1)	0.00 (0)	0.38 (0.47)	0.00 (0)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.04 (0.08)	0.00 (0)
	RM225	3	0.03 (0.01)	0.22 (0.42)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.33 (0.44)	0.00 (0)	0.24 (0.31)	0.00 (0)	0.15 (0.21)	0.03 (0.02)	0.00 (0)
Fall 2007															
	RM60	5	0.03 (0.04)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.46 (0.41)	0.00 (0)	0.34 (0.36)	0.00 (0)	0.16 (0.26)	0.00 (0)	0.00 (0)
	RM125	3	0.00 (0)	0.26 (0.51)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.22 (0.29)	0.01 (0.01)	0.50 (0.54)	0.01 (0.02)	0.00 (0.01)	0.00 (0)	0.00 (0)
	RM165	4	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0.02)	0.12 (0.23)	0.01 (0.01)	0.10 (0.18)	0.74 (0.48)	0.00 (0.01)	0.02 (0.04)	0.00 (0)
	RM225	3	0.02 (0.03)	0.00 (0)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.79 (0.26)	0.00 (0.01)	0.14 (0.16)	0.01 (0.01)	0.02 (0.05)	0.01 (0.02)	0.00 (0)
Winter 2008															
	RM30	10	0.03 (0.06)	0.05 (0.1)	0.00 (0)	0.03 (0.03)	0.00 (0)	0.00 (0)	0.77 (0.22)	0.00 (0)	0.06 (0.04)	0.00 (0)	0.05 (0.07)	0.00 (0)	0.00 (0)
	RM60	4	0.04 (0.05)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.05)	0.67 (0.34)	0.00 (0.01)	0.19 (0.19)	0.00 (0)	0.06 (0.07)	0.00 (0)	0.00 (0)
	RM125	4	0.03 (0.02)	0.02 (0.04)	0.19 (0)	0.00 (0.01)	0.00 (0)	0.01 (0.01)	0.15 (0.16)	0.04 (0.02)	0.41 (0.27)	0.00 (0)	0.15 (0.1)	0.00 (0.01)	0.00 (0)
	RM165	5	0.04 (0.03)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.59 (0.34)	0.00 (0)	0.24 (0.21)	0.00 (0)	0.11 (0.1)	0.01 (0.01)	0.00 (0)
	RM225	1	0.07 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.79 (na)	0.00 (na)	0.11 (na)	0.02 (na)	0.00 (na)
Spring 2008															
	RM30	2	0.01 (0.02)	0.07 (0.14)	0.00 (0)	0.00 (0.01)	0.00 (0)	0.00 (0)	0.72 (0.54)	0.00 (0)	0.02 (0.05)	0.00 (0.01)	0.16 (0.32)	0.00 (0)	0.00 (0)
	RM60	11	0.01 (0.01)	0.26 (0.23)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.04)	0.14 (0.09)	0.00 (0)	0.48 (0.17)	0.00 (0)	0.07 (0.05)	0.00 (0)	0.00 (0)
	RM125	3	0.02 (0.02)	0.33 (0.62)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.16 (0.32)	0.01 (0.01)	0.36 (0.47)	0.00 (0)	0.12 (0.15)	0.01 (0.03)	0.00 (0)
	RM165	4	0.04 (0.07)	0.11 (0.15)	0.00 (0)	0.00 (0)	0.11 (0.22)	0.00 (0)	0.34 (0.36)	0.00 (0)	0.38 (0.43)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0.01)
	RM225	6	0.00 (0)	0.42 (0.37)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.32 (0.29)	0.00 (0)	0.00 (0)	0.09 (0.17)	0.00 (0)	0.17 (0.33)	0.00 (0)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Common Carp continued…															
Summer 2008															
	RM30	7	0.06 (0.07)	0.33 (0.31)	0.00 (0)	0.18 (0.21)	0.00 (0)	0.00 (0)	0.19 (0.28)	0.00 (0.01)	0.16 (0.13)	0.01 (0.02)	0.07 (0.1)	0.00 (0)	0.00 (0)
	RM60	12	0.02 (0.02)	0.21 (0.18)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.07)	0.44 (0.19)	0.01 (0.02)	0.18 (0.16)	0.00 (0)	0.09 (0.08)	0.01 (0.01)	0.00 (0)
	RM125	2	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.85 (0.21)	0.00 (0)	0.15 (0.21)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	6	0.01 (0.01)	0.44 (0.39)	0.00 (0)	0.00 (0)	0.17 (0.33)	0.00 (0)	0.22 (0.3)	0.00 (0)	0.02 (0.02)	0.14 (0.27)	0.01 (0)	0.00 (0)	0.00 (0)
	RM225	2	0.05 (0.09)	0.47 (0.92)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.34 (0.67)	0.00 (0)	0.07 (0.11)	0.00 (0)	0.05 (0.06)	0.01 (0.01)	0.00 (0)
Fall 2008															
	RM60	1	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.01 (na)	0.97 (na)	0.00 (na)	0.01 (na)	0.00 (na)	0.00 (na)
	RM125	1	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	1.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)
	RM165	5	0.03 (0.05)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.13 (0.16)	0.20 (0.34)	0.19 (0.23)	0.09 (0.18)	0.00 (0)	0.36 (0.43)	0.00 (0)
	RM225	2	0.00 (0)	0.10 (0.2)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.50 (0.98)	0.00 (0)	0.01 (0.02)	0.39 (0.76)	0.00 (0)	0.00 (0)	0.00 (0)
Winter 2009															
	RM60	2	0.25 (0.23)	0.01 (0.02)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.01 (0.02)	0.30 (0.58)	0.01 (0.02)	0.25 (0.25)	0.00 (0)	0.17 (0.11)	0.00 (0)	0.00 (0)
	RM125	4	0.00 (0)	0.40 (0.45)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.22 (0.35)	0.00 (0)	0.36 (0.42)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	5	0.02 (0.02)	0.00 (0)	0.05 (0.09)	0.00 (0)	0.00 (0)	0.01 (0.02)	0.09 (0.15)	0.03 (0.05)	0.24 (0.19)	0.20 (0.39)	0.21 (0.21)	0.00 (0.01)	0.15 (0.29)
	RM225	5	0.07 (0.08)	0.17 (0.26)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.67 (0.2)	0.01 (0.01)	0.03 (0.03)	0.01 (0.02)	0.03 (0.03)	0.01 (0.02)	0.00 (0)
Fathead Minnow															
Spring 2007															
	RM60	10	0.21 (0.22)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.74 (0.27)	0.05 (0.09)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM125	5	0.09 (0.11)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.62 (0.38)	0.11 (0.21)	0.00 (0)	0.00 (0)	0.11 (0.21)	0.08 (0.15)	0.00 (0)
