

**Ecology of Sympatric Catostomid Fishes in a Glaciated Riverine
System: Habitat, Food, and Biogeography**

By

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ABSTRACT – Several fundamental hypotheses derived from theoretical community ecology were tested using habitat and diet patterns for six species of the catostomid fishes of the Assiniboine River, Manitoba. Specifically, I examined expected assemblage patterns based on the equilibrium-nonequilibrium continuum that are based on competition as a structuring mechanism. The catostomid assemblage showed patterns characteristic of both equilibrium and nonequilibrium assemblages. Habitat utilization was not proportional to habitat availability for depth, velocity, and substrate indicating that habitat selection was occurring. These patterns are influenced by the spatial distributions of soft Lake Agassiz sedimentary deposits and harder glacial till-plain derived habitats and therefore localized in nature. Species co-occurred in relation to their abundance indicating that negative associations assumed in competition-based theory were not apparent. In addition, species from the same subfamily co-occurred more often than expected by chance, indicating most within-group comparisons were positive, except for silver redhorse, which did not co-occur differently than expected from random. Species from the same feeding group co-occur most frequently with conspecifics, indicating species have specific habitat patterns. Benthic invertebrate distributions and fish distributions were positively correlated with fish diet. Within-feeding-group comparisons indicated species that co-occurred most frequently consumed the same food items, but showed subtle differences in abundance of diet items. The most common diet items varied among white sucker, silver redhorse, golden redhorse, and shorthead redhorse, indicating that, although these species co-occur, subtle differences in specific feeding behavior may account for differences in relative abundance and frequency of diet items. Quillback and bigmouth buffalo shared a few core food items, but these two species co-occurred infrequently. Inter-specific interactions showed silver redhorse diets were a subset of white sucker diets, white sucker diets were a subset of golden redhorse diets, shorthead redhorse diets were a subset of silver redhorse and golden redhorse diets, while bigmouth buffalo diets were a subset of quillback diets. The lower richness and prevalence of organisms in quillback and bigmouth buffalo diets were due to highly aggregated prey items. Benthic invertebrate distributions were aggregated and dependent on the predictable patterns of substrates, based on hydraulic sorting in the meandering along the river. Large-scale redundancy of species-habitat associations was correlated with historical (phylogenetic) or adaptive (morphological) constraints on habitat selection. Stream habitats are constrained by regional factors of slope and sediments, but also determined by stable, repetitive and predictable local processes of erosion, transport, and deposition (meandering). The fish-habitat associations of catostomids in the Assiniboine River provide an example of interaction between the abundance of the component species, the phylogenetic constraints on the niche, and the deterministic nature of the spatial distribution of habitats. Within-feeding-group pairs showed that local habitat overlap is positively correlated with geographic overlap, while local diet overlap is negatively correlated with geographic overlap. Two species pairs (silver redhorse and golden redhorse and bigmouth buffalo and quillback) were concluded to have symmetric overlaps at the geographic scale and stable interactions. Using the functional niche concept ecological theory provides a link between local ecology and biogeography of sympatric species. The multi-analytical approaches used in this study provide insights into the structuring of north temperate prairie river fish communities, through hypothesis testing and correlation that have application beyond Prairie Rivers.

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DEDICATION

For the late Professor Emeritus Carl Robert Nelson Jr. my father, mentor, and best friend... It is done!

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CHAPTER 1: GENERAL INTRODUCTION TO CATOSTOMID FISHES

Taxonomy of the Catostomidae

Catostomids are 'otophysic' Ostariophysan fishes, a large group that include Cypriniformes (Cypriniphysi), Characiformes (Characiphysi), Siluriformes and Gymnotiformes (Siluriphysi) (Fink and Fink 1996). Within the Cypriniformes, the Catostomidae is placed within the monophyletic Cobitoidea with Cobitidae and Gyrinocheilidae (Harris and Mayden, 2001). The family Catostomidae has 81 species worldwide (Jenkins, 1970; Smith 1992; Nelson, 1994; Burr and Mayden, 1999; Harris and Mayden, 2001; Harris et al., 2002; Suttkus and Bart, 2002; Table 1). In North America, there are 80 species distributed from Guatemala to Alaska (Scott and Crossman 1973; Lee et al. 1980; Nelson and Paetz, 1992; Figure 1). *Myxocyprinus asiaticus*, is found only in China, and the range of *Catostomus catostomus* extends into northeastern Siberia.

The first published account of 'suckers' was by Forster (1773) with the description of *Cyprinus* [= *Catostomus*] *catostomus*, from the Hudson Bay area. Later Lacépède (1803) described *Cyprinus communis* [= *Catostomus commersoni*] and *Catostomus* [= *Erimyzon*] *sucetta*. Lesueur (1817) erected the genus *Catostomus* after the species name of Forster and described 19 species in the genus *Catostomus*. In 1820, Rafinesque used the subgenus *Myxostoma* [= *Moxostoma*] for the "redhorses" in his *Ichthyologia Ohiensis*. Later, Agassiz (1854) erected the genus *Ictiobus* for the "buffalo-fish" and elevated *Moxostoma* to genus. Jordan (1878a; 1878b; 1878c) organized the classifications into present arrangement. Over the last 125 years many new species have been

described and the generic classification has been modified (Gill, 1861; Cope, 1872; Cope and Yarrow, 1896; Jordan and Evermann, 1896; Jordan and Evermann, 1900; Meek, 1902; Meek, 1903; Fowler, 1913; Hubbs, 1930; Robins and Raney, 1956; Jenkins, 1970; Burr and Mayden, 1999; Harris and Mayden, 2002; Suttikus and Bart, 2002). Three subfamilies were recognized in the early classifications of Gill (1878), the Bupalichthyinae [=Ictiobinae], the Cycleptinae, and the Catostominae. Hubbs (1930) subdivided the subfamily Catostominae into three tribes; the Catostomini, Moxostomatini, and Erimyzontini. Hubbs's (1930) classification was modified by Nelson (1948; 1949; 1959; 1961), Bailey (1959), Miller (1959), Miller and Evans (1965), and Smith (1966). Smith (1992) presented a phylogeny using the primitive Cobitid genus, *Leptobotia* and the Cyprinine genus, *Cyprinus* as outgroups. Smith's phylogeny recognized three subfamilies; the Ictiobinae, Cycleptinae, and Catostominae. Harris and Mayden (2001) proposed some changes to Smith's phylogeny including the erection of the subfamily Myxocyprininae (containing *M. asiaticus* in China) and restricting the Cycleptinae to the two North American *Cycleptus* species. They further restricted the Moxostomatini to *Moxostoma* and "*Scartomyzon*" but Erimyzontini (*Erimyzon* and *Minytrema*) were considered *incertae sedis* within the Catostominae. Finally they erected the tribe Thoburniini, comprised of *Thoburnia* and *Hypentelium*. Recently, Harris et al. (2002) merged *Scartomyzon* with *Moxostoma*. In all phylogenetic studies, the Ictiobinae are considered morphologically primitive and ancestral to the more recent Cycleptinae and Catostominae (Smith 1992; Harris and Mayden, 2001; Bart et al. submitted).

Evolutionary Relationships of the of Catostomidae found in Manitoba

The evolution of the Catostomidae is believed to have progressed from deep-bodied Ictiobinae (and Myxocyprinae) to slender-bodied Catostominae (Smith, 1992; Harris and Mayden, 2001). This trend is supported by the Eocene †*Amyzon aggregatum* (Cope, 1894). The subfamilies Ictiobinae and Cycleptinae are considered descendants of an extinct *Amyzon*-group from the early Cenozoic. Ictiobine fossils occur from the Eocene and Oligocene (Cavender, 1986), but the Catostominae are not known to occur until the early Miocene (Smith, 1975). Speciation in the Catostomini corresponds to the orogeny of the western coastal mountain ranges and the development of the continental divide in North America (~40mya). Smith (1992) considers the marine Mississippi embayment (36.5-23mya) to be the key vicariant event that led to speciation in the Moxostomatini and Ictiobinae.

Most of the Ictiobines are sympatric in the larger streams of interior North America, such as the Mississippi, Missouri, and Ohio rivers (Figures 2 & 3). In addition, there are three allopatric species: *Carpionodes elongatus* in the Rio Grande River of northern Mexico and Texas (Figure 2), *Ictiobus labiosus* in Mexico, and *I. meridionalis* in Guatemala (Figure 3). The speciation of this group also is considered to be tied to the marine Mississippi embayment for all *Carpionodes* spp. and *Ictiobus* spp., except for *I. labiosus* and *I. meridionalis*, which may be tied to the development of coastal areas of relief and/or potential isolation of a larger more cosmopolitan common ancestor (Bart et al., in review). Smith

(1992) described two separate mechanisms of speciation in Catostominae. The first mechanism concerns 28 species of western Catostomini (*Catostomus*, *Chasmistes*, *Deltistes*, and *Xyrauchen*) that are distributed in higher gradient montane streams in western North America and northern Mexico, and exhibit a high degree of allopatry/endemism (Figures 4 and 5). In addition, there are two widely distributed Catostomini species, *Catostomus commersoni* and *C. catostomus* (Figure 4). The second mechanism concerns the remaining eastern tribes; Erimyzontini, Moxostomatini, and Thoburniini, which are broadly sympatric throughout central (Mississippi/Missouri/Ohio basin) and the Atlantic slope of North America, in which species diversity declines to the north to two species, the widely distributed *Catostomus commersoni* and *C. catostomus*, at the Hudson Bay Coast. Moxostomatine species are allopatric in Mexico, but become more sympatric in Gulf Coastal drainages. The Moxostomatini generally are sympatric throughout the central portions of their range declining in number to the three species known from Manitoba. Sister species typically are allopatric (Figures 6 and 7), parapatric (Figure 8), or comprise one broad ranging species and a peripherally isolated endemic species, such as *Moxostoma carnatum* Cope and *M. sp. cf. macrolepidotum* "sicklefin". Smith (1992) considers the speciation of this clade to have been allopatric during the marine Mississippi embayment. However, Atlantic slope and Gulf Coastal speciation may be tied to drainage capture and multiple dispersals. Sister pairs of *Catostomus*, "*Scartomyzon*" + *Moxostoma*, *Thoburnia*, and *Hypentelium* are allopatric in distribution, while most of the Ictiobines and Erimyzontini are sympatric. Lastly, species rich clades

appear to oppose Cope's rule, having a tendency for decreased size with increased evolutionary specialization (Smith, 1992).

Post-Glacial Dispersal of Manitoba Fishes

The area currently occupied by the Assiniboine River basin and the entire Hudson Bay drainage system was covered by ice during the most recent Wisconsinan glaciation (Elson, 1967; Stewart and Lindsey 1983). The present fish assemblage of the region is the result of a series of immigration events as the ice retreated and advanced between 12,000 and 7,500 years B.P. (Stewart and Lindsey 1983; Pielou 1991). Three main colonization periods mark the post-glacial range expansion opportunities for the Catostomidae. The earliest dispersal routes into the Lake Agassiz region were an upper Missouri connection into the Saskatchewan River drainage (Qu'Appelle Lakes area) in Saskatchewan estimated at 12,500 years BP (Elson 1967; Figure 9). The permanency of fish populations colonizing via this route has been questioned (Stewart and Lindsey 1983). The Minnesota spillway provided a connection between the headwaters of the Red River and the headwaters of the Minnesota River (Lake Traverse-Big Stone Lake area Minnesota) when glacial Lake Agassiz drained into the upper Mississippi River watershed (Clayton 1983; Figure 9). Fish species entering Lake Agassiz via this route probably were pushed back several times by a series of ice re-advances up until about 12,000 B.P. (Stewart and Lindsey 1983). By 10,900 B.P. the retreating ice opened a drainage outlet into the Lake Superior region, which drained Lake Agassiz substantially and closed off the Minnesota

spillway (Clayton 1983; Figure 9). Re-advancing ice in northwestern Ontario recreated the Minnesota spillway between 9,900 and 9,500 B.P. (Clayton 1983; Figure 9) and probably was the earliest opportunity for permanent colonization of Lake Agassiz by fish from the Mississippian refugium (Stewart and Lindsey 1983). The Minnesota spillway was permanently abandoned shortly after 8,500 B.P. as Lake Agassiz dropped (Stewart and Lindsey 1983). Between 9,500 and 8,500 B.P. the retreating ice opened a series of outlets into Lake Superior in the Nipigon region (Teller and Thorleifson 1983; Figure 9) allowing fish to colonize the Laurentian Great Lakes region as well as the Rainy River and Lake of the Woods-Winnipeg River systems. By 7,500 B.P. Lake Agassiz drained into Hudson Bay via present routes; the Nelson, Churchill and probably Severn rivers (Stewart and Lindsey 1983; Figure 9). In addition, colonization of the region by upper Missouri River fishes was possible for a relatively long period through southward draining water across western Manitoba and southern Saskatchewan (Stewart and Lindsey 1983; Figure 9). The only catostomid species presently inhabiting the Assiniboine River basin that may be representative of the Missouri drainage is *I. cyprinellus*. The bigmouth buffalo occurs in both the Upper Mississippi and the Upper Missouri. The goldeye (Rafinesque) and flathead chub (Richardson) are the only species that are found in the upper Missouri but not the Upper Mississippi. Also, the distributions of the goldeye and flathead chub are typical of species that entered the Hudson Bay Drainage during Lake Agassiz times (presence in the Mackenzie/Athabasca watershed, and, in the goldeye, presence in the area covered by Glacial Lake Barlow-Ojibway (it's now

in Lake Temiskaming). The restricted distribution of the bigmouth buffalo rules out it having reached the Hudson Bay Drainage before Lake Agassiz had drained. Since water connections between the Upper Missouri and the Hudson Bay Drainage apparently have not existed since early Lake Agassiz times, the bigmouth buffalo must be from the Upper Mississippi. Its present distribution is also consistent with this. The fauna of Manitoba waterways are being augmented continually by ongoing post-glacial range expansions (Stewart and Lindsey 1983; Stewart et al., 2001; Franzin et al., 2003; Stewart and Watkinson, 2004).

Three distinct periods mark the colonization of the Hudson Bay drainage (Stewart et al. 2001). The first was during the late glacial period when glacial Lake Agassiz was still in existence. All of these early colonizers would have been cold water tolerant, and most have present distributions well beyond the Nelson River drainage (Stewart et. al., 2001). The late glacial period would have been the first opportunity for *C. catostomus* and *C. commersoni* to colonize northern waters. The second time period was following the post-glacial period during and following the drainage of Lake Agassiz. Two possible routes have been identified, a direct route from the Minnesota River into the Red River mainstem and a northeastern dispersal route from Mississippi River headwaters east of the Red Lake, MN into the Rainy River, Lake of the Woods, and Winnipeg River. Species that probably used the direct route are presumed tolerant of both warm and turbid water and comprise *I. cyprinellus* and *C. cyprinus*. All species using the northeastern route are found in the Winnipeg River, but not in the Red

River mainstem or tributaries in Manitoba, except in isolated portions of the Assiniboine River drainage. All of these species (not including and Manitoba suckers) probably are intolerant of turbid water, but are warm water tolerant. The third group probably used both the direct and northeastern routes into northern waters, and the species are found in both the Winnipeg River above Great Falls and in the Red River mainstem. These species are *M. anisurum*, *M. erythrurum*, and *M. macrolepidotum* all of which are tolerant of turbidity and warm water.

The Red River remains a principal route of colonization in recent times particularly during high water years as seen during the floods of 1950, 1979, and 1997. Extreme natural flood events potentially are the main inter-glacial process for transfer of species between basins when headwaters are close. With global warming, aquatic ecosystems in temperate regions are expected to exhibit changing hydrologies resulting in increases in the frequencies and amplitudes of extreme droughts or floods. Species at the northern edge of their North American ranges may be temperature limited and the present apparent trend towards longer, warmer seasons may account for increases in recent colonizers. Species in this category include *Moxostoma erythrurum*, *Ictiobus bubalus* (Rafinesque), *Moxostoma valenciennesi* Jordan, and *Carpionodes velifer* (Rafinesque). Although the latter three species are confirmed from the Ottertail River, MN (Luther Aadland MN Department of Natural Resources Personal Communication) reports in recent years from North Dakota portions of the Red River tributaries, particularly the lower Pembina River remain unconfirmed.

CHAPTER 2: DEVELOPMENT AND STATEMENT OF HYPOTHESES

Rationale

Habitat, in its broadest form defines the type of environment where an organism normally occurs, such as aquatic habitat. Clements and Shelford (1939) defined habitat as "...solely in relation to the physical and chemical factors", that is, factors that are readily measured, without abstraction, and controlled by basic laws of physics and chemistry (see Whittaker, 1972). In Canada, fish habitat is defined legally as:

"Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes (Government of Canada, Fisheries act 34(1)).

Fish are dependent on aquatic habitat to satisfy their life history stages and processes, but the inclusion of several levels of ecological and life history processes into any habitat definition invokes a larger principle explaining the distribution and organization of species at larger spatial scales, such as the functional niche concept (Hutchinson, 1959). The emergence of properties defining the realized niches of species are revealed through interactions, both intra- and inter-specific, within habitats or along gradients. A logical extrapolation is that the distribution of a species is the physical and spatial manifestation of its ecology.

Habitat itself has structuring processes rooted in physics and chemistry, but the functional niche is the cumulative result of evolution, and therefore is a consequence of speciation and a trait of species. A niche must be based on biological, physical, and chemical constraints relevant to the watershed scale

(Figure 10) in order to be definitive at the biogeographic scale. Notwithstanding the inherent perceptual complexity of the niche, many workers have viewed distributions simply as results produced by the spatial patterns of survival of species (Elton, 1927; Lack, 1947; Margalef, 1958). The relationship of form and function of species to niches and interactions has been studied by Grinnell, (1917); Elton, (1927); Hutchinson, (1957); and MacArthur (1972). Major developments in ecological theory such as the species-area concept (Arrhenius, 1921; Gleason, 1922; Fisher et al., 1943; Williams, 1947, Williams, 1950), character displacement (Brown and Wilson, 1956), competitive exclusion (Hardin, 1960) and limiting similarity (MacArthur and Levins, 1967) are based on the concept of the niche, or, at a minimum, its existence.

The niche defines species' ecology through the cumulative traits which make species distinct and limits how species exploit their environments (Lack, 1947), disperse and are distributed (Taylor and Gotelli, 1994; Pyron, 1999). The process of speciation from the perspective of either ecological pattern (Hutchinsonian niche) or genetic process (phylogeography) is a spatial phenomenon that is linked inextricably to the interactions of species with their environment. This makes ecology a complex component of modern evolutionary studies. Indeed, the complexity of ecological processes in evolution has been integrated into the process of speciation (Schluter and Nagel, 1995; Schluter, 1996) and ecological differentiation (Brown and Wilson, 1956; Dunham et al., 1979).

Biogeography can be defined simply as the science of distribution of organisms (Meyers and Giller, 1988). Biogeography often is divided into two (artificial) divisions, ecological biogeography and historical biogeography. In a more contemporary and evolutionary sense, these divisions become the interactions of species and the processes of speciation. While the latter by definition requires a phylogenetic analysis, the former can be considered a parallel of macroecology, the study of partitioning of physical space and resources by species (Brown and Maurer, 1989). A key development in the study of distributions of species was the theory of island biogeography (MacArthur and Wilson, 1967). An underlying assumption of that theory and many other major developments in ecology, such as competitive exclusion (Hardin, 1960) and limiting similarity (MacArthur and Levins, 1967) is that equilibrium exists or can be reached. Hutchinson (1961) stated that although equilibrium can be true analytically it seldom, if ever, is demonstrated in reality. The failure of real systems to reach equilibrium does not negate theories based on equilibrium because such processes may be continual and adaptive in fluctuating systems (Hutchinson, 1961). Although populations are maintained by the recruitment, immigration, emigration, and mortality of individuals, in the context of biogeography species distributions are maintained by natural selection and its effects on colonization and extinction. More generally, the distributions of animals reflect some principle habitat plus fragments of others caused by species roving among those available (Elton, 1927) such that a sample or series of samples literally translates into a message of community information (Margalef,

1958) from which we determine niches. It could be extrapolated from Margalef and Elton that biogeographic distributions reflect the distribution of principle habitats at large spatial scales and essentially approximate the functional niche of Hutchinson (1959).

A major problem in ecological studies is the synthesis of testable hypotheses that have a basis in ecological theory (i.e. not random or neutral). Ecological theory of assemblage patterns and processes are based on the premises that assemblages are saturated, resource limited, and thus driven by biotic interactions such as competitive exclusion and limiting similarity. However, some assemblages are perceived as being in a state of non-equilibrium (see review by Wiens, 1984) and therefore viewed as being in transition between non-equilibrium and equilibrium. Given a continuum from non-equilibrium to equilibrium, assemblages at the extremes would have expected properties governing patterns (Figure 11). When variability is determined by homology, geneology should fill niches and competition should be restricted to recently evolved forms (Douglas and Matthews, 1992). Fish assemblages within glacial refugia are more likely to exhibit equilibrium-type properties of biotic coupling, competition, and resource limitation because assemblages have been interacting for millennia, have more saturated assemblages, and more congeneric sympatric species. The question then becomes whether such properties were maintained by fish species during the re-formation of northern assemblages. If northern assemblages were reset during the post-glacial re-colonization of watersheds, they are more likely to exhibit non-equilibrium properties linked to saturation

and/or competition because of fewer congeneric sympatric species, extending the view of Douglas and Matthews (1992). Non-equilibrium patterns linked to saturation and competition may include biotic decoupling, species independence, abiotic limitation, and loose patterns (Figure 11). Evolution by natural selection has produced organisms that are unique and adapted, but not necessarily highly specialized. Morphology in its simplest extrapolation limits a species' location and can be perceived as a major mechanism generating observed patterns of similarity at larger spatial scales (Wikramanayake, 1990). Within the Catostomidae, there is an expectation that congeners and/or morphologically similar species will overlap, given that only three functional feeding groups exist (Eastman, 1977).

The question, whether morphologically similar forms co-occur more frequently with each other than with less similar species has been posed (see Winston, 1995). Limiting similarity should produce patterns of uniform character displacement (*sensu* Hutchinson, 1961) in a variable environment where resources are limiting through centrifugal niche partitioning (Wisheu, 1998) and/or historical legacy (Connell, 1980). These ideas answer the question with similar begets similar in so far as limiting similarity and historical constraints allow but begs the further question, how much interaction exists among co-occurring species before interactions become limiting. Feeding or functional ecology may permit the stable co-existence of species in space through differential exploitation of resources but, as pointed out by Lack (1947), dietary differences may indicate differences in habitat favoring adaptation over diet as a causal mechanism.

Wisheu (1998) defines centrifugal niche partitioning as similarity in some dimensions and segregation on one or more other dimensions. Thus, the problem becomes one of space, where similarity of form constrains the co-occurrence of species in physical space while similarity in function constrains interactions in sympatry. A final and complex part of ecological biogeography is the reconciliation of ecological theory with reality, particularly in the absence of information from the entire range of a species. This problem generates potentially exciting hypotheses that draw up on the large volume of both ecological and evolutionary theory.

Statement of Hypotheses

The following hypotheses attempt to characterize the relationships among six species of broadly sympatric Catostomid fishes from the Assiniboine River, Manitoba, Canada. Specifically, functional resource use at the local stream scale was investigated to determine whether a northern catostomid assemblage exhibits non-equilibrium-type properties:

- I. Species habitat utilization is proportional to habitat availability;
- II. Species habitat breadth is proportional to abundance;
- III. Species co-occur in relation to their abundance;
- IV. Species from the same subfamily co-occur as often with each other as they do with random pairs of species;

- V. Species that co-occur most frequently will eat similar food items in similar proportions;
- VI. Species from the same feeding group will have the same general diet and relative proportions of organisms in the diet;
- VII. Species that co-occur most frequently will have intra-specific to inter-specific overlap ratios ≈ 1 ;
- VIII. Benthic invertebrate distributions are not uniform and are dependent on habitat;
- IX. Benthic invertebrate distributions and fish distributions are linked as indicated by fish diet i.e. fish eat mainly benthic organisms that occur in the dominant habitats of the fish species;
- X. Local habitat overlaps will be positively related to biogeographic sympatry due to similar morphology and common glacial and post-glacial distributions; and
- XI. Local diet overlap will be inversely related to sympatry through the assumed evolution of niche segregation via centrifugal niche partitioning.

Hypotheses I and II, test basic habitat selection and differential effects of species abundance. Hypotheses III and IV test the more specific question of how species co-occurrence patterns may allow coexistence. Hypotheses V and VI test whether co-occurrence determines interaction or whether interaction is predetermined, respectively. Hypothesis VIII tests whether habitat-resource associations represent an allocated complex (*sensu* Juhász-Nagy, 1993) that is

determined by hydraulics. Hypothesis IX tests whether interaction is a function of random feeding behavior in 'preferred' habitats or whether species-specific patterns emerge. Hypotheses X and XI test the idea that similar forms will co-exist through centrifugal niche partitioning. The typical assumptions are that species saturation, related and/or similar potential competitors, and limiting resources leads to equilibrium-type patterns outlined in Figure 11 and demonstrated in speciose stream fish assemblages from warmer climates (Winemiller, 1991; Piet and Guruge 1997; Piet, 1998; Piet et al., 1999).

CHAPTER 3: MATERIALS AND METHODS

Description of Assiniboine River

The Assiniboine River drains 162,000km² in Saskatchewan, North Dakota, and Manitoba (Figure 12). About 95% of the area is used for agriculture and about 70% is in annual cultivation. The Assiniboine River originates at Preeceville, SK and flows 1266km eastward to join the Red River at Winnipeg, MB (Andres and Thompson, 1995). The Assiniboine River has a total relief of 350m, a mean slope of 27.7cm/km (Andres and Thompson, 1995) and is considered a low slope turbid prairie river. The entire Assiniboine drainage is part of the English-Winnipeg Lakes freshwater ecoregion (Abell et al., 2000) and lies within the temperate grasslands/savanna/shrub biome of the central lowland physiographic region (Ricketts et al., 1999). Although the Assiniboine drainage occupies the mid-continental Canadian forests and northern mixed grasslands, the mainstem of the Assiniboine River principally flows through the Canadian aspen forest parklands terrestrial ecoregions (Ricketts et al. 1999).

Assiniboine Study Area

The study area is a 162-km reach of the Assiniboine River, Manitoba between a dam near Portage la Prairie and the river's confluence with the Red River at Winnipeg (Figure 13). The majority of the Assiniboine River lies in the drift prairie north and west of the Pembina escarpment, however, the study area lies east of the escarpment in the Red River valley having sediments largely determined by glacial Lake Agassiz deltaic and alluvial deposits (Elson, 1967;

Rannie et al., 1989) as well as Wisconsinan till-plain exposures (E. Nielsen, MB Department of Energy and Mines Personal Communication). The study area has a median peak discharge of about 120 m³/s during mid to late April measured at Headingley, MB. Discharge declines steadily through summer until mid to late October, but frequently rises in November due to the operation of the Shellmouth Dam (Lake of the Prairies at kilometer 996) the reservoir normally is drawn down over winter to make room for spring discharge. The flood control dam at Portage la Prairie, MB, shunts Assiniboine River flood peaks into the south end of Lake Manitoba, to maintain lower peak flows in the remaining 162 kilometers of the river.

The study reach has few instream macrophytes and when present emergent species such as bulrushes (*Scirpus* spp.) and cattail (*Typha* spp.) are found only in backwater areas of channel. The limited occurrence of submerged macrophytes in the mainstem probably is due to high turbidity, but till-plain exposures often have attached algae. There is significant 'snag' habitat from fallen trees on eroding outside bends. The Assiniboine River floodplain has a gallery forest composed of sandbar willow (*Salix interior*) associated with sand bars and point-bars, peachleaf willow (*S. amygdaloides*), green ash (*Fraxinus pennsylvanicus*), elm (*Ulmus americana*), cottonwood (*Populus deltoides*), Manitoba maple (*Acer negundo*), and to a lesser extent basswood (*Tilia americana*) and bur oak (*Quercus macrocarpa*). The lower reach below Portage Dam is largely an agricultural landscape, with many areas where riverbanks are in annual crops or pasture with little or no woody vegetation.

Habitat Sampling

The river was divided into 16 10-km blocks within which three one-km sample sites were selected randomly each period. Each kilometer was sampled in three approximately 333m-length, sequential transects; first along the right-bank, second in the center of the channel, and third along the left-bank (progressing downstream) totaling 144 samples per month. Depth, velocity and substrate data were collected along the length of each transect. Depths were measured using a graduated 5m-aluminum pole; velocities were measured at 6/10 depth using a variety of methods including an electronic velocity meter, Pygmy meter, Ottmeter and a floating orange. Velocities acquired using a floating orange were subsequently calibrated to the Ottmeter and corrected to 6/10 depth. Substrates were assessed remotely using a 5-metre aluminum pole as a sensor and were classified by particle size. Substrate assessments were verified using Ponar grabs. Seven sampling runs were done at monthly intervals in each of August and September 1995 and from May to September 1996. All but three of the 162 kilometers were sampled over the course of the seven runs. Depth and substrate distributions in relation to meander geometry were assessed using 77 cross-sections over 11 kilometers of the river (Figure 14).

Fish Sampling

Fish were sampled in three approximately 333m-length, sequential transects; first along the right-bank, second in the center of the channel, and third

along the left-bank (progressing downstream) with a Smith Root Mark VI boat-mounted electro-shocker set at 450 volts and 3.0-3.5 amperes for 150 seconds drifting downstream under power in each transect. Fish were netted, placed in a holding tank, measured for length, and returned to the water. Seven sampling runs were done at monthly intervals in each of August and September 1995 and from May to September 1996.

Phylogeny and Fish Distributions

Smith (1992) provided a phylogenetic hypothesis to explain the evolution of subgroups of the Catostomidae. A reduced cladogram for the species present in the Assiniboine River, based on selected traits from Smith (1992), was derived to estimate historical constraints on habitat utilization. Gut length (number of coils), body form, position of the mouth, fin shape, pharyngeal arch cross-section, specific number of pharyngeal teeth (Becker, 1983), and number of swim bladder chambers (Smith, 1992) were mapped onto the reduced cladogram. The cladogram was generated using PAUP (Swofford, 1991) these characters were chosen because they may affect the interactions of the species with their environment and/or their functionality in habitats. It was assumed that at the subfamily level, the morphological traits used for describing general form and function would determine in part the organization of this assemblage with respect to physical habitat overlaps. Both the feeding groups of Eastman (1977) and the colonization routes outlined by Franzin et al. (2003) are given.

Raw fish catch data are given in Appendix 1. Data were pooled because species co-occurrence patterns and habitat patterns were consistent across months (Appendix 2). Data from May 1996 were collected at substantially higher flows with increased turbidity, water depth, and different electrofishing efficiency and were therefore not used in the analyses. Habitat variables were divided into eight categories (Table 2), in order to reduce rarity and equalize sample sizes. An interval of 45cm was used for depth while velocity intervals were 0.15m/s. Substrates were determined based on both hydraulic state (erosion, transport, and deposition) as well as glacially derived till plain habitats. Categories were clay, silt-debris, silt-sand, sand, gravel, gravel-cobble, cobble-boulder, and snag (Table 2). Fish lengths were summarized to demonstrate that the individuals used in the subsequent analyses are from sub-adult to adult populations, and therefore represent populations largely unaffected by ontogenetic variation in habitat and feeding associated with different life history stages (Appendix 3). Habitat utilization and availability were tested using a χ^2 maximum likelihood estimate after Manly et al. (1993).

Niche Analyses and Models

To assess the niche breadth (NB) of the species in three niche dimensions (depth by velocity by substrate), the joint entropy was calculated using the following equation:

$$NB = H_{jkl} = -\sum \sum \sum p_{jkl} \ln p_{jkl}$$

Where j , k , and l are depth, velocity and substrate combinations from an 8 by 8 by 8 jkl cubic dataset. Total or joint entropy is the three-dimensional case of Shannon's (1948) index and measures the joint entropy among two or more qualitative variables considered together. It has the same properties as Shannon's H' i.e. it is maximal in the case where all array elements have the same value (or $\ln(\text{elements})$) and minimal in the case when a diagonal of equal values connects opposite corners of an array. To assess the effective niche breadth (ENB) Hill's (1973) 'effective richness' was used given as:

$$ENB = e^{H_{jkl}}$$

The ENB indicates the number of categories, assuming equitability, required to produce a given NB estimate. Maximum niche breadth (MNB) or H_{max} is estimated by:

$$MNB = H_{max} = \ln(s)$$

Where s is the number of jkl combinations occupied by a given fish species. The evenness is typically considered as $J = H'/H_{max}$ (Frontier, 1987), here ENB/s was used. Evenness for each species is an estimate of the dispersion of species occurrences within the dataset bound by an upper limit of H_{max} . As a proportion, evenness has the property of scaling between zero and 1, allowing comparison between species.

Three different randomization models were developed in Microsoft Excel using Visual Basic for Applications (VBA) to test whether niche breadth and overlaps were different than random associations. The first was a Poisson model

(*Sub RDVS* Appendix 4), which randomly assigned fish to a three dimensional array defined by depth, velocity, and substrate. The second model was based on independent selection of habitat variables using the frequency distributions of habitat utilization curves typical of a classic IFIM-type approach during the calculation weighted useable area or WUA (*Sub IDVS* Appendix 4). The third model was based on actual observed depth, velocity, substrate frequency distributions from the 3-D arrays (*Sub ODVS* Appendix 4). In the *RDVS* model fish colonize the array randomly and all locations within the array can be colonized and tests whether niche breadth values can be the result of a purely random process. In the *IDVS* model habitat variables are randomly assigned based on their independent utilization frequencies. *IDVS* tests whether classic WUA assumptions of independent selection of variables based on utilization can produce observed niche breadth values. In the *ODVS* model the actual utilization for each array location was used to randomly colonize the array and is therefore only sensitive to sample size.

Species Co-occurrence, Overlaps, and Models

Frequency distributions for co-occurrences were compiled for each species based on the number of other species with which it co-occurred as well as the number of times it occurred alone. The number of times each species co-occurred with another species is presented as a function of niche breadth.

Both co-occurrence and abundance were tested using randomization models. The models tested whether species co-occurred randomly and whether

the average abundance of the other species encountered was random. The model was run for each species holding each of the species constant in turn while randomly re-colonizing the environment with the same observed number of individuals of the other species. This allowed each species to be tested relative to their observed distribution. These randomizations were run using a macro *Sub Co_Occurrence* (Appendix 4).

Horn's (1966) index was used to examine the degree of habitat overlap among the six species of Catostomids. Horn's index is defined as follows:

$$R_0 = \frac{\sum (p_{ij} + p_{ik}) \ln(p_{ij} + p_{ik}) - \sum p_{ij} \ln(p_{ij}) - \sum p_{ik} \ln(p_{ik})}{2 \ln(2)}$$

Where p_{ij} and p_{ik} are the concentration values for species j and k in the i^{th} habitat category. This index was chosen because it ranges from 0 (no overlap) to 1 (complete overlap), it is a symmetric measure, and is related to information theory indices used for the niche analyses. This allowed each overlap value in the matrix to be subtracted from 1 and used as a dissimilarity matrix for direct input to principal coordinates analysis (PCoA) and hierarchical cluster analysis (HCA).

PCoA is related to principal components analysis (PCA). However, while PCA is restricted to eigenanalysis of a dispersion (correlation or covariance) matrix, PCoA recognizes the relationship between dispersion and Euclidean distance. PCoA performs an eigenanalysis on a distance matrix, such that the relationship of the points in ordination spaces reflects as closely as possible the distances in the input matrix. PCoA was used to examine the relationships

among the species based on concentration values. PCoA summarizes the cumulative variance accounted for by the axes and was used to select the HCA clustering algorithm that best reflected the spatial patterns from the PCoA. While PCoA compliments HCA, but has only one solution once a distance measure is chosen and therefore can be used to constrain the selection of linkage method used for final HCA.

Canonical correspondence analysis (CCA) allows both species and sites to be represented in the same ordination space and to be constrained by environmental variables. CCA was performed on the species data to examine the degree of association between species and habitat. To study the combined effects of depth and velocity on the distribution of species, Froude numbers (dimensionless) were calculated following Statzner and Higler (1986) as follows:

$$FR = \frac{velocity}{\sqrt{depth \times 9.8m/s^2}}$$

Froude numbers were used because velocity measurements were highly variable and showed variable relationships with substrate distributions. Substrate and Froude data were divided into eight categories. CCA quantifies the relationship among variables and categories while summarizing the amount of the variation accounted for by each of the retained axes.

Collection of Stomachs and Identification of Food Items

Some fish obtained in the seven sampling runs were sub-sampled for stomach analyses. Additional stomachs were required to increase the sample

size due to an unforeseen freezer malfunction which destroyed sub-sampled fish, so more fish were collected using the same setup and settings as the seven monthly runs. Captured fish were anesthetized and frozen for later processing. Because suckers have a long and coiled intestine of varying length and the fact that entire gut contents can represent a large time frame of feeding, only the anterior of the gut, between the esophagus and the first bend was used for dietary analyses. All food items and parts were collected and stored in 70% ETOH for later identification. Food items were identified (Merritt and Cummings, 1996) as accurately as possible, given the condition of the specimens. In cases where multiple body parts of organisms were recovered, the minimum number of individuals of identifiable taxa required to account for the number of parts recovered was recorded. General habitat was recorded and used to test whether fish foraged differentially based on habitat e.g. ETD and TILL.

General and Paired Diet Comparisons

All stomach samples are given in Appendix 5. In order to characterize diet diversity all stomachs from each species were randomly re-sampled with replacement using a macro *Compositional_Diversity* (Appendix 4). Five diversity estimates were calculated to characterize the data matrix species richness, Shannon's for row vectors, Shannon's for column vectors, joint entropy, and mutual entropy. It has been demonstrated that the more commonly used indices are mathematically related by Renyi's (1961) process of order α that is defined as:

$$H^\alpha = \frac{\left[\ln \sum p_i^\alpha \right]}{(1-\alpha)}$$

Varying α , changes the entropy measure. Although the commonly used indices are related, each index's interpretation and meaning is different. Used together, various measures can be used to address questions regarding the various aspects of biotic diversity. To address the larger questions of compositional patterns within the data set itself we need classes of vectors which lend to inferences regarding dependence, information, and complexity of composition (Juhász-Nagy, 1984; 1993). The mutual information of order α (Shannon, 1948) is defined as:

$$H_{12}^\alpha = \frac{\left[\ln \sum \sum \left(\frac{p_{jk}^\alpha}{(p_{j.} p_{.k})^{\alpha-1}} \right) \right]}{(\alpha-1)}$$

The most commonly used measure occurs when $\alpha \rightarrow 1$, referred to as the mutual entropy:

$$H_{12} = \sum \sum p_{jk} \ln \left[\frac{p_{jk}}{(p_{j.} p_{.k})} \right]$$

When used in conjunction with the joint entropy (total information) is defined as:

$$H_{1+2} = H_1 + H_2 - H_{12} = -\sum \sum p_{jk} \ln p_{jk}$$

The relationship between H_1 , H_2 , H_{12} and H_{1+2} shows that two qualitative variables H_1 and H_2 may be independent $H_{12} \approx 0$ or dependent $H_{12} > 0$. In a classic example H_1 and H_2 may be biotic diversity and sample richness, or more

precisely column total vector and row total vector of a sample by species data matrix. The joint entropy H_{1+2} represents the total information of H_1 and H_2 considered together less any dependence they may exhibit, when considered together and therefore H_{12} is thought of as a qualitative covariance.

Species diets were summarized by presenting mean abundance of each taxon and mean abundance weighted by the prevalence of each dietary item. This allowed the downweighting of rarely occurring but numerous dietary items.

To examine the overall patterns of intra- and inter-specific diet overlap within and between feeding groups, all individuals of each species were compared with one another. For each pair, both symmetric Horn's Index and asymmetric MacArthur and Levins (1967) limiting similarity equations, as follows, were calculated:

$$M_{jk} = \frac{\sum p_{ij} p_{ik}}{\sum p_{ij}^2} \quad M_{kj} = \frac{\sum p_{ij} p_{ik}}{\sum p_{ik}^2}$$

Where p_{ij} and p_{ik} are the proportion of the distribution of species j and k in the i^{th} grid location. M_{jk} is the overlap of species k on species j and M_{kj} is the overlap of species j on species k . These measures are asymmetric and depend on the differential number of categories each species occupies. M_{jk} and M_{kj} were plotted against each other as an overall image of direction and complexity of interaction. Such a graph can be thought of as a representation of the composite population-level Lotka-Volterra model. All pair wise comparisons were run using a macro *Sub Overlap* (Appendix 4). For each point, an angle was calculated using basic trigonometry to assess whether the average inter-specific interaction

differed from 45°, the symmetric intra-specific average angle. Deviation from 45° indicates that one species feeds on a subset of the species with the broader or more general diet.

Randomized and Multivariate Diet Analyses

To examine the overall average diet overlaps among the six species, the cumulative mean prevalence and mean abundance for each of the 33 diet taxa were calculated using Horn's index. Three models were developed following the approach used by Lawlor (1980). The first model, *RA1* macro (*Sub RA1* Appendix 4) kept the zeroes in place, but had random numbers assigned for proportional abundance and prevalence of all 33 diet taxa. *RA1* tests whether the observed dietary items in their observed proportions can be differentiated from overlaps produced if the same dietary items had random proportions. The second model *RA2* macro (*Sub RA2* Appendix 4) kept the observed proportional abundance and prevalence values but randomly shuffled them, varying the location of the zero values. *RA2* tests whether the observed number of dietary items and their proportions can be differentiated if the dietary items were random, but the proportions were randomized. The third model *RA3* macro (*Sub RA3* Appendix 4) randomly shuffled only the non-zero proportional abundance and prevalence values keeping zeroes constant. *RA3* tests whether the observed proportions and dietary items could be differentiated from random.