	RM165	7	0.08 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.86 (0.28)	0.06 (0.12)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM225	8	0.18 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.08)	0.66 (0.27)	0.06 (0.07)	0.01 (0.01)	0.00 (0)	0.01 (0.02)	0.03 (0.06)	0.00 (0)
Summer 2007															
	RM60	9	0.33 (0.23)	0.01 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.54 (0.23)	0.04 (0.04)	0.02 (0.02)	0.00 (0)	0.05 (0.05)	0.00 (0)	0.01 (0.01)
	RM125	7	0.20 (0.14)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.50 (0.27)	0.06 (0.05)	0.00 (0)	0.00 (0)	0.21 (0.12)	0.00 (0)	0.02 (0.02)
	RM165	10	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.88 (0.19)	0.00 (0)	0.02 (0.02)	0.00 (0)	0.09 (0.18)	0.01 (0.01)	0.00 (0)
	RM225	1	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.92 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.08 (na)
Fall 2007															
	RM60	10	0.05 (0.08)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.58 (0.29)	0.03 (0.03)	0.00 (0)	0.00 (0)	0.30 (0.26)	0.02 (0.05)	0.02 (0.04)
	RM125	2	0.12 (0.23)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.40 (0.79)	0.01 (0.02)	0.19 (0.02)	0.00 (0)	0.29 (0.56)	0.00 (0)	0.00 (0)
	RM165	10	0.22 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.51 (0.23)	0.18 (0.13)	0.09 (0.07)	0.00 (0)	0.01 (0.01)	0.00 (0)	0.00 (0)
Winter 2008															
	RM60	10	0.16 (0.19)	0.00 (0)	0.00 (0)	0.10 (0.11)	0.00 (0)	0.00 (0)	0.63 (0.19)	0.03 (0.05)	0.04 (0.04)	0.00 (0)	0.05 (0.07)	0.00 (0)	0.00 (0)
	RM125	10	0.24 (0.21)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.40 (0.28)	0.02 (0.04)	0.01 (0.02)	0.00 (0)	0.33 (0.23)	0.00 (0)	0.00 (0)
	RM165	10	0.19 (0.07)	0.00 (0)	0.00 (0)	0.03 (0.05)	0.00 (0)	0.00 (0)	0.42 (0.18)	0.05 (0.05)	0.04 (0.04)	0.00 (0)	0.23 (0.17)	0.04 (0.08)	0.01 (0.01)
	RM225	12	0.08 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.91 (0.16)	0.00 (0)	0.00 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0.01)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Fathead Minnow cont'd…															
Spring 2008															
	RM60	3	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.78 (0.42)	0.17 (0.33)	0.05 (0.09)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM125	4	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.89 (0.12)	0.05 (0.1)	0.05 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	7	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.87 (0.1)	0.00 (0)	0.13 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM225	1	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.96 (na)	0.00 (na)	0.04 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)
Summer 2008															
	RM60	3	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.98 (0.03)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM125	3	0.08 (0.15)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.66 (0.35)	0.01 (0.01)	0.13 (0.25)	0.00 (0)	0.12 (0.23)	0.00 (0.01)	0.00 (0)
	RM165	2	0.11 (0.22)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.56 (0.86)	0.00 (0)	0.00 (0)	0.00 (0)	0.31 (0.61)	0.00 (0)	0.00 (0)
	RM225	3	0.23 (0.44)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.42 (0.52)	0.00 (0)	0.36 (0.42)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Fall 2008															
	RM60	9	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.83 (0.21)	0.00 (0)	0.03 (0.03)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.00 (0)
	RM125	10	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.79 (0.25)	0.10 (0.18)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM165	10	0.08 (0.12)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.83 (0.18)	0.00 (0)	0.09 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
	RM225	10	0.03 (0.06)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.79 (0.21)	0.06 (0.06)	0.01 (0.01)	0.00 (0)	0.10 (0.13)	0.00 (0)	0.00 (0)
Winter 2009															
	RM60	8	0.30 (0.3)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.57 (0.33)	0.03 (0.06)	0.02 (0.03)	0.00 (0)	0.07 (0.09)	0.00 (0)	0.00 (0)
	RM125	7	0.06 (0.1)	0.10 (0.2)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.68 (0.29)	0.00 (0)	0.05 (0.11)	0.00 (0)	0.11 (0.18)	0.00 (0)	0.00 (0)
	RM165	9	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.65 (0.23)	0.04 (0.08)	0.25 (0.21)	0.00 (0)	0.04 (0.06)	0.00 (0)	0.00 (0)
	RM225	4	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.83 (0.12)	0.00 (0)	0.17 (0.12)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Plains Killifish															
Year 1															
	All Sites	15	0.44 (0.21)	0.06 (0.12)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.06 (0.09)	0.35 (0.2)	0.02 (0.03)	0.00 (0)	0.02 (0.04)	0.05 (0.05)	0.00 (0)
Year 2															
	All Sites	9	0.34 (0.23)	0.04 (0.08)	0.00 (0)	0.05 (0.08)	0.00 (0)	0.00 (0)	0.25 (0.25)	0.19 (0.12)	0.02 (0.04)	0.00 (0)	0.05 (0.05)	0.06 (0.06)	0.00 (0)
Rainbow Trout															
Spring 2007															
	RM0	9	0.21 (0.11)	0.59 (0.23)	0.05 (0.09)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.01 (0.01)	0.11 (0.2)	0.01 (0)	0.00 (0)	0.00 (0)
	RM30	12	0.01 (0)	0.10 (0.07)	0.00 (0)	0.10 (0.12)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.07 (0.06)	0.00 (0)	0.70 (0.14)	0.01 (0.01)	0.00 (0)
	RM60	6	0.07 (0.12)	0.20 (0.24)	0.05 (0.1)	0.01 (0.01)	0.00 (0)	0.01 (0.01)	0.01 (0)	0.02 (0.02)	0.04 (0.04)	0.00 (0)	0.52 (0.37)	0.06 (0.07)	0.00 (0)
	RM125	12	0.02 (0.01)	0.35 (0.18)	0.00 (0)	0.00 (0)	0.12 (0.17)	0.00 (0)	0.00 (0)	0.08 (0.07)	0.08 (0.05)	0.00 (0)	0.22 (0.14)	0.12 (0.15)	0.00 (0)
	RM165	2	0.02 (0.03)	0.85 (0.16)	0.01 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.05 (0.09)	0.01 (0.02)	0.00 (0)	0.03 (0.03)	0.03 (0.03)	0.00 (0)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Rainbow Trout cont'd…															
Summer 2007															
	RM0	7	0.00 (0)	0.27 (0.21)	0.00 (0)	0.14 (0.17)	0.00 (0)	0.00 (0)	0.11 (0.12)	0.08 (0.1)	0.03 (0.01)	0.11 (0.14)	0.24 (0.22)	0.02 (0.01)	0.00 (0)
	RM30	9	0.00 (0)	0.74 (0.1)	0.00 (0)	0.02 (0.01)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0)	0.06 (0.03)	0.00 (0)	0.17 (0.07)	0.00 (0)	0.00 (0)
	RM60	3	0.00 (0)	0.61 (0.59)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.00 (0)	0.08 (0.03)	0.00 (0)	0.30 (0.57)	0.00 (0)	0.00 (0)
	RM125	4	0.00 (0)	0.55 (0.43)	0.00 (0)	0.00 (0)	0.00 (0)	0.15 (0.08)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.29 (0.36)	0.00 (0)
	RM165	5	0.00 (0)	0.19 (0.36)	0.00 (0)	0.00 (0)	0.41 (0.41)	0.02 (0.04)	0.00 (0)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.37 (0.37)	0.00 (0)
Fall 2007															
	RM0	10	0.42 (0.21)	0.45 (0.25)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.05 (0.06)	0.03 (0.02)	0.02 (0.01)	0.00 (0)	0.03 (0.03)	0.00 (0)
	RM30	13	0.00 (0)	0.44 (0.17)	0.00 (0)	0.02 (0.01)	0.00 (0)	0.03 (0.03)	0.07 (0.07)	0.01 (0)	0.08 (0.03)	0.01 (0.01)	0.22 (0.16)	0.10 (0.06)	0.02 (0.02)
	RM60	1	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.78 (na)	0.14 (na)	0.00 (na)	0.00 (na)	0.03 (na)	0.04 (na)	0.00 (na)
	RM125	15	0.00 (0)	0.13 (0.12)	0.00 (0)	0.00 (0)	0.25 (0.21)	0.06 (0.04)	0.04 (0.03)	0.00 (0)	0.03 (0.02)	0.02 (0.03)	0.01 (0)	0.46 (0.21)	0.00 (0)
	RM165	1	0.00 (na)	0.16 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.52 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.32 (na)	0.00 (na)
Winter 2008															
	RM30	10	0.01 (0.01)	0.22 (0.16)	0.00 (0)	0.40 (0.17)	0.00 (0)	0.00 (0)	0.00 (0)	0.07 (0.08)	0.12 (0.11)	0.00 (0)	0.17 (0.19)	0.00 (0)	0.00 (0)
	RM60	6	0.01 (0.01)	0.16 (0.29)	0.00 (0)	0.00 (0)	0.00 (0)	0.02 (0.04)	0.34 (0.3)	0.00 (0)	0.27 (0.21)	0.10 (0.2)	0.09 (0.1)	0.00 (0)	0.00 (0)
	RM125	9	0.04 (0.04)	0.29 (0.16)	0.11 (0.21)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.08 (0.08)	0.16 (0.06)	0.01 (0.02)	0.32 (0.15)	0.00 (0)	0.00 (0)
	RM165	8	0.03 (0.02)	0.14 (0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.04 (0.05)	0.00 (0)	0.06 (0.11)	0.31 (0.21)	0.00 (0)	0.26 (0.26)	0.16 (0.22)	0.00 (0)
Spring 2008															
	RM0	3	0.05 (0.09)	0.20 (0.39)	0.00 (0)	0.18 (0.2)	0.00 (0)	0.00 (0)	0.21 (0.22)	0.00 (0)	0.01 (0)	0.15 (0.24)	0.19 (0.37)	0.00 (0)	0.00 (0)
	RM30	13	0.00 (0)	0.45 (0.12)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (0)	0.05 (0.03)	0.00 (0)	0.47 (0.11)	0.01 (0.01)	0.00 (0)
	RM60	2	0.01 (0)	0.72 (0.27)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.05 (0.09)	0.02 (0.03)	0.02 (0)	0.00 (0)	0.09 (0.06)	0.06 (0.11)	0.00 (0)
	RM125	11	0.00 (0)	0.18 (0.1)	0.00 (0)	0.00 (0)	0.51 (0.25)	0.01 (0.02)	0.00 (0)	0.03 (0.03)	0.07 (0.07)	0.00 (0)	0.05 (0.03)	0.14 (0.12)	0.00 (0)
	RM165	5	0.01 (0.01)	0.36 (0.27)	0.00 (0)	0.01 (0.01)	0.05 (0.09)	0.02 (0.02)	0.03 (0.03)	0.01 (0.01)	0.03 (0.03)	0.00 (0)	0.06 (0.05)	0.42 (0.33)	0.00 (0)
	RM225	1	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	0.00 (na)	1.00 (na)	0.00 (na)
Summer 2008															
	RM0	23	0.02 (0.01)	0.69 (0.15)	0.00 (0)	0.05 (0.04)	0.00 (0)	0.00 (0)	0.03 (0.06)	0.06 (0.04)	0.01 (0)	0.01 (0)	0.10 (0.11)	0.04 (0.04)	0.00 (0)
	RM30	15	0.04 (0.02)	0.80 (0.11)	0.00 (0)	0.01 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.05 (0.04)	0.00 (0)	0.08 (0.05)	0.01 (0)	0.00 (0)
	RM60	3	0.00 (0)	0.49 (0.5)	0.11 (0.21)	0.01 (0.01)	0.00 (0)	0.03 (0.04)	0.23 (0.41)	0.00 (0)	0.08 (0.11)	0.00 (0)	0.00 (0)	0.05 (0.07)	0.00 (0)
	RM125	9	0.03 (0.02)	0.17 (0.12)	0.00 (0)	0.00 (0)	0.09 (0.16)	0.00 (0)	0.00 (0)	0.04 (0.05)	0.10 (0.1)	0.00 (0)	0.20 (0.1)	0.38 (0.25)	0.00 (0)
	RM165	9	0.01 (0)	0.23 (0.21)	0.00 (0)	0.00 (0)	0.32 (0.19)	0.02 (0.01)	0.09 (0.07)	0.01 (0)	0.02 (0)	0.00 (0)	0.02 (0.01)	0.29 (0.19)	0.00 (0)
Fall 2008															
	RM0	11	0.01 (0)	0.20 (0.19)	0.00 (0)	0.17 (0.13)	0.00 (0)	0.00 (0)	0.00 (0)	0.15 (0.18)	0.01 (0.01)	0.10 (0.12)	0.35 (0.22)	0.00 (0)	0.00 (0)
	RM30	10	0.01 (0)	0.84 (0.08)	0.00 (0)	0.01 (0.02)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.08 (0.04)	0.00 (0)	0.06 (0.04)	0.00 (0)	0.00 (0)