Fish by diet matrix was transformed by weighting abundance values by the prevalence of dietary items. The transformed matrix was then clustered

using a global optimization clustering algorithm option in the Nonhierarchical clustering package of Syntax 2000 (Podani, 2001). Horn distance was used and clustering was based on using random seeds with 100 iterations. The global optimization procedure minimizes the ratio of the average within-cluster and the average between-cluster distances during relocations. Because the final partitions are not unique starting from random seeds 100 iterations were run and the best criterion value search was selected. The number of groups started at six for the number of species and then was reduced to four. The groups with the least overlap were then selected as the final number, which were four feeding groups. The matrix was then analyzed using PCoA using Horn distance and the groups scores were then run through a canonical variates analysis (CVA) using the Ord package of Syntax 2000. The mean abundance and weighted mean abundance of feeding group diets were summarized in the same manner as the species diet data.

Collection of Benthic Invertebrates

All benthic invertebrate samples are given in Appendix 6. Benthic invertebrates were collected at the DFO Lido Plage IFN site located 4 kilometers downstream of the Trans Canada Highway Bridge over the Assiniboine River 8 kilometers west of Headingley, MB. The site is a 1.2km reach of the Assiniboine River with 12 benchmarked cross-sections. Eight cross-sections were chosen randomly to be sampled at 2.5m from each shore, at 16.5m from each shore and in the middle of the river, totaling five systematic locations across the river. At

each of the five locations the boat was anchored facing upstream and five samples were collected; first off the starboard side amidships, then starboard forward quarter, then bow, then port side forward quarter and then port amidships. Sampling was done during early July and early September 2001 using an airlift sampler (Watkinson et al., 2004). Samples comprised a 10 second burst of air at 120psi. Although this time is far less than sampling periods suggested by some authors, it was sufficient to estimate the presence and abundance of most invertebrate species during a period similar to that which a fish might spend foraging in a similar area of substrate. Invertebrates were washed into a mesh bag of 200 μ m Nytex mesh, rinsed into bags, and fixed in 5% formalin. Depth and substrate type were recorded at each location. Invertebrate samples were changed from formalin using a 200 μ m screen rinsed in water and stored in 70% ETOH for later enumeration and Identification. Invertebrates were identified to the same taxon level as diet items using the same sources.

Concordance of Fish Diet and Benthic Invertebrates

A minimum spanning tree was used to determine the optimized association among invertebrates based on co-occurrence and Horn distance. Sample by invertebrate matrix was transformed by weighting abundance values by the prevalence of benthic invertebrates as was done for the dietary analysis. The transformed matrix was then clustered using a global optimization clustering algorithm option in the Nonhierarchical clustering package of Syntax 2000 (Podani, 2001). Horn distance was used and clustering was based on using

random seeds with 100 iterations. The global optimization procedure minimizes the ratio of the average within-cluster and the average between-cluster distances during relocations. Because the final partitions are not unique starting from random seeds 100 iterations were run and the best criterion value search was selected. Four groups were selected because there were four feeding groups. The matrix was then analyzed using PCoA using Horn distance and the groups scores were then run through a canonical variates analysis (CVA) using the Ord package of Syntax 2000.

To examine the concordance of the prevalence of benthic invertebrates with the abundance of fish species in relation to substrate only the 6 most prevalent food items from each of the six catostomid diets were used. The benthic invertebrate groups defined by global optimization were summarized by mean abundance and weighted mean abundance in the same manner as the species diets and feeding group diets were.

Biogeographic Richness, Sympatry, and Limiting Similarity

Distributions for all 81 described and pending catostomid species were collated using a variety of sources (Scott and Crossman, 1973; Lee et al., 1980; Smith, 1992; Burr and Mayden, 1999; Harris et al., 2002; Suttkus and Bart, 2002; and Robert Jenkins, Roanoke College, VA personal communication). To measure biogeographic overlaps for species, distributions were exported from ArcView (as equal area projections) in *jpeg* format at 300dpi. Images were scaled to 250 pixels wide by 279 pixels tall in Corel Photopaint and exported in

gif format. The choice of 250 pixels was used due to the column limitations of Microsoft Excel. The *gif*-file data then were translated to *csv*-files using the *Sub gif_to_csv*, a Visual Basic script (Appendix 4) and opened in Microsoft Excel. The species distributions were extracted to Excel cells using the *Sub Extract* macro (Appendix 4) as presence or absence from spreadsheet rows and columns in Excel corresponding to populated or unpopulated pixels of the image. Each cell was calculated to correspond to an equal area (25km²) grid on a map of North America. In order to assess the variance of the methodology actual areas were taken from ArcView and compared to those estimated from the approach outlined above and percent difference ranged from 1.37%-1.99%.

Sympatry of species distributions was estimated according to McAllister et al. (1986) who defined a “Coefficient of Sympatry” as follows:

$$Sympatry_{jk} = \frac{(s_j + s_k)}{(t_j + t_k)}$$

Where s_j and s_k are the number of shared cells between species j and k , and t_j and t_k are the total number of cells occupied by species j and k , respectively. Overlaps were assessed on a cell by cell basis using a macro *Sub Sympatry* (Appendix 4). The coefficient of sympatry was used because it accounts for the differential ranges of the two species in question. To examine whether local overlaps and interactions reflect biogeographic patterns MacArthur and Levins (1967) M_{jk} and M_{kj} were used.

CHAPTER 4: RESULTS

Habitat Pattern and Distribution

Stream morphology measurements indicate general habitat patterns at larger spatial scales. In general, ETD substrates (silt, sand, clay, and gravel) are of glacial Lake Agassiz deltaic and alluvial origins. These finer substrates are re-worked by the meandering process to create repetitive patterns of deposition on inside bends and erosion on outside bends. Reaches of inertial TILL substrates (gravel, cobble, and boulder) are restricted to glacial till-plain exposures which resist the meandering process and tend to be localized. ETD reaches are characterized by more degrees in bend, larger bend radii, longer arc lengths, and have narrower channels with comparable velocities (Table 3). The mean surface elevation ranges from ~262 mASL to ~226 mASL having a mean slope of 18.9 cm/km (Figure 15). Figure 16 shows that the river is relatively wider, with fewer degrees in bend in TILL habitats compared to ETD habitats. Arc angle decreases as a power function with increasing radius of curvature (Figure 17) while arc length increases with radius of curvature as a power function (Figure 18). These patterns indicate that smaller bends have significantly more degrees in arcs, or more specifically smaller bends characterize sinuous reaches. Meandering is characteristic in ETD habitat reaches, by a longitudinal pattern of repeating deep outside bends, shallow inside bends, and wider shallow sandy reaches between bends when bedload deposition occurred due to slower velocities and width of channel (Figures 19-22). In areas of TILL habitats, erosion on outside bends is unable to produce depth and river grows wider as a

result (Figures 19J-M; 22R-T). These patterns are repeated along the entire length of the study reach creating variable amounts and areas of substrates for exploitation. It cannot be determined from this study whether the meandering process consolidates loose TILL substrates as the channel migrates or whether TILL substrates vary in depth and concentration (Figures 19D, 19O-Q; 20A; 20S; 21A; 21P; 22P-R).

Phylogeny and Fish Distributions

The reduced phylogeny reproduced the basic relationships of these species (Smith, 1992) defining two subfamilies: the Ictiobinae comprised of *I. cyprinellus* (BB) and *C. cyprinus* (QB) and the Catostominae comprised of *C. commersoni* (WS), *M. anisurum* (SR), *M. erythrurum* (GR), and *M. macrolepidotum* (SHR) (Figure 23). The first group represents two basal species that are central North American in origin following Smith's (1992) hypothesis. The typical habitats for Ictiobine species are larger rivers of central North America (Mississippi, Missouri and Ohio Rivers) (Lee et al., 1980). The Ictiobinae typically are larger and more robust than the Catostomine species. The second group consists of members from two tribes within the subfamily Catostominae: the Catostomini and the Moxostomatini, that are western montane and eastern montane in origin, respectively. Both groups have a slender body form, short dorsal fins, intermediate pharyngeal tooth counts, and relatively shorter intestine to body length ratios. Both BB and QB represent functional feeding group three of Eastman (1977), are broadly sympatric throughout central

North America, and both probably colonized Manitoba via Minnesota Spillway (Figure 23). All four Catostomines are from functional feeding group two of Eastman (1977) and broadly sympatric throughout the upper Mississippi River and Great Lakes drainages. The WS and SHR probably colonized this area during the late glacial period via the Minnesota Spillway while the GR and SR probably colonized this area post-glacially via both the Minnesota Spillway and the northeastern Rainy-Winnipeg system route (Figure 23).

Six species of Catostomids were caught in the Assiniboine River during the 1995 and 1996 sampling periods (Table 4). Depth utilization indicated that all species utilized depth in differently relative to availability (Figure 24). Velocity utilization was different than expected based on availability for all species except SR (Figure 25). Substrate utilization was significantly different than expected based on availability for all six species (Figure 26). Species mean abundance values along the length of the study reach were calculated when more than one sample was collected at that site. All abundance and mean abundance values were normalized, dividing into the largest value. The locations of TILL sediments interspersed within the finer alluvial ETD sediments along the length of the sample reach were summarized to show the heavy concentrations of some species over these substrates (Figure 27). A summary of comparisons of catch numbers for ETD and TILL substrates for each species is given in Table 5. WS were heavily concentrated over TILL substrates, especially the larger exposure found at the downstream end of the reach (last 25km) (Table 5; Figure 27). SR showed a more dispersed pattern along the length of the reach, primarily

because this species generally occurred in lower abundance per sample (Table 5; Figure 27). GR distribution was similar to that of WS, having high affinities for coarser TILL substrates at the lower end of the reach (Table 5; Figure 27). SHR was the most abundant species and was encountered along the entire study reach. However, this species was concentrated over the TILL substrates at the lower end of the reach, similar to GR and WS (Table 5; Figure 27). QB showed high affinities for ETD substrates and were concentrated at the upper end of the reach (Table 5; Figure 27). BB had a discontinuous distribution and is considered rare. With the exception of a spawning group encountered at the upper end of the reach, this species was encountered as solitary or as a few individuals outside of the spawning period (Table 5; Figure 27).

Niche Analyses and Models

NB, *ENB*, *MNB*, and evenness calculations are given in Table 6. Although *MNB* generally increased with species abundance, SR *NB* and *MNB* was higher than the other species for the number of fish sampled and QB was relatively low (Table 6). Evenness generally decreased logarithmically with species abundance when BB were removed (Figure 28). The relationship between abundance and evenness should be logarithmic if all species are similarly distributed in data space, however, BB were dispersed differently in the data space compared to the other species due to their rare and over-dispersed pattern (Figure 28).

The *RDVS* model generated *NB* values much larger than observed values for all species using the observed number of individuals (Table 7). The *IDVS* model produced *NB* values less than the *RDVS*, but still significantly greater than the observed *NB* values for all species (Table 7). Second runs on both the *RDVS* and *IDVS* models using larger number of fish further increased the *NB* values. The *ODVS* model and the observed abundance values produced *NB* values significantly less than observed *NB* values in all cases except for SHR, which was not significantly different from observed value (Table 7). Second iterations with 2000 fish (except BB with 1000 fish) produced *NB* values not significantly different from observed (Table 7).

Species Co-occurrence, Overlaps, and Models

In the analysis of co-occurring species WS, SR, and GR co-occurred most often with 1 or 2 other species and relatively rarely were caught alone (Figure 29). SHR occurred most frequently with one other species or alone (Figure 29). QB occurred most frequently with one other species and BB occurred most frequently with 3 other species and rarely alone (Figure 29). In general the more abundant species (SHR and QB) had increased tendencies to occur alone or with fewer other species than did less abundant species (GR and BB). Randomized co-occurrence relative to observed WS showed that SR, GR, and BB co-occurred with WS more frequently than randomly and SHR and QB co-occurred with WS less often than randomly (Table 8; Figure 30). Random co-occurrence relative to observed SR showed that WS and GR co-occurred with

SR randomly, SHR and QB co-occurred with SR less frequently than randomly, and BB co-occurred with SR more frequently than randomly (Table 8; Figure 30). Random co-occurrence relative to observed GR showed WS and SR co-occurred with GR more frequently than randomly, SHR and QB co-occurred with GR less frequently than randomly, and BB co-occurred with GR randomly (Table 8; Figure 30). Random co-occurrence relative to observed SHR showed that WS, GR, QB, and BB co-occurred with SHR less frequently than randomly and SR co-occurred with SHR randomly (Table 8; Figure 30). Random co-occurrence relative to observed QB showed that WS, GR, and SHR co-occurred with QB less frequently than randomly and SR and BB co-occurred with QB more frequently than random (Table 8; Figure 30). Random co-occurrence relative to observed BB showed that WS, SR, and QB co-occurred with BB more frequently than randomly and GR and SHR co-occurred with BB randomly (Table 8; Figure 30). All observed abundance values were significantly greater than random abundances (Table 9). This is expected as observed abundances are more negative binomial in distribution than Poisson.

The Horn overlaps based on species co-occurrence were analyzed by PCoA and HCA. The first axis of the PCoA summarized 31.79% of the variance, second axis summarized 23.08% of the variance, and the third axis summarized 19.48% of the variance (Figure 31). HCA was used to supplement the PCoA, requiring complete linkage, a conservative method. HCA resulted two groups WS:GR:SHR and SR:QB:BB with dissimilarity values given (Figure 31). The cophenetic correlation for the HCA was 0.68 (Figure 31).

The Horn overlaps based on the DVS array were subtracted from 1 and used for direct input into PCoA and HCA. PCoA summarized 40.18% of the variance on the first axis, which corresponds to the separation of BB and to a lesser extent QB from the remaining species (Figure 32). The second axis summarized 28.87% of the variance and represented two groups, SR:QB and WS:GR:SHR (Figure 32). HCA was used to supplement the PCoA, requiring complete linkage, a conservative method. HCA resulted in BB alone and two groups SR:QB and WS:GR:SHR, with dissimilarity values given at the fusion junctions (Figure 32). The cophenetic correlation for the HCA was 0.78, which corresponds to the dissimilarity for the entire group of 0.78. The two primary groups had a dissimilarity of 0.65, excluding BB (Figure 32).

CCA results are summarized in Figure 33. The variation on the first axis is dominated by substrate and Froude constraints, summarizing 96.02% of the interspecies relations, while the second axis summarized the remaining 3.98%. The first axis separates the finer alluvial ETD sediments with relatively more QB and SR from the coarser TILL substrates where WS, GR, and SHR are concentrated (Figure 33). These results conform to the PCoA and HCA results based on Horn overlaps (Figures 31 and 32) showing that species that are most similar morphologically (i.e. from the same functional feeding group) and most closely related, at the subfamily level generally overlap more with respect to habitat, with the exception of BB, which dominated the first axis, due to its heavy concentration in clay substrates (Figure 26).

General and Paired Diet Comparisons

Mean richness accumulation curves showed that WS had the richest diet, followed by SR and GR which had very similar accumulation curves, then SHR. QB and BB have different shapes of accumulation curves (Figure 34).

Randomization of diversity estimates showed that both diet diversity and mutual diversity reached asymptotes after which sample diversity remained the principal contributor to joint diversity. This indicates that additional stomachs over the numbers noted with arrow in Figure 35 represent redundant information.

Numbers represent the minimum number of stomachs required using the given data, demonstrating that sufficient data were acquired for all six species (Figure 35).

A total of 33 identifiable taxa were recovered from 385 stomachs of six species of Catostomid fishes (Figure 36; Table 10). Matrix fill varied from 20.44% to 34.01% for feeding group 2 (see Figure 23) 14.0% for QB and 20.82% for BB (Table 10). Empty stomachs varied from 3.28% to 14.09% in feeding group 2 and 23.86% to 37.04% in feeding group 3 (Table 10). All 33 taxa were recovered from 71 WS stomachs, having an observed mean of 8.16 taxa per stomach and a randomized mean of 6.99 taxa per stomach (Table 10). SR had an observed mean of 7.47 taxa per stomach and a randomized mean 6.41 taxa per stomach (Table 10). GR had an observed mean of 10.20 taxa per stomach and a randomized mean 10.19 taxa per stomach (Table 10). SHR had an observed mean of 6.74 taxa per stomach and a randomized mean 6.16 taxa per stomach (Table 10). QB had an observed mean of 3.78 taxa per stomach and a

randomized mean 2.93 taxa per stomach (Table 10). BB had an observed mean of 2.71 taxa per stomach and a randomized mean 1.64 taxa per stomach (Table 10). The ability of randomization procedures to accurately reach the observed mean richness is dependent on the degree of uniformity or redundancy that exists in the data matrices. More precisely if all individuals eat the same items then the mean is equal to any one stomach and the variance is zero.

Due to the repeated use of the same individuals in the paired comparisons direct statistical tests were not appropriate. WS intra-specific comparisons were based on 1830 unique pairs, with 90.66% of the pairs interacting and a mean overlap of 0.33 (Figure 37; Table 11). WS:SR comparisons had 3355 pairs, with 90.22% of the pairs interacting, and a mean overlap of 0.28 (Figure 37; Table 11). WS:GR comparisons had 3599 pairs, with 94.58% of the pairs interacting, and a mean overlap of 0.35 (Figure 37; Table 11). WS:SHR comparisons had 4087 pairs, with 87.60% of the pairs interacting, and a mean overlap of 0.26 (Figure 37; Table 11). WS:QB and WS:BB comparisons had 4087 and 1037 pairs, with 70.0% and 40.31% of the pairs interacting, and a mean overlaps of 0.12 and 0.05, respectively (Figure 37; Table 11). SR intra-specific comparisons are based on 1485 unique pairs, with 91.11% of the pairs interacting and a mean overlap of 0.28 (Figure 37; Table 11). SR:GR comparisons had 3245 pairs, with 95.01% of the pairs interacting, and a mean overlap of 0.31 (Figure 37; Table 11). SR:SHR comparisons had 3685 pairs, with 85.62% of the pairs interacting, and a mean overlap of 0.23 (Figure 37; Table 11). SR:QB and SR:BB comparisons had 3685 and 935 pairs, with 66.11% and 34.97% of the pairs

interacting, and a mean overlaps of 0.13 and 0.03, respectively (Figure 37; Table 11). GR intra-specific comparisons are based on 1711 unique pairs, with 98.07% of the pairs interacting and a mean overlap of 0.53 (Figure 37; Table 11).

GR:SHR comparisons had 3953 pairs, with 94.84% of the pairs interacting, and a mean overlap of 0.43 (Figure 37; Table 11). GR:QB and GR:BB comparisons had 3953 and 1003 pairs, with 72.50% and 39.18% of the pairs interacting, and a mean overlaps of 0.13 and 0.03, respectively (Figure 37; Table 11). SHR intra-specific comparisons are based on 2211 unique pairs, with 90.73% of the pairs interacting and a mean overlap of 0.46 (Figure 37; Table 11). SHR:QB and SHR:BB comparisons had 4489 and 1139 pairs, with 61.44% and 30.99% of the pairs interacting, and a mean overlaps of 0.12 and 0.03, respectively (Figure 37; Table 11). QB intra-specific comparisons are based on 2211 unique pairs, with 64.18% of the pairs interacting and a mean overlap of 0.22 (Figure 37; Table 11). QB:BB comparisons had 1139 pairs, with 48.90% interacting, and a mean overlap of 0.19 (Figure 37; Table 11). BB intra-specific comparisons are based on 136 unique pairs, with 68.38% of the pairs interacting and a mean overlap of 0.38 (Figure 37; Table 11).

All species pairs have the same number of pairwise comparisons and percent of pairs interacting and the Horn overlap comparisons. Table 12 summarizes mean $\pm$ SD for M_{jk} and M_{kj} . WS intra-specific comparisons had a mean angle of 45° with 50% of pairs greater than 45° (Table 13; Figure 38). WS:SR comparisons had a mean angle of 40.28° with 35.17% of pairs greater than 45° weighting the interaction in favor of WS (Table 13; Figure 38). WS:GR

comparisons had a mean angle of 49.71° with 56.88% of pairs greater than 45° weighting the interaction in favor of GR (Table 13; Figure 38). WS:SHR comparisons had a mean angle of 36.51° with 27.23% of pairs greater than 45° weighting the interaction in favor of WS (Table 13; Figure 38). WS:QB comparisons had a mean angle of 30.56° with 12.85% of pairs greater than 45° weighting the interaction in favor of WS (Table 13; Figure 38). WS:BB comparisons had a mean angle of 25.39° with 5.79% of pairs greater than 45° weighting the interaction in favor of WS (Table 13; Figure 38). SR intra-specific comparisons had a mean angle of 45° with 50% of pairs greater than 45° (Table 13; Figure 38). SR:GR comparisons had a mean angle of 54.61° with 69.40% of pairs greater than 45° weighting the interaction in favor of GR (Table 13; Figure 38). SR:SHR comparisons had a mean angle of 41.08° with 34.44% of pairs greater than 45° weighting the interaction in favor of SR (Table 13; Figure 38). SR:QB comparisons had a mean angle of 35.0° with 16.99% of pairs greater than 45° weighting the interaction in favor of SR (Table 13; Figure 38). SR:BB comparisons had a mean angle of 28.05° with 5.13% of pairs greater than 45° weighting the interaction in favor of SR (Table 13; Figure 38). GR intra-specific comparisons had a mean angle of 45° with 50% of pairs greater than 45° (Table 13; Figure 38). GR:SHR comparisons had a mean angle of 31.85° with 16.44% of pairs greater than 45° weighting the interaction in favor of GR (Table 13; Figure 38). GR:QB comparisons had a mean angle of 25.78° with 4.38% of pairs greater than 45° weighting the interaction in favor of GR (Table 13; Figure 38). GR:BB comparisons had a mean angle of 20.90° with 4.59% of pairs greater

than 45° weighting the interaction in favor of GR (Table 13; Figure 38). SHR intra-specific comparisons had a mean angle of 45° with 50% of pairs greater than 45° (Table 13; Figure 38). SHR:QB comparisons had a mean angle of 37.67° with 19.63% of pairs greater than 45° weighting the interaction in favor of SHR (Table 13; Figure 38). SHR:BB comparisons had a mean angle of 31.01° with 5.44% of pairs greater than 45° weighting the interaction in favor of SHR (Table 13; Figure 38). QB intra-specific comparisons had a mean angle of 45° with 50% of pairs greater than 45° (Table 13; Figure 38). QB:BB comparisons had a mean angle of 37.06° with 12.56% of pairs greater than 45° weighting the interaction in favor of QB (Table 13; Figure 38). BB intra-specific comparisons had a mean angle of 45° with 50% of pairs greater than 45° (Table 13; Figure 38).

Randomized and Multivariate Analysis of Diet

The random model (RA1), based on mean prevalence, resulted in all of feeding group 2 (see Figure 23) having observed Horn overlaps greater than at random, except for SR:SHR pair for which 11% of random overlaps were greater than observed (Table 14; Figure 39). All of the between feeding group RA1 results showed observed Horn overlaps that were not different from random (Table 14; Figure 39). For QB:BB results, 13% of the random overlaps were greater than the observed overlap (Table 14; Figure 39). The random shuffle model (RA2) based on mean prevalence resulted in all of the observed overlaps within feeding group 2 being greater than random (Table 14; Figure 39). The

between feeding group RA2 results for all of feeding group 2 with QB and BB showed observed Horn overlaps that were not different from random. The exceptions were WS:QB which had only 4% of random overlaps greater than observed and SR:QB which had 8% of random overlap greater than observed (Table 14; Figure 39). QB:BB results showed that observed overlap was greater than random (Table 14; Figure 39). The shuffle model (RA3) based on mean prevalence resulted in all of the observed overlaps within feeding group 2 being greater than random (Table 14; Figure 39). Between feeding group RA3 results for all of feeding group 2 with QB and BB showed all observed Horn overlaps were not different from random, except for WS:QB which had only 5% of random overlaps greater than observed and SR:QB with 10% of random overlap greater than observed (Table 14; Figure 39). QB:BB results showed that observed overlap was greater than random (Table 13; Figure 45).

The random model (RA1) based on mean abundance resulted in all within feeding group 2 (see Figure 23) having observed Horn overlaps less than random, except for the GR:SHR pair for which overlap was greater than expected at random (Table 15; Figure 40). The between feeding group RA1 results showed that all observed Horn overlaps were less than expected at random except for the WS:BB pair in which 90% of modeled random overlaps were greater than observed overlap (Table 15; Figure 40). QB:BB results showed that 14% of the random overlaps were greater than the observed overlap (Table 15; Figure 40). The random shuffle model (RA2) based on mean abundance resulted in all of the observed overlaps within feeding group 2 being

greater than random, except for SR:GR pair in which 8% of the random overlaps were greater than observed (Table 15; Figure 40). Between feeding group RA2 results for all of feeding group 2 with QB had observed Horn overlaps that were not different from random (Table 15; Figure 40). Between feeding group RA2 results for all of feeding group 2 with BB showed that with the exception of the WS:BB pair (4% of random overlaps greater than observed overlap) observed values were less than random (Table 15; Figure 40). QB:BB results showed that observed overlap was greater than if random (Table 15; Figure 40). The shuffle model (RA3) based on mean abundance resulted in all of the observed overlaps within feeding group 2 being greater than if random, except for SR:GR pair with 6% of the random overlaps were greater than observed (Table 15; Figure 40). The between feeding group RA3 results and for all comparisons of feeding group 2 with QB had observed Horn overlaps that were not different from random (Table 15; Figure 40). The between feeding group RA3 results and for all feeding group 2 with BB had observed values were less than random (Table 15; Figure 40). An exception was the pair WS:BB for which 6% of random overlaps were greater than observed overlap. QB:BB had observed overlap that was greater than random (Table 15; Figure 40).

Global optimization clustering produced four groups for PCoA. The PCoA scores analyzed by CVA indicated the four feeding groups were significant (Table 16). Feeding Group 1 was comprised of mainly SR, WS, and QB, with lesser numbers of GR and SHR (Figure 41). Diets of Feeding Group 1 were dominated by *Axarus*, Tanypodinae, and *Ephoron* (Figure 42). Feeding Group 2

was comprised of SHR, GR, WS, and lesser numbers of SR and a few QB. Diets of Feeding Group 2 were dominated by Hydropsychidae, Heptageniidae, Caenidae, Chironomidae A, Tanypodinae, Sphaeriidae, and Elmidae (Figure 42). Feeding Group 3 was comprised mainly of QB, WS, and SR with a few individuals of GR, SHR, and BB (Figure 41). The diet of Feeding Group 3 was dominated by Chironomidae A and Orthocladiinae pupae with some Sphaeriidae (Figure 42). Feeding Group 4 was comprised of QB and BB, with a few individuals of SHR, WS, and SR (Figure 41). The diet of Feeding Group 4 was dominated by Cladocera, Copepoda, and Ostracoda (Figure 42).

Concordance of Fish Diet and Benthic Invertebrates

A minimum spanning tree was used to show proximity of benthic invertebrates and recognized 4 groups, with two of the groups having 2 subgroups. The first group branched out from Heptageniidae and consisted of Elmidae, Hydropsychidae, Tipulidae, Tanypodinae, Chironomidae E and F, Isonychidae, Plecoptera (Perlidae and Perlodidae), Sphaeriidae, Coleoptera, limpets, and Oligochaeta (Figure 43). The second group branched from Caenidae and comprised two subgroups. The first caenid-subgroup comprised Tricorythidae, Ceratopogonidae, Orthocladiinae, Empididae, and *Ephoron* (Figure 43). The second caenid-subgroup branching from Caenidae comprised *Hexagenia* sp., Brachycentridae, Acara (mites), and Hydra (Figure 43). The third group branched from Ostracoda and comprised two subgroups. The first ostracod-subgroup comprised Chironomidae G, Polymitarcyidae, and Corixidae

(Figure 43). The second ostracod-subgroup comprised Chironomidae I, Nematoda, Copepoda, and Cladocera (Figure 43). The fourth group branched from Chironomidae A and comprised *Axarus* sp., Chironomidae B, H, and J, Gomphiidae, Amphipoda, and Gastropoda (Figure 43).

Global optimization clustering produced four groups for PCoA. The PCoA scores analyzed by CVA indicated the four feeding groups were significant (Table 17). Benthic Group 1 was comprised of mainly sand samples with lesser numbers gravel, cobble, snag, and clay (Figure 44). Benthic Group 1 was dominated by Gastropoda, Ceratopogonidae, Sphaeriidae, Orthoclaadiinae pupae, Hydropsychidae, Plecoptera, Caenidae, and Elmidae (Figure 45). Benthic Group 2 was comprised gravel, cobble and sand substrates with lesser amounts of snag, clay and silt (Figure 44). Benthic Group 2 was dominated by Heptageniidae, Plecoptera, Elmidae, Caenidae, Ostracoda, Hydropsychidae, Baetidae, and Chironomidae A (Figure 45). Benthic Group 3 comprised sand, and few samples of cobble and gravel (Figure 44). Benthic Group 3 was dominated by Chironomidae A and a few Ostracoda (Figure 45). Benthic Group 4 comprised sand, gravel, clay, cobble, silt-sand, and silt, in order (Figure 44). Benthic Group 4 was dominated by Ostracoda, Copepoda, Caenidae, and Chironomidae A with several other species (Figure 45).

It is noted that although there are differences in effectiveness of the airlift sampler to estimate abundance with substrate (C. Podemski DFO Winnipeg, Personal Communication) it was effective at determining the presence of invertebrate species in all substrates, including Hydropsychidae which live under

gravel. As a result only invertebrate prevalence was inferred from the airlift samples. Fish abundance with substrate versus benthic invertebrate prevalence with substrate, were in general concordance for WS, SR, GR, and SHR (Figures 46-51). Tanypodinae, Hydropsychidae, Sphaeriidae, Heptageniidae, Chironomidae A and *Axarus* sp. were the 6 most prevalent taxa recovered from the stomachs of WS (Figure 36). With the exception of Chironomidae A which was present almost uniformly in all substrates and *Axarus* sp. which only were recovered from finer substrates, the remaining taxa were positively associated with the same substrates over which WS were most abundant (Figure 46). Tanypodinae, Hydropsychidae, *Axarus* sp., Orthoclaadiinae, Sphaeriidae, and Elmidae were the 6 most prevalent taxa recovered from the stomachs of SR (Figure 36). With the exception of Orthoclaadiinae which was present almost uniformly in all substrates and *Axarus* sp. which were recovered only from finer substrates, the remaining taxa were positively associated with the same substrates over which SR were most abundant (Figure 47). Hydropsychidae, Elmidae, Heptageniidae, Tanypodinae, Chironomidae A and Sphaeriidae were the 6 most prevalent taxa recovered from the stomachs of GR (Figure 36). With the exception of Chironomidae A which was present almost uniformly in all substrates, the remaining taxa were positively associated with the same substrates over which GR were most abundant (Figure 48). Hydropsychidae, Chironomidae A, Heptageniidae, Plecoptera, Elmidae, and Brachycentridae were the 6 most prevalent taxa recovered from the stomachs of SHR (Figure 36). With the exception of Chironomidae A which was present almost uniformly in all

substrates, the remaining taxa were positively associated with the same substrates over which SHR were most abundant (Figure 49). Chironomidae A, Orthocladinae, *Axarus* sp., Ostracoda, Ceratopogonidae, and Hydropsychidae were the 6 most prevalent taxa recovered from the stomachs of QB (Figure 36). With the exception of Hydropsychidae being more prevalent in TILL habitats and *Axarus* sp. only being recovered from two of the substrates, the prevalence of remaining taxa were associated with the same substrates over which QB were most abundant (Figure 50). Cladocera, Ostracoda, Corixidae, *Axarus* sp., Copepoda, and Chironomidae A were the 6 most prevalent taxa recovered from the stomachs of BB (Figure 36). Ostracoda and Copepoda were positively associated with BB and substrate, while Chironomidae A was uniformly present in all substrates (Figure 51). Anecdotally, the taxa associated with BB and QB diets were highly aggregated with lower weighted abundance (Figure 36; Table 10) and higher percent empty stomachs (Table 10) indicate that these taxa may be spatially over-dispersed.

Biogeographic Richness, Sympatry, and Limiting Similarity

There are 81 species of catostomid fishes dispersed throughout North America. Overlaying all species distributions on a 25km² grid of North America indicates species richness is highest in the region of the middle Mississippi and lower Ohio rivers having over 20 species that potentially are sympatric and interacting in some fashion (Figure 52). There are roughly 12 geographic groups of catostomids, excluding allopatric species from Mexico and Guatemala. These

groups are localized in areas of sympatry dependent on the connectivity of major river systems in the interior (12), while Atlantic slope, Gulf Coastal, Southwestern United States and western montane regions are linked more to vicariant events and speciation (2-10) and glaciation patterns (1 and 12) (Figure 53). For the six species from Assiniboine River, the principal area of sympatry is with the Great Lakes, upper Mississippi, and lower Ohio and lower Missouri rivers (Figure 54). The four species from feeding group 2 (see Figure 23) are sympatric in glacial refugia regions of the lower Great Lakes and the Upper Mississippi River. These patterns indicate that the degree of sympatry exhibited by Manitoba suckers in their post-glacial ranges is similar to the degree of sympatry from refugium of origin.

All *Carpionodes* species are sympatric except for the sister pair *Cca: Cel* which is allopatric (Table 18). All *Ictiobus* species are sympatric in central North America except *I. labiosus* in Mexico and *I. meridionalis* in Guatemala (Table 18). *Moxostoma breviceps* and *M. pisolabrum* are parapatric with *M. macrolepidotum*, but allopatric with each other, while *M. hubbsi* is peripheral to *M. macrolepidotum* and allopatric with *M. breviceps* and *M. pisolabrum* (Table 19). *Moxostoma collapsum* is allopatric with sister *M. anisurum* but sympatric with *M. pappillosum* (Table 19). *Moxostoma erythrurum* is allopatric with hypothesized sister species *M. sp. "Carolina"* (Table 19).

All the species found in the Assiniboine River are broadly sympatric within feeding groups (Table 20). A comparison of local habitat overlap with biogeographic sympatry showed that, generally, within-feeding-group pairs were

positively correlated with sympatry (Figure 55). Comparison of local diet overlap with biogeographic sympatry indicated that diet overlap decreased within feeding group pairs with increasing biogeographic sympatry (Figure 56). If local relationships reflect evolutionary relationships and genealogy fills niches then the different local habitat patterns from Figure 55, are definitive and the degree of symmetry of overlap using MacArthur and Levins overlaps can be estimated at $1:1 \pm 30\%$, showing that only QB:BB and GR:SR are symmetric at the biogeographic scale (Figure 57) based on local habitat and diet information. Therefore, despite their dietary interactions these related, morphologically similar species pairs maintain their broad scale sympatry through habitat difference.

CHAPTER 5: DISCUSSION

Habitat Pattern and Distributions

In streams, potential energy provided by the slope and hydrology of the watershed, produces discharge with increasing water flow downstream from headwaters. The energy provided by slope and discharge produces within streams, scale-independent processes of erosion, transport, and deposition or ETD (Figure 58). It is these processes that create major spatial features of physical habitat in streams from ephemeral creeks (e.g. riffle-pool-run) to large rivers (e.g. meandering and downstream transport of bedload). The result of ETD is spatial variation in energy and substrate particle sizes (Figure 59).

Meandering is a predominant pattern in flowing waters and is the manifestation of an open system at steady state (Leopold and Wolman, 1960). Einstein (1926) believed that erosion was greater at faster velocities where water contacted the bank, or more precisely the point at which velocity more steeply dropped to zero. Because energy can neither be created nor destroyed, it has a general tendency to change from a high to a low state (entropy) and meandering is a result of this tendency (Leopold, 1994). In meandering, water enters the bend, meets the bank and is forced down by deflection of flow (Figure 60). This causes a temporary coriolis effect that rotates lateral flow in opposition to the downstream direction of curvature shown in Figure 60. The bend curves clockwise, while secondary flow creates a counter clockwise rotation resulting in lateral particle sorting. The longitudinal flow direction remains linear, but repeatedly changes from laminar to circular in meandering. Thus most kinetic energy is bundled up

until it is redistributed again. The remaining kinetic energy is turned into erosion at the sediment interface through turbulence in a process analogous to heat loss (Leopold and Wolman, 1960; Leopold, 1994). In addition to meandering, downstream transport of bedload sediments is a dominant pattern with a temporal component related to annual discharge cycles e.g. spring to fall decreases in temperate streams (Jackson, 1975; Figure 61). Figure 61 summarizes patterns observed in the Assiniboine River and reported by Jackson (1975) from the Wabash River, Illinois. Sand dunes may develop on the bottoms of rivers that carry sufficient bedload under the right slope and flow conditions as discharge decreases through the season, adding complexity to meandering and substrate sorting. Such processes undoubtedly have subsidiary effects on benthic invertebrate communities, particularly in the scenario shown in Figure 61. The manner in which the sediment is reworked is determined by regional geology and local hydrology (Lotspeich, 1980; Frissell et al., 1986). These processes occur in all types of flowing bodies (Leopold, 1994), are characteristic of running waters, and predictable. Indeed, the ecology of lotic systems is a result of the interaction between hydraulics and the geomorphological features of the watershed (Margalef, 1960). Within watersheds energy results from gravity in small mountain streams to large meandering lowland rivers, wind fetch in lakes and oceans and also tides in marine bays and estuaries (Figure 62).

The ecology of running waters is linked intimately with the carbon cycle, its sources, processing, and assimilation along the upstream-downstream axis. It is well known since at least the late 1950's and early 1960's that upstream reaches

affect the downstream reaches, with respect to nutrients and structure (Margalef, 1960). The accumulation of biomass through productivity does not occur in the same reach as the productivity but progresses downstream through nutrient spiraling (Newbold et al., 1983) such that production to biomass ratio decreases downstream, with a concurrent increase in organic matter in deposited sediments (Margalef, 1960). These general patterns cause a downstream increase in the number of niches, but a decrease in the diversity within the niches (Margalef, 1960). These same principles were used to define the river continuum concept (RCC) which related hydraulics to longitudinal carbon processing dynamics in the stream basin (Vannote et al., 1980). Subsequent additions to these basic principles include: effects of large-scale flood disturbances such as that seen in the Red River of the North during the spring of 1997 when the river overcame its banks and in places reached widths of greater than 40 miles. A similar occurrence in the Ohio River led to the general foundations and predictions of the flood pulse concept (FPC) (Junk et al., 1989). The riverine productivity model (RPM) stated that the lateral variation in benthic invertebrate composition constituted a large enough difference to infer local autochthonous production as a significant contributor to riverine production (Thorp and Delong, 1994). None of these theories are mutually exclusive, but rather are both longitudinally additive and laterally concomitant in larger reaches downstream (e.g. meandering sections). Within the annual water cycle, and in the case of the FPC, infrequent large events may have lasting effects into the future. Using Figure 62, the RCC begins at A and develops downstream to C (Margalef, 1960; Vannote et al.,

1980). FPC may have significant effects in flood years particularly in reach C, affecting everything from establishment of riparian vegetation to fish production (Junk et al., 1989), while local autochthonous production discussed by Thorp and Delong (1994) in the RPM, may be a constant process in certain types of rivers from reach B through C.

Phylogeny and Fish Distributions

Catostomids are well-adapted benthic fishes, and except for BB, have a highly protrusible ventral mouth (Edwards, 1926). Catostomids have relatively high ratios of intestine length to body length and a flat ventral surface (Weisel, 1962). The anterior fin rays of paired and anal fins are widened and foreshortened where they contact the substrate and are used to maintain position, provide for lift, and are used during spawning (Lundberg and Marsh, 1976). Catostomids have an adapted food selection apparatus comprised of gill rakers and pharyngeal teeth. Eastman (1977) describes three basic groups based on the structure of the pharyngeal teeth and bones. The first group is comprised of the copper redhorse *Moxostoma hubbsi* Legendre and river redhorse *M. carinatum* Cope, which have 21-42 large molariform teeth and heavy pharyngeal bones used for crushing mollusc shells (Eastman, 1977). The second group (includes the remaining *Moxostoma*, *Cycleptus*, *Hypentelium*, *Lagochila*, *Catostomus*, *Chasmistes*, *Erimyzon*, *Xyrauchen*, and *Minytrema*) are benthic invertebrate feeders with 43-90 moderately compressed teeth arranged in a row on each pharyngeal arch (Eastman, 1977). The third group consists of

Ictiobus and *Carpionodes* which have 134-184 fine teeth and pharyngeal arches indicating they are microphagous feeders (Eastman, 1977). These morphological characteristics are key indicators of general ecology and phylogeny. The following interpretation is based on the idea that a species functional morphology will affect the distribution and interaction of each species with respect to their environment.

Component species abundance in a community reflects the relative breadth of the habitat or niche inhabited (Elton, 1927). In general, the distribution of species between aggregated and uniform states has profound effects on niche breadth (Angermeier and Smogor, 1995) as demonstrated by BB, QB, GR and SR in the present study. If biotic communities at small scales follow the natural survival of the component species (Margalef, 1958) then species are constrained by their morphology to a greater or lesser extent to inhabit some adaptive range (Lack, 1947) or “niche” *sensu* Hutchinson (1957). Two basic processes that define a niche are physical environment and intra/inter-specific interactions (Leibold, 1995). The former is deterministic and controlled by hydrology and geology, while the latter two are complex interactions among, biotic and abiotic factors at various spatial scales (Jackson et al., 2001).

A general pattern emerges, with respect to species-habitat associations, indicating that derived species (accepting Smith’s (1992) hypothesis) are associated with historical habitat types or substrates similar to those found in hypothesized regions of speciation. That is, the adaptations which made certain migration routes available may be the same adaptations, which make certain

habitats more 'preferential' in any given stream (extension of Smith, 1992). The Ictiobinae are distributed in central North America, inhabiting larger rivers of the interior (Scott and Crossman, 1973; Lee et al., 1980). These central rivers are low-gradient streams, flowing mostly over fine sediments. In contrast, the Catostomini and Moxostomatini are most widely distributed, respectively, in the western and eastern montane streams of North America (Scott and Crossman, 1973; Lee et al., 1980). Montane streams tend to be high-energy environments typified by high gradients and coarse substrates. If the evolution of these two subfamilies is indicative of adaptation to the physical energetics of higher gradient streams, the species distributions in the Assiniboine River may be a result of substrate; particle size distribution and flow being cues that invoke an adaptive mechanism for post-glacial physical habitat associations. GR collections have increased steadily since their initial discovery in 1985 (Franzin et al., 1986, Franzin and Watkinson unpublished data, present study). This combined with their absence from the Assiniboine River above the Portage la Prairie dam (Est. 1970) indicate that populations currently are increasing (i.e. they attained some 'critical mass' equivalent for population size and species expansion), even though they have been established for a long time in the Ottertail River, MN (Red River headwater) (L. Aadland, MN Department of Natural Resources Personal Communication) and upper Rainy River, MN (J. Hatch, Bell Natural History Museum MN Personal Communication; K. Schmidt MN Department of Natural Resources Personal Communication). The local increases in collections may be due to downstream dispersal and colonization

during high water years, combined with recent climatic changes in length and mean temperature of the growing season. It is apparent that there are many open niches available for colonization and abundant resources waiting for exploitation, particularly given that species richness of northern communities frequently is lower relative to more southern source fauna communities.