	RM60	4	0.01 (0.01)	0.60 (0.16)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.25 (0.1)	0.00 (0)	0.04 (0.03)	0.00 (0)	0.05 (0.07)	0.05 (0.08)	0.00 (0)
	RM125	9	0.00 (0)	0.43 (0.25)	0.00 (0)	0.00 (0)	0.20 (0.25)	0.00 (0)	0.00 (0)	0.00 (0)	0.17 (0.07)	0.00 (0)	0.01 (0.01)	0.15 (0.2)	0.04 (0.04)
	RM165	11	0.00 (0)	0.06 (0.11)	0.00 (0)	0.00 (0)	0.15 (0.19)	0.00 (0)	0.00 (0)	0.00 (0)	0.02 (0.03)	0.00 (0)	0.00 (0)	0.75 (0.23)	0.01 (0.01)
	RM225	2	0.00 (0)	0.17 (0.32)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.05 (0.09)	0.00 (0)	0.00 (0)	0.55 (0.87)	0.23 (0.45)

Season	Site	n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrates	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrat	Unknown
Rainbow Trout continued…															
Winter 2009															
	RM0	10	0.21 (0.17)	0.20 (0.18)	0.00 (0)	0.13 (0.13)	0.00 (0)	0.00 (0)	0.00 (0)	0.14 (0.17)	0.03 (0.01)	0.00 (0)	0.30 (0.23)	0.00 (0)	0.00 (0)
	RM30	13	0.06 (0.03)	0.46 (0.17)	0.00 (0)	0.08 (0.06)	0.00 (0)	0.00 (0)	0.00 (0)	0.03 (0.02)	0.16 (0.14)	0.00 (0)	0.21 (0.12)	0.00 (0)	0.00 (0)
	RM60	15	0.15 (0.06)	0.20 (0.14)	0.00 (0)	0.04 (0.04)	0.00 (0)	0.02 (0.02)	0.06 (0.1)	0.06 (0.03)	0.13 (0.12)	0.01 (0.01)	0.30 (0.15)	0.03 (0.03)	0.00 (0)
	RM125	12	0.21 (0.11)	0.12 (0.08)	0.00 (0)	0.05 (0.03)	0.00 (0)	0.00 (0)	0.06 (0.06)	0.17 (0.14)	0.11 (0.09)	0.00 (0)	0.25 (0.09)	0.04 (0.04)	0.00 (0)
	RM165	10	0.03 (0.01)	0.57 (0.17)	0.00 (0)	0.00 (0)	0.06 (0.11)	0.00 (0)	0.02 (0.02)	0.05 (0.02)	0.12 (0.1)	0.00 (0)	0.08 (0.06)	0.07 (0.08)	0.00 (0)
	RM225	4	0.01 (0.01)	0.75 (0.19)	0.00 (0)	0.00 (0)	0.03 (0.05)	0.00 (0)	0.00 (0)	0.01 (0)	0.03 (0.05)	0.00 (0)	0.02 (0.02)	0.15 (0.1)	0.00 (0)
Red Shiner															
Year 1															
	All Sites	4	0.49 (0.27)	0.00 (0)	0.00 (0)	0.00 (0)	1.00 (0)	0.00 (0)	0.00 (0)	0.28 (0.41)	0.00 (0)	0.00 (0)	0.06 (0.08)	0.17 (0.15)	0.00 (0)
Year 2															
	All Sites	10	0.50 (0.25)	0.03 (0.06)	0.00 (0)	0.00 (0)	1.00 (0)	0.00 (0)	0.01 (0.02)	0.25 (0.23)	0.00 (0)	0.00 (0)	0.11 (0.16)	0.10 (0.1)	0.00 (0)
Yellow Bullhead															
All Sites/Seasons		18	0.05 (0.04)	0.08 (0.08)	0.09 (0.12)	0.31 (0.17)	0.00 (0)	0.07 (0.08)	0.00 (0)	0.08 (0.09)	0.10 (0.07)	0.05 (0.1)	0.16 (0.11)	0.01 (0.01)	0.01 (0.01)

Appendix C. Annualized trophic basis of secondary production for native and non-native fishes in the Grand Canyon reach of the Coloado River. UCI and LCI represent boot-strapped upper and lower 95% confidence intervals. For species with low sample size, trophic basis of production is based on the average of all individuals caught within a year.

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Native Fishes															
Bluehead Sucker															
Year 1															
RM60	Ave	21	0.03	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.03	0.00	0.02	0.00	0.00
	UCI		0.06	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.06	0.00	0.04	0.00	0.00
	LCI		0.00	0.00	0.00	0.00	0.00	0.00	0.86	0.00	0.01	0.00	0.01	0.00	0.00
RM125	Ave	8	0.01	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
	UCI		0.01	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.01	0.00	0.00	0.00	0.00
	LCI		0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
RM165	Ave	9	0.01	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.01	0.00	0.06	0.00	0.00
	UCI		0.01	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.01	0.00	0.17	0.00	0.00
	LCI		0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00
RM225	Ave	7	0.03	0.00	0.00	0.00	0.00	0.00	0.36	0.01	0.00	0.00	0.60	0.00	0.00
	UCI		0.05	0.00	0.00	0.00	0.00	0.00	0.47	0.02	0.01	0.00	0.68	0.00	0.00
	LCI		0.01	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.51	0.00	0.00
Year 2															
RM60	Ave	26	0.04	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.01	0.00	0.01	0.00	0.00
	UCI		0.06	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.01	0.00	0.01	0.00	0.00
	LCI		0.02	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.01	0.00	0.00
RM125	Ave	12	0.01	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.01	0.00	0.18	0.00	0.00
	UCI		0.02	0.01	0.00	0.00	0.00	0.00	0.98	0.00	0.01	0.00	0.35	0.00	0.00
	LCI		0.01	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00
RM165	Ave	12	0.02	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.04	0.00	0.00
	UCI		0.04	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.11	0.00	0.00
	LCI		0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00
RM225	Ave	17	0.04	0.09	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.09	0.00	0.00
	UCI		0.09	0.22	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.17	0.00	0.00
	LCI		0.01	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.02	0.00	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Juv. Bluehead Sucker															
Year 1															
RM60	Ave	15	0.34	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.01	0.00	0.28	0.00	0.00
	UCI		0.60	0.00	0.00	0.01	0.00	0.00	0.64	0.01	0.03	0.00	0.57	0.00	0.00
	LCI		0.08	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.04	0.00	0.00
RM125	Ave	5	0.41	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.04	0.00	0.00
	UCI		0.72	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.10	0.00	0.00
	LCI		0.18	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
RM165	Ave	8	0.61	0.00	0.00	0.01	0.00	0.00	0.27	0.05	0.01	0.00	0.03	0.01	0.00
	UCI		0.86	0.00	0.00	0.03	0.00	0.00	0.66	0.12	0.03	0.00	0.08	0.03	0.00
	LCI		0.16	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.00	0.00
RM225	Ave	2	0.57	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.01	0.00	0.29	0.00	0.00
	UCI		0.85	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.03	0.00	0.60	0.00	0.00
	LCI		0.25	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Year 2															
RM60	Ave	7	0.32	0.00	0.00	0.00	0.00	0.00	0.66	0.01	0.00	0.00	0.01	0.00	0.00
	UCI		0.35	0.00	0.00	0.00	0.00	0.00	0.70	0.02	0.00	0.00	0.03	0.00	0.00
	LCI		0.29	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00
RM125	Ave	19	0.32	0.02	0.00	0.00	0.00	0.00	0.60	0.00	0.02	0.00	0.01	0.03	0.00
	UCI		0.49	0.04	0.00	0.00	0.00	0.00	0.79	0.00	0.03	0.00	0.01	0.07	0.00
	LCI		0.16	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.01	0.00	0.01	0.00	0.00
RM165	Ave	10	0.07	0.04	0.00	0.00	0.00	0.00	0.69	0.14	0.05	0.00	0.01	0.00	0.00
	UCI		0.08	0.05	0.00	0.00	0.00	0.00	0.80	0.25	0.07	0.00	0.01	0.00	0.00
	LCI		0.06	0.04	0.00	0.00	0.00	0.00	0.60	0.00	0.04	0.00	0.01	0.00	0.00
RM225	Ave	19	0.52	0.01	0.00	0.00	0.00	0.00	0.26	0.05	0.03	0.00	0.11	0.02	0.00
	UCI		0.63	0.03	0.00	0.00	0.00	0.00	0.34	0.06	0.04	0.00	0.17	0.02	0.00
	LCI		0.43	0.00	0.00	0.00	0.00	0.00	0.18	0.04	0.02	0.00	0.08	0.01	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Flannelmouth Sucker															
Year 1															
RM30	Ave	8	0.11	0.00	0.00	0.19	0.00	0.00	0.06	0.00	0.01	0.00	0.63	0.00	0.00
	UCI		0.16	0.01	0.00	0.44	0.00	0.00	0.14	0.00	0.01	0.00	0.82	0.00	0.00
	LCI		0.06	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.42	0.00	0.00
RM60	Ave	32	0.30	0.07	0.00	0.01	0.00	0.00	0.21	0.09	0.03	0.00	0.28	0.01	0.00
	UCI		0.43	0.15	0.00	0.02	0.00	0.00	0.28	0.18	0.04	0.00	0.37	0.01	0.00
	LCI		0.18	0.00	0.00	0.00	0.00	0.00	0.14	0.02	0.02	0.00	0.18	0.00	0.00
RM125	Ave	36	0.15	0.02	0.00	0.02	0.00	0.00	0.42	0.14	0.05	0.00	0.19	0.02	0.00
	UCI		0.21	0.04	0.00	0.03	0.00	0.00	0.54	0.27	0.08	0.00	0.25	0.03	0.00
	LCI		0.09	0.00	0.00	0.00	0.00	0.00	0.31	0.05	0.03	0.00	0.12	0.01	0.00
RM165	Ave	31	0.40	0.06	0.00	0.01	0.00	0.00	0.28	0.05	0.04	0.00	0.11	0.04	0.00
	UCI		0.58	0.10	0.00	0.02	0.00	0.00	0.42	0.07	0.05	0.00	0.19	0.06	0.00
	LCI		0.21	0.02	0.00	0.01	0.00	0.00	0.18	0.03	0.02	0.00	0.05	0.02	0.00
RM225	Ave	22	0.30	0.04	0.00	0.02	0.00	0.00	0.35	0.02	0.02	0.00	0.24	0.01	0.00
	UCI		0.41	0.08	0.00	0.04	0.00	0.00	0.44	0.03	0.04	0.01	0.38	0.02	0.00
	LCI		0.18	0.01	0.00	0.00	0.00	0.00	0.26	0.00	0.01	0.00	0.11	0.00	0.00
Year 2															
RM30	Ave	6	0.18	0.08	0.00	0.06	0.00	0.00	0.26	0.05	0.01	0.00	0.35	0.00	0.00
	UCI		0.33	0.26	0.00	0.15	0.00	0.00	0.41	0.08	0.01	0.01	0.52	0.01	0.00
	LCI		0.06	0.00	0.00	0.00	0.00	0.00	0.14	0.01	0.00	0.00	0.15	0.00	0.00
RM60	Ave	43	0.29	0.02	0.00	0.02	0.00	0.00	0.33	0.08	0.01	0.00	0.23	0.01	0.00
	UCI		0.37	0.04	0.00	0.04	0.00	0.00	0.42	0.18	0.02	0.00	0.30	0.01	0.00
	LCI		0.20	0.00	0.00	0.01	0.00	0.00	0.25	0.03	0.01	0.00	0.17	0.00	0.00
RM125	Ave	31	0.32	0.01	0.00	0.11	0.00	0.00	0.39	0.04	0.02	0.00	0.11	0.01	0.00
	UCI		0.49	0.03	0.00	0.24	0.00	0.00	0.49	0.08	0.03	0.00	0.18	0.02	0.00
	LCI		0.14	0.00	0.00	0.00	0.00	0.00	0.32	0.01	0.01	0.00	0.06	0.00	0.00
RM165	Ave	34	0.21	0.06	0.00	0.01	0.00	0.00	0.47	0.04	0.02	0.00	0.13	0.05	0.00
	UCI		0.30	0.11	0.00	0.02	0.00	0.00	0.62	0.10	0.04	0.00	0.18	0.09	0.00
	LCI		0.13	0.02	0.00	0.00	0.00	0.00	0.35	0.01	0.01	0.00	0.08	0.02	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Flannelmouth Sucker continued…															
Year 2															
RM225	Ave	28	0.45	0.02	0.00	0.01	0.00	0.00	0.38	0.01	0.03	0.00	0.10	0.01	0.00
	UCI		0.57	0.06	0.00	0.02	0.00	0.00	0.52	0.02	0.05	0.00	0.17	0.02	0.00
	LCI		0.31	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.01	0.00	0.04	0.00	0.00
Juv. Flannelmouth Sucker															
Year 1															
RM60	Ave	19	0.74	0.00	0.00	0.00	0.00	0.00	0.10	0.04	0.01	0.00	0.10	0.00	0.00
	UCI		0.83	0.00	0.00	0.00	0.00	0.00	0.17	0.07	0.01	0.00	0.20	0.00	0.00
	LCI		0.65	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.02	0.00	0.00
RM125	Ave	10	0.70	0.00	0.00	0.01	0.00	0.00	0.14	0.04	0.01	0.00	0.09	0.01	0.00
	UCI		0.78	0.00	0.00	0.02	0.00	0.00	0.28	0.05	0.01	0.00	0.12	0.02	0.00
	LCI		0.57	0.00	0.00	0.00	0.00	0.00	0.06	0.03	0.01	0.00	0.06	0.00	0.00
RM165	Ave	25	0.45	0.00	0.00	0.03	0.00	0.00	0.17	0.11	0.03	0.00	0.14	0.06	0.00
	UCI		0.57	0.00	0.00	0.07	0.00	0.00	0.30	0.16	0.05	0.00	0.22	0.16	0.00
	LCI		0.31	0.00	0.00	0.01	0.00	0.00	0.09	0.06	0.02	0.00	0.07	0.01	0.00