The disparate abundance values of the component species in this study is a pattern characteristic of most communities. The question of why the SHR ($n = 2072$) is so abundant while the closely related GR ($n = 110$) is so rare, cannot be answered at this point, however, several possible explanations exist. First, the northern distributions of the Catostomidae indicate that four of the six species (SR, GR, QB, and BB) are at the northern limit of their geographic ranges, and their abundance may reflect a geographic edge effect. While this explanation may hold true for the Moxostomatine and Ictiobine species, it does not hold for the WS. The Assiniboine River is in the center of the range of WS. WS is the most abundant and widespread species within its range and there is evidence of dwarf populations (Lafontaine and Dodson, 1997) in smaller tributary streams and even in some lakes. This suggests that among this group of Catostomid species, WS has the broadest habitat tolerance and therefore has greatest capacity to occupy diverse habitats, accounting for its broad post-glacial distribution. While other members of this species group, SR, SHR, QB, also occur in some lakes, none is as widespread in lakes as is WS. The presence of dwarf WS populations simply may reflect an independent phenotypic response to prevalent habitat conditions, and it has been suggested to have arisen in

sympatry with normal ecotypes (Lafontaine and Dodson, 1997). The larger river patterns of WS probably are related more to productivity than habitat specificity, given the phenotypic plasticity of this species.

A second possible explanation for the relative abundances of certain species is the importance of riverine habitats to post-glacial distributions of these species. Habitat associations could be a function of abundance of the individual species at the scale of the study, as alluded to by Angermeier and Smogor (1995). BB (rare and contagious) and SHR (abundant and ubiquitous) are two extreme cases in the present study. However, the abundance of the habitat categories also must be accounted for to understand species distributions. For example one might find 40% of the individuals of a species in “habitat A” which comprises 60% of the total habitat (by area), and 40% of the individuals in “habitat B” which comprises 20% of the total habitat (by area). Accounting for the relative abundance of the habitats, “habitat A” has a mean occupancy of 0.66 individuals per sample, while “habitat B” has 2.0 individuals per unit area. This kind of distribution becomes relevant if a large patch of under-utilized abundant habitat falls between small patches of over-utilized rare habitats that are well separated. In the Assiniboine River, the less abundant till-plain substrates are distributed in just that way.

Niche Analyses and Models

Stream fish communities have been well studied in relation to spatial and temporal associations (Sheldon, 1968; Gorman and Karr, 1978; Grossman et al.,

1982; Wright and Biehl, 1982; Herbold, 1984; Rahel et al., 1984; Yant et al., 1984; Grossman et al., 1985; Angermeier, 1987; Mayden, 1987; Mayden, 1992; Aadland, 1993; Angermeier and Smogor, 1995). Monophyletic groups of fishes have been used to infer different mechanisms and patterns of distribution including: eco-morphology, latitude, historical ecology, competition and co-occurrence (Gatz, 1979; Gotelli and Pyron, 1991; Mayden, 1992; Douglas and Matthews, 1992; Winston, 1995). Many of these studies were done in streams of southern North America, a region of relatively long-term biogeographic stability. As indicated earlier, fish communities of northern environments that were glaciated during the Pleistocene are in transition and therefore one might expect that species associations differ from more speciose assemblages from central parts of their ranges. This feature of northern communities makes them uniquely suited for the study of the mechanisms of niche partitioning and species interactions as they relate to community assembly. When combined with broad sympatry at the biogeographic scale, stable coexistence through niche segregation is assumed, given that species within-feeding-group pairs are sufficiently closely related and/or similar. Competition need not be restricted to pairs of phylogenetically related species; functionally similar species within guilds (as per Root, 1967) may exhibit competitive interactions. It is clear, short of inferring that competition is taking place through some form of core-satellite or dominant-subordinate (i.e. differential abundance of the six species), that further information is required to solidify 'competitive' interactions as an organizing principle here. However in a loose sense of competition (sensu Nicholson, 1954;

Brown and Wilson, 1956) similar species with similar requirements are bound to interact in scenarios where resources are abundant and likely to compete when resources become limiting (Zaret and Rand, 1971; Winemiller, 1991; Piet and Guruge 1997; Piet, 1998; Piet et al., 1999). Walker et al. (1999) showed that plant functional attribute redundancy provided an entire assemblage resistance to disturbance favoring stability through differential tolerances. Although a dominant species may decline with disturbance, the system diversity is maintained through subordinate compensation (Walker et al., 1999). This resilience explanation provides an alternative view of abundance differences within feeding groups and may simply indicate that during the recent history e.g. 10 years preceding data collection, conditions in the river favored SHR and QB over the other species from their feeding groups. Community resilience lends support to the 'super-organism' view that defines the community as a social organism adaptive through its own emergent properties (Clements and Shelford, 1939) but only in so far as interactions are an emergent property as species respond to environment.

Biogeographic distributions show that the Assiniboine River sucker species coexist at broad spatial scales, both currently and historically, with 6 or more interacting similar species being the status quo throughout North America (Figure 55) and especially this particular group (Figure 56). Biogeography is the largest spatial scale at which the niche is revealed and although local variability probably is large, some general patterns exist among north temperate fish assemblages which allow extrapolation from the local scale to larger spatial

scales. First, all species by definition are unique, but all species are not uniquely adapted, and homology thus acts to constrain related (or convergent) species to a greater or lesser degree to similar habitat types and similar resource requirements (Douglas and Matthews, 1992). Second, Tilman (1980) has shown that it is theoretically possible for several similar competitors to coexist in a heterogeneous environment. If niche segregation and/or coexistence are derived from some behavioral pattern (see e.g. Labropoulou and Papadopoulou-Smith, 1999) then coexistence depends even more on evolutionary adaptation and less on adaptive responses to interactions with competitors. Recently, Silvertown (2004) re-emphasized the importance of competition in structuring island communities, citing the monophyletic nature of some archipelago plant communities as evidence for a single colonization event, thereby inhibiting establishment of subsequent arrivals or pre-empting some portion of the available niches. Furthermore, Gotelli and McCabe (2002) re-emphasized Diamond's (1975) idea that communities had non-random assembly rules or rather they found support for the patterns upon which Diamond's rules were based. In light of the requirements for competition and niche differentiation to be a co-evolving mechanism, Connell's (1980) statement that historical legacy structures niche differentiation is as equally valid as the 'ghost of competition past' remains a fundamental issue in ecology.

Species Co-Occurrence, Overlaps, and Models

The merits and breadth of overlap indices have been discussed by several authors (Hurlbert, 1978; Abrams, 1980; Slobodchikoff and Schulz, 1980; Zaret and Smith, 1984; Holt, 1987; Linton et al., 1989); it is not the intent here to repeat these works, but to discuss some of the reasons for studying overlap. Species overlaps have been measured using several indices (Horn, 1966; MacArthur and Levins, 1967; Schoener, 1968; Pianka, 1973). Such studies often have been restricted to a single group of organisms and typically to smaller spatial scales, such as the niche or habitat (Pianka, 1973). MacArthur and Levins (1967) overlaps were a key development in studying niche dynamics, because they allowed an asymmetric measure of potential species-pair interactions based on species specific abundances and distributions. Most other indices are symmetrical estimates (Horn, 1966; Schoener, 1968; Pianka, 1973) meaning they produce a single value for a species pair, while an asymmetric overlap weights the overlap for each species based on their individual distributions. This is a great advantage for examining overlaps among sympatric species because it allows the interaction to be weighted along gradients, such as generalist-specialist. The ways that species partition resources in a community is a major determinant of both species diversity and coexistence (Pianka, 1974). Competition as a structuring mechanism of distribution and abundance of animals has led to some of the most fundamental ideas in ecology such as, character displacement (Brown and Wilson, 1956; Dunham et al., 1979), competitive exclusion (Hardin, 1960; Grime, 1973) and limiting similarity

(MacArthur and Levins, 1967; Abrams, 1983). These concepts have their basis in the idea that species will compete for resources given that resources are limiting. To allow coexistence of similar forms, species must partition resources along some niche axis, assuming that equilibrium can be attained. It has been suggested and shown under the niche overlap hypothesis (Pianka, 1972) that competition itself is inversely related to the ratio of resource demand to supply. It is further assumed that sister species are more likely to compete because they are the result of a more recent speciation event (Douglas and Matthews, 1992) and will not be different enough to exhibit specific niche segregation.

The species of suckers present in Manitoba have been interacting ecologically or, at least, have been sympatric, in glacial refugia and southern waterways for millennia. Because of this they provide an excellent opportunity to test some general ecological concepts, such as the expected patterns of non-equilibrium or equilibrium-type assemblages (Wiens, 1984). The idea that species' niches are determined through mutual co-evolution is axiomatic in ecological literature (Case, 1979). Strange and Foin (1999) acknowledged the physical environment as being important but they concluded that more focus has to be placed on biotic interactions in the assembly process. Biotic interaction requires that species co-occur. It is clear that the catostomid assemblage from the Assiniboine River demonstrate a combination of non-equilibrium and equilibrium characteristics. There is evidence of both species independence and significant interaction, if not competition, among WS, SR, GR, and SHR, even in an apparently unsaturated assemblage, as well as tight habitat patterns and few

stochastic patterns. The mechanisms determining the expected properties of equilibrium-type assemblages probably are historical (morphological adaptation) and probably are not driven by competitive interactions (co-evolution through competition), particularly considering that the assemblage is both unsaturated and resources are not limiting. The result for this recently colonized system is a combination of equilibrium-type properties (optimality, few stochastic effects and tight patterns) although not derived from competition and non-equilibrium properties (species independence, density independence).

There are pluralisms in biology (Beatty, 1994) from the importance of competition in ecological theory and/or the duality of the niche concept (Leibold, 1995). The ecology of stream fish assemblages has seen its own polarized arguments, particularly concerning species co-occurrence. Grossman et al. (1982) concluded that there was no long term stability in the most abundant species, over several years, and therefore the assemblage was not at equilibrium and was the result of random population flux. However, May (1972) suggested that, in a variable environment, natural systems have subsets of the community that are strongly connected through complimentary trophic and niche requirements. Herbold (1984), upon re-examination of Grossman et al. (1982), found by restricting assemblage inclusion to only interacting species, that Connell's (1978) niche diversification model fit best. The model states that diversity is a function of the total range of available habitats and of the degree of specialization of component species to parts of that range (Connell, 1978). The niche diversification hypothesis is given by Connell (1978) under equilibrium-type

diversity assumptions. Yant et al. (1984) found that there was a higher than expected 'constancy' of fauna and trophic group abundance across years, neither of which are considered characteristic of stochastic assemblages. These conclusions also are not characteristic of nonequilibrium communities but indicate that there is determinism in stream structure, which is a characteristic of equilibrium communities (Wiens, 1984). There are clear examples of niche segregation but whether they can be deemed centrifugal partitioning (i.e. determined by competition) remains unclear. When contemporary competition is important in regulating assemblage structure, negative associations should dominate, if in fact competition and niche partitioning are co-evolving. Most of the 'negative' or at least differential resource utilization occurs among more distantly related species. When many diverse families were used, genealogy filled niches. Therefore, by restricting analyses to within family, a more precise estimation of morphological controls on niche patterns may be attained (Douglas and Matthews, 1992). One obvious pattern in the present study (although not surprising) is juxtaposing QB with WS, GR, and SHR. This habitat 'dichotomy' is most certainly genealogical in nature and probably has little if anything to do with competition among these species. Character displacement has been documented in catostomid fishes (Dunham et al., 1979) but further examination of Assiniboine River species would be required to demonstrate similar mechanisms here. Winston (1995) analyzed a single subfamily (Cyprininae) and found that morphologically very similar species co-occurred less frequently than morphologically less similar species. He also determined that there was no

significant difference in co-occurrence between the most related pairs and the less related pairs. However, Winston did not include all species from all sites; only those that occurred at 5 or more sites were analyzed and only gut length was used as a general indicator of trophic ecology (i.e. no actual interaction was demonstrated). In addition, the rankings of several morphologically similar pairs were changed because of either disparate average size or gut length (e.g. *Pimephales promelas* and *P. vigilax*). However, the reasoning for their rank change is also likely the reason for coexistence i.e. sympatric sister taxa whose inter-specific differences likely are the result of allopatric speciation. Lastly, Winston's (1995) data was collected over a wide area and may reflect several different macroecological processes, among a fauna that had coexisted for a long time. The present work was carried out on a much smaller continuous reach of river bounded by a physical barrier at the upstream end, and on an assemblage that has existed in this area for less than 8000 years.

General and Paired Diet Comparisons

MacArthur (1972) theorized that when species interact weakly, communities are vulnerable to invasion by additional species, increasing interaction. However, when species interact strongly, they are vulnerable to extinction, reducing the interaction. The range between these weak and strong extremes must be robust to maintain coexistence among interacting species (MacArthur, 1972). These conclusions reflect an adaptive dynamism between and/or among sympatric species that often is perceived as being static (syn. at

equilibrium). Allopatric species are disconnected (*sensu* Hutchinson, 1961) and spatially distinct exhibiting no competition. Although, competition may occur in secondary contact scenarios, allopatric species are separated by physical barriers. Certain patterns from studies of island biogeography indicate that initial colonization leads to niche pre-emption given that dispersal is not limited (Silvertown, 2004). Conversely, species that have similar distributions and resource requirements represent the other side of the paradox. That is, they are so similar that short-term advantages simply do not have time to have an effect given environmental variability and the temporal requirements of competitive exclusion to occur. Similar species that interact constrain themselves as much as they constrain other species (MacArthur, 1972).

Given that there is a positive correlation of benthic invertebrate richness with habitats having larger stones (e.g. Hart, 1978; Douglas and Lake, 1994) the increased fish abundance found in these areas in this study simply may be a function of local productivity. Morphology suggests two possible, but not mutually exclusive, explanations. The first is that a pharyngeal apparatus adapted to feeding on “meiofauna” species (subfamily Catostominae) may make those species inefficient foragers in habitats that are dominated by microbenthos. On the other hand, microbenthic specialists (subfamily Ictiobinae) still are able to feed in sub-optimal habitats (e.g. among stones) simply by virtue of their filtration capabilities. The second explanation might be that deep-bodied species are less efficient in the shallower, faster water of 'till-type' habitats, while slender-bodied fish may be able to exploit a broad range of flow regimes more effectively.

Probably there is interaction of the two principles to be combinative and interactive with theoretical benthic invertebrate patterns in till-plain derived habitats. Another possible explanation related to feeding concerns the relative abundances of certain species. Although there is significant interaction and variability between feeding and species abundance, the most prevalent dietary items also are different among the species as are the relative mean and weighted mean abundances of those dietary items (Figures 36). The differences highlighted in Table 10 probably are due to species-level variation in habitat, for example, the dispersed distribution pattern of SR combined with the high relative abundance of *Axarus* sp. in the diet may reflect more selective feeding in ETD habitats. While GR was the rarest of feeding group 2 (see Figure 23) they had the richest average diet while SHR exhibited the narrowest mean diet of this group even though it was the most abundant species. GR has a large gape (Observation, data or what?) and feeds in productive TILL habitats having Elmidae living on top of gravel, while SHR has a small gape and feeds heavily on Hydropsychidae living under gravel. Although both species co-occur the relative proportions of the dietary items indicate that differences exist with respect to the way that substrates are manipulated and prey are captured and consumed.

Randomized and Multivariate Diet Analyses

Randomized average overlaps indicate that species diets are not random but highly selective. The within-feeding-group comparisons show that observed overlaps based on prevalence are greater than random, while between-feeding-

group overlaps based on prevalence were no different from random (Figure 38). The within-feeding-group overlaps based on abundance indicate than observed overlaps are not random (Figure 39). A striking feature is the degree of overlap among the within-feeding-group pairs WS, SR, GR with SHR and QB with BB. Although there is niche partitioning between SR and other within-feeding-group members as well as for QB and BB on the basis of local habitat differences, there must be some broader scale pattern in order to demonstrate support for an evolutionary mechanism. There is diet overlap between QB and BB, but they can be considered independent based on habitat differences. It appears Douglas and Matthews (1992) were correct in surmising that history drives niche and trophic structure, as demonstrated by the catostomid assemblage of the Assiniboine River.

The global optimization routine produced four feeding groups from six species (Figure 41), indicating further the degree of overlap within phylogenetic-based feeding group species pairs (Figure 37). The delineation of fewer feeding groups than species confirms the level of interaction and indicates either a certain degree of opportunistic behavior concerning fish and diet that relates to habitat overlaps or behavioral differences in prey capture (Figure 43). Behavioral responses to abiotic environmental factors (e.g. light) have been determined to be primary niche axes along which sympatric percids segregate (Bergman, 1988). Low overlaps are characteristic of species with differing foraging activity (Coelho et al., 1997; Bergman and Greenberg, 2003) and are most often representative of genealogy filling niches (see Douglas and Mathews, 1992; Piet

and Guruge 1997). Typically, within-family differences are more subtle such as position in water column (Mendelson, 1975) or prey size (Darnaude et al., 2001). Mendelson (1975) found that four species of cyprinids segregated space resulting in minimal diet overlaps and reducing competition in sympatric populations. It was determined for juvenile soleid and bothid flatfish that the two families ate the dominant benthic taxa and segregated by day and night foraging, but also within-family segregations during day and night foraging (Darnaude et al., 2001). Although it was found that within-family overlaps were higher, the results were not statistically significant, and it was concluded that the differences reduced competition and allowed the coexistence of four related forms in the same nursery zones even with similar periods of settlement (Darnaude et al., 2001). It has been shown for two sympatric species of *Mullus* spp. (Family Mullidae), that slight variation in diet, all else being equal, can be attributed to differences between specific behaviors of substrate manipulation (Labropoulou and Papadopoulou-Smith, 1999). Anecdotal and initial laboratory observations show that there is inter-specific variation in the way some *Moxostoma* species feed. Fin-flicking of gravel by *M. breviceps* and gravel rolling by *M. pisolabrum* (sister species of SHR) have been observed (Minckley, 1963). If a similar behavior is exhibited by SHR, then the increased abundance of Hydropsychidae larvae in SHR diets represents a case where this species has greater access to Hydropsychidae inhabiting interstices of gravel substrates, as a consequence of feeding behavior. The abundance and breadth of dietary items of WS and GR reflect the high food productivity of the lower Assiniboine and a more generalist

feeding strategy by engulfing substrates and extracting food. That is, larger gapes lead to larger substrate particle sizes available for engulfing and therefore potentially larger richness of invertebrates ingested. Previous studies on catostomid diets and interacting catostomids yielded similar results and general published diet information is broadly similar (Meyer, 1962; Minckley, 1963; Gatz, 1979; Yant, 1979; Beecher, 1980; Becker, 1983; Jenkins and Burkhead, 1993; Appendix A from Willink, 2002; Welker and Scarnecchia, 2003).

Concordance of Fish Diet and Benthic Invertebrates

Global optimization produced four groups of benthic invertebrates which showed variation in dominant substrate (Figure 44). The groups were indicative of the four fish feeding groups (Figures 43 and 45). The implication that habitat determines benthic invertebrate composition appears to be variable and requires further quantitative sampling and exploration. In tropical rivers niche partitioning often is demonstrated along very tight and/or distinct axes during periods of abundant resources (Zaret and Rand, 1971; Winemiller, 1991; Piet and Guruge 1997; Piet, 1998; Piet et al., 1999). In temporal streams partitioning is typically related to habitat classifications (riffle or pool) which are spatially explicit habitats related to hydraulic features. Certain properties of the system are reflected in the variable composition of the feeding groups. First, the planktonic-benthic prey items create an obvious niche axis (Adamek et al., 2003; Welker and Scarnecchia, 2003). These data lend credibility to the long held assertion that BB are plankton feeders, however, in the present study these dietary items were

recovered from stomachs with a significant amount of fine particle sediments, in addition to being recovered in benthic samples. Further data are required to solidify the role of benthic versus pelagic feeding for BB, but chydorid cladocerans are known to be benthic and several planktonic forms also are known to exhibit diurnal activity patterns. If this is considered along with the higher percentage of empty stomachs in BB and that BB from the Assiniboine River ate both forms of cladocerans there may be behavioral traits related to location and timing of feeding that further support centrifugal niche partitioning between QB and BB that go beyond simple habitat differences. Considering that there are four feeding groups and four benthic invertebrate groups that correspond fairly well it is concluded that six unique species foraging in the same habitat does not produce a mirror image that might be expected from the phylogenetic functional groups (Figure 23) but that variability in behavior and opportunism will produce increased overlap particularly in habitats that are highly productive. The lack of positive correlations between QB substrate and diet and BB substrate and diet is the result of poor taxon sampling by airlift sampler and the fact that habitats where cladocerans and copepods are abundant in streams may be more spatially explicit than a systematic random sampling design might detect. Correlations with substrate and diet for WS, SR, GR, and SHR were higher and indicative that the species were foraging in the habitats they frequented in high numbers (Figures 46-49). The variation is attributed to specific differences in gape size and the way species engulf prey and/or substrates with prey.

Biogeographic Richness, Sympatry, and Limiting Similarity

Biogeography is the science of distribution of organisms in the real world (Meyers and Giller, 1989). Macroecology is the study of partitioning of physical space and resources by species (Brown and Maurer, 1989). The two areas of biology are linked through the study of fish habitat associations and the functional niche concept. Species geographic distributions are a third inclusive process that defines the bounds of the Hutchinsonian niche. Although, most of the attention in macroecology of North American freshwater fishes has been with geographical range size and species size characteristics, such as length (Taylor and Gotelli, 1994; Pyron, 1999; Knouft and Page, 2003) characteristics of space (fish distributions) have been drawn on to infer speciation (Wiley and Mayden, 1985; Lynch, 1989). Distributions of contemporary fish communities depend on the historical continuity of habitat whether one examines drainages from the perspective of historical development (Gorman, 1992) or contemporary assemblage composition (Osborne and Wiley, 1992; Matthews and Robison, 1998).

A fundamental assumption of this thesis is that dispersal is a key factor allowing communities to develop over relatively short periods (e.g. 10,000 years) given connectivity and opportunity (Stewart and Lindsey, 1983). Indeed, the adaptive radiation of cichlids in the African great lakes is now believed to have occurred during the last ~7000 years, through sexual selection and sympatric speciation (Meyer et al., 1990; Seehausen, 2000; Lande et al., 2001). Ecological

factors are noted as important mechanisms in the recent speciation of sympatric stickleback species from British Columbia (McPhail, 1984; Schluter and Nagel, 1995; Schluter, 1996; Schluter, 1998). Present distributions are not necessarily indicative of speciation and/or species origins however, several distribution patterns of suckers are redundant and implicate involvement of vicariant processes in distributions (Wiley and Mayden, 1985). There are several instances of multiple dispersals and/or drainage captures in the Atlantic slope that have produced *M. pappillosum* and *M. collapsum* (Figure 6) and *M. sp.* "Carolina" (Figure 7) and the central highland distribution of *M. pisolabrum* and its limited post-speciation dispersal (Figure 8). Post-speciation dispersal of allopatric species pairs does not require that both species disperse. Ecological theory suggests that secondary contact after dispersal or contact inhibition may be a major factor determining resultant distributions (Bull, 1991). This may have created the parapatric boundaries in the *M. macrolepidotum* complex (Figure 8). Given the range of interactions that are possible, niche compression and/or compartmentalization is a likely scenario for these speciose communities (Winemiller, 1991). Ross (1972) suggests that diversity is proportional to both geological age of fauna and number of geographic disjunctions and reconnections (or ecological stability and geological instability). These are suggested for southern refugia given the distribution of richness of catostomids in North America (Figure 52) which peaks in the Tennessee River drainage which is home to many highly adapted and/or restricted species (Warren et al., 2000). In order for species to coexist at larger spatial and temporal scales in sympatry

there must be some stable mechanism whereby they remain cohesive propagating populations.

Members of three of the larger clades of catostomid fishes are present in northern waters: the subfamily Ictiobinae and the tribes Catostomini and Moxostomatini. In a group of closely related species (confamilial), homology combined with variable tolerances may act to confer stability on functional resource use (Walker et al., 1999). Species persistence can be limited both by internal and external factors such as minimum viable population size, predators, and parasitism (Bull, 1991). These factors also may limit the maximum population size for any one species, although specifically, in reference to parapatric distributions, the same factors pose limits for all species populations. Environmental instability may impose a limit on specialization and limit the similarity of competing individuals (MacArthur and Levins, 1967). Indeed local colonization and extinction is temporally dynamic in stream fish assemblages (Grossman et al., 1982). Disturbances influence species abundance through variable tolerance, but redundant forms or morphotypes represent buffers that allow assemblage function to persist (Walker et al., 1999). These properties allow diversity itself to act as a buffer for its own conservation while providing assemblage stability. Disturbances essentially are boundaries along which the adaptability of species is revealed. These processes in combination with competition presumably result in spatial patterns of related and/or similar forms. The drainage patterns of North American rivers has changed significantly since the hypothesized period of speciation for major catostomid clades (Smith, 1992),

the Missouri River flowed to Hudson Bay during the Pliocene as recently as 1.8mya (Wayne et al., 1991) and it is acknowledged that distributions are not necessarily indicative of a species' origins. Indeed, probably there were several extinctions and re-colonizations of northern watersheds due to glacial advances during the four recognized Pleistocene advances (Nebraskan, Kansan, Illinoian, and Wisconsinan). Furthermore several of the Manitoba fish distributions cannot be explained as simply as Mississippi, Missouri, or Lake of the Woods. GR for example exists in the upper Rainy River and has been reported in Lake of the Woods, but the absence of this species from the Assiniboine River above Portage la Prairie Dam (est. 1970) indicates a much more recent dispersal. That being said, there are several key concomitant patterns from southern regions among this diverse group of fishes to warrant using both distribution-type approaches to explore theory from speciation to ecological interactions. Examples include the central highlands of the Ozarks (*Moxostoma pisolabrum*), Atlantic slope drainages (*Moxostoma collapsum*, *M. pappillosum*, *M. robustum*, *M. sp. "Carolina"*), and Gulf coastal plain (*Cycleptus meridionalis*, *Erimyzon tenuis*, *Hypentelium etowanum*, *Moxostoma poecilurum* and *Scartomyzon sp. cf. poecilurum "Apalachicola"*).

If the visual representation of diversity by Juhász-Nagy (1993) is considered: point set (species list) to simplex (abundance of species) to V-complex (species interactions) to S-complex (topological tree) to A-complex ('real' space), an understanding of local and/or regional diversity is attained. There exists also an N-complex (N-dimensional hypervolume) alluded to by

Hutchinson that is defined by the cumulative local patterns of all A-complexes. An N-complex would have to be linked directly to both the evolutionary attributes of the species as well as watershed effects on the fish niche (i.e. habitat processes) in order to be definitive at the biogeographic scale, regardless of evolutionary mechanism. Given that Hypothesis X is accepted for most within-feeding-group pairs and Hypothesis XI is accepted for all within-feeding-group pairs, Figure 57 defines QB:BB and SR:GR as being symmetric associations that may have an evolutionary basis (i.e. they stably coexist as similar but remain ecological segregated). While the remaining species coexist and exhibit subtle dietary segregation, they also represent a greater potential for interaction based on their local interactions and geographic asymmetry. It could be hypothesized that in areas where resources are limiting, those pairs that are symmetric coexist with little or no interaction while remaining pairs may begin to exhibit negative associations more typical of competition-driven equilibrium-type systems. The habitat patterns in the Assiniboine River are determined by river meandering and similar habitats exist throughout the interior of North America in comparable streams; therefore extrapolation from this study to the broader distribution of catostomids seems reasonable, especially given that phylogeny and/or morphology appear to determine complimentary habitat use.

Evidence from parasite communities indicates that fish host species have characteristic and predictable parasite assemblages (Dogiel, 1964; Hålvorsen, 1971; Wootten, 1973; Leong and Holmes, 1981) that are maintained in northern waters through stable habitat and diet patterns, even at larger (biogeographic)

spatial scales (Choudhury and Dick, 1998; Nelson and Dick, 2002). In order for parasite communities to be re-assembled with the same species, entire trophic webs must maintain a relatively stable fauna and fish must exploit trophic webs in the same fashion. Such functional similarities must be based on natural mechanisms i.e. evolution and the innate behaviors of the component species.

CHAPTER 6: SUMMARY AND CONCLUSIONS

The hypotheses tested in this thesis (pages 14-15) reflect basic distributions of a catostomid fish assemblage in the local environment of the recently colonized (<10,000y) Assiniboine River, Manitoba. Specifically the following tests were completed: Hypothesis I (species habitat utilization is proportional to habitat availability) was rejected for all species (Figures 24-26) with the exception of SR with velocity which was not different than expected (Figure 25). This pattern became more evident once the spatial distributions of ETD and TILL habitats were superimposed on species abundance distributions (Figure 27). Hypothesis II (species habitat breadth is proportional to their abundance) was shown to have a general pattern for maximum niche breadth (Table 6) and evenness decreased with increasing species abundance (Figure 28). These data indicate that the habitat selection demonstrated from testing Hypothesis I, probably is maintained and as abundance increases there is a concomitant increase in range of habitat variables, but abundance still is patterned mainly around 'preferred' habitat types e.g. contrasting 115 GR with 325 WS, and 2072 SHR in Figure 27 shows the same basic pattern but increased encounters in upstream ETD reaches for WS and SHR as compared to GR.

Hypothesis III (species co-occur in relation to their abundance) was accepted for all combinations except for QB with WS, QB with GR, and WS with QB which showed negative associations (Figure 30) based on WS and GR being significantly more abundant in TILL habitats while QB were significantly more

abundant in ETD habitats (Table 5; Figure 27). Hypothesis IV (species from the same subfamily co-occur as often with each other as they do with random pairs of species) was accepted for some pairs, but rejected for other pairs. Based on longitudinal distributions (Figure 27) the high coincidence of GR with WS relates to complimentary use of TILL habitats, where they interact with SR and SHR irrespective of abundances. SR interacts consistently with SHR in both ETD and TILL habitats. QB and BB connected through complimentary diets, while remaining segregated by habitat. The results indicate the complexity that exists in co-occurrence data once interactions are accounted for. Within feeding group 2 (Figure 23) all species co-occur most frequently with conspecifics (Table 8) supporting the potential for species habitat 'preference'. However, based on the abundance of SHR alone there is potential for significant inter-specific interactions with other feeding group 2 species (Table 8). Interaction weights based on numbers of co-occurrences for WS (WS, SHR, SR, and GR), SR (SR, SHR, WS, and GR), GR (GR, SHR, WS, and SR), SHR (SHR, SR, WS, and GR) and QB co-occurrences with BB are rare. In all cases species co-occur most frequently with themselves followed by SHR. These results further suggest that these species are independent with no appreciable negative effects on habitat or diet selection that cannot be explained by basic functional morphology and phylogeny (Figure 23).

Hypothesis V (species that co-occur most frequently will eat the same food items in the same proportions) is accepted for the average WS, SR, GR, and SHR, as well as for QB and BB (Table 8; Figures 31, 32, and 36). Specific

differences exist as to highest mean abundance and weighted mean abundance (Figure 36) but most items were shared among co-occurring WS, SR, GR, and SHR. QB and BB shared a few core items (Figure 36) but the larger sample size of QB accounted for richer average diet (Figure 34), but these two species did not co-occur frequently together (Figure 27). Hypothesis VI (species from the same feeding group will have the same general diet and relative proportions of organisms in the diet) was accepted, but in this case similar morphology probably has more to do with diet overlap than co-occurrence, as evidenced from the randomization of co-occurrence i.e. not all species are positively associated based on co-occurrence (Table 8) even though they may share common habitat 'preferences' (Table 5; Figure 27). SR in particular had a very different distribution and perhaps even could be considered a habitat generalist (Table 5; Figure 27) having interactions that largely are by chance encounter (Table 8) while relative to other species encounters may be more than random and occur in productive TILL habitats frequented by WS and GR. Hypothesis VII (species that co-occur most frequently will have intra-specific to inter-specific overlap ratios ≈ 1) was accepted as all intra-specific interactions demonstrated a 45° angle or 1:1 ratio (Table 13). Average inter-specific interactions showed that WS ate a subset of the GR diet, SR ate a subset of the GR and WS diets and SHR ate a subset of the WS, SR and GR diets, while BB ate a subset of QB (Table 13; Figure 38). Although, SHR had the greatest habitat breadth and abundance it had the narrowest average diet richness within that feeding group (Table 10; Figure 34). WS ate all taxa recovered, but GR had the highest average diet

richness (Table 10; Figure 34). QB diet richness probably reflected a larger sample size compared to BB (Table 10; Figure 34). The lower relative richness and prevalence for QB and BB probably was due to highly aggregated 'preferred' prey items, and not specifically related to general feeding mode or life history (see discussion of Arrington et al., 2002).

Hypothesis VIII (benthic invertebrate distributions are not uniform and are dependent on habitat) was accepted (Figures 43 and 44). However, further development of the airlift sampler is required in order to achieve accurate abundance estimates for all invertebrates from all substrates. The predictable patterns of meandering and substrates (Figures 19-22) indicate that expected patterns of benthic invertebrates based on substrates may be determined by hydraulic sorting and discharge dependent factors affecting microhabitats.

Hypothesis IX (benthic invertebrate distributions and fish distributions are concordant with fish diet i.e. fish eat the organisms that occur in their dominant habitat) was accepted for WS, SR, GR, and SHR (Figures 46-49) but patterns remained unclear for QB and BB (Figures 50-51). Both mean and weighted mean abundance of diet items varied among WS, SR, GR, and SHR indicating that there may be subtle differences in the specific feeding behavior that could account for differences considering how frequently these species co-occurred. Anecdotal observation from clear water streams that indicate WS and GR take a mouthful of sediment, strain out benthos and eject sediment either by mouth (WS observation in lab) or opercular ejection. Observations of QB feeding on sand indicate they feed in a similar manner, but by removing smaller organisms from

finer sediments (Franzin Personal Communication). SHR may have fin-flicking or rolling of gravel sized stones, similar to sister species, which could very well account for the high prevalence and mean abundance of Hydropsychidae larvae in the diet.

Hypothesis X (if biogeography reflects the n-dimensions of the Hutchinsonian niche and genealogy fills niches, then local overlap will be positively related to geographic overlap through similar morphology and history) was accepted for all within-feeding-group pairs except QB:BB and SR:GR (Figure 55). While Hypothesis XI (local diet will be negatively associated with geographic overlap in order to support co-existence at such a broad scale through centrifugal niche partitioning) was accepted for all within-feeding-group pairs (Figure 56). Hutchinson's assertion that similar 'connected' species will segregate based on feeding was borne out for all within-feeding-group pairs. However, the mechanism causing partitioning cannot be determined as being adaptation or resulting from competition. Hypotheses X and XI combined with MacArthur and Levins overlaps (Figure 57) indicate some within-feeding-group pairs exhibit local ecological segregation that can be considered a mechanism to explain symmetric and stable coexistence at the biogeographic scale. Although the mechanism for the segregated habitat use remains undetermined, the lack of negative associations at the local scale indicates competition is minimal favoring an adaptive or morphological explanation.

The single most difficult problem encountered in developing this thesis was framing hypotheses based on ecological theory as opposed to a null model

based on randomness as the H_0 . In order to address specific patterns of the equilibrium-nonequilibrium continuum several hypotheses were required making a multi-analytical approach necessary. The methodology employed contributed to the predictability of benthic stream fish assemblages in meandering rivers as well as improved our understanding of how the niche and biogeography are connected. While the results of this study are limited to this group of fish, the approach has wide ranging applicability. In general this thesis contributes to several aspects of management and ecology that range from the general to the specific.

First, habitats are linked through energetics whether the environment is a low order headwater stream, a meandering river like the Assiniboine, or a lake. The patterns highlighted for the Assiniboine River are the same patterns and processes ongoing in all meandering rivers. By taking a process based approach to habitat, food, and biogeography two typically separate perceptual scales (A-complexes and the N-complex) are linked through predictable patterns of riverine habitat at local scales. Habitat processes lead to redundant spatial patterns of instream habitat and although species (both fish and invertebrates) are not necessarily predictable, they represent stable functional associations governed by predictable habitat processes. In linking the niche to habitat it is clear why there is a duality concerning the perception of the niche (see Leibold, 1995) but also why that duality is all perception. That is habitat is more than the abiotic physical space where organisms live, it is the boundary where the abiotic and biotic merge to define the niche.

Second, the classical approach for calculating WUA employed in IFIM studies (i.e. habitat variable utilizations being treated as independent) leads to a gross over-estimate of niche breadth. This specific issue has far reaching ramifications for management practices considering the national and international use of IFIM and WUA. In particular, considering the current legal issues tied to habitat management through the Canadian Fisheries Act and Productive Capacity initiatives, as well as the Canadian Species at Risk Act. These issues highlight a very important duality in science, that between theory and application. In striving to be all inclusive through definition (see page 9) fish habitat has proved a very difficult ideal to study in application, but an ideal that can be addressed appropriately once hydraulic processes among scales of perception (i.e. habitat) are recognized as fundamentally the same.

Third, the idea that assemblages represent some stage of development between equilibrium and nonequilibrium has deep roots. However, it is clear that in this recent assemblage that different species have different strategies that range from random to highly specific. This thesis supports the views of Connell (1980) that historical legacy may very well be a dominant factor determining many, if not all of the equilibrium-type patterns exhibited here. The lack of negative associations aside from genealogical, indicate that competition plays a minimal role. It is likely that with increased species richness this assemblage would show the same pattern that Gatz (1979) found, more species would simply use more of the available resources as opposed to exhibiting niche compression and/or displacement.

Finally, the idea that local overlap relates to biogeographic sympatry is a logical extrapolation of the ecological and parasitological literature and probably is borne from the same line of thought that led fisheries researchers to seek answers regarding transferability of habitat preferences. However, the idea that local overlaps of habitat and diet can be used to infer symmetric-asymmetric types of biogeographic patterns is a novel synthesis that has several broader implications for ecological biogeography. In particular Figure 57 can generate new hypotheses regarding the relationship between ecology and biogeography in the absence of any local knowledge. Indeed MacArthur and Levins overlaps could be used infer expected types of ecological associations among sympatric taxa or even speciation processes much in the same fashion as Lynch (1989) used sympatry and relatedness to infer speciation patterns among sister taxa.

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FIGURES



Figure 1. North American distribution of 81 described and tentative species of Catostomid fishes (compiled from Jenkins, 1970; Scott and Crossman, 1973; Lee et. al., 1980; Burr and Mayden, 1999; Bart et al., in review; Suttkus and Bart, 2003).

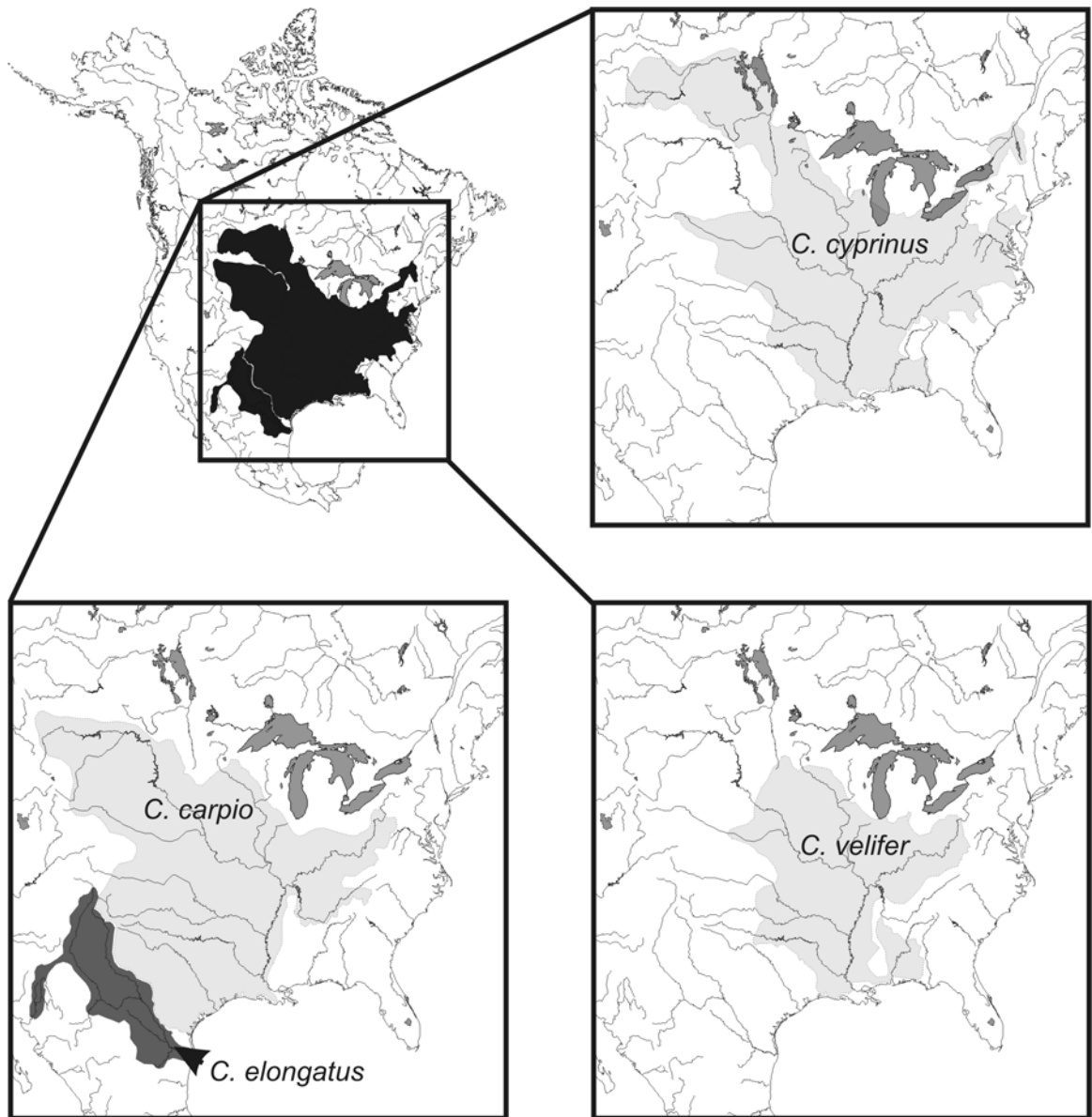


Figure 2. Combined and individual distributions of the four *Carpiodes* species in North America.