RM225	Ave	35	0.60	0.00	0.00	0.00	0.00	0.00	0.22	0.05	0.02	0.00	0.06	0.03	0.00
	UCI		0.71	0.00	0.00	0.01	0.00	0.00	0.32	0.08	0.04	0.00	0.12	0.08	0.00
	LCI		0.48	0.00	0.00	0.00	0.00	0.00	0.14	0.03	0.01	0.00	0.02	0.00	0.00
Year 2															
RM60	Ave	8	0.67	0.00	0.00	0.02	0.00	0.00	0.01	0.07	0.01	0.00	0.17	0.04	0.00
	UCI		0.74	0.00	0.00	0.03	0.00	0.00	0.01	0.11	0.02	0.00	0.23	0.07	0.00
	LCI		0.59	0.00	0.00	0.02	0.00	0.00	0.00	0.04	0.01	0.00	0.11	0.02	0.00
RM125	Ave	22	0.59	0.00	0.00	0.00	0.00	0.00	0.06	0.12	0.01	0.00	0.08	0.13	0.00
	UCI		0.65	0.01	0.00	0.01	0.00	0.00	0.09	0.15	0.01	0.00	0.11	0.16	0.00
	LCI		0.53	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.00	0.00	0.04	0.10	0.00
RM165	Ave	21	0.64	0.00	0.00	0.01	0.00	0.00	0.13	0.03	0.02	0.00	0.15	0.01	0.00
	UCI		0.68	0.00	0.00	0.02	0.00	0.00	0.16	0.06	0.03	0.00	0.22	0.02	0.00
	LCI		0.61	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.02	0.00	0.10	0.00	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Juv. Flannelmouth Sucker continued…															
Year 2															
RM225	Ave	25	0.56	0.00	0.00	0.00	0.00	0.00	0.11	0.11	0.01	0.00	0.09	0.11	0.00
	UCI		0.66	0.01	0.00	0.00	0.00	0.00	0.18	0.17	0.03	0.00	0.15	0.17	0.00
	LCI		0.46	0.00	0.00	0.00	0.00	0.00	0.07	0.06	0.00	0.00	0.04	0.05	0.00
Humpback Chub															
Year 1															
RM60	Ave	26	0.13	0.00	0.00	0.09	0.00	0.01	0.00	0.04	0.15	0.00	0.51	0.06	0.00
	UCI		0.16	0.00	0.00	0.13	0.00	0.02	0.00	0.06	0.20	0.00	0.56	0.09	0.00
	LCI		0.10	0.00	0.00	0.06	0.00	0.00	0.00	0.03	0.12	0.00	0.46	0.04	0.00
Year 2															
RM60	Ave	51	0.20	0.04	0.02	0.03	0.00	0.01	0.00	0.03	0.06	0.00	0.45	0.14	0.00
	UCI		0.22	0.06	0.06	0.05	0.00	0.01	0.01	0.04	0.08	0.00	0.49	0.17	0.00
	LCI		0.19	0.03	0.00	0.02	0.00	0.01	0.00	0.02	0.05	0.00	0.41	0.12	0.00
Speckled Dace															
Year 1															
RM60	Ave	32	0.42	0.00	0.00	0.00	0.00	0.00	0.11	0.09	0.00	0.00	0.35	0.03	0.00
	UCI		0.54	0.00	0.00	0.00	0.00	0.00	0.16	0.18	0.00	0.00	0.50	0.10	0.00
	LCI		0.30	0.00	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.00	0.21	0.00	0.00
RM125	Ave	26	0.30	0.00	0.00	0.00	0.00	0.00	0.06	0.07	0.01	0.00	0.54	0.02	0.00
	UCI		0.40	0.00	0.00	0.00	0.00	0.00	0.08	0.16	0.02	0.00	0.64	0.06	0.00
	LCI		0.21	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.43	0.00	0.00
RM165	Ave	36	0.49	0.00	0.00	0.02	0.00	0.00	0.05	0.17	0.01	0.00	0.24	0.03	0.00
	UCI		0.61	0.00	0.00	0.07	0.00	0.00	0.08	0.26	0.02	0.00	0.32	0.05	0.00
	LCI		0.37	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.00	0.00	0.16	0.01	0.00
RM225	Ave	39	0.43	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.02	0.00	0.23	0.14	0.00
	UCI		0.53	0.00	0.00	0.00	0.00	0.00	0.14	0.16	0.03	0.00	0.34	0.23	0.00
	LCI		0.32	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.01	0.00	0.14	0.07	0.00
Year 2															
RM60	Ave	25	0.41	0.00	0.00	0.01	0.00	0.00	0.10	0.13	0.01	0.00	0.34	0.00	0.00
	UCI		0.55	0.00	0.00	0.03	0.00	0.00	0.19	0.20	0.02	0.00	0.49	0.00	0.00
	LCI		0.25	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.00	0.00	0.20	0.00	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Speckled Dace continued…															
Year 2															
RM125	Ave	24	0.22	0.00	0.00	0.01	0.00	0.00	0.08	0.17	0.02	0.00	0.33	0.18	0.00
	UCI		0.33	0.00	0.00	0.04	0.00	0.00	0.17	0.28	0.04	0.00	0.46	0.32	0.00
	LCI		0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.20	0.05	0.00
RM165	Ave	25	0.38	0.00	0.00	0.00	0.00	0.00	0.09	0.05	0.01	0.00	0.39	0.08	0.00
	UCI		0.52	0.00	0.00	0.00	0.00	0.00	0.17	0.10	0.01	0.00	0.53	0.15	0.00
	LCI		0.24	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.24	0.03	0.00
RM225	Ave	25	0.31	0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.01	0.00	0.43	0.11	0.00
	UCI		0.43	0.00	0.00	0.00	0.00	0.00	0.08	0.16	0.01	0.00	0.55	0.20	0.00
	LCI		0.22	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.30	0.03	0.00
Non-native Fishes															
Brown Trout															
Year1 & 2															
All	Ave	11	0.00	0.00	0.69	0.04	0.00	0.00	0.00	0.15	0.00	0.01	0.10	0.01	0.00
	UCI		0.01	0.01	0.91	0.10	0.00	0.00	0.01	0.33	0.00	0.03	0.29	0.02	0.00
	LCI		0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Channel Catfish															
Year1 & 2															
All	Ave	31	0.03	0.25	0.01	0.00	0.43	0.00	0.00	0.01	0.04	0.00	0.05	0.18	0.00
	UCI		0.08	0.39	0.03	0.00	0.57	0.00	0.00	0.02	0.07	0.00	0.09	0.28	0.00
	LCI		0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.01	0.00	0.00	0.07	0.00
Common Carp															
Year 1															
RM30	Ave	14	0.05	0.08	0.00	0.10	0.00	0.00	0.59	0.00	0.04	0.00	0.13	0.00	0.00
	UCI		0.12	0.19	0.00	0.17	0.00	0.00	0.78	0.00	0.06	0.01	0.21	0.00	0.00
	LCI		0.01	0.01	0.00	0.03	0.00	0.00	0.39	0.00	0.02	0.00	0.05	0.00	0.00
RM60	Ave	15	0.26	0.00	0.00	0.00	0.00	0.00	0.25	0.02	0.08	0.00	0.37	0.00	0.00
	UCI		0.42	0.00	0.00	0.00	0.00	0.01	0.41	0.05	0.13	0.00	0.53	0.00	0.00
	LCI		0.12	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.04	0.00	0.19	0.00	0.00