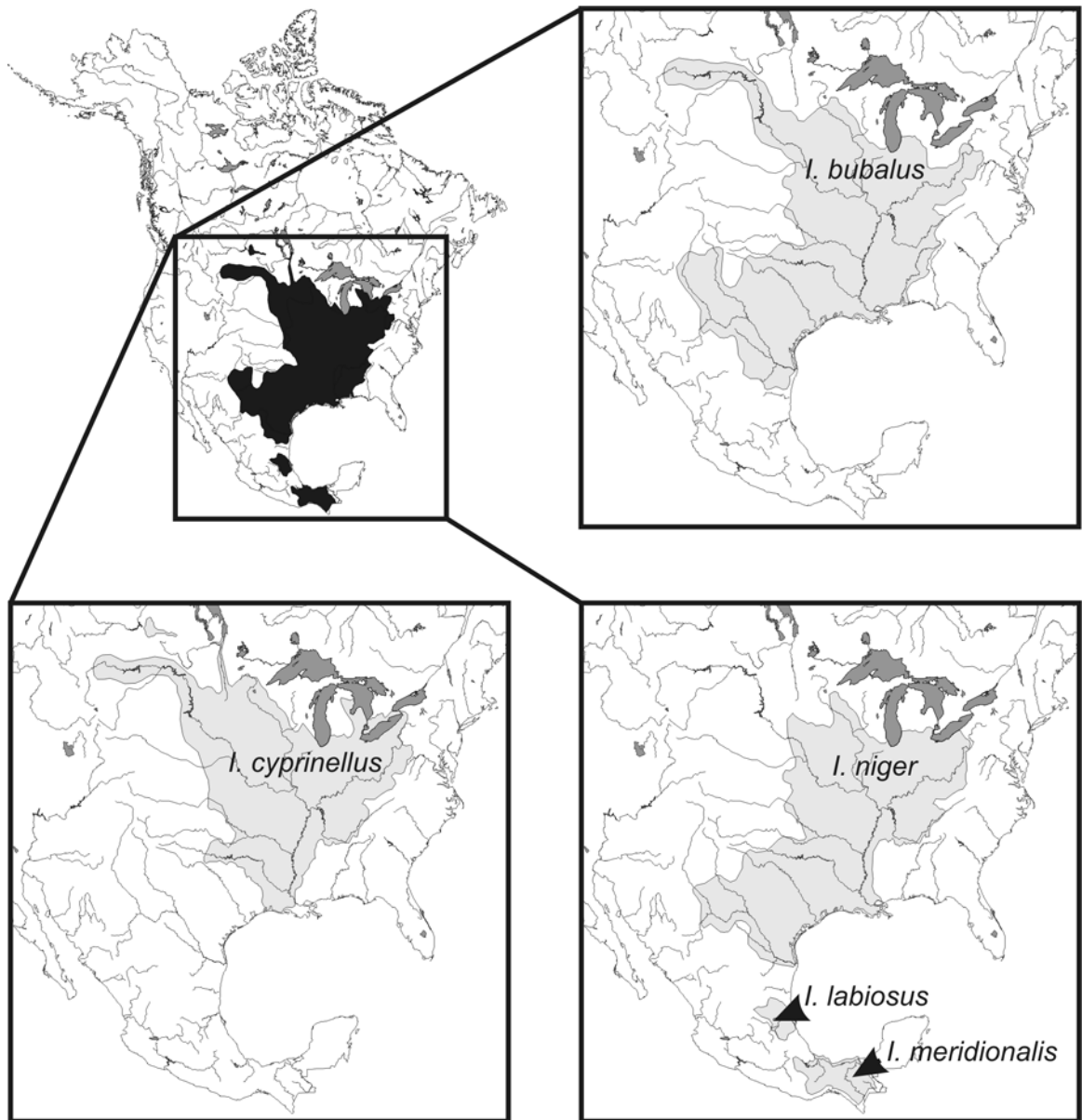


Figure 3. Combined and individual distributions of the five *Ictiobus* species in North America.

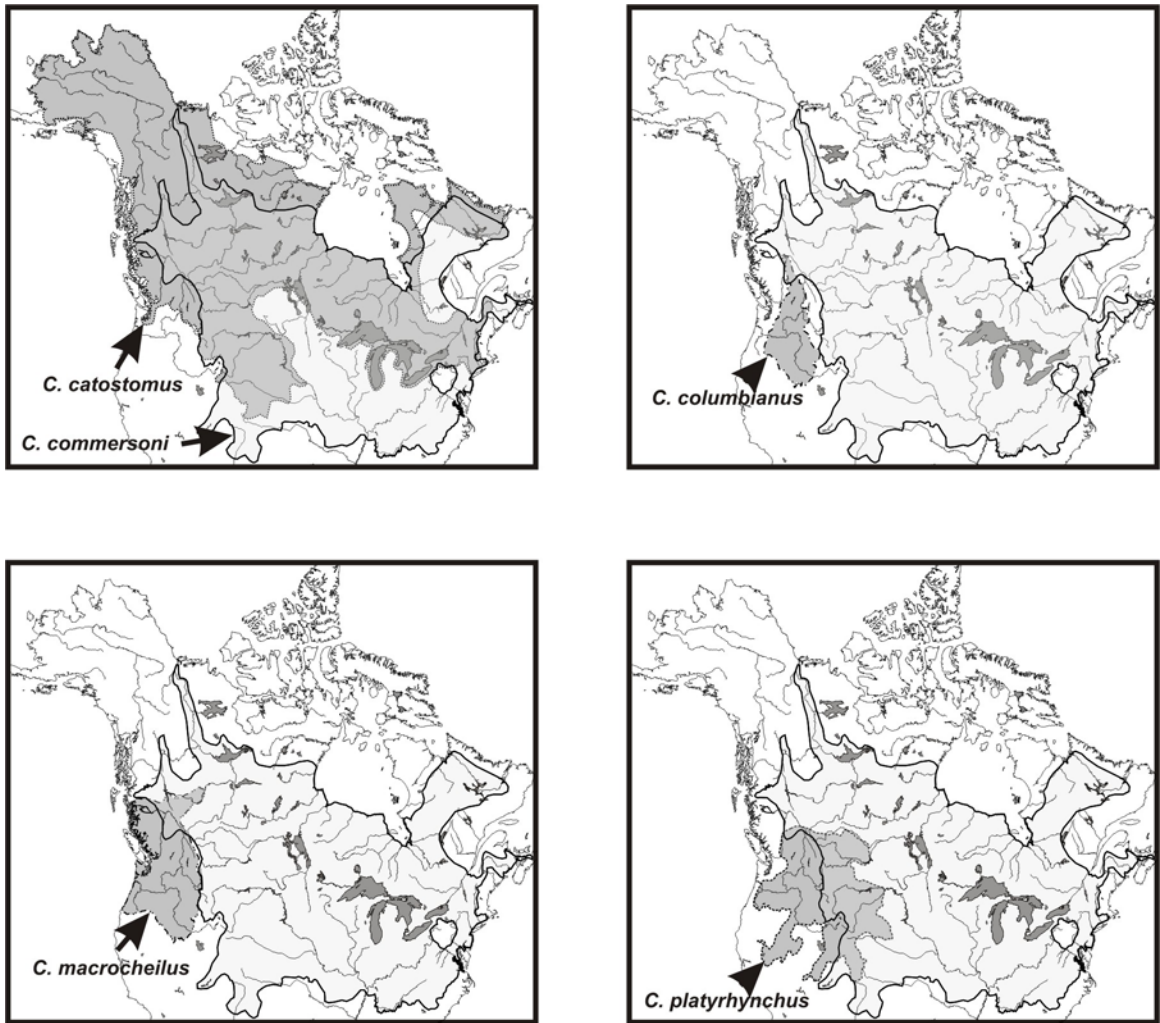


Figure 4. The distribution of *Catostomus commersoni* (solid line) in North America. All sympatric *Catostomus* spp. are shown. Extensive overlap with *C. Catostomus* throughout northern extents of range, in eastern slope montane drainages with *C. platyrhynchus*, and a few drainages of northern British Columbia with *C. columbianus* and *C. macrocheilus*. *Catostomus commersoni* does not occur in the Pacific northwest and southern British Columbia where other species shown are sympatric.

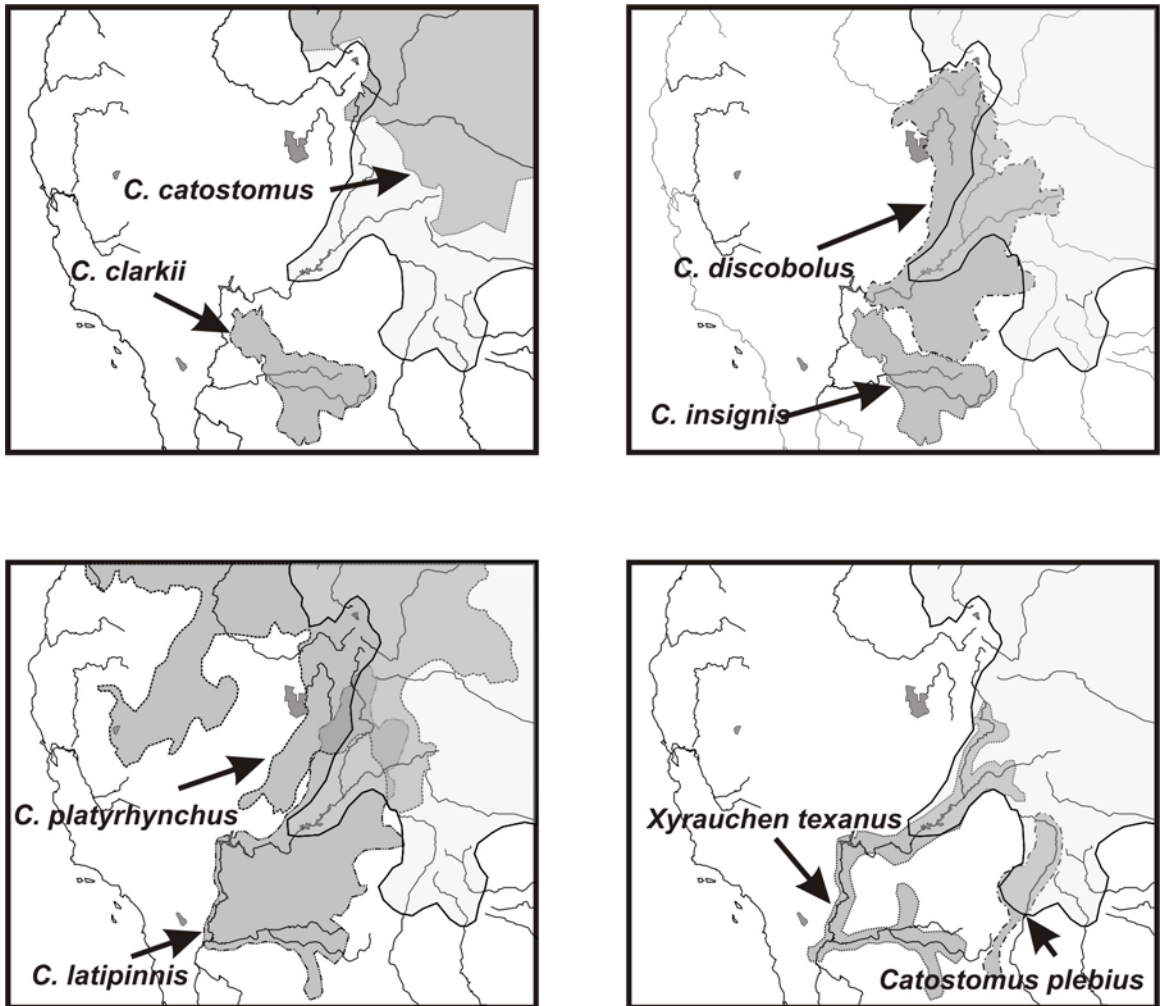


Figure 5. The distribution of *Catostomus commersoni* (solid line) in southwestern North America. All *Catostomus* spp. plus *Xyrauchen texanus* are shown. Most overlap is restricted to upper reaches of the Colorado River drainage and eastern slope drainages. Both *C. clarkii* and *C. insignis* are shown to highlight the drainage restrictions and 'endemism' of the catostomini in great divide and western montane drainages.

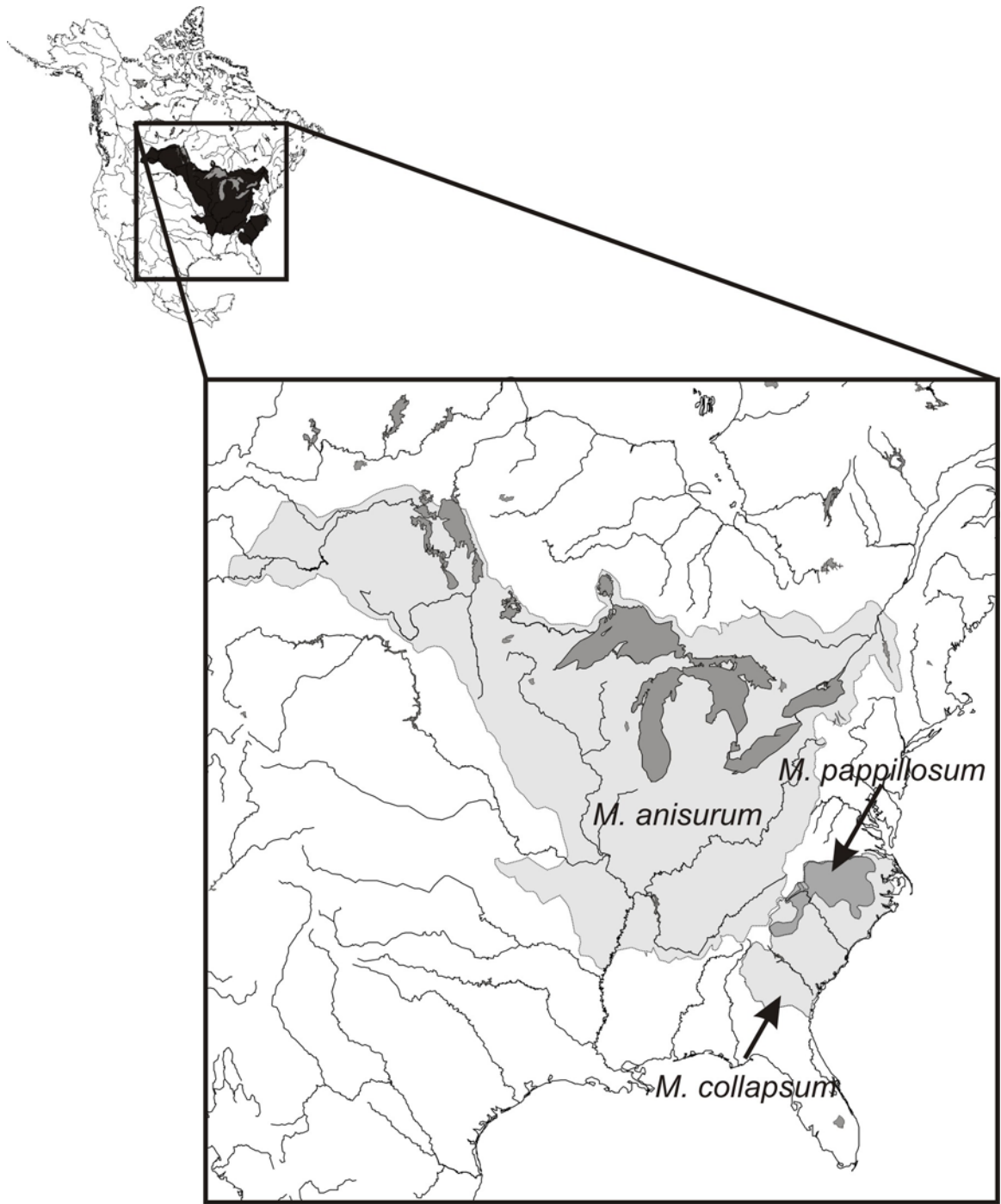


Figure 6. Combined and individual distributions of the three *Moxostoma* species of the "anisurum" complex in North America.

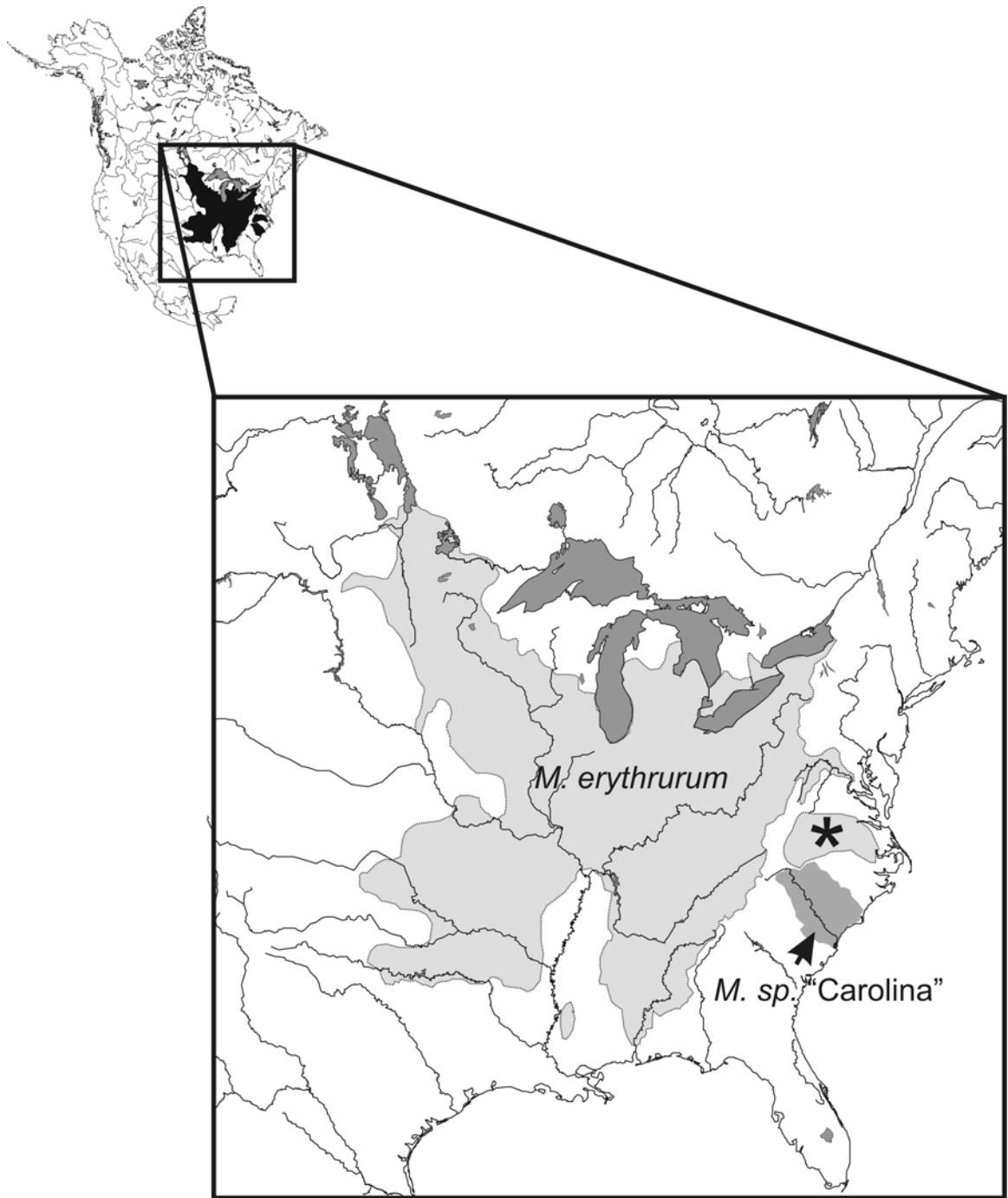


Figure 7. Combined and individual distributions of *Moxostoma erythrurum* and *M. sp. "Carolina"* in North America (* denotes distribution of *M. erythrurum* in Atlantic Slope drainages).

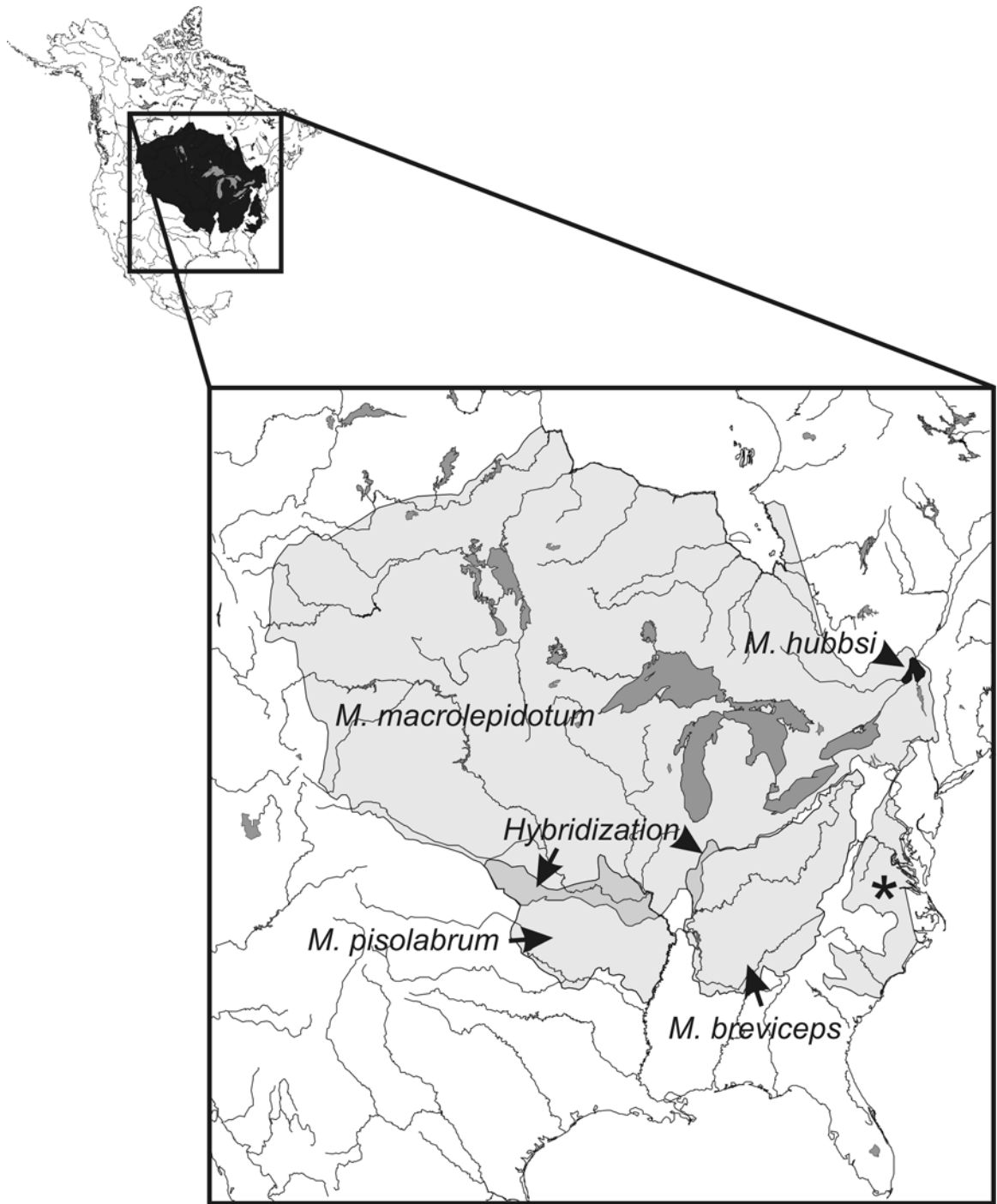


Figure 8. Combined and individual distributions of the four *Moxostoma* species of the “*macrolepidotum*” complex in North America (* denotes distribution of *M. macrolepidotum* in Atlantic Slope drainages).

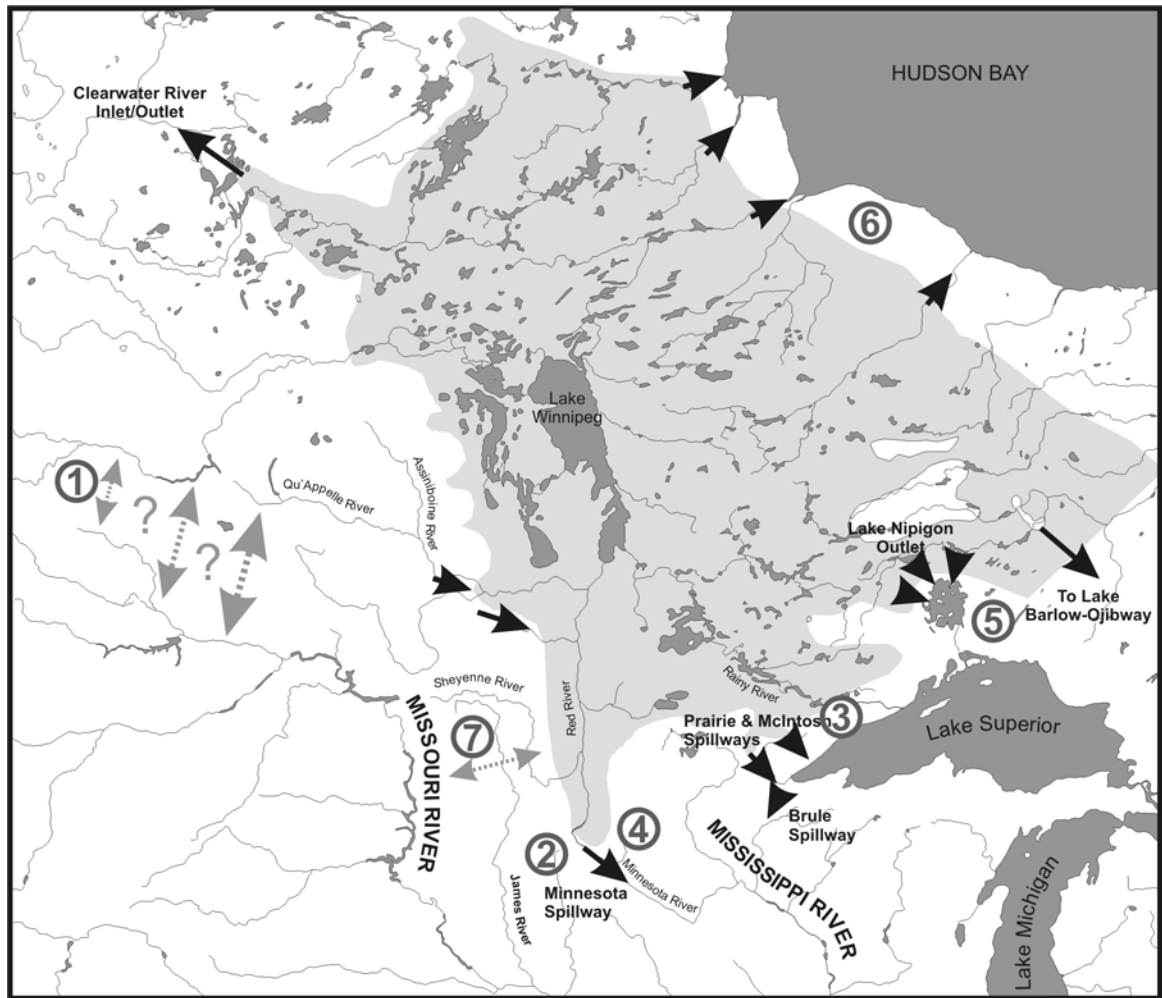


Figure 9. Composite maximum extent of glacial Lake Agassiz, arrows indicate known inlets/outlets (modified from Franzin et al., 2003; after Teller and Thorleifson, 1983). 1) Southward flowing meltwater 12500BP. 2) First access into glacial Lake Agassiz through Minnesota Spillway 9900-9500BP. 3) Prairie & MacIntosh Spillways connecting upper Mississippi and Lake Superior to Upper Rainy River 8000BP. 4) Final Minnesota Spillway connection 8000-7500BP. 5) Lake Nipigon drainage closed Minnesota Spillway 9500-8500BP. 6) Final drainage of Lake Agassiz into Hudson Bay through Churchill, Nelson, Seal, and Hayes Rivers 7500BP. 7) Missouri meltwater exchange for a long period.

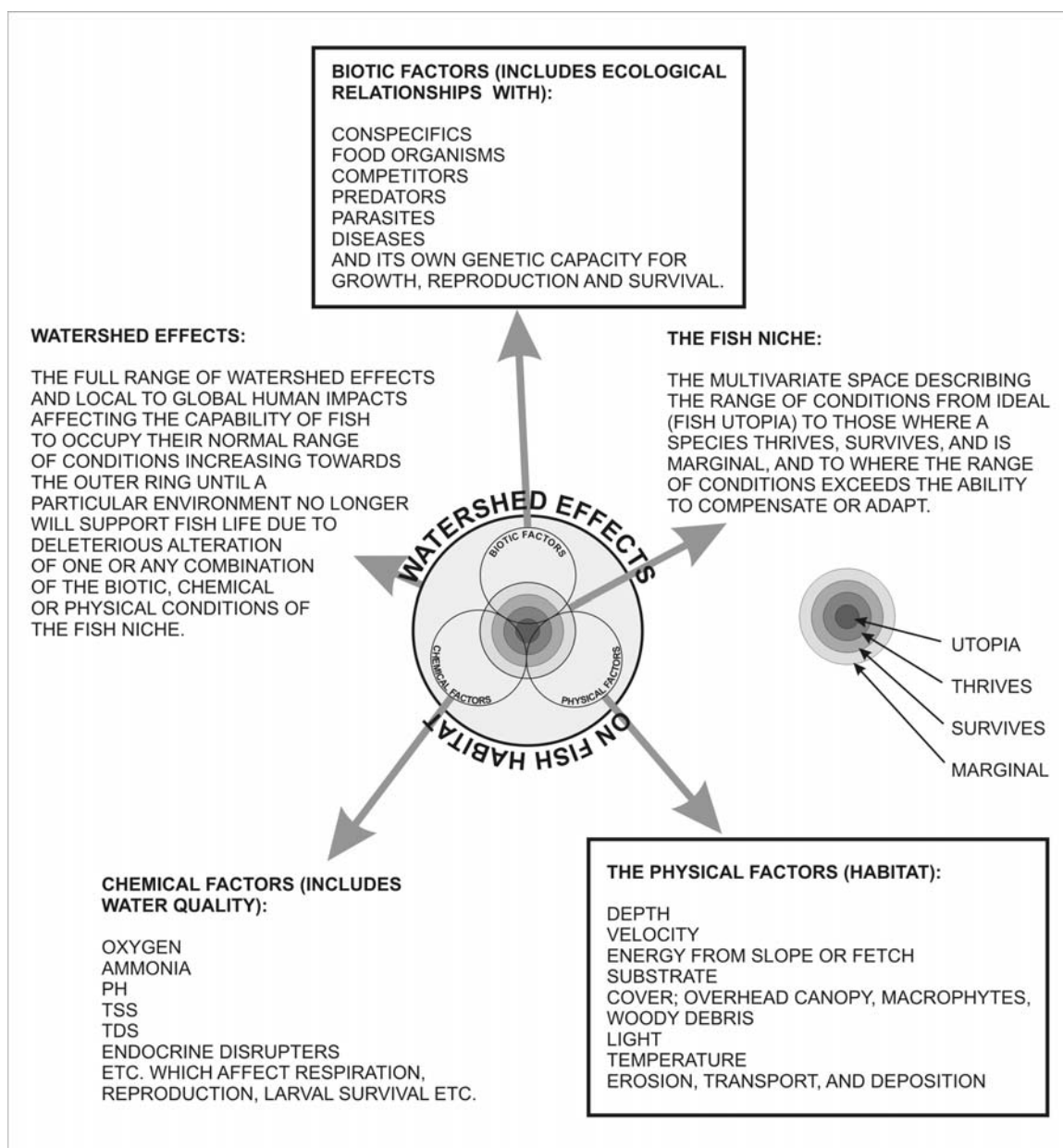


Figure 10. Conceptual representation of the fish niche at the watershed scale highlighting biotic, physical and chemical factors that affect the fish niche within watersheds (after Franzin et al., 2002). Boxes highlight factors in relation to the niche are specifically addressed herein.

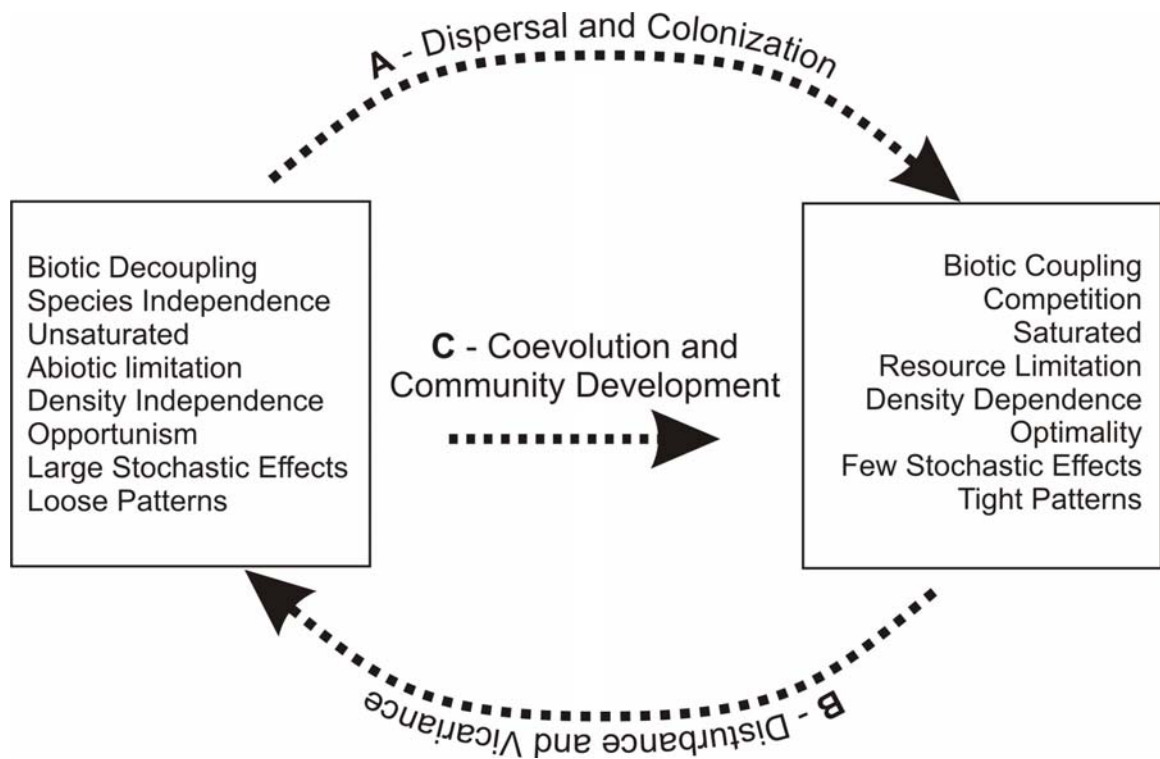


Figure 11. Theoretical expected properties of non-equilibrium and equilibrium communities given by Wiens (1984) with three developmental processes: A) Dispersal and colonization increase saturation and competition; B) Disturbance and vicariance reset biotic coupling through fragmenting diversity; and C) Long-term community stability with coevolution and endemism. North temperate assemblages are currently undergoing a dispersal and colonization phase following the Wisconsinan glaciation.

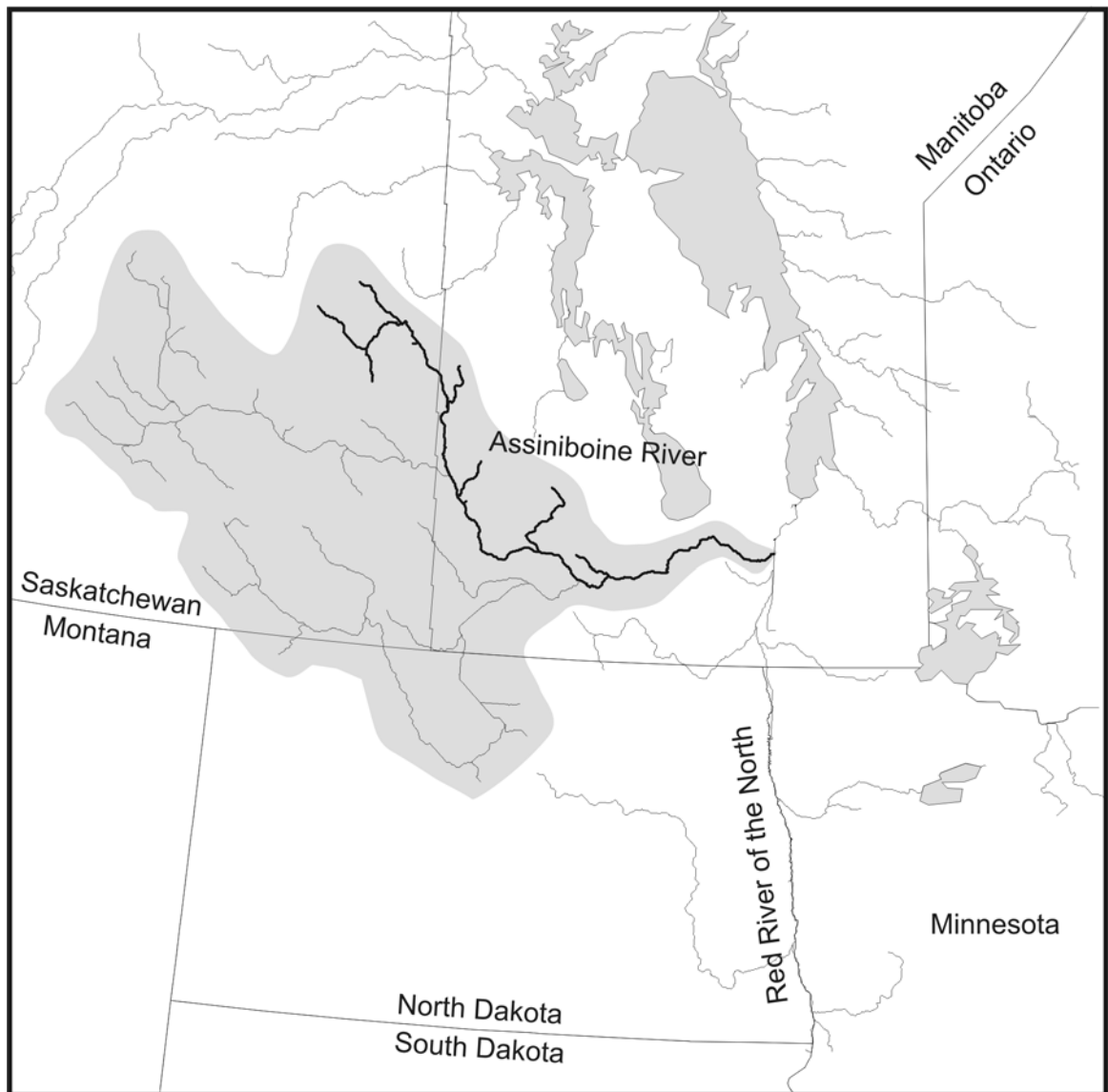


Figure 12. Location of the Assiniboine catchment highlighting its location within the Hudson Bay drainage.