RM125	Ave	16	0.11	0.05	0.00	0.02	0.00	0.00	0.27	0.06	0.20	0.11	0.17	0.01	0.00
	UCI		0.17	0.13	0.00	0.05	0.00	0.00	0.39	0.08	0.30	0.25	0.23	0.02	0.00
	LCI		0.05	0.00	0.00	0.01	0.00	0.00	0.17	0.03	0.11	0.01	0.11	0.00	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Common Carp continued…															
Year 1															
RM165	Ave	19	0.05	0.12	0.00	0.00	0.02	0.00	0.20	0.01	0.08	0.40	0.08	0.04	0.00
	UCI		0.09	0.23	0.00	0.01	0.05	0.00	0.32	0.02	0.15	0.56	0.13	0.08	0.00
	LCI		0.02	0.04	0.00	0.00	0.00	0.00	0.10	0.00	0.03	0.21	0.03	0.01	0.00
RM225	Ave	12	0.12	0.06	0.00	0.01	0.00	0.00	0.26	0.01	0.21	0.08	0.20	0.04	0.00
	UCI		0.16	0.14	0.00	0.01	0.00	0.00	0.37	0.02	0.25	0.23	0.29	0.05	0.00
	LCI		0.08	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.18	0.00	0.12	0.02	0.00
Year 2															
RM30	Ave	9	0.07	0.13	0.00	0.19	0.00	0.00	0.29	0.00	0.06	0.01	0.25	0.00	0.00
	UCI		0.13	0.26	0.00	0.40	0.00	0.00	0.53	0.01	0.09	0.03	0.43	0.01	0.00
	LCI		0.02	0.03	0.00	0.03	0.00	0.00	0.12	0.00	0.03	0.00	0.02	0.00	0.00
RM60	Ave	26	0.18	0.08	0.00	0.01	0.00	0.01	0.15	0.02	0.33	0.00	0.22	0.01	0.00
	UCI		0.24	0.14	0.00	0.01	0.00	0.02	0.25	0.03	0.38	0.00	0.26	0.02	0.00
	LCI		0.11	0.04	0.00	0.00	0.00	0.00	0.07	0.01	0.29	0.00	0.16	0.00	0.00
RM125	Ave	10	0.02	0.17	0.00	0.00	0.00	0.00	0.28	0.01	0.42	0.00	0.09	0.01	0.00
	UCI		0.03	0.34	0.00	0.00	0.00	0.00	0.36	0.02	0.55	0.01	0.20	0.03	0.00
	LCI		0.00	0.04	0.00	0.00	0.00	0.00	0.19	0.00	0.30	0.00	0.00	0.00	0.00
RM165	Ave	20	0.04	0.07	0.03	0.00	0.09	0.00	0.10	0.12	0.11	0.17	0.11	0.16	0.00
	UCI		0.08	0.13	0.09	0.00	0.21	0.00	0.18	0.28	0.18	0.35	0.21	0.33	0.00
	LCI		0.01	0.02	0.00	0.00	0.00	0.00	0.04	0.01	0.05	0.00	0.03	0.00	0.00
RM225	Ave	15	0.07	0.19	0.00	0.01	0.00	0.00	0.32	0.01	0.02	0.23	0.05	0.11	0.00
	UCI		0.13	0.35	0.00	0.01	0.00	0.00	0.53	0.01	0.03	0.44	0.08	0.29	0.00
	LCI		0.02	0.06	0.00	0.00	0.00	0.00	0.14	0.00	0.01	0.00	0.02	0.01	0.00
Fathead Minnow															
Year 1															
RM60	Ave	39	0.07	0.36	0.00	0.00	0.05	0.00	0.00	0.33	0.00	0.00	0.00	0.18	0.01
	UCI		0.12	0.49	0.00	0.00	0.10	0.00	0.00	0.47	0.00	0.01	0.00	0.30	0.03
	LCI		0.02	0.22	0.00	0.00	0.01	0.00	0.00	0.22	0.00	0.00	0.00	0.07	0.00
RM125	Ave	24	0.08	0.27	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.01	0.00	0.39	0.03
	UCI		0.18	0.36	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.01	0.00	0.53	0.09
	LCI		0.02	0.17	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.01	0.00	0.23	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Fathead Minnow continued…															
Year 1															
RM165	Ave	37	0.15	0.25	0.00	0.00	0.01	0.00	0.00	0.38	0.00	0.01	0.00	0.17	0.02
	UCI		0.23	0.34	0.00	0.00	0.05	0.00	0.00	0.50	0.00	0.02	0.00	0.29	0.07
	LCI		0.08	0.17	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.01	0.00	0.07	0.00
RM225	Ave	21	0.06	0.25	0.00	0.00	0.00	0.00	0.01	0.64	0.00	0.00	0.00	0.01	0.03
	UCI		0.13	0.42	0.00	0.00	0.00	0.00	0.02	0.84	0.00	0.00	0.00	0.03	0.08
	LCI		0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00
Year 2															
RM60	Ave	23	0.13	0.21	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.01	0.00	0.06	0.00
	UCI		0.31	0.37	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.02	0.00	0.11	0.00
	LCI		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
RM125	Ave	24	0.11	0.09	0.01	0.00	0.00	0.00	0.00	0.60	0.00	0.02	0.00	0.15	0.00
	UCI		0.25	0.17	0.04	0.00	0.00	0.00	0.00	0.86	0.00	0.06	0.00	0.29	0.01
	LCI		0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00
RM165	Ave	28	0.03	0.14	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.04	0.00	0.23	0.00
	UCI		0.09	0.22	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.07	0.00	0.40	0.00
	LCI		0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.02	0.00	0.02	0.00
RM225	Ave	18	0.05	0.19	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.06	0.00	0.08	0.00
	UCI		0.09	0.43	0.00	0.00	0.00	0.00	0.00	0.86	0.00	0.12	0.00	0.17	0.00
	LCI		0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.03	0.00	0.00	0.00
Plains Killifish															
Year 1 & 2															
All	Ave	13	0.25	0.00	0.00	0.03	0.00	0.02	0.07	0.36	0.01	0.00	0.20	0.05	0.00
	UCI		0.37	0.01	0.00	0.08	0.00	0.04	0.12	0.48	0.02	0.00	0.32	0.09	0.00
	LCI		0.14	0.00	0.00	0.00	0.00	0.01	0.04	0.25	0.01	0.00	0.09	0.01	0.00
Rainbow Trout															
Year 1															
RM0	Ave	26	0.44	0.20	0.03	0.08	0.00	0.00	0.02	0.07	0.01	0.02	0.11	0.02	0.00
	UCI		0.54	0.30	0.09	0.18	0.00	0.00	0.04	0.14	0.01	0.03	0.22	0.04	0.00
	LCI		0.33	0.12	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.01	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Rainbow Trout continued…															
Year 1															
RM30	Ave	44	0.02	0.18	0.00	0.23	0.00	0.00	0.01	0.04	0.02	0.00	0.46	0.05	0.00
	UCI		0.03	0.23	0.00	0.32	0.00	0.00	0.02	0.07	0.03	0.00	0.55	0.07	0.00
	LCI		0.01	0.14	0.00	0.15	0.00	0.00	0.00	0.01	0.01	0.00	0.36	0.02	0.00
RM60	Ave	16	0.07	0.14	0.04	0.01	0.00	0.00	0.16	0.09	0.03	0.01	0.41	0.05	0.00