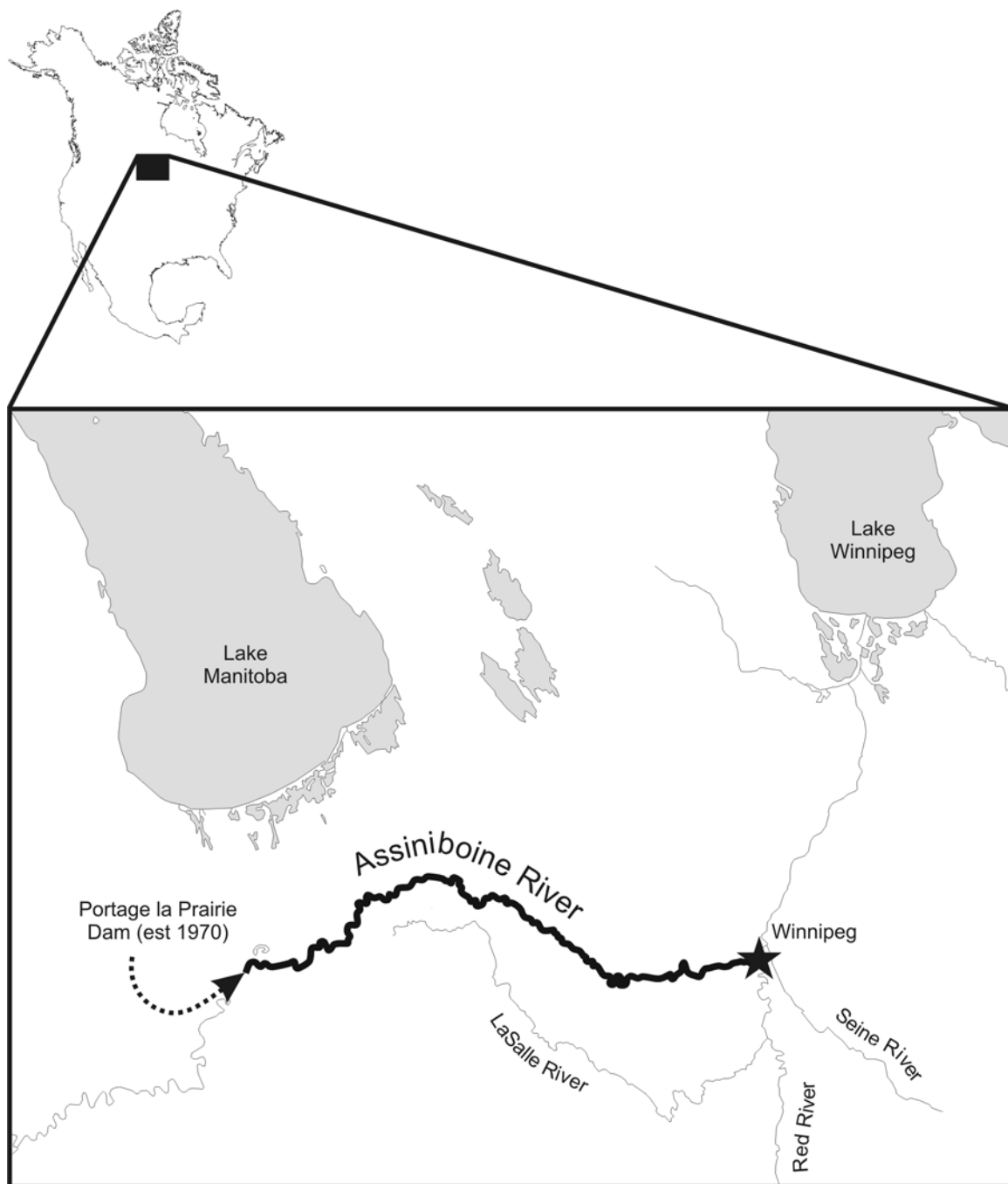


Figure 13. The 160km study area between Portage la Prairie dam (est. 1970) and the Red River of the North at Winnipeg.

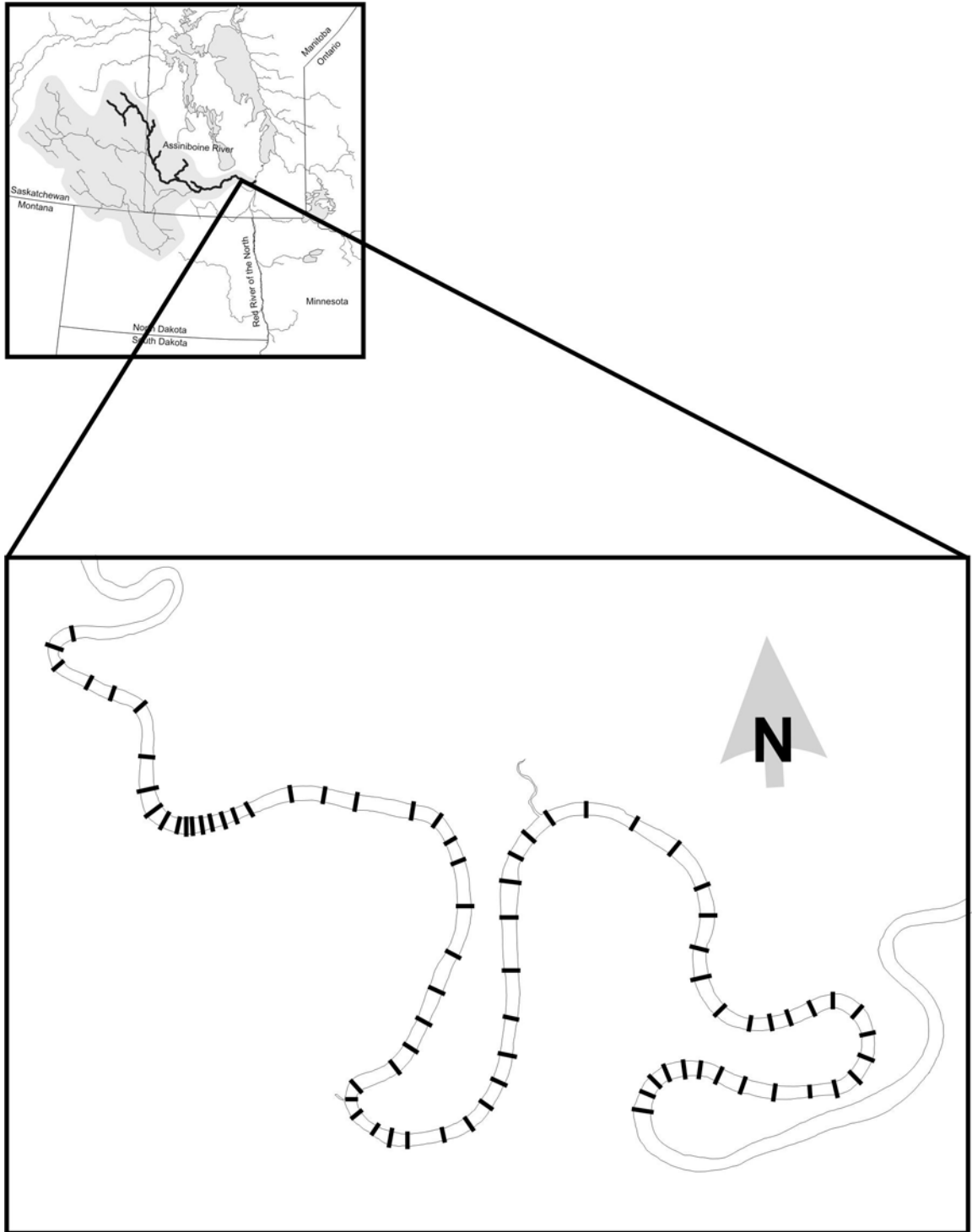


Figure 14. Location of 77 cross-sections measured during 1999 and 2000 between the DFO Lido Plage IFIM site and Beaudry Park boat launch.

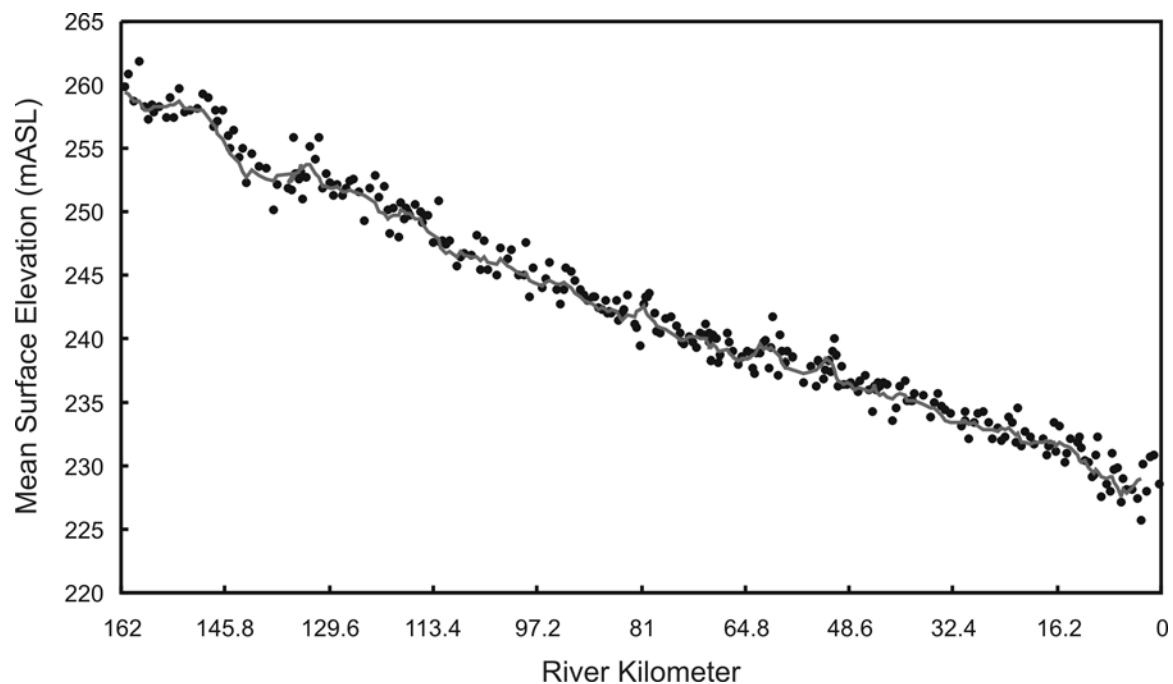


Figure 15. Mean surface elevation between Portage la Prairie Dam (162) and Red River at Winnipeg (0). Data are mean values from a 200m radius around the center of each of the 272 arcs.

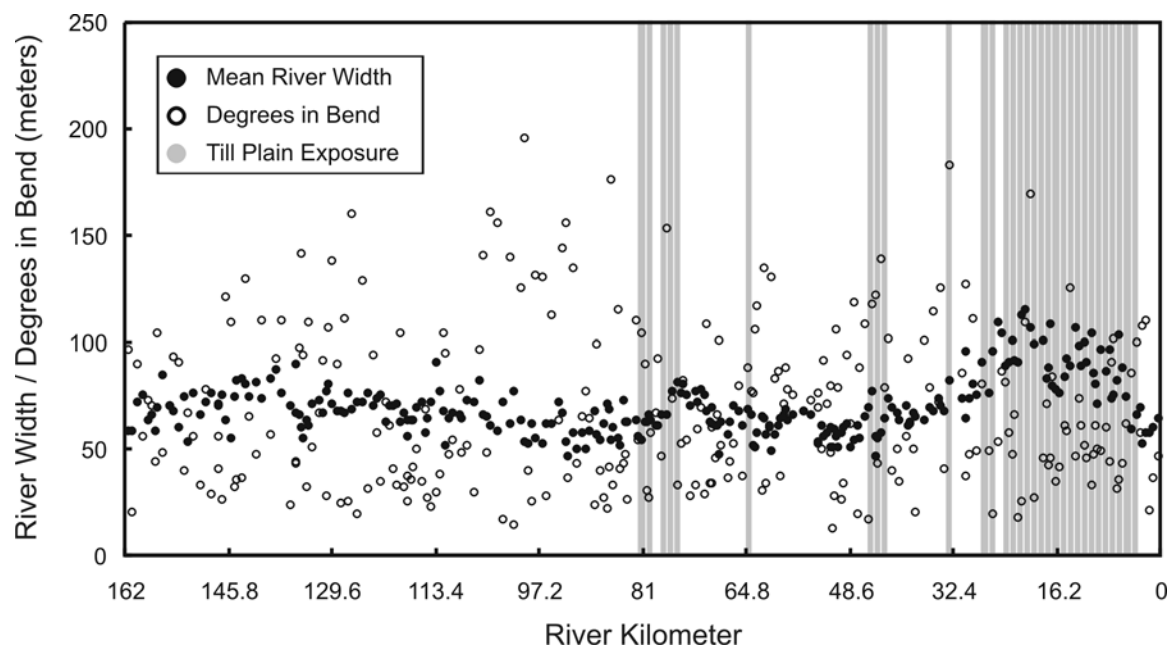


Figure 16. Mean river width, degrees in bend, and location of TILL exposures between Portage la Prairie Dam (162) and Red River at Winnipeg (0). Data are mean width values at three locations along each of the 272 arcs and observed degrees in arcs.

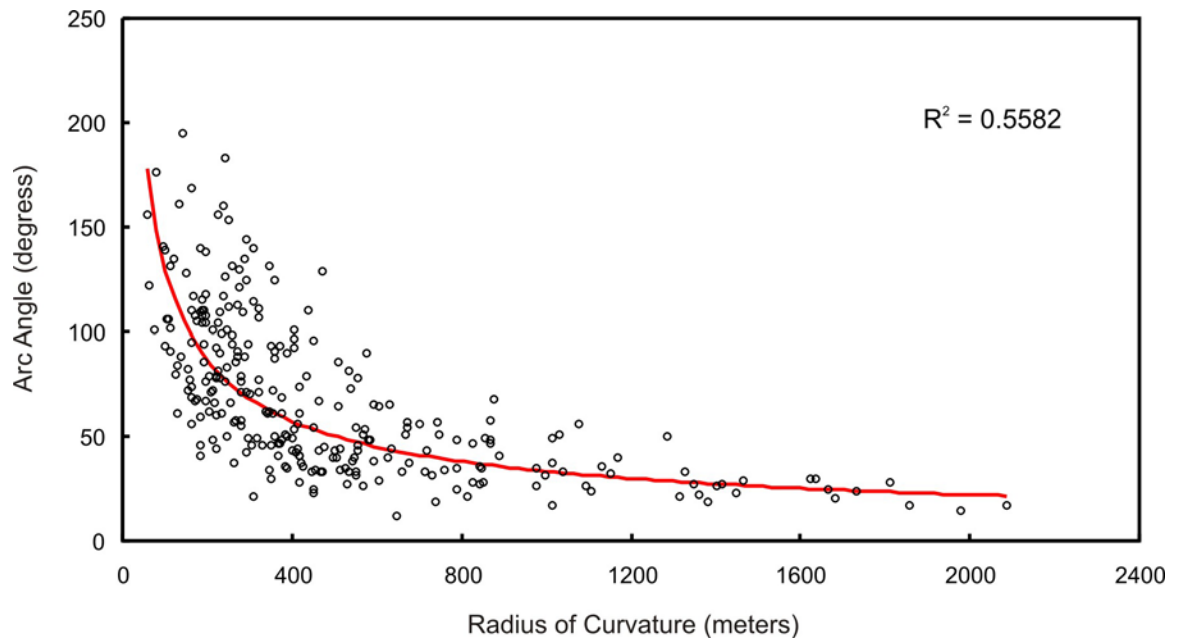


Figure 17. Arc angle with radius of curvature for 272 arcs measured between Portage la Prairie Dam (162) and Red River at Winnipeg (0).

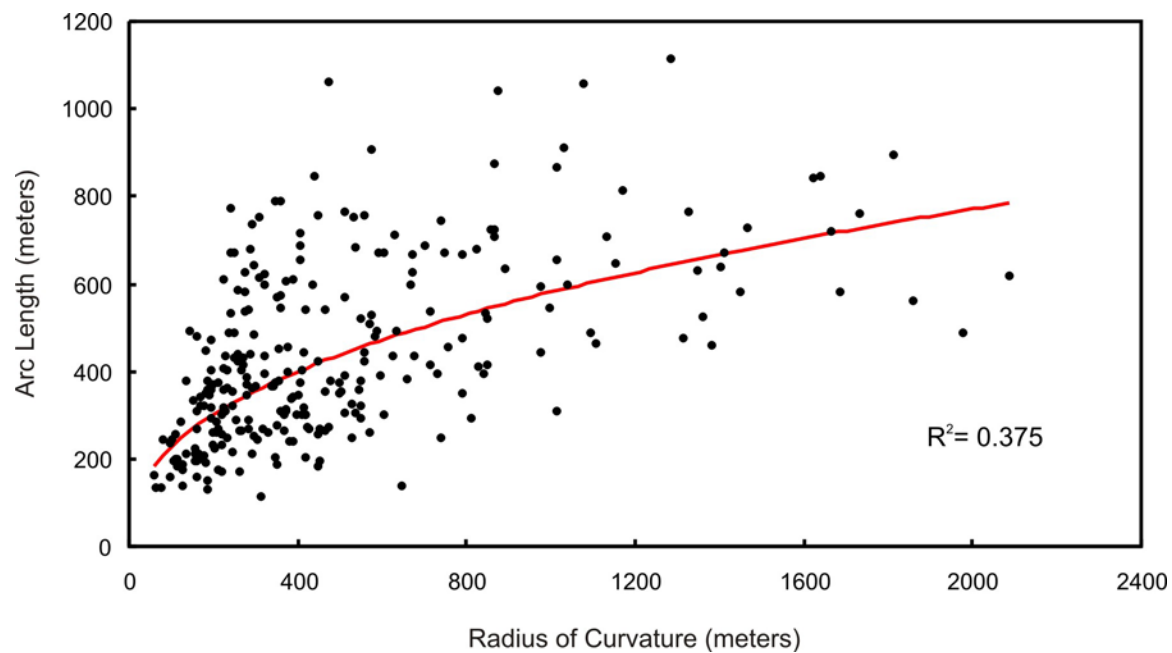


Figure 18. Arc length with radius of curvature for 272 arcs measured between Portage la Prairie Dam (162) and Red River at Winnipeg (0).

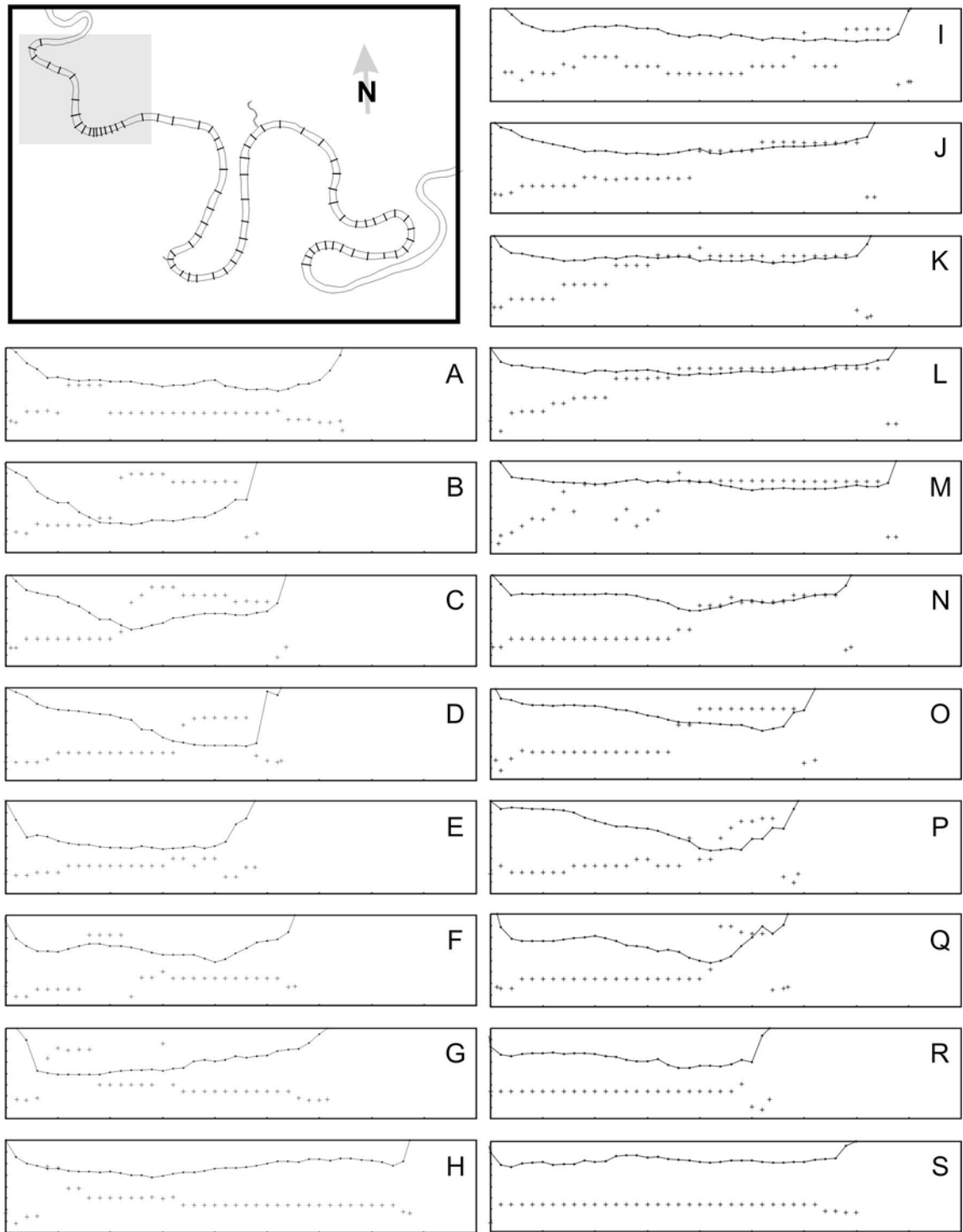


Figure 19. Stream width, depth profile (line) and mean substrate particle size (cross) from left bank to right bank (looking downstream) for the first 19 cross-sections. Cross-sections downstream from A to S. River widths (X-Axis) range from 0 to 90m and river depth (Y-Axis) ranges from 0 to 4.0m.

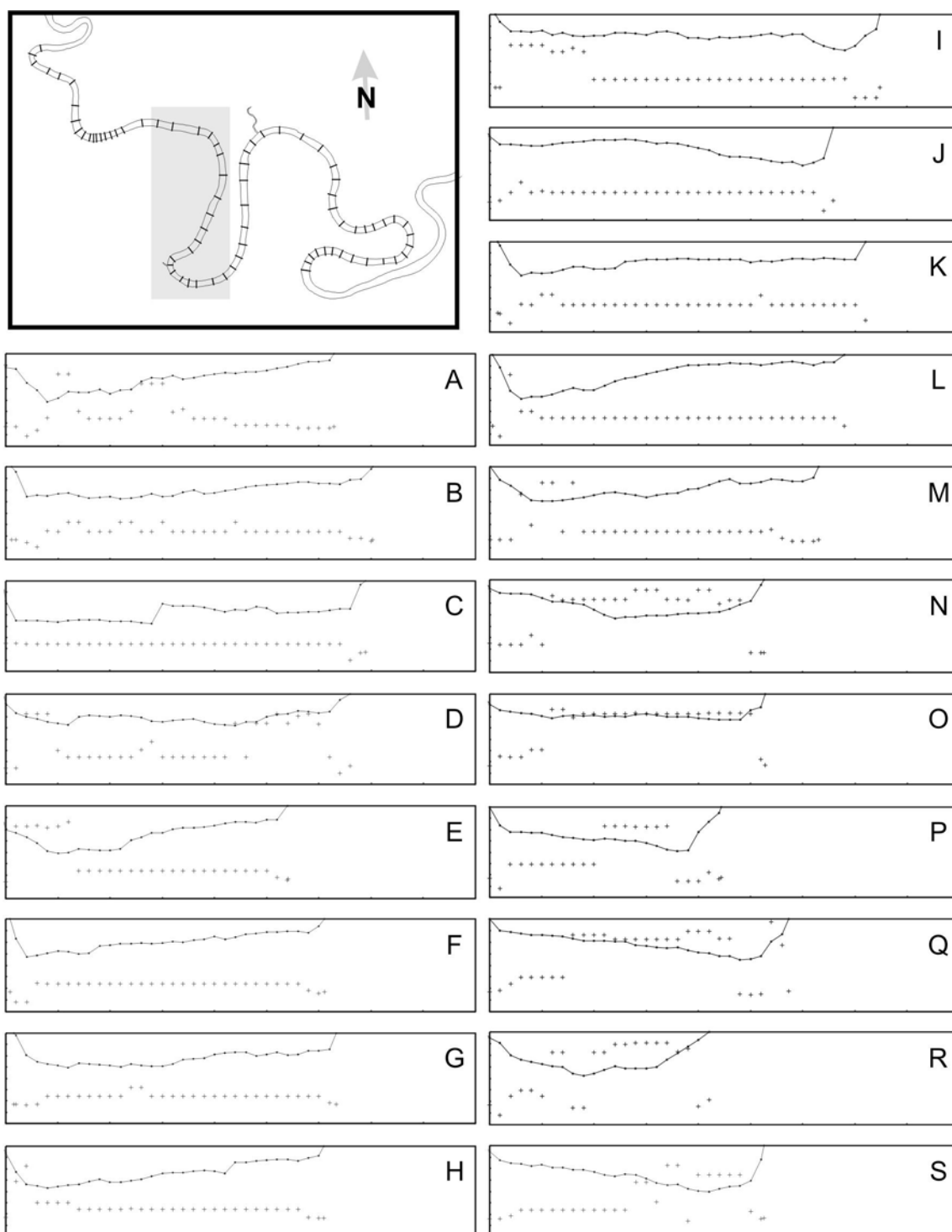


Figure 20. Stream width, depth profile (line) and mean substrate particle size (cross) from left bank to right bank (looking downstream) for the second set of 19 cross-sections downstream from A to S. River widths (X-Axis) range from 0 to 90m and river depth (Y-Axis) ranges from 0 to 4.0m.

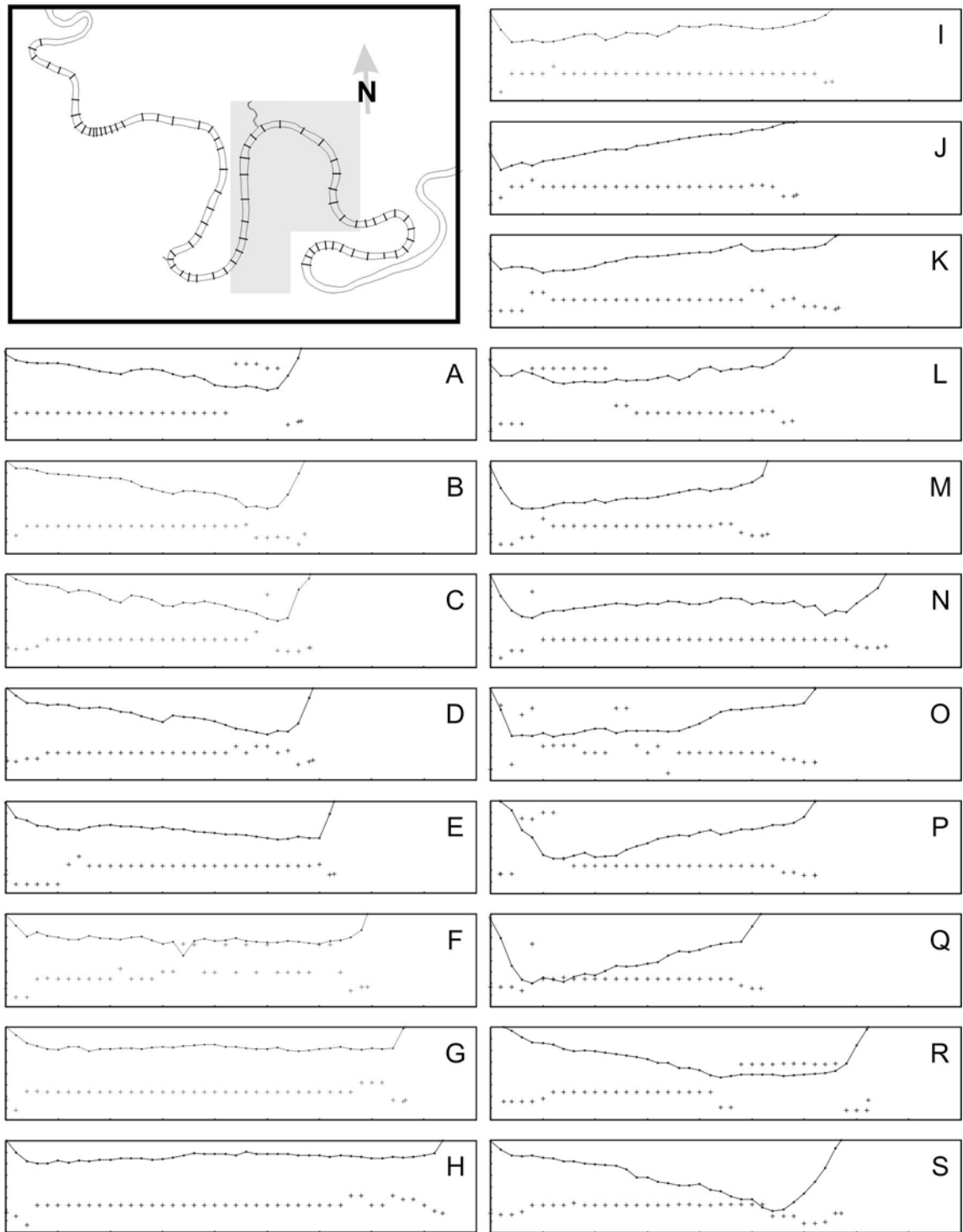


Figure 21. Stream width, depth profile (line) and mean substrate particle size (cross) from left bank to right bank (looking downstream) for the third set of 19 cross-sections. Cross-sections downstream from A to S. River widths (X-Axis) range from 0 to 90m and river depth (Y-Axis) ranges from 0 to 4.0m.

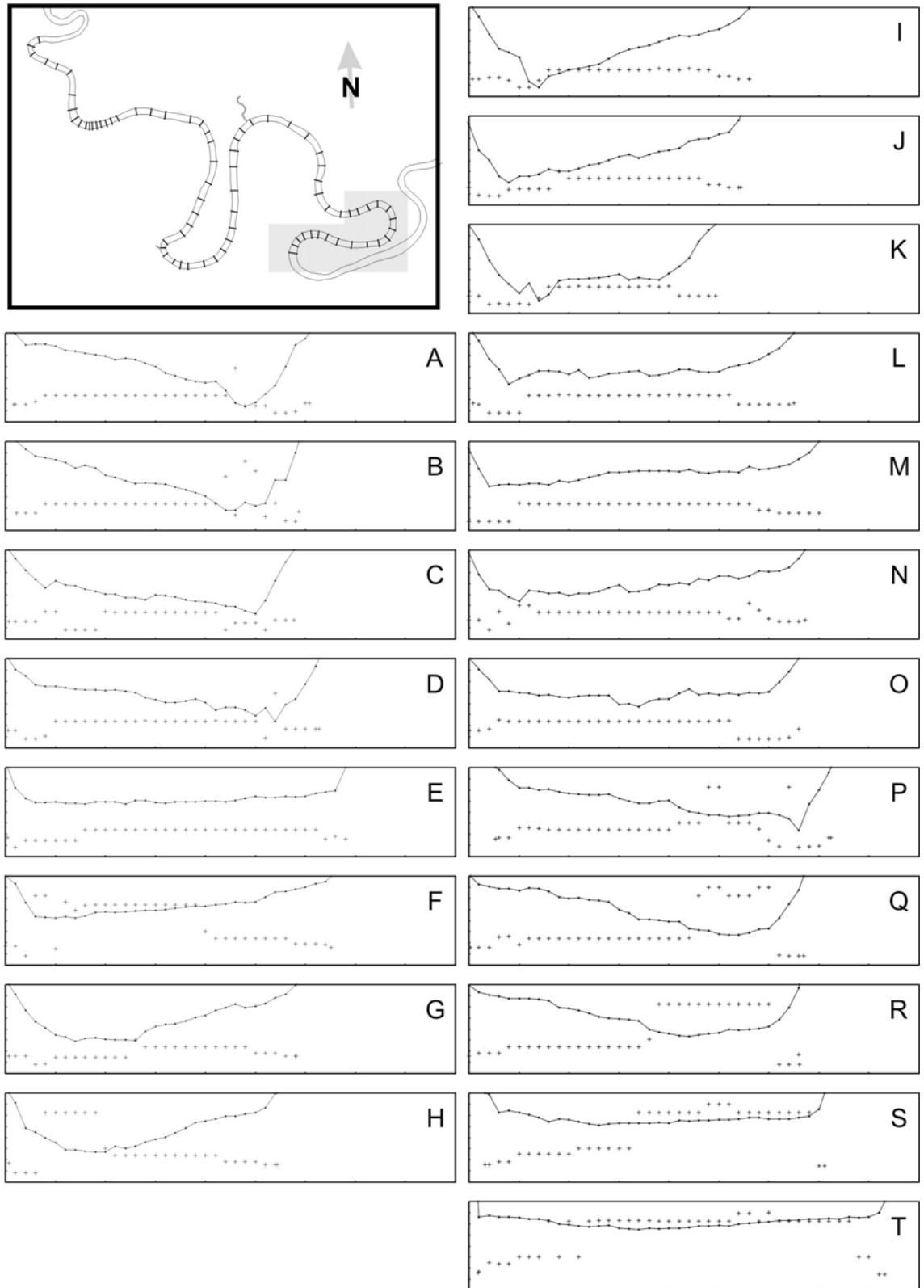


Figure 22. Stream width, depth profile (line) and mean substrate particle size (cross) from left bank to right bank (looking downstream) for the last 20 cross-sections. Cross-sections downstream from A to T. River widths (X-Axis) range from 0 to 90m and river depth (Y-Axis) ranges from 0 to 4.0m.

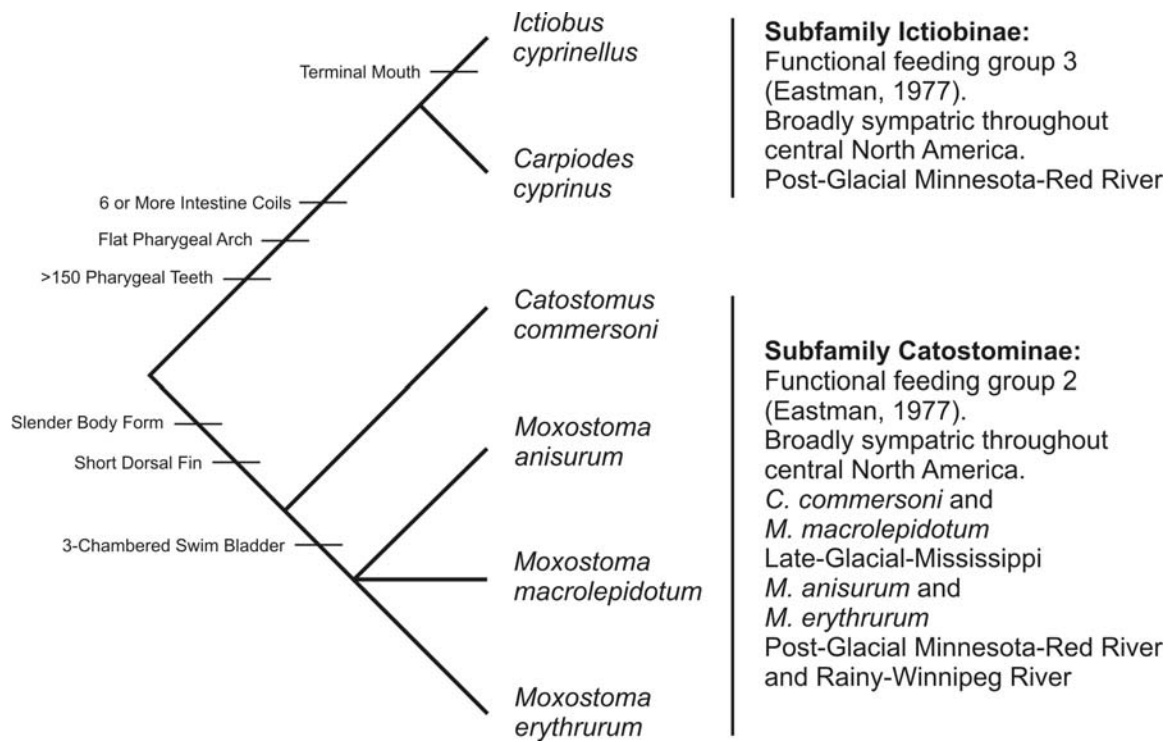


Figure 23. Reduced phylogeny for six Catostomid species from the Assiniboine River based on traits from Smith (1992) and specific teeth counts from Becker (1983). Functional feeding group membership (Eastman, 1977) and northern colonization timing and routes (Franzin et al., 2003) are shown.

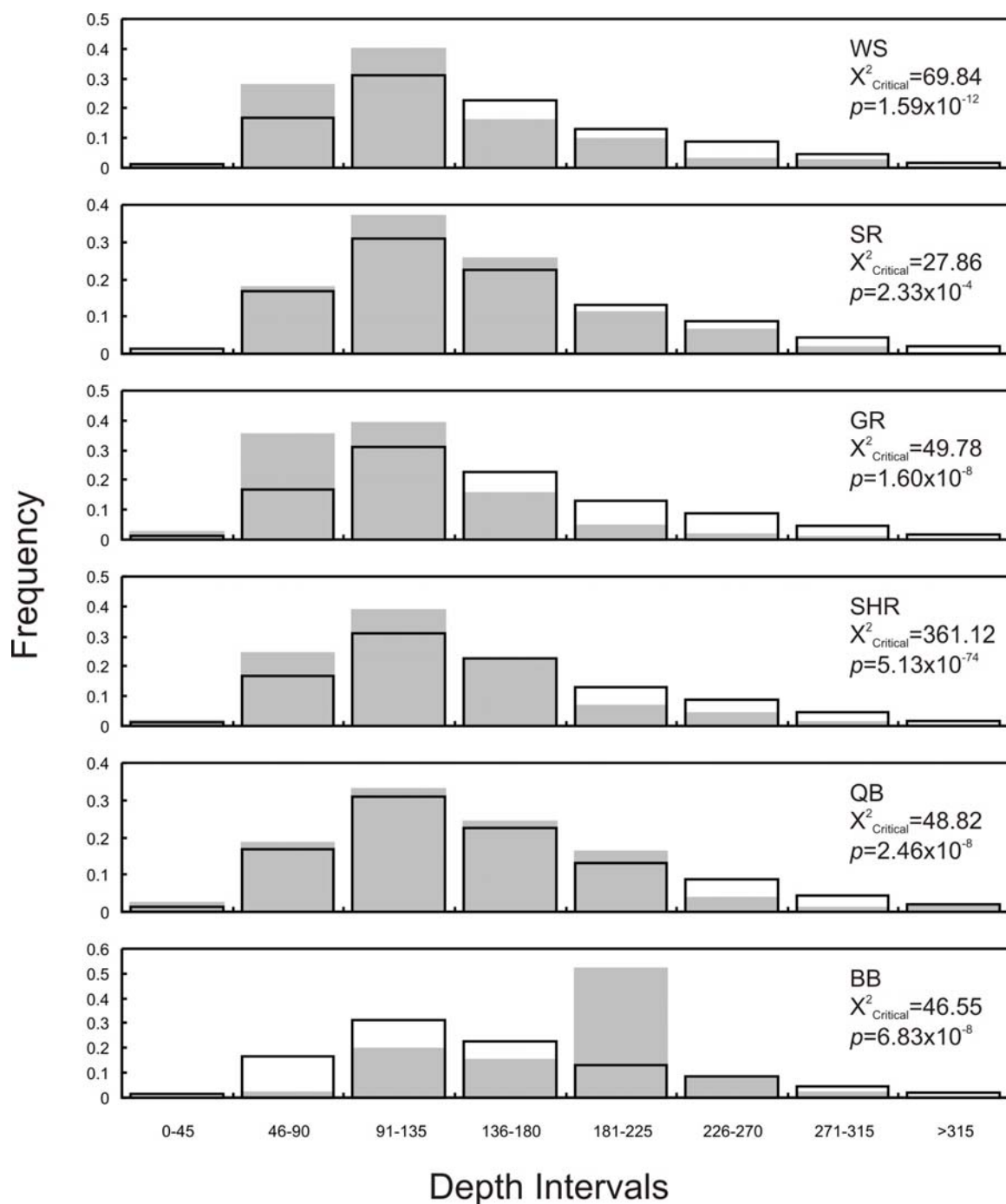


Figure 24. Frequency histograms of depth availability (Open Bars) and utilization (Gray Bars) for WS, SR, GR, SHR, QB, and BB. Chi-square maximum likelihood critical values and probabilities are given. Probability <0.01 indicates that utilization is different than expected based on availability.

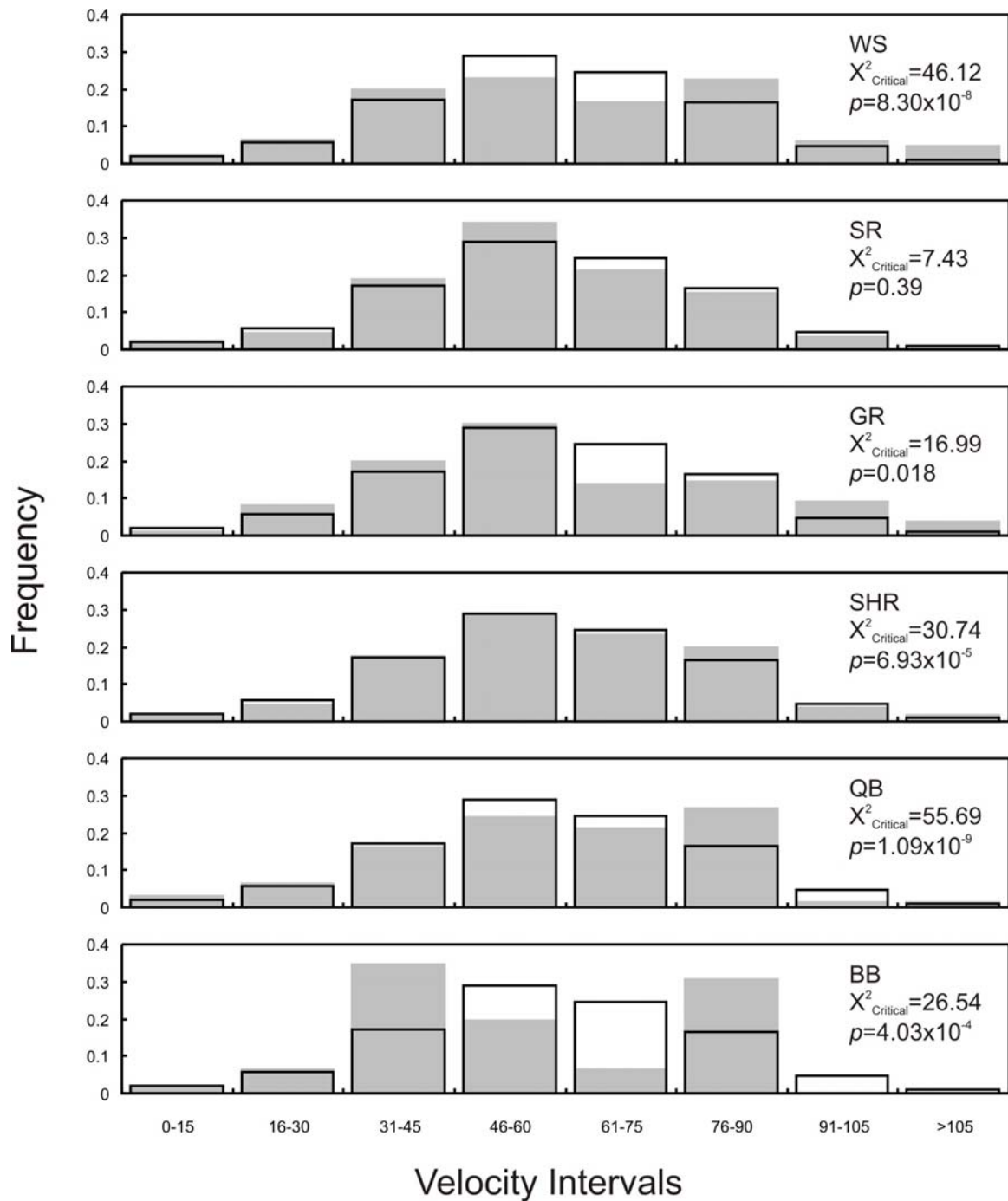


Figure 25. Frequency histograms of velocity availability (Open Bars) and utilization (Gray Bars) for WS, SR, GR, SHR, QB, and BB. Chi-square maximum likelihood critical values and probabilities are given. Probability <0.01 indicates that utilization is different than expected based on availability.

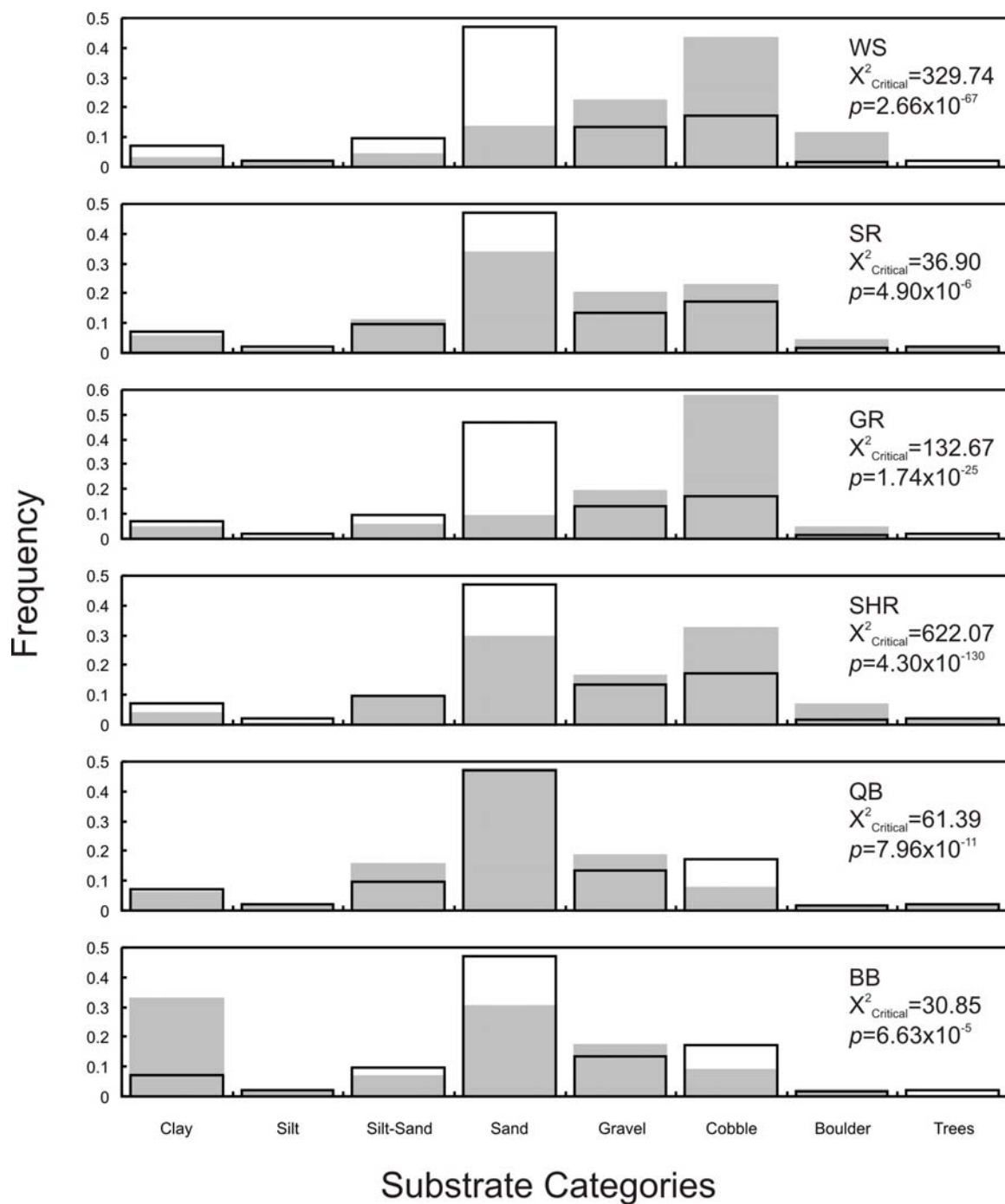


Figure 26. Frequency histograms of substrate availability (Open Bars) and utilization (Gray Bars) for WS, SR, GR, SHR, QB, and BB. Chi-square maximum likelihood critical values and probabilities are given. Probability <0.01 indicates that utilization is different than expected based on availability.

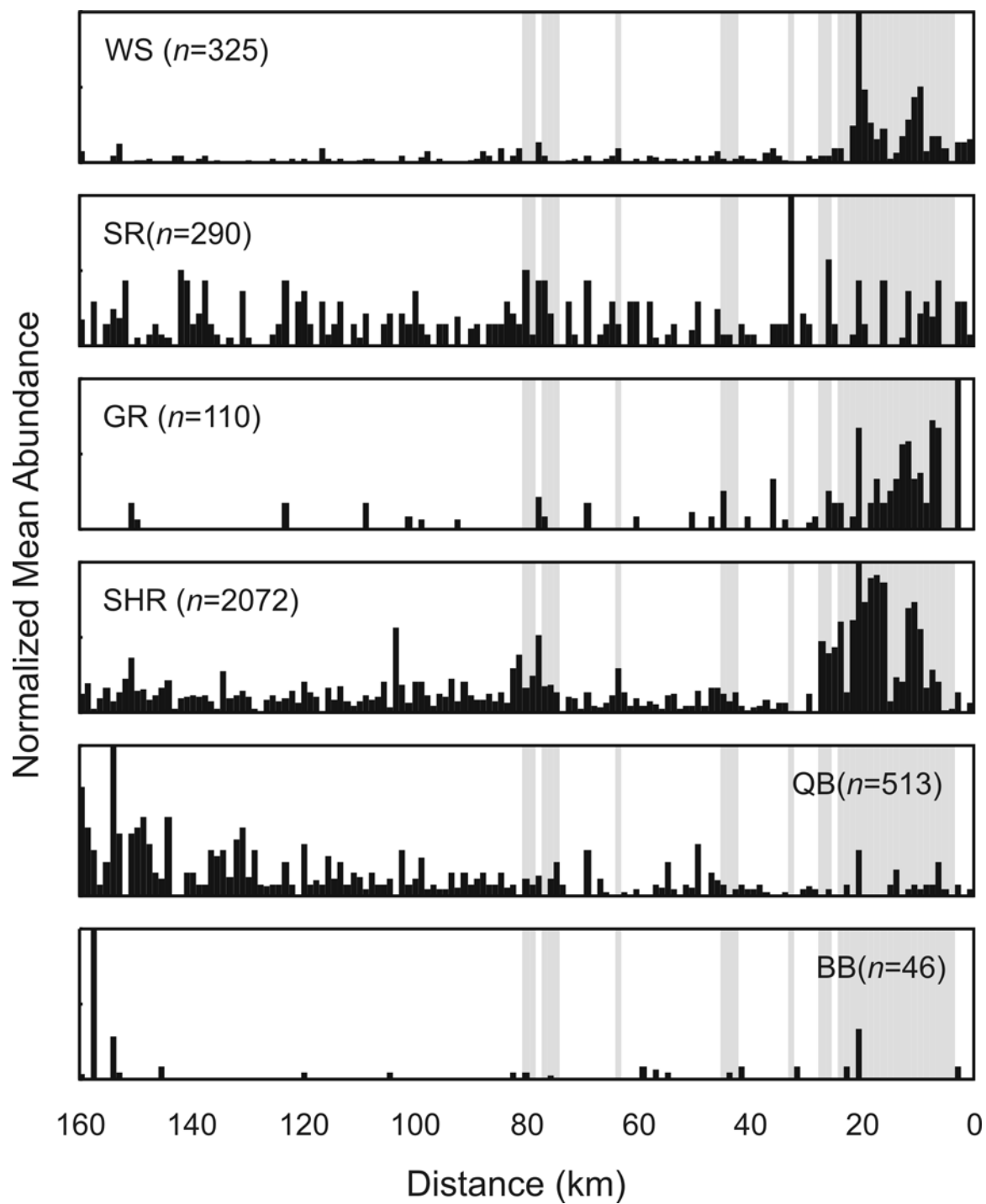


Figure 27. Normalized mean species abundance patterns and sediment distribution along the study reach for six species. Distance begins at Portage la Prairie dam (160km) and ends at the confluence with the Red River of the North at Winnipeg (0km). Gray bars indicate locations of glacial till-plain exposures.

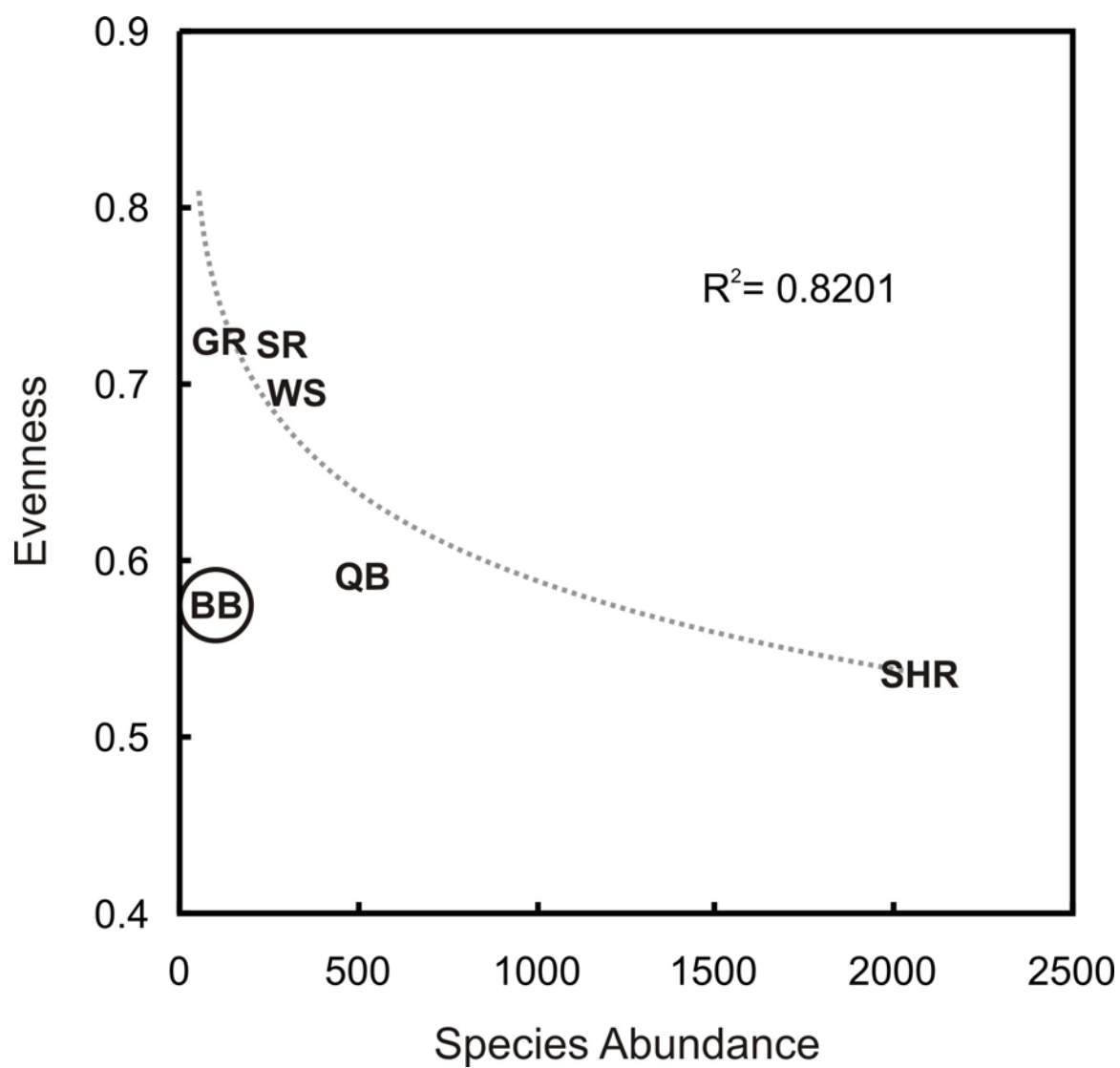


Figure 28. Evenness with species abundance for the five catostomids from the Assiniboine River. BB is shown as an outlier, not included in correlation. Evenness values were calculated based on a three-dimensional habitat array.

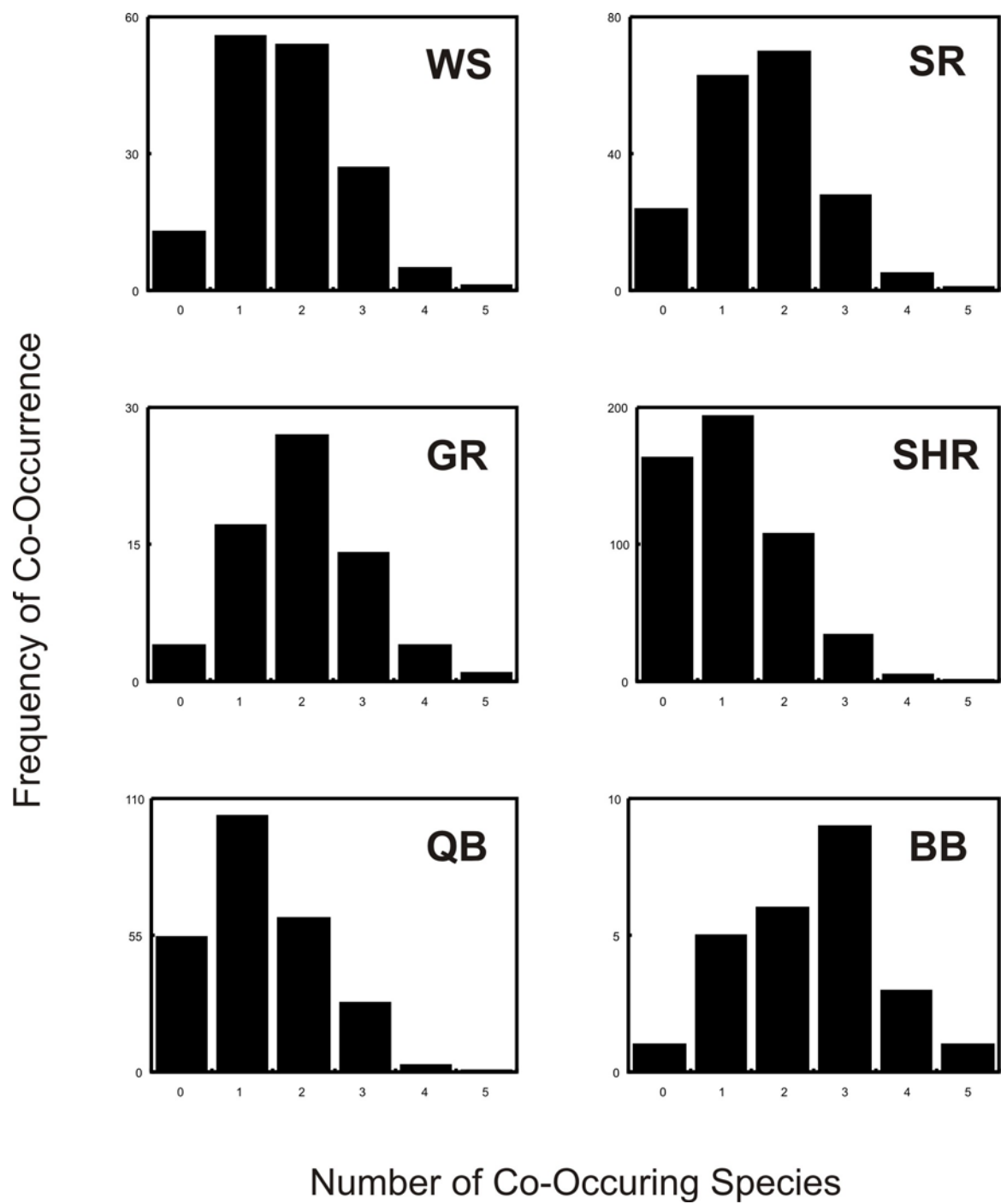


Figure 29. Frequency of number of co-occurring species for six species. Value of 0 indicates the frequency with which a species occurred alone.

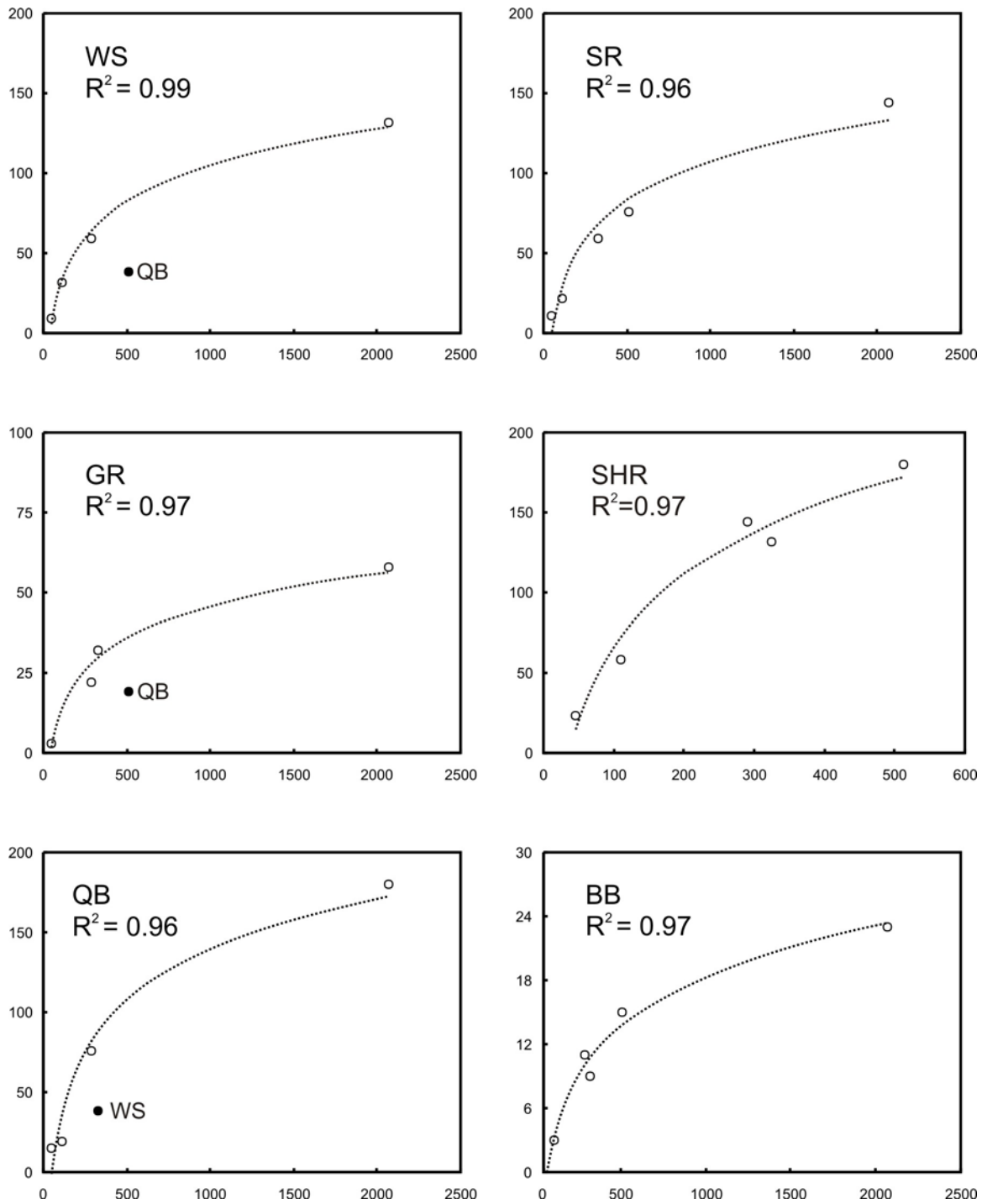


Figure 30. Total number of individuals captured (ln - transformed) versus the number of times they co-occurred with each of the six species (open circles). Solid circles are outlier species with negative associations. Species codes occur next to their observed intra-specific co-occurrence when associations were negative.

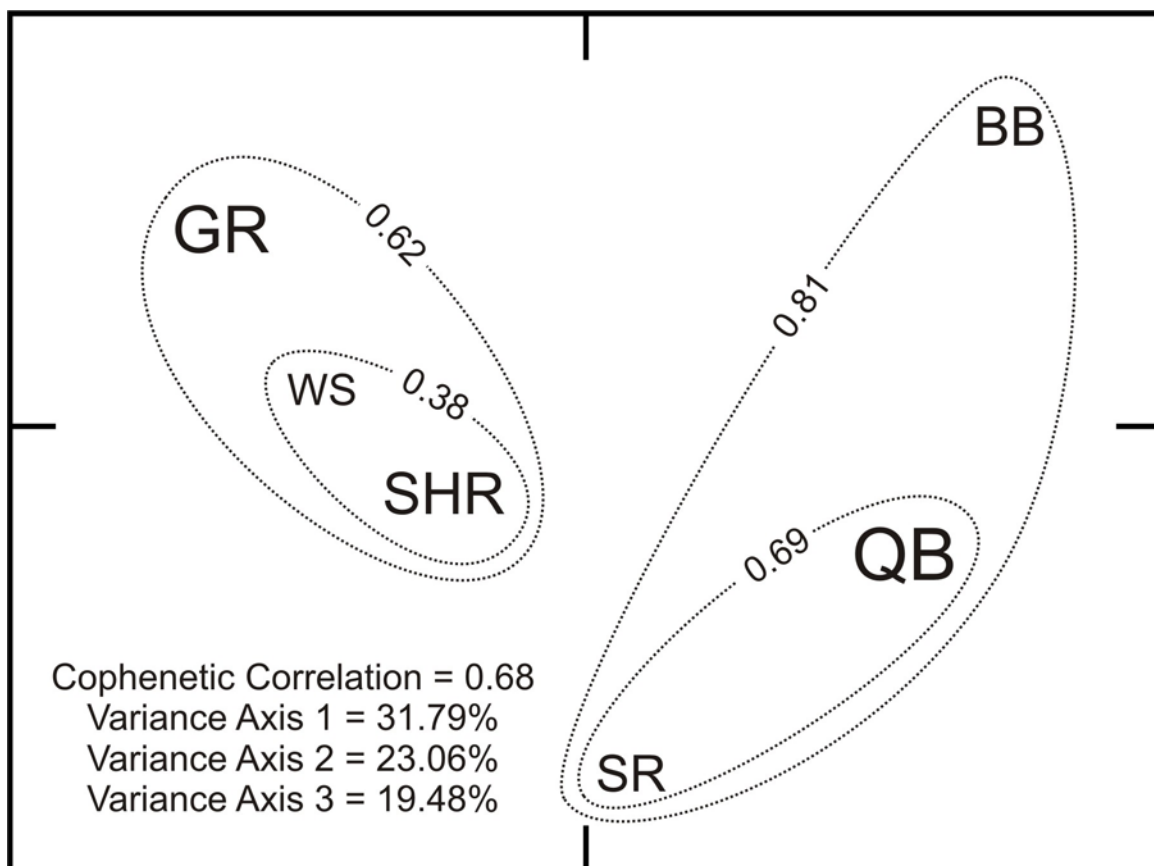


Figure 31. Principal co-ordinates analysis (PCoA) based on a species co-occurrence, using Syntax 2000 (Podani, 2001). Size of font represents third axis (larger positive smaller negative). Contours and numbers represent group fusion and dissimilarity from complete linkage hierarchical cluster analysis (HCA). Cophenetic correlation from HCA and variance of PCoA axes are given.

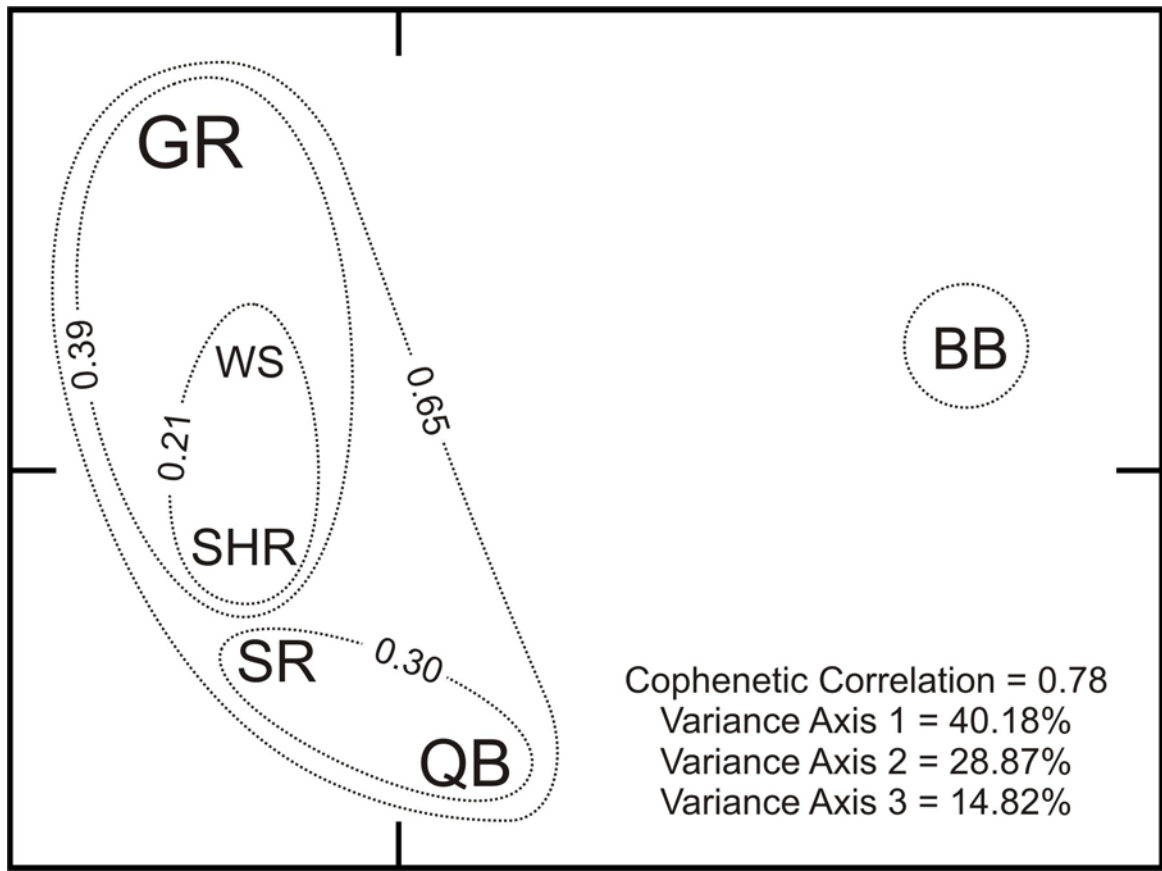


Figure 32. PCoA ordination based on three-dimensional Horn overlap in habitat space, subtracted from 1 and used as a direct input dissimilarity semi-matrix, using Syntax 2000 (Podani, 2001). Size of font represents third axis (larger positive smaller negative). Contours and numbers represent group fusion and dissimilarity from complete linkage HCA. Cophenetic correlation from HCA and variance of PCoA axes are given.

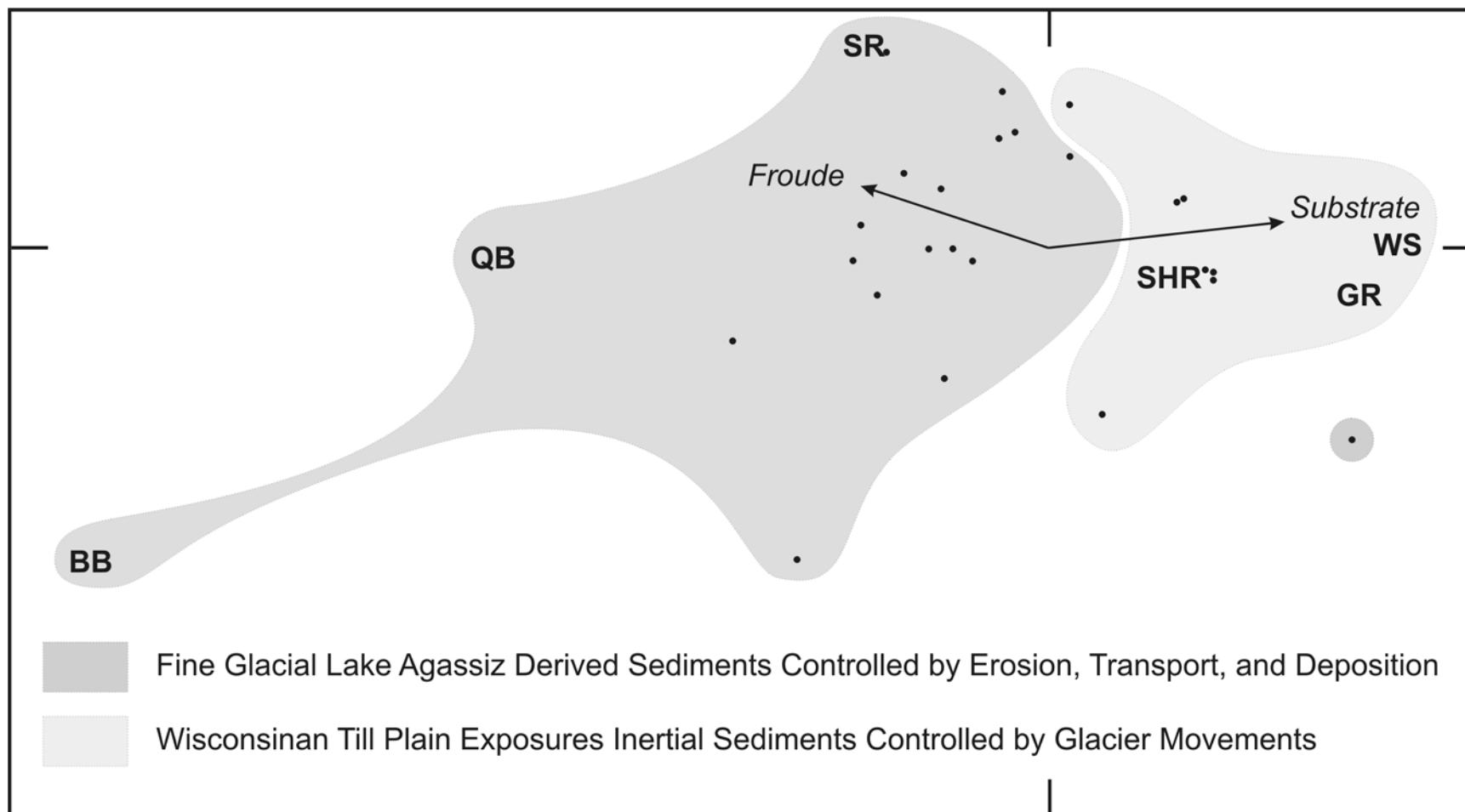


Figure 33. Canonical correspondence analysis (CCA) for 24 combinations of substrate and Froude for six species constrained by substrate and Froude number. Percentage variances of inter-set relations were 96.02% and 3.98% for axes 1 and 2, between-set correlations were 0.52 and 0.23 respectively, and symmetric weighting was used.

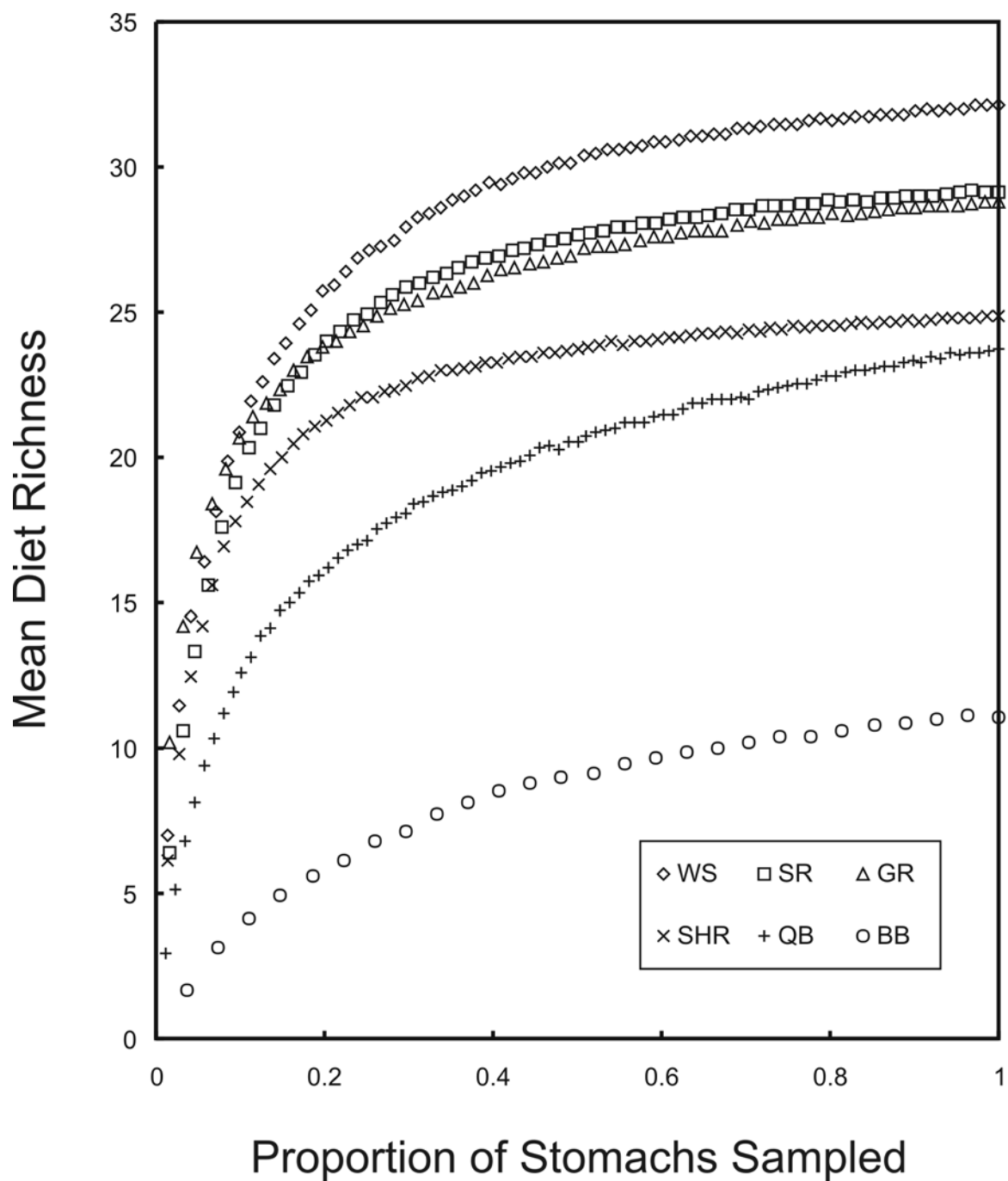


Figure 34. Mean richness accumulation of diet items with proportion of stomachs sampled. Data are from 1000 randomizations with replacement for each of the six catostomids.

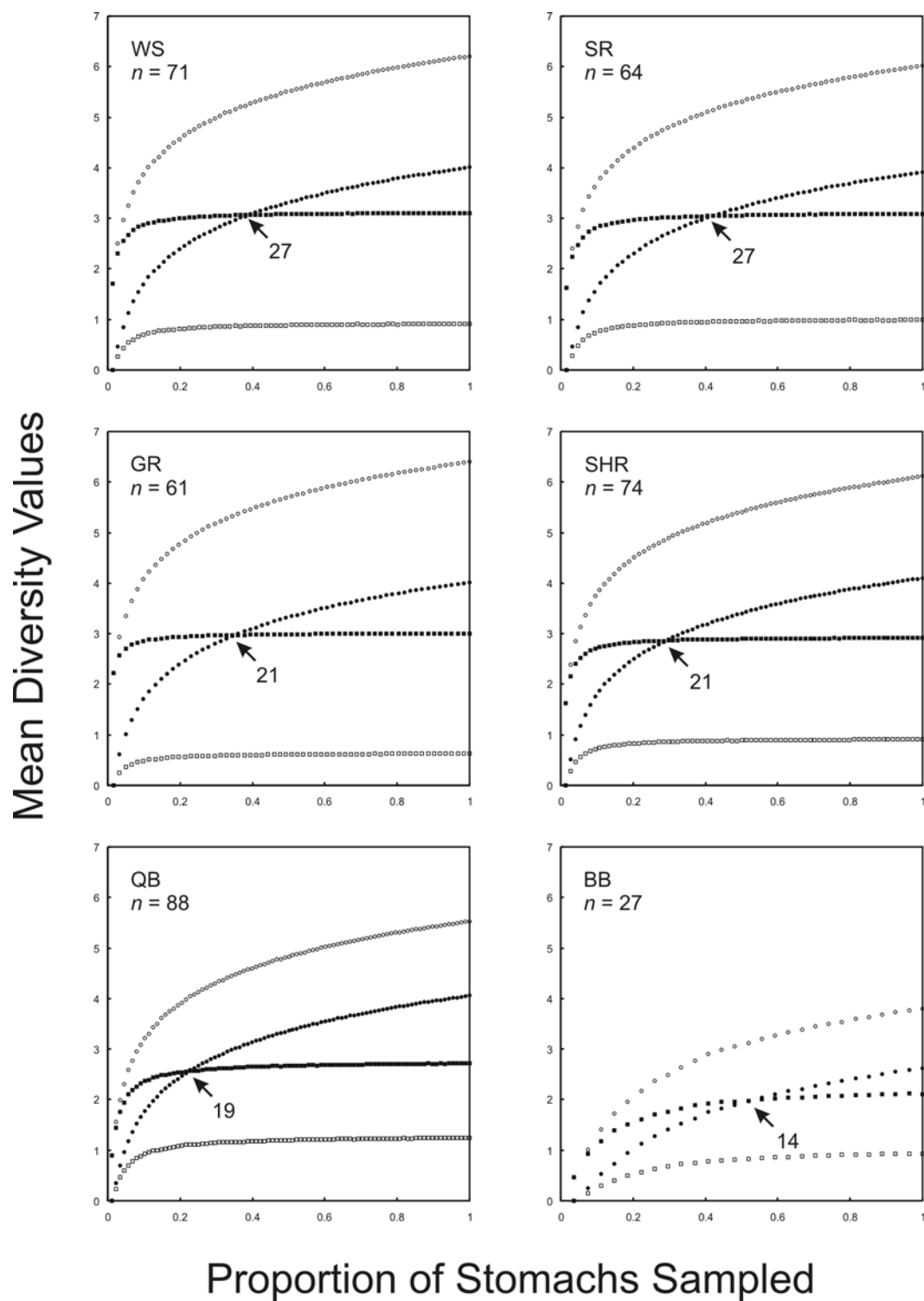


Figure 35. Joint diversity, sample diversity, diet diversity and mutual diversity for 1000 randomizations with replacement for each of the six catostomids. Arrows indicate the number stomachs beyond which contain redundant information.

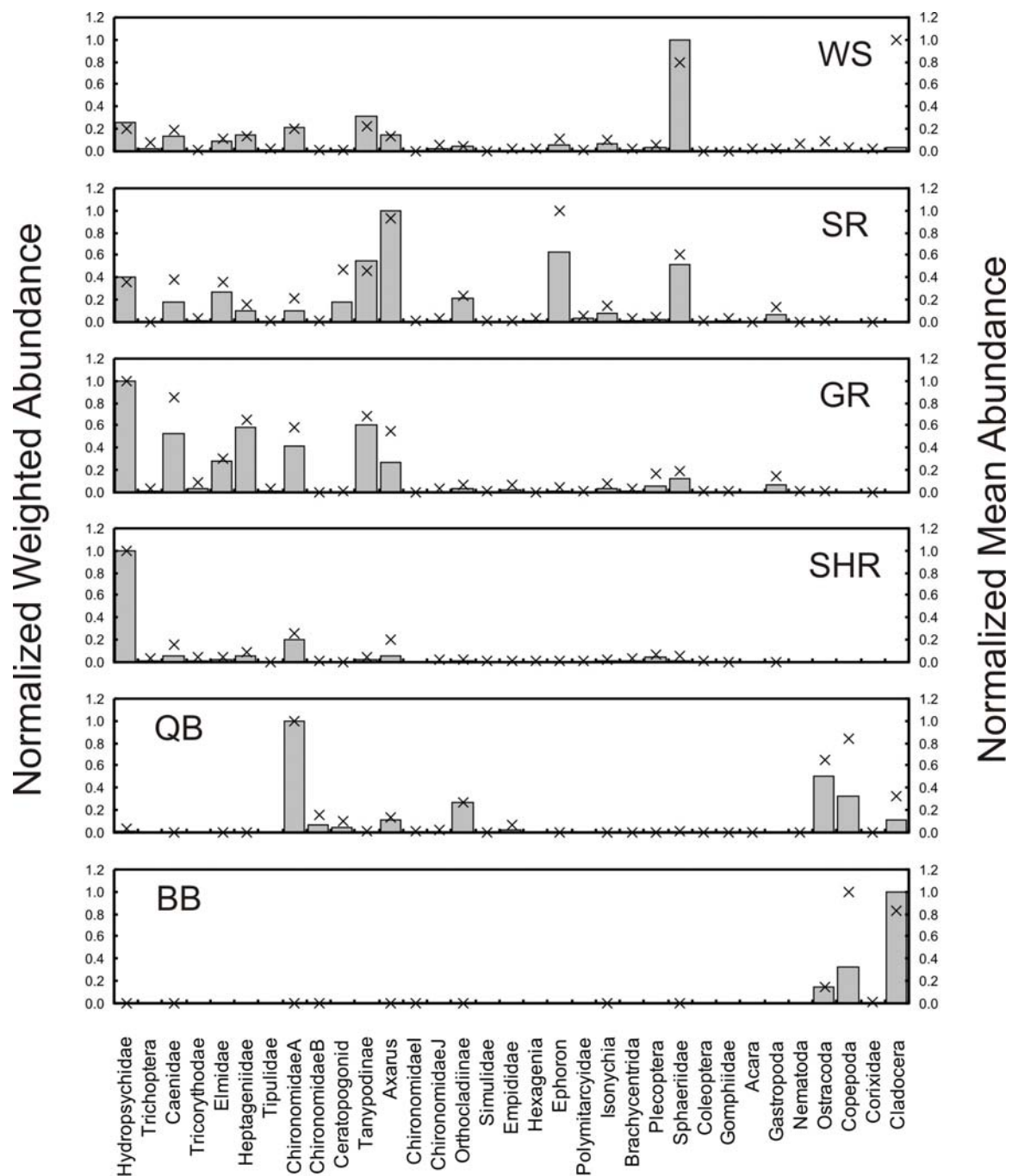


Figure 36. Normalized mean abundance (X) and mean abundance weighted by mean prevalence (bars) for 33 taxa identified from stomachs of six catostomid species.