	UCI		0.15	0.25	0.12	0.01	0.00	0.01	0.22	0.11	0.04	0.02	0.60	0.09	0.00
	LCI		0.01	0.05	0.00	0.00	0.00	0.00	0.12	0.07	0.01	0.00	0.20	0.02	0.00
RM125	Ave	40	0.03	0.15	0.06	0.00	0.11	0.01	0.00	0.07	0.02	0.00	0.20	0.35	0.00
	UCI		0.06	0.23	0.18	0.00	0.19	0.02	0.01	0.12	0.02	0.00	0.28	0.48	0.00
	LCI		0.01	0.09	0.00	0.00	0.03	0.01	0.00	0.03	0.01	0.00	0.13	0.22	0.00
RM165	Ave	16	0.03	0.18	0.01	0.00	0.13	0.00	0.07	0.05	0.02	0.00	0.12	0.40	0.00
	UCI		0.05	0.26	0.01	0.00	0.26	0.01	0.08	0.11	0.04	0.00	0.21	0.55	0.00
	LCI		0.01	0.12	0.00	0.00	0.02	0.00	0.06	0.00	0.01	0.00	0.03	0.24	0.00
Year 2															
RM0	Ave	47	0.15	0.14	0.00	0.20	0.00	0.00	0.03	0.14	0.00	0.01	0.31	0.01	0.00
	UCI		0.23	0.20	0.00	0.32	0.00	0.00	0.05	0.24	0.00	0.03	0.46	0.03	0.00
	LCI		0.07	0.09	0.00	0.11	0.00	0.00	0.01	0.05	0.00	0.00	0.17	0.00	0.00
RM30	Ave	51	0.08	0.40	0.00	0.06	0.00	0.00	0.00	0.02	0.03	0.00	0.39	0.01	0.00
	UCI		0.11	0.47	0.00	0.10	0.00	0.00	0.00	0.04	0.04	0.00	0.45	0.02	0.00
	LCI		0.06	0.34	0.00	0.03	0.00	0.00	0.00	0.01	0.02	0.00	0.33	0.01	0.00
RM60	Ave	24	0.12	0.31	0.08	0.04	0.00	0.00	0.09	0.04	0.02	0.00	0.20	0.10	0.00
	UCI		0.16	0.42	0.20	0.07	0.00	0.01	0.14	0.06	0.03	0.00	0.27	0.16	0.00
	LCI		0.09	0.21	0.00	0.01	0.00	0.00	0.04	0.02	0.01	0.00	0.13	0.03	0.00
RM125	Ave	41	0.12	0.10	0.00	0.02	0.21	0.00	0.01	0.09	0.02	0.00	0.16	0.27	0.00
	UCI		0.17	0.14	0.00	0.04	0.32	0.00	0.02	0.15	0.04	0.00	0.22	0.38	0.00
	LCI		0.07	0.06	0.00	0.01	0.12	0.00	0.00	0.04	0.02	0.00	0.12	0.16	0.00
RM165	Ave	35	0.03	0.13	0.00	0.00	0.16	0.00	0.02	0.03	0.01	0.00	0.05	0.57	0.00
	UCI		0.04	0.19	0.00	0.01	0.24	0.00	0.03	0.04	0.02	0.00	0.08	0.68	0.00
	LCI		0.02	0.08	0.00	0.00	0.08	0.00	0.01	0.01	0.01	0.00	0.03	0.46	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Juv. Rainbow Trout															
Year 1															
RM0	Ave	2	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.85	0.02	0.00
	UCI		0.20	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.91	0.04	0.00
	LCI		0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00
RM30	Ave	11	0.04	0.00	0.00	0.17	0.00	0.00	0.00	0.02	0.00	0.00	0.73	0.03	0.00
	UCI		0.07	0.00	0.00	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.89	0.07	0.00
	LCI		0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.01	0.00
RM60	Ave	2	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.89	0.05	0.00
	UCI		0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.89	0.09	0.00
	LCI		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.89	0.00	0.00
RM125	Ave	16	0.05	0.04	0.00	0.03	0.04	0.00	0.01	0.03	0.00	0.01	0.35	0.44	0.00
	UCI		0.11	0.08	0.00	0.11	0.15	0.00	0.01	0.06	0.01	0.02	0.52	0.65	0.00
	LCI		0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.17	0.25	0.00
RM165	Ave	5	0.35	0.03	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.39	0.15	0.00
	UCI		0.44	0.06	0.00	0.00	0.00	0.00	0.17	0.08	0.00	0.00	0.65	0.25	0.00
	LCI		0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.05	0.00
Year 2															
RM0	Ave	29	0.30	0.02	0.00	0.46	0.00	0.00	0.00	0.04	0.00	0.00	0.11	0.05	0.00
	UCI		0.45	0.03	0.00	0.65	0.00	0.00	0.01	0.12	0.00	0.01	0.23	0.13	0.00
	LCI		0.16	0.01	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
RM30	Ave	22	0.20	0.02	0.00	0.11	0.00	0.00	0.00	0.15	0.00	0.00	0.49	0.02	0.00
	UCI		0.30	0.04	0.00	0.21	0.00	0.00	0.00	0.32	0.01	0.00	0.63	0.05	0.00
	LCI		0.11	0.00	0.00	0.04	0.00	0.00	0.00	0.03	0.00	0.00	0.35	0.00	0.00
RM60	Ave	7	0.39	0.00	0.09	0.01	0.00	0.00	0.00	0.05	0.00	0.00	0.43	0.04	0.00
	UCI		0.58	0.00	0.26	0.02	0.00	0.00	0.00	0.12	0.00	0.00	0.67	0.07	0.00
	LCI		0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.21	0.01	0.00
RM125	Ave	3	0.12	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.57	0.20	0.00
	UCI		0.15	0.62	0.00	0.01	0.00	0.00	0.00	0.02	0.05	0.00	0.68	0.24	0.00
	LCI		0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.09	0.00

Site		n	Chironomidae	*Cladophora*	Fish	*Gammarus*	Human Food	Insect Parts	Detrital Aggregate	Other aquatic invertebrate	Plant Material	*Potamopyrgus*	Simuliidae	Terrestrial invertebrate	Unknown
Juv. Rainbow Trout continued…															
Year 2															
RM165	Ave	7	0.13	0.02	0.00	0.00	0.21	0.00	0.01	0.01	0.00	0.00	0.13	0.49	0.00
	UCI		0.34	0.07	0.00	0.00	0.42	0.00	0.02	0.03	0.00	0.00	0.26	0.76	0.00
	LCI		0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.03	0.19	0.00
Red Shiner															
Year 1 & 2															
All	Ave	14	0.58	0.00	0.00	0.00	0.00	0.02	0.00	0.24	0.00	0.00	0.11	0.03	0.00
	UCI		0.78	0.01	0.00	0.00	0.00	0.04	0.01	0.45	0.00	0.00	0.24	0.07	0.00
	LCI		0.38	0.00	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.00	0.01	0.00	0.00
Yellow Bullhead															
Year 1 & 2															
All	Ave	18	0.06	0.03	0.10	0.37	0.00	0.04	0.00	0.11	0.03	0.04	0.23	0.01	0.00
	UCI		0.10	0.06	0.23	0.55	0.00	0.09	0.00	0.22	0.04	0.12	0.37	0.03	0.00
	LCI		0.02	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.01	0.00	0.09	0.00	0.00