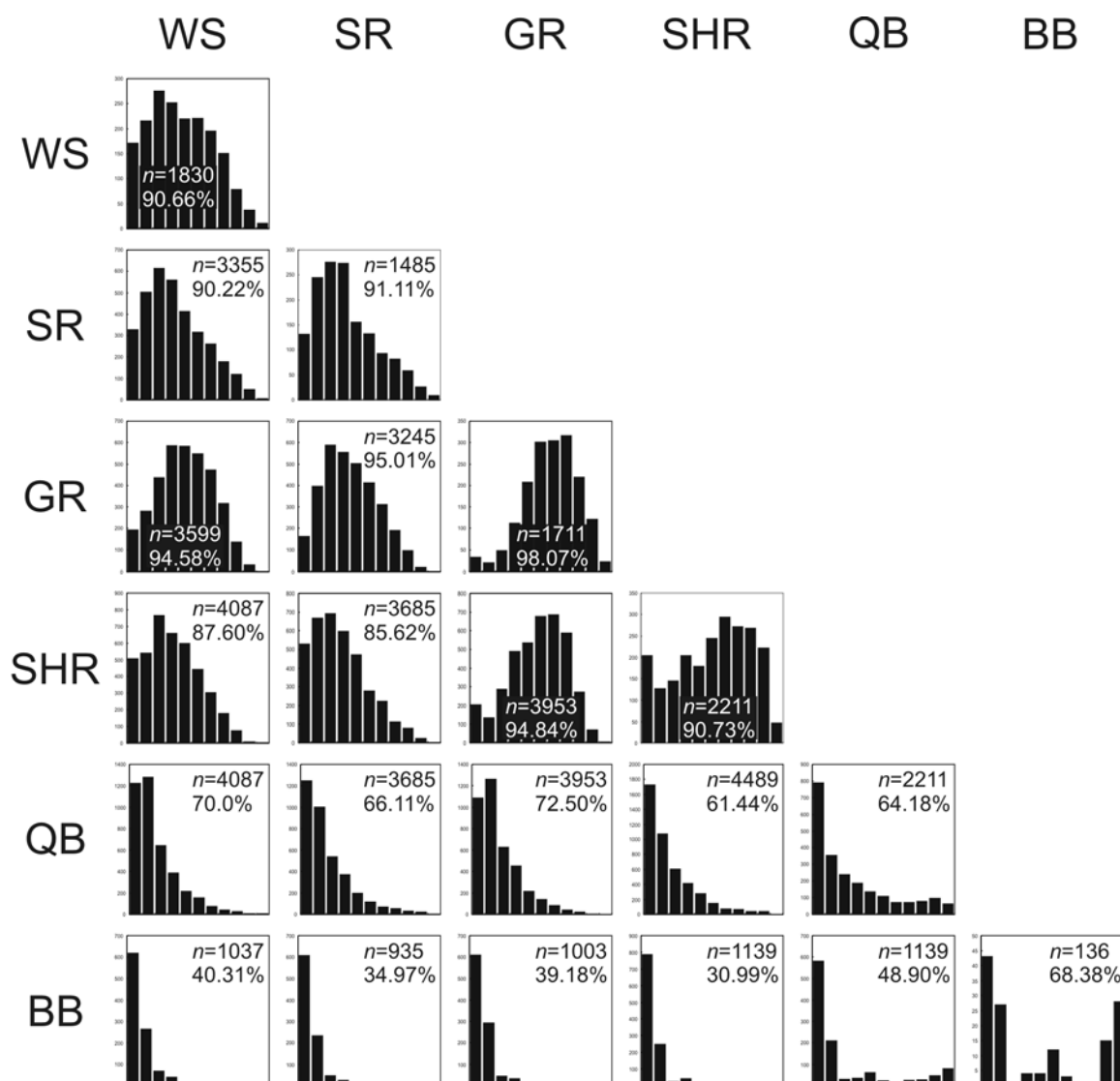


Figure 37. Frequency histograms of Horn's Index for all pairwise comparisons within and between species. N-values given are number of non-redundant pairs and percentages are the percentage of those non-redundant pairs that have a Horn value greater than zero.

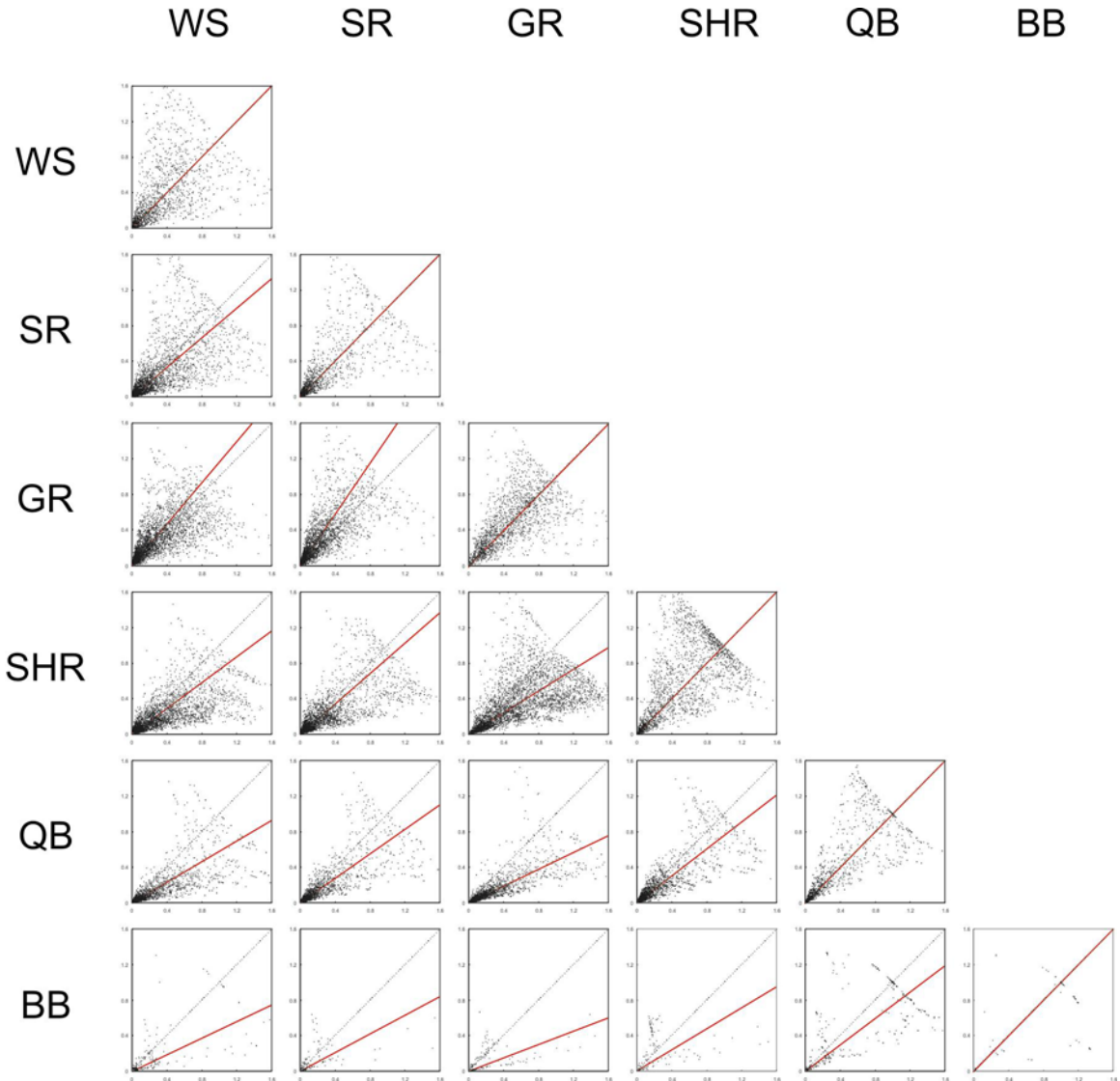


Figure 38. Scattergrams of MacArthur and Levins M_{jk} versus M_{kj} for all pair wise comparisons within and between species. N-values are the same as the Horn comparison. Species j is row species and species k is column species. Red line represents the mean vector angle weighting the relationship towards one species in the pair. When mean angle vector is less than 45° then the interaction is dominated by the column species and vice versa.

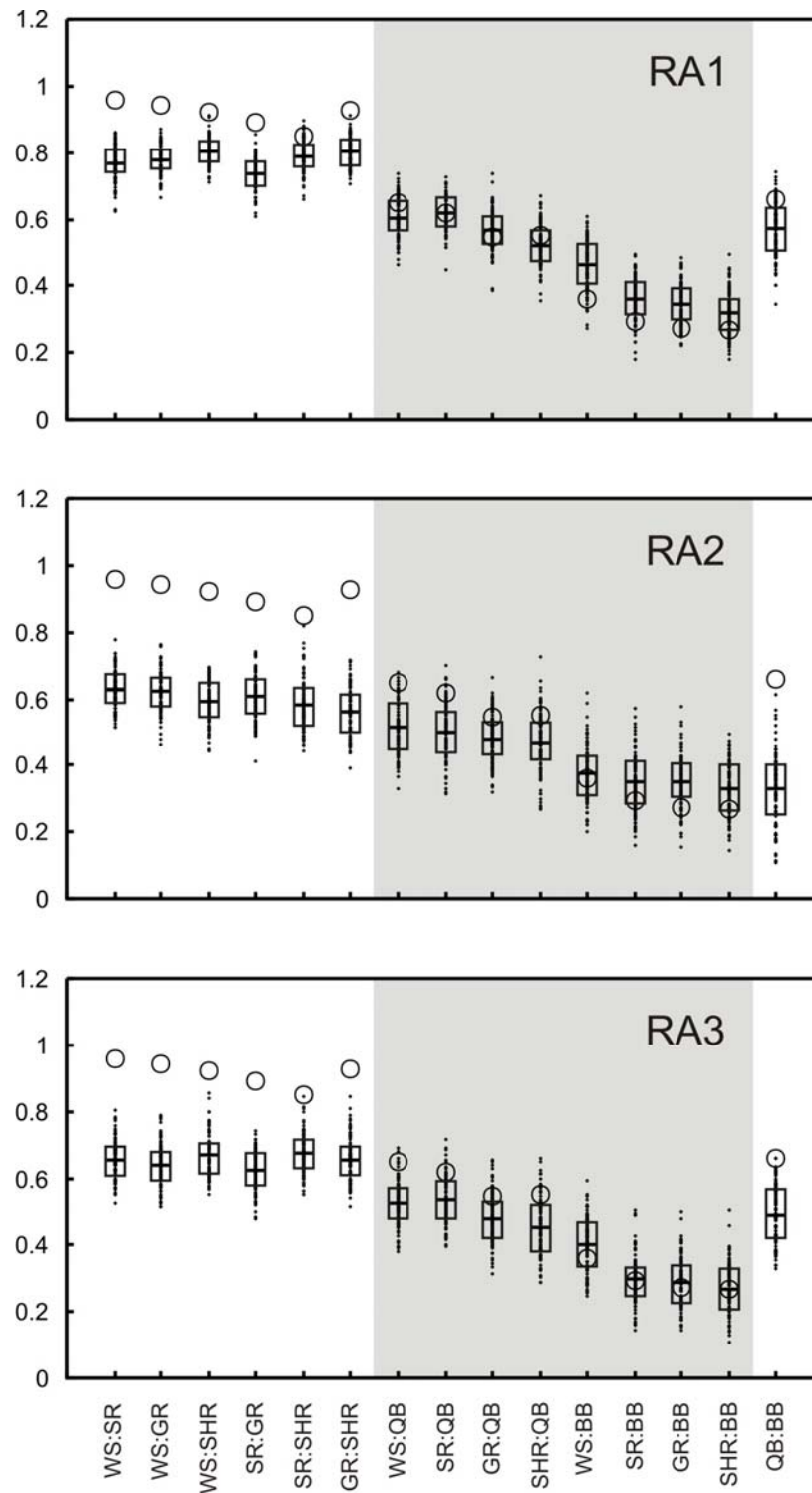


Figure 39. Comparison of average observed mean prevalence (open circles) with three different randomizations following Lawlor (1980). Gray area denotes comparisons between feeding groups 2 and 3 from Figure 27.

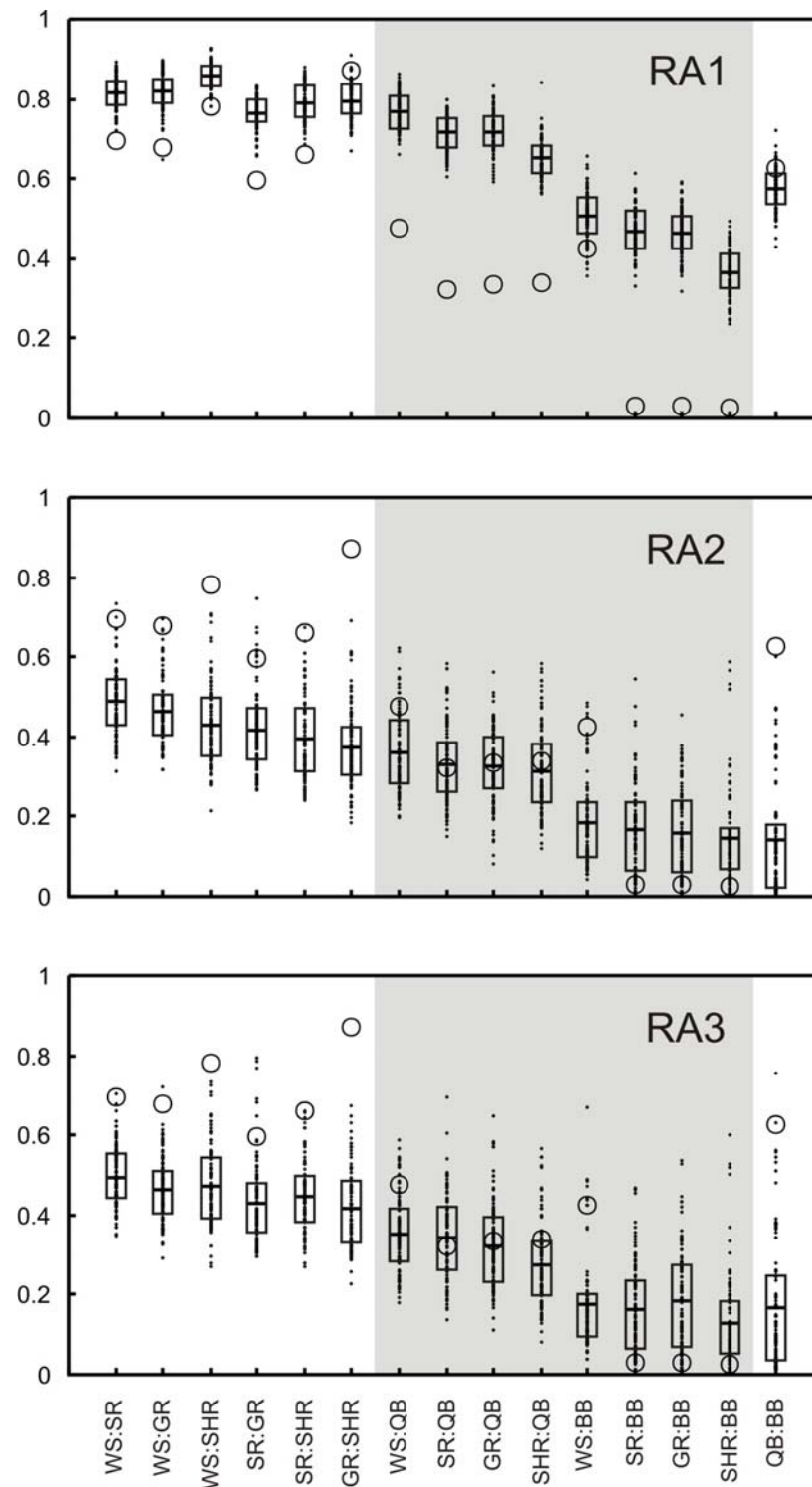


Figure 40. Comparison of average observed mean abundance (open circles) with three different randomizations following Lawlor (1980). Gray area denotes comparisons between feeding groups 2 and 3 from Figure 27.

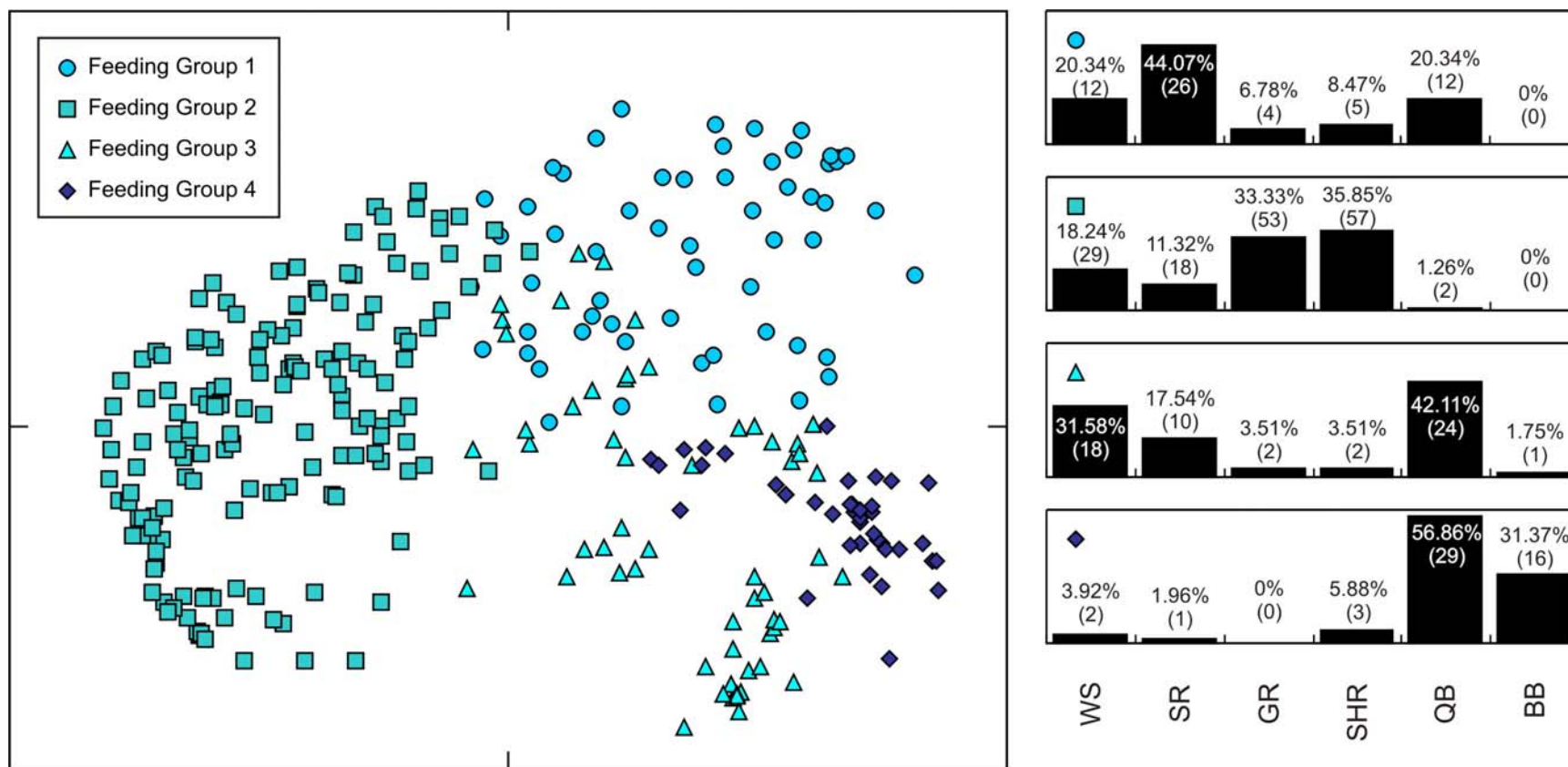


Figure 41. PCoA ordination of 326 gut content samples highlighting four feeding groups determined by non-hierarchical global optimization clustering using Horn distance, random seeds, and 100 iterations. The relative frequency of six catostomid species is given in histograms as percentage of group followed by number of gut samples in parentheses. Canonical variates analysis (CVA) of PCoA scores for the first four axes indicated that groups were significantly different (see Table 16 for CVA results).

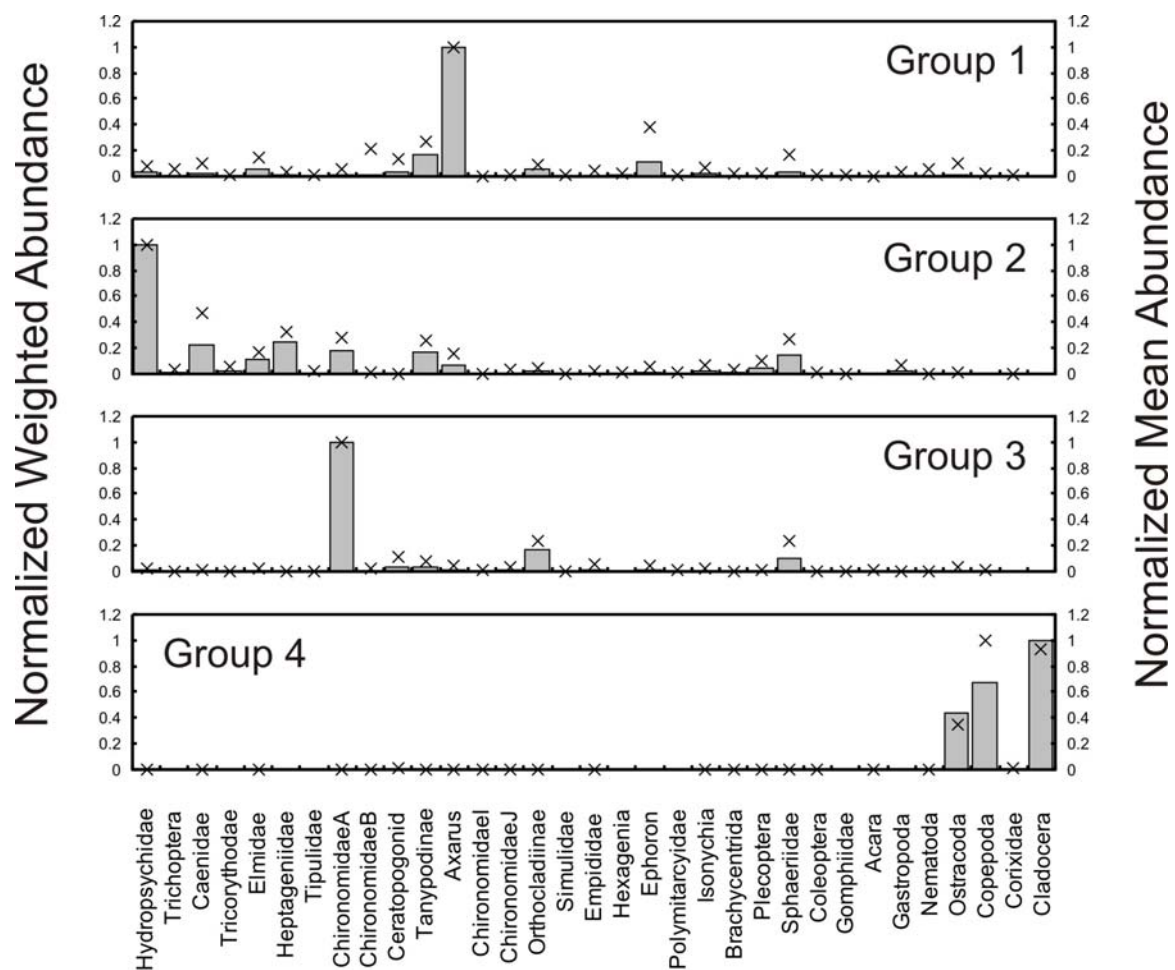


Figure 42. Normalized mean abundance (X) and mean abundance weighted by mean prevalence (bars) for gut contents from four groups identified in Figure 41. .

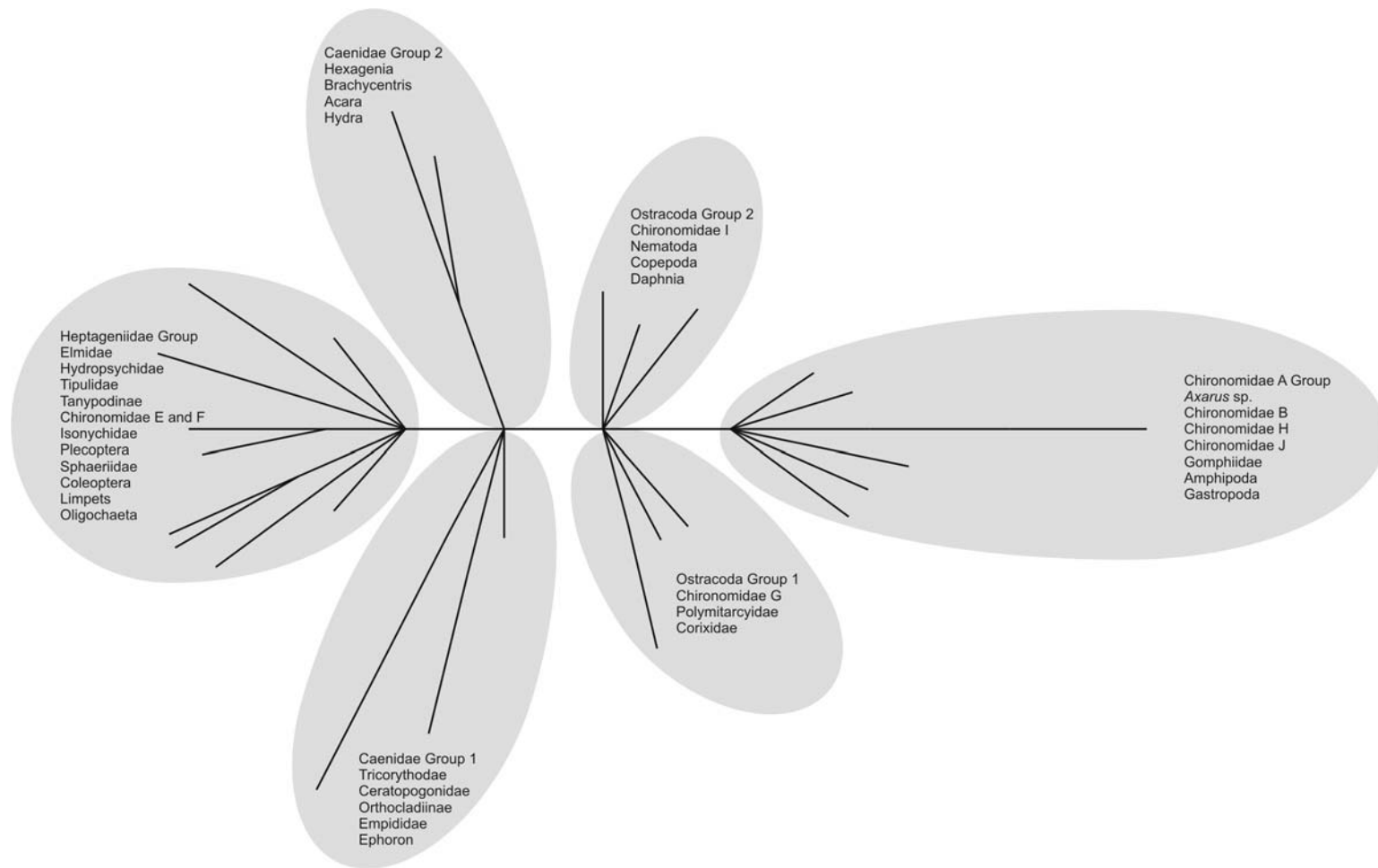


Figure 43. Minimum spanning tree for all benthic invertebrates identified from 384 airlift samples at the DFO Lido Plage site.

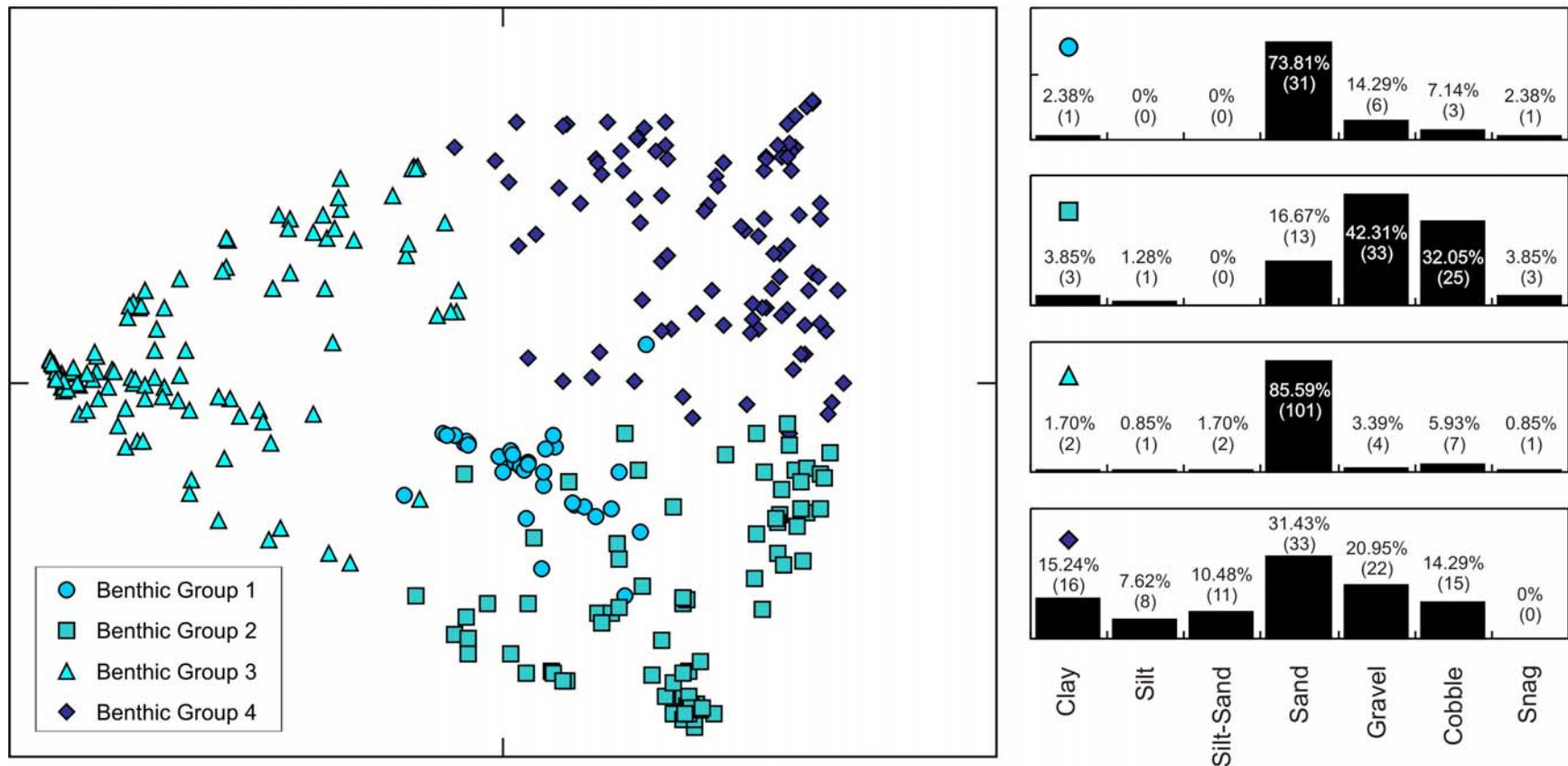


Figure 44. PCoA ordination of 343 benthic invertebrate samples highlighting four different groups determined by non-hierarchical global optimization clustering using Horn distance, random seeds, and 100 iterations. The relative frequency of substrates from four groups is given in histograms as percentage of group followed by number of samples in parentheses. Canonical variates analysis (CVA) of PCoA scores for the first four axes indicated that groups were significantly different (see Table 17 for CVA results). The group ordering corresponds to the group ordering from dietary PCoA from Figure 41.

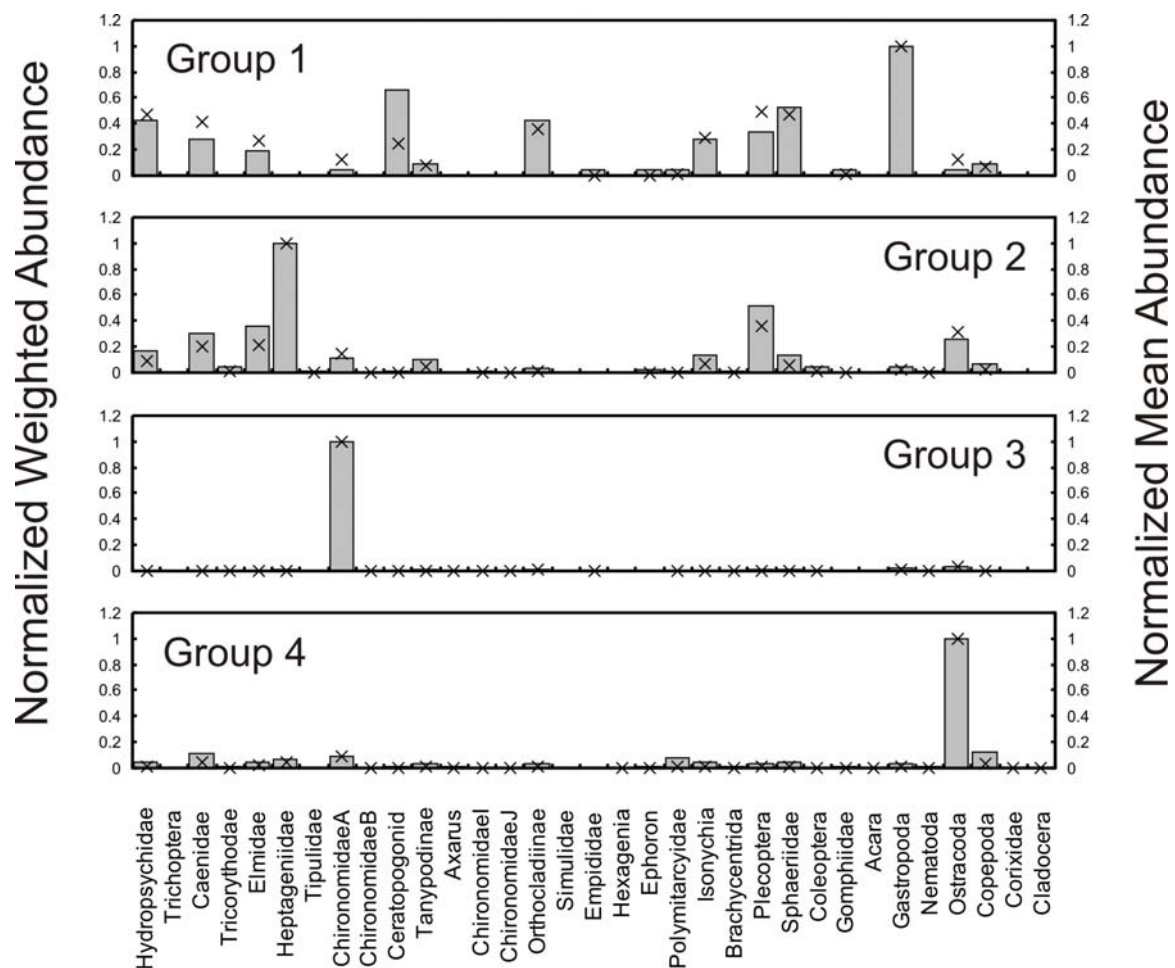


Figure 45. Normalized mean abundance (X) and mean abundance weighted by mean prevalence (bars) for invertebrate composition from four groups identified in Figure 43 these groups correspond to the feeding group compositions in Figure 42. .

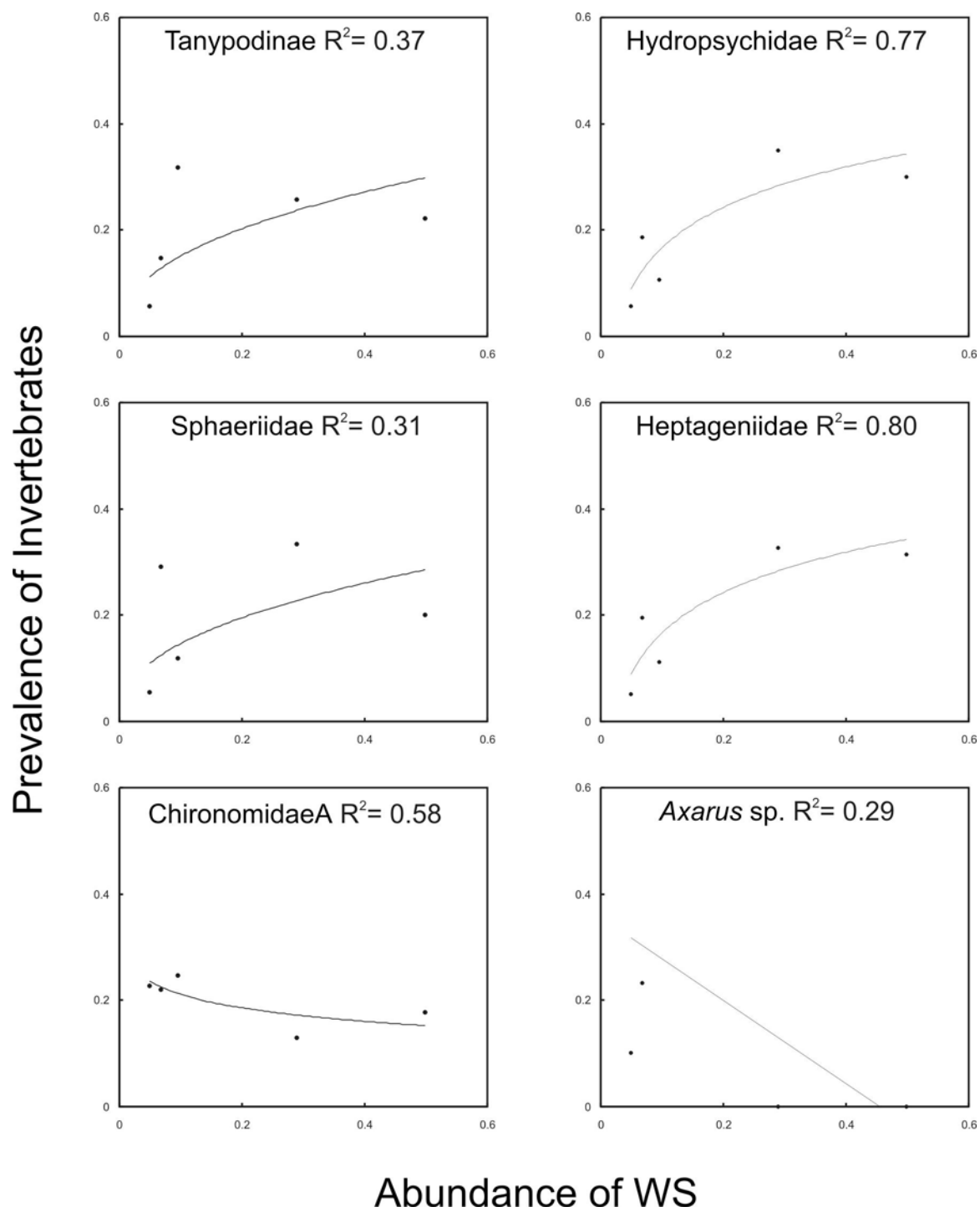


Figure 46. Normalized mean prevalence of benthic invertebrate species with substrate in relation to normalized mean abundance of WS with substrate, for 6 most prevalent dietary items.

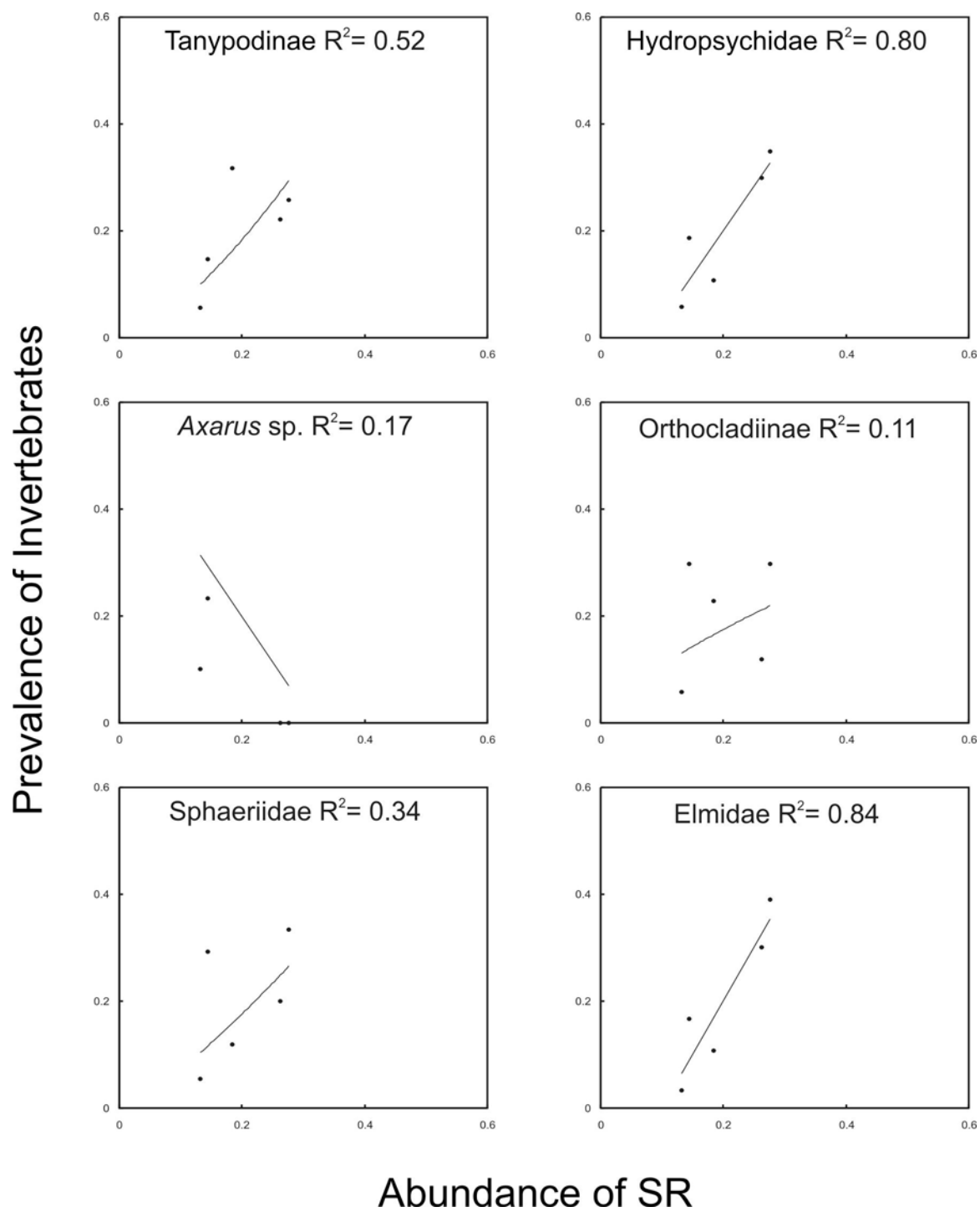


Figure 47. Normalized mean prevalence of benthic invertebrate species with substrate in relation to normalized mean abundance of SR with substrate, for 6 most prevalent dietary items.

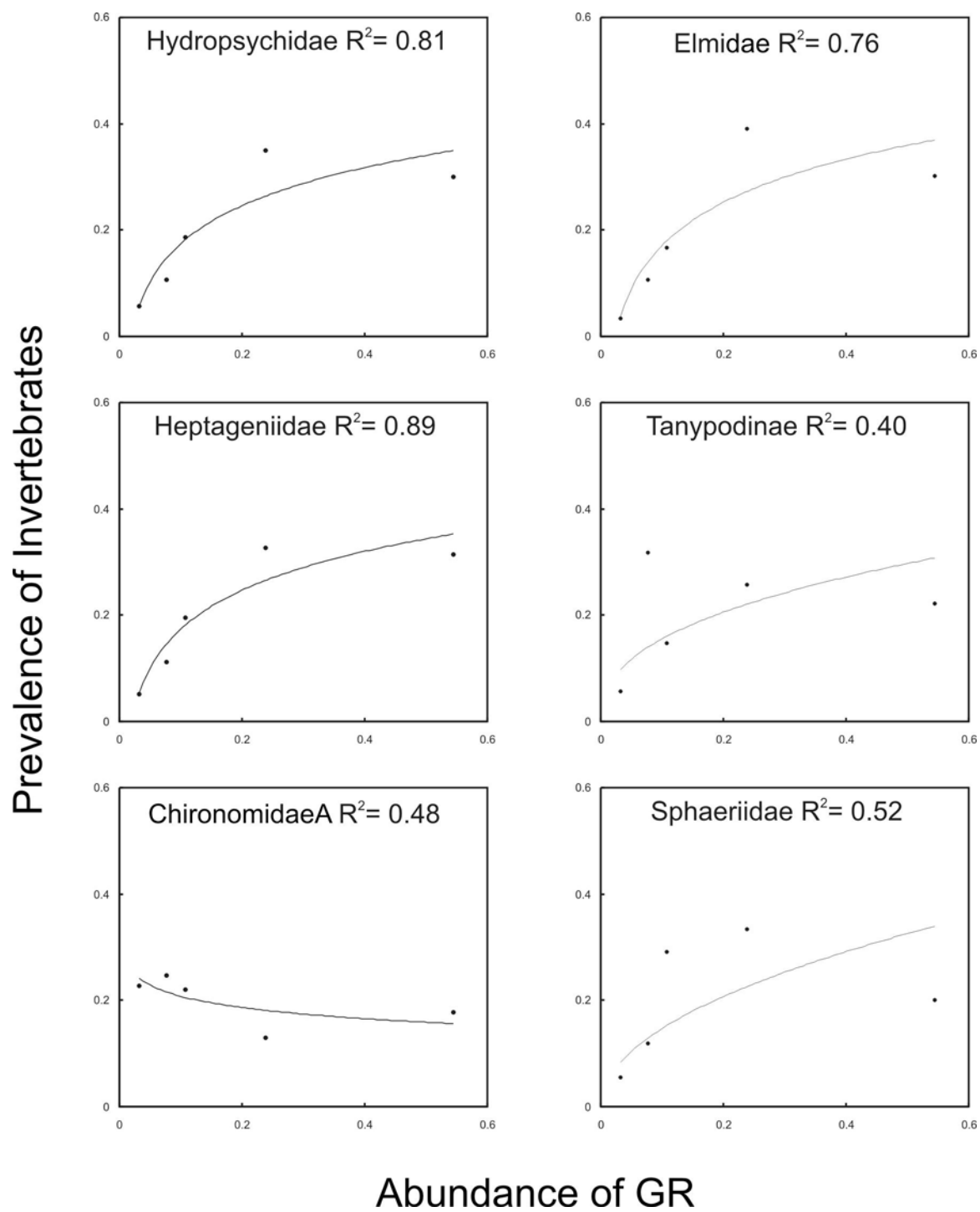


Figure 48. Normalized mean prevalence of benthic invertebrate species with substrate in relation to normalized mean abundance of GR with substrate, for 6 most prevalent dietary items.

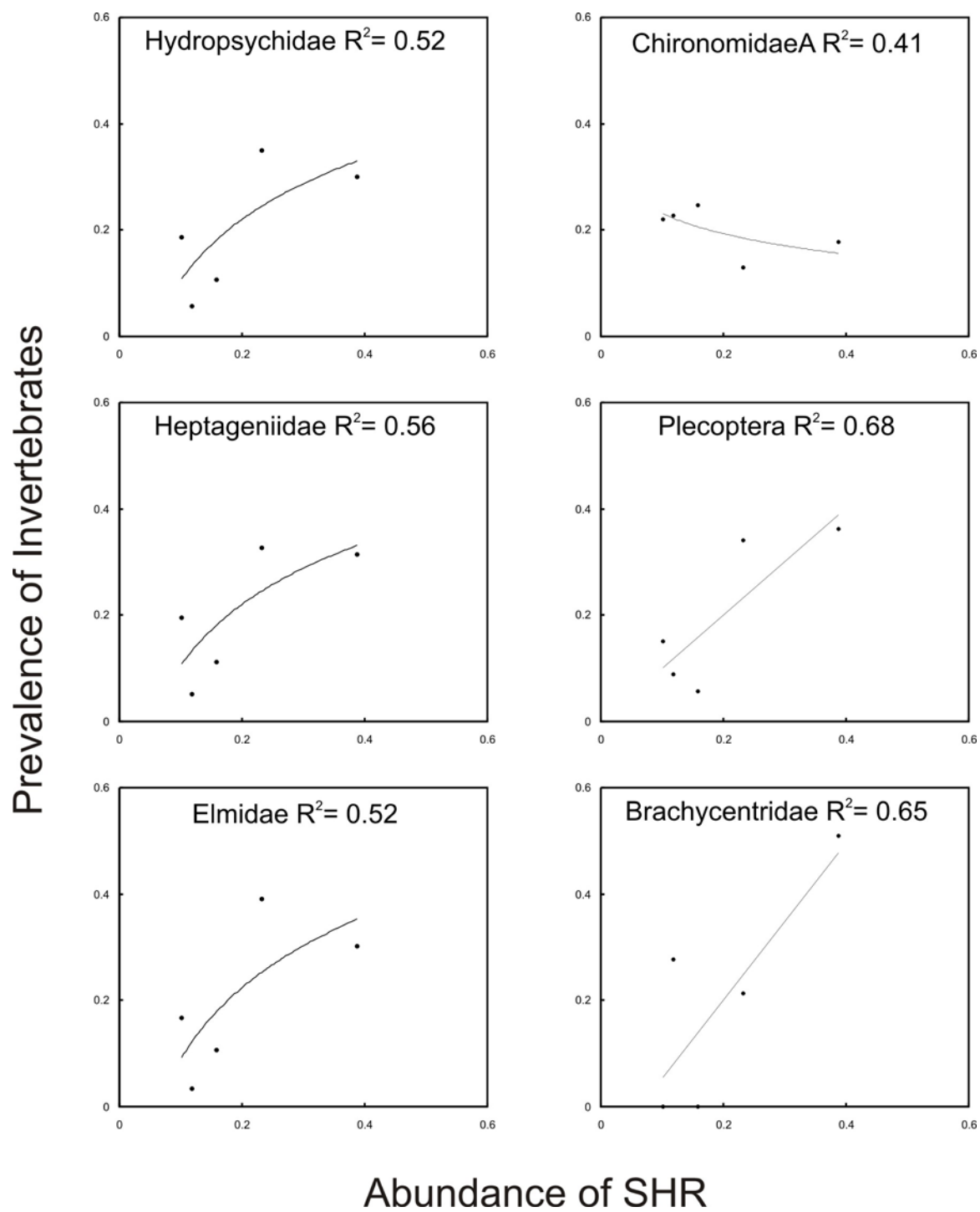


Figure 49. Normalized mean prevalence of benthic invertebrate species with substrate in relation to normalized mean abundance of SHR with substrate, for 6 most prevalent dietary items.

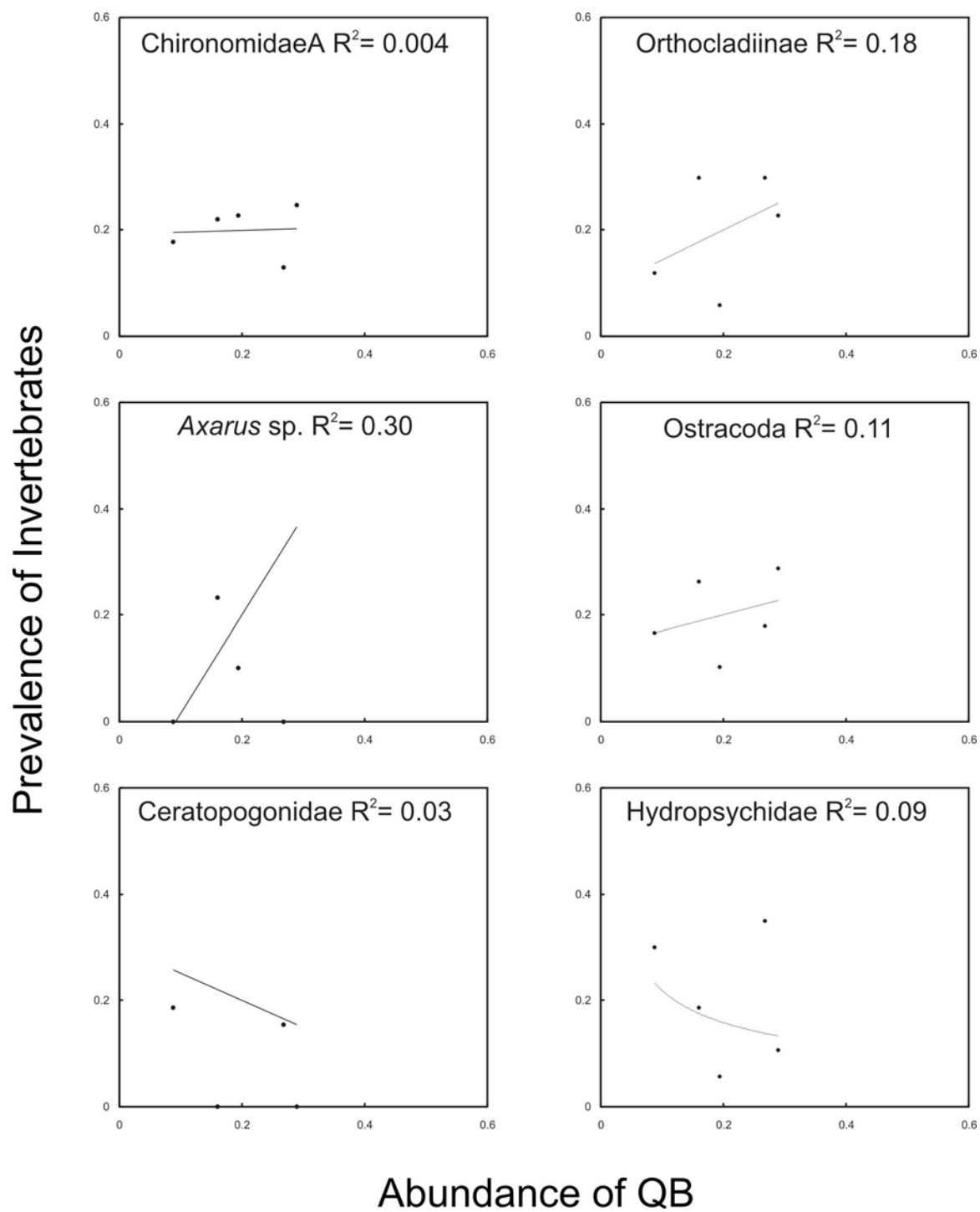


Figure 50. Normalized mean prevalence of benthic invertebrate species with substrate in relation to normalized mean abundance of QB with substrate, for 6 most prevalent dietary items.

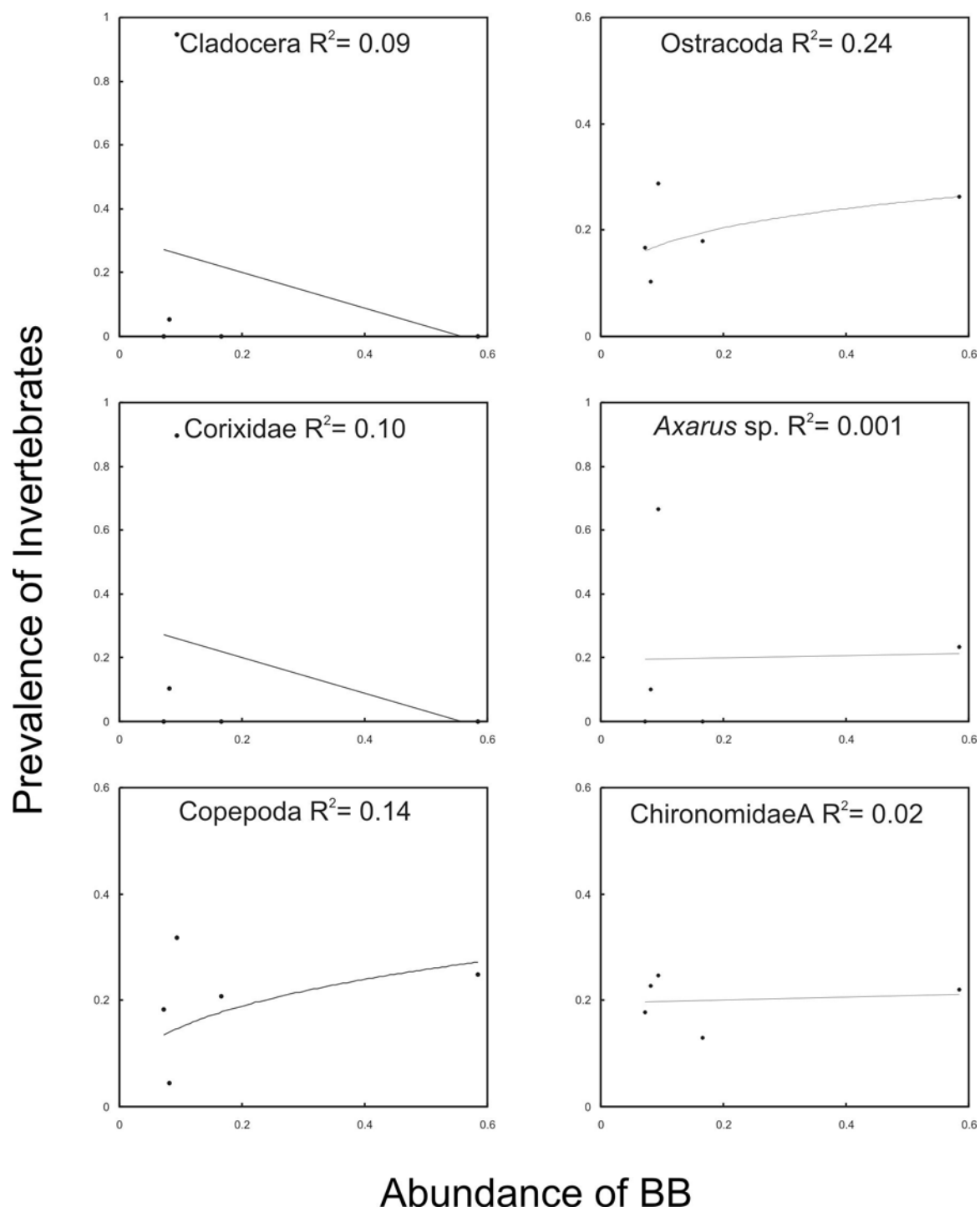


Figure 51. Normalized mean prevalence of benthic invertebrate species with substrate in relation to normalized mean abundance of BB with substrate, for 6 most prevalent dietary items.

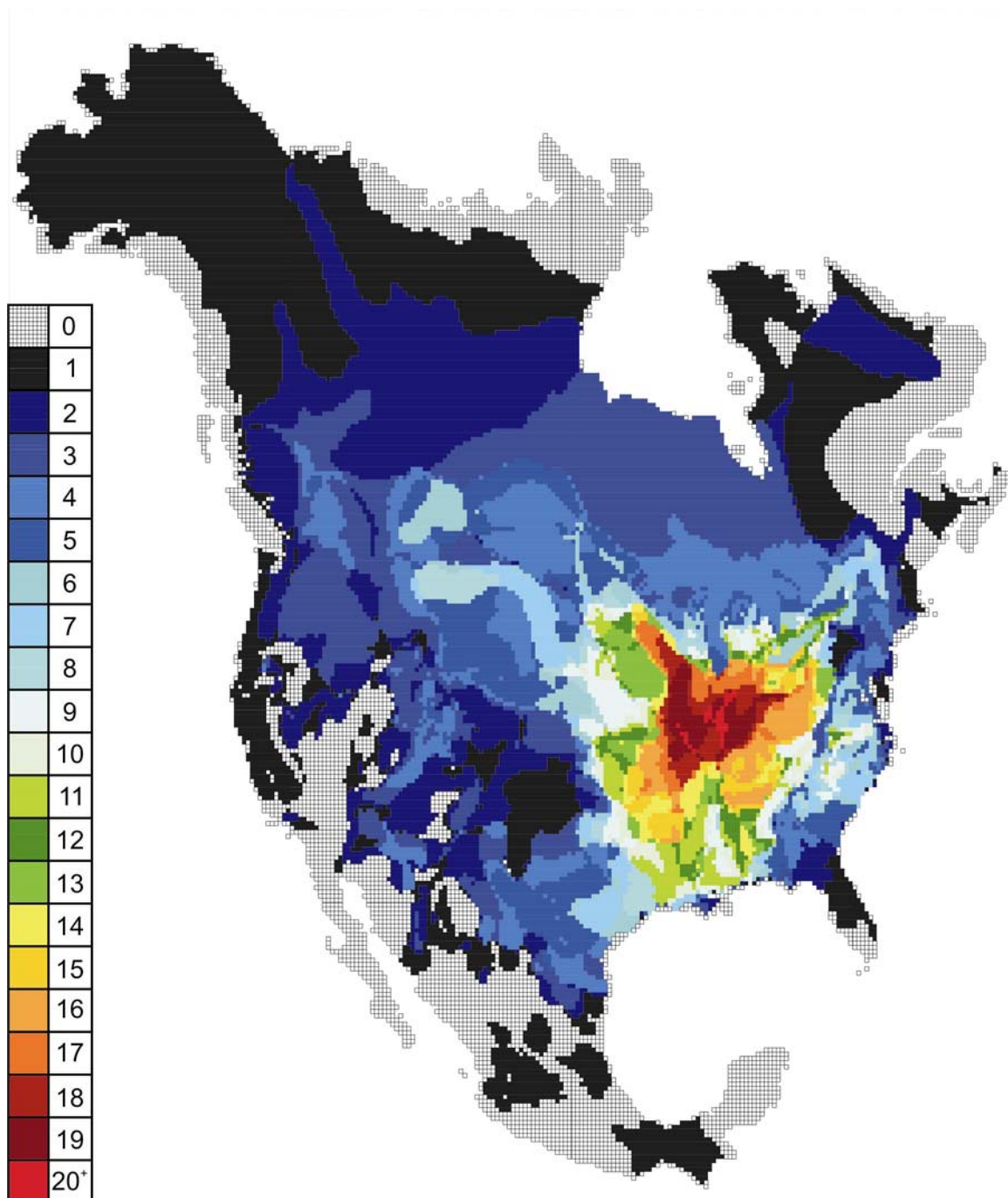


Figure 52. North American composite distribution for all 81 described and pending species of Catostomidae based a 25km² grid of North America.

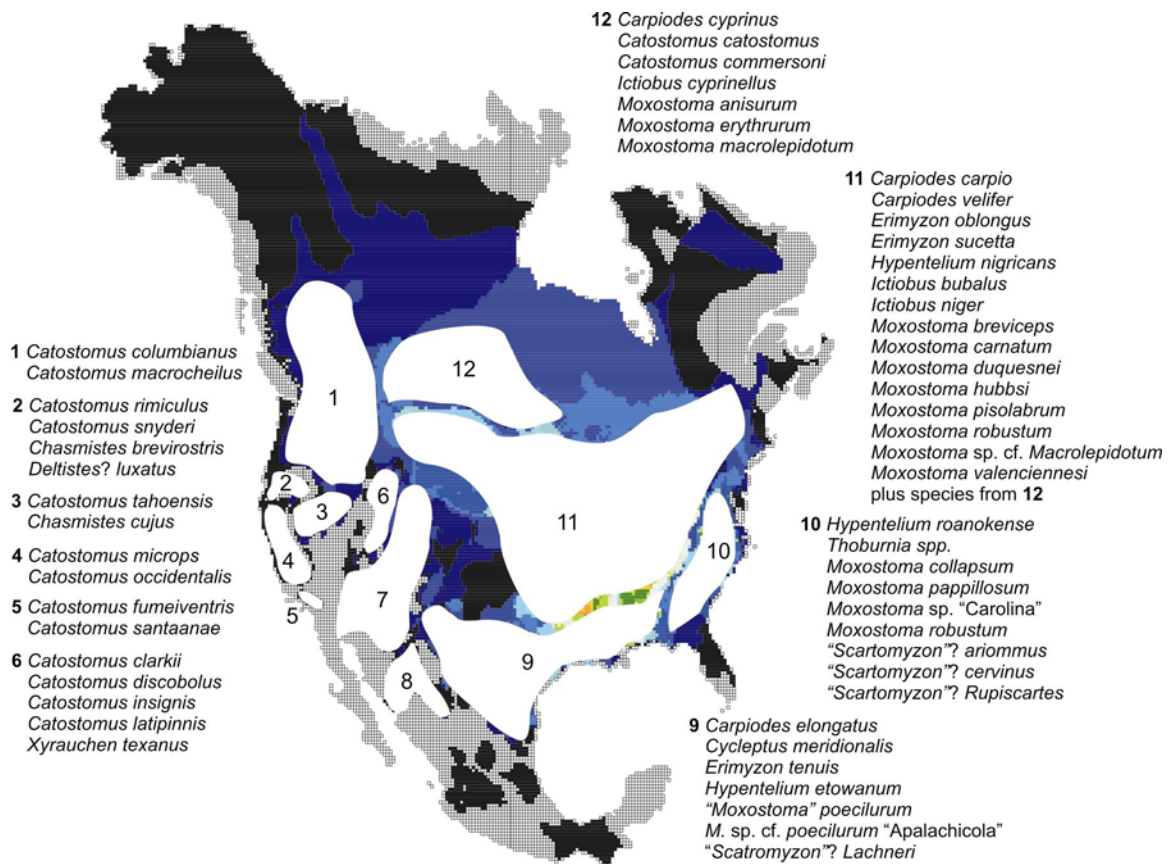


Figure 53. Twelve basic biogeographic zones of interacting catostomid species excluding allopatric species from Mexico and Guatemala.

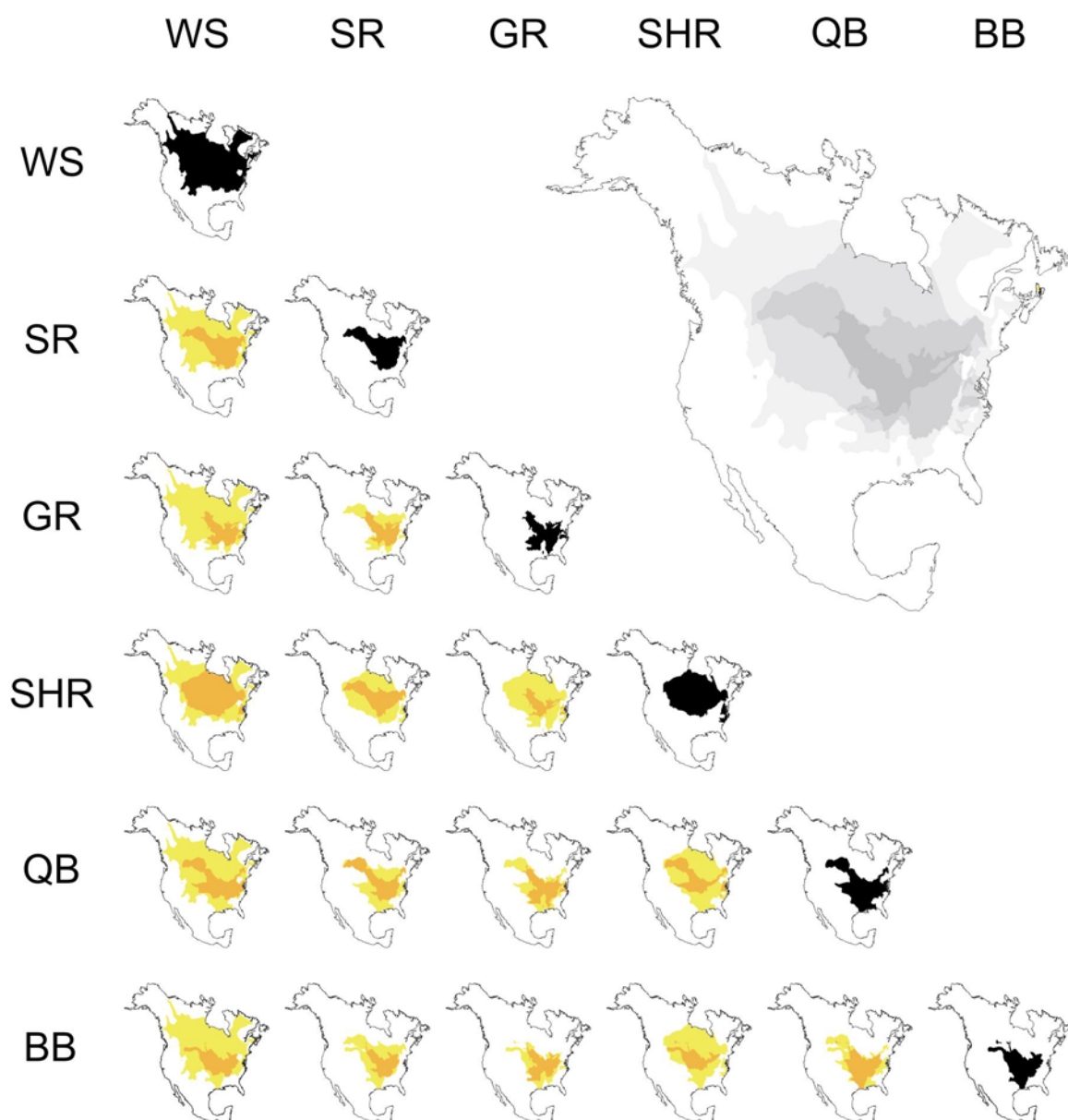


Figure 54. Pairwise geographic overlap for each feeding groups 2 and 3 from Figure 23, including composite zone of overlap for all four species from feeding group 2.

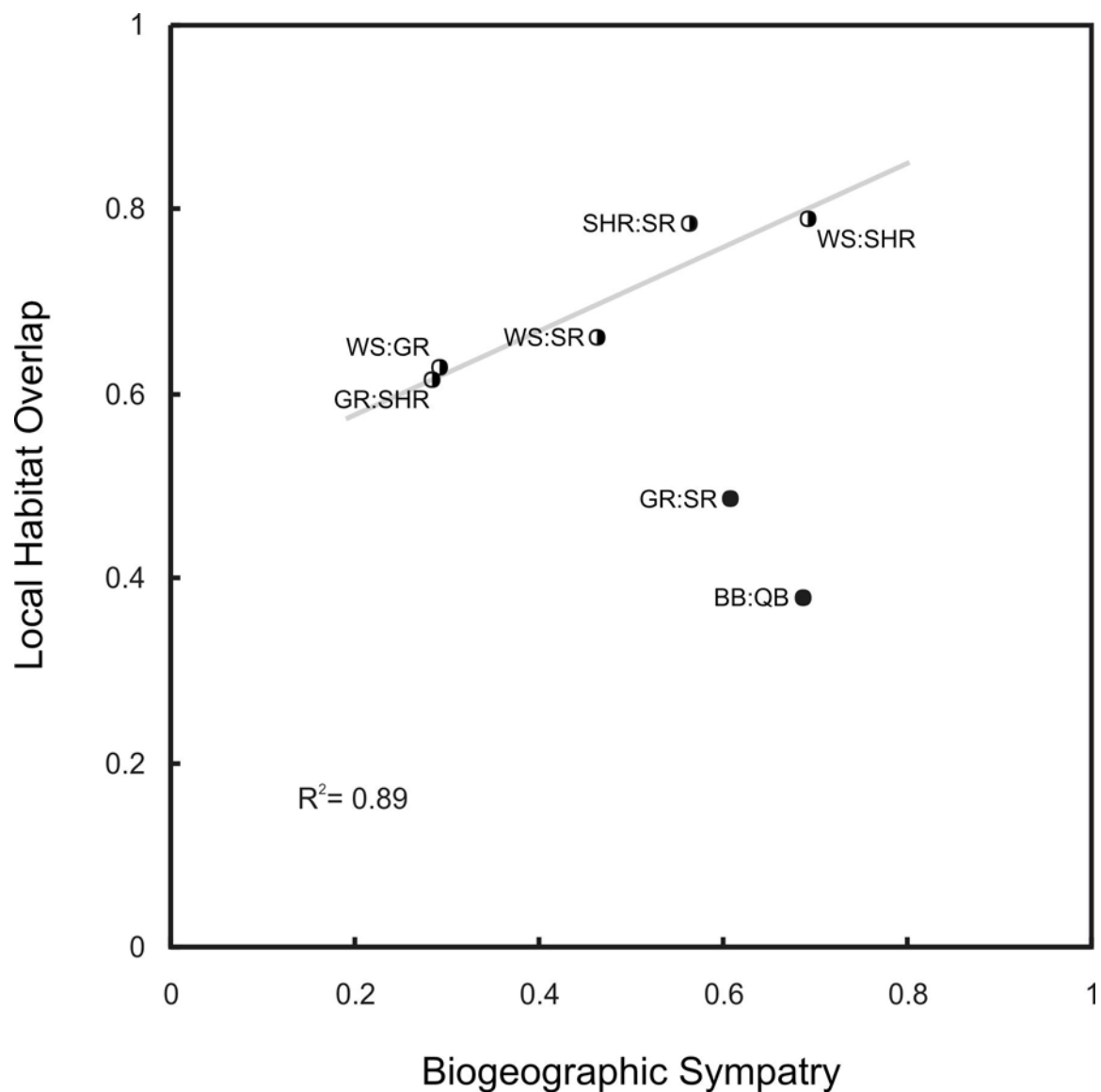


Figure 55. Local habitat overlaps based on Horn overlaps with biogeographic sympatry. Two 'groups' are indicated, half-filled circles represent species pairs that show pattern, filled circles represent species pairs that do not follow the same pattern. Sympatry was calculated based on 25km² grid geographic overlap for all within feeding group pairs for species from Manitoba.

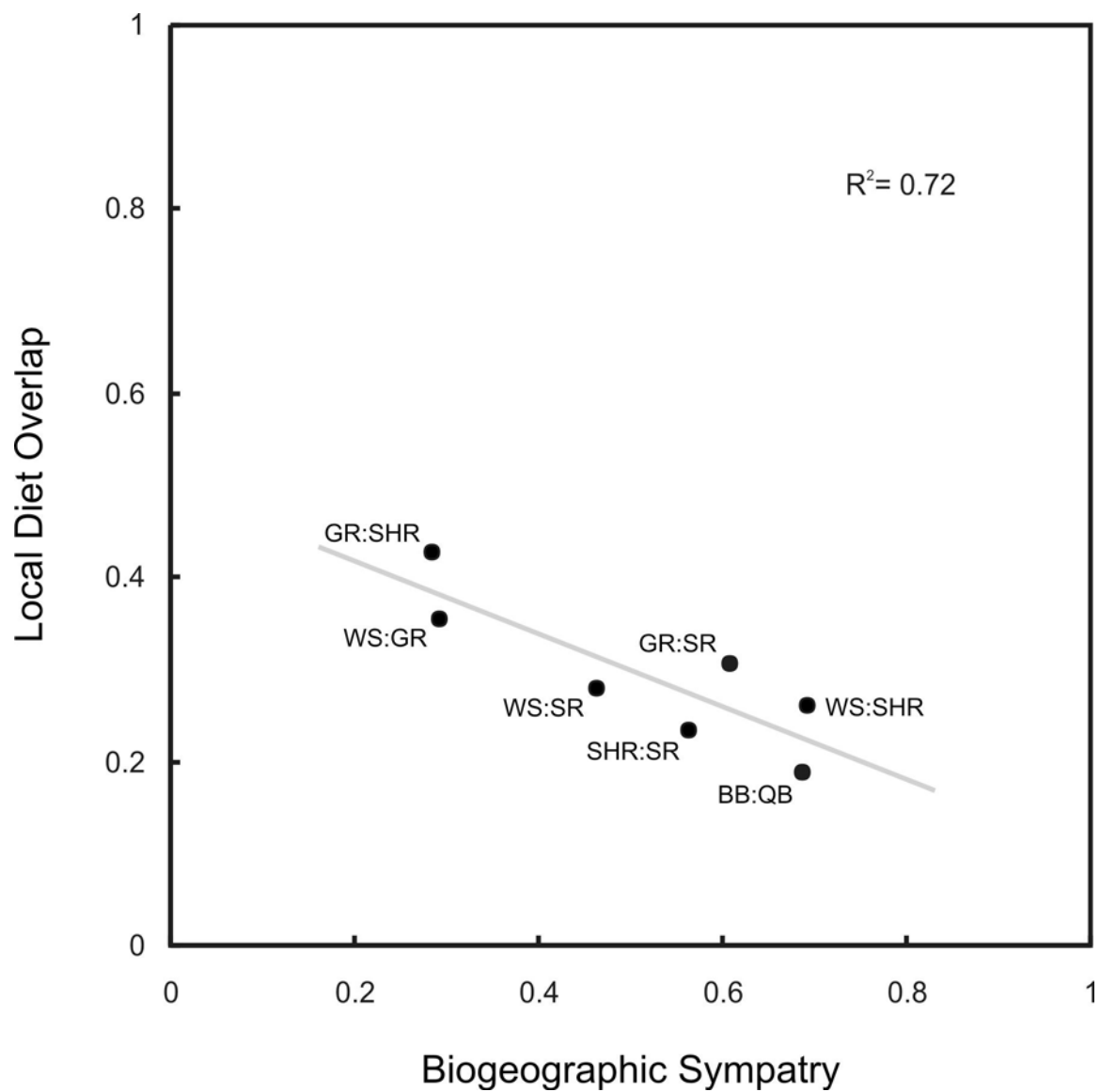


Figure 56. Local diet overlaps based on Horn overlaps with biogeographic sympatry. All species appear to follow the same pattern. Sympatry was calculated based on 25km² grid geographic overlap for all within-feeding-group pairs for species from Manitoba.

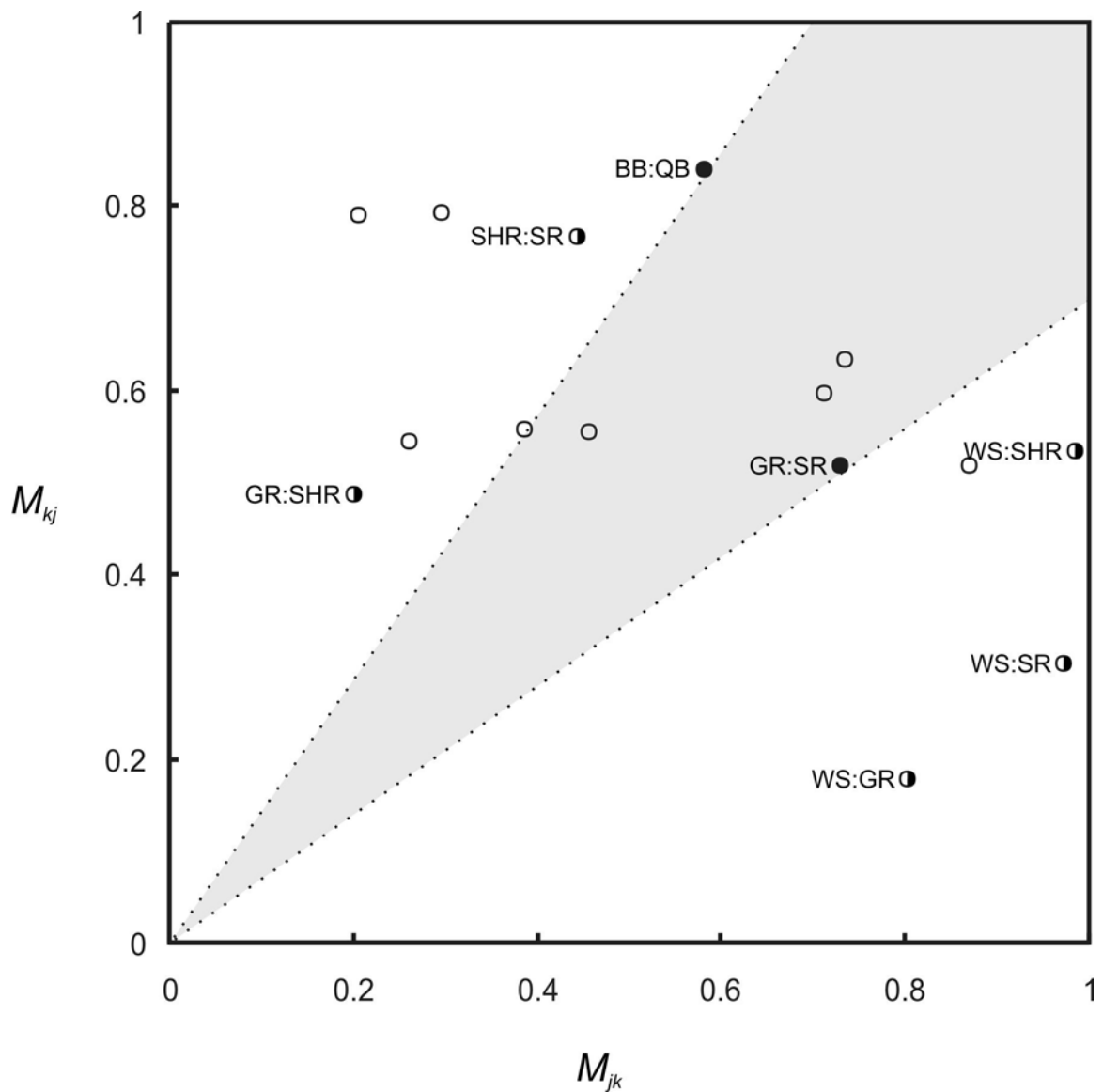


Figure 57. Limiting similarity values graphed as M_{jk} versus M_{kj} for all species pairs based on their geographic overlaps. (1) Open circles represent species pairs that are not from the same functional feeding group. (2) Half-filled circles represent asymmetric overlaps indicating that a) species ranges are comparable but range overlaps are marginal or b) one species range is encompassed by a broad ranging species. (3) Solid circles represent symmetric overlaps between species that are related and from the same functional feeding group. Gray shaded area represents the region of $\pm 30\%$ to indicate area of symmetry.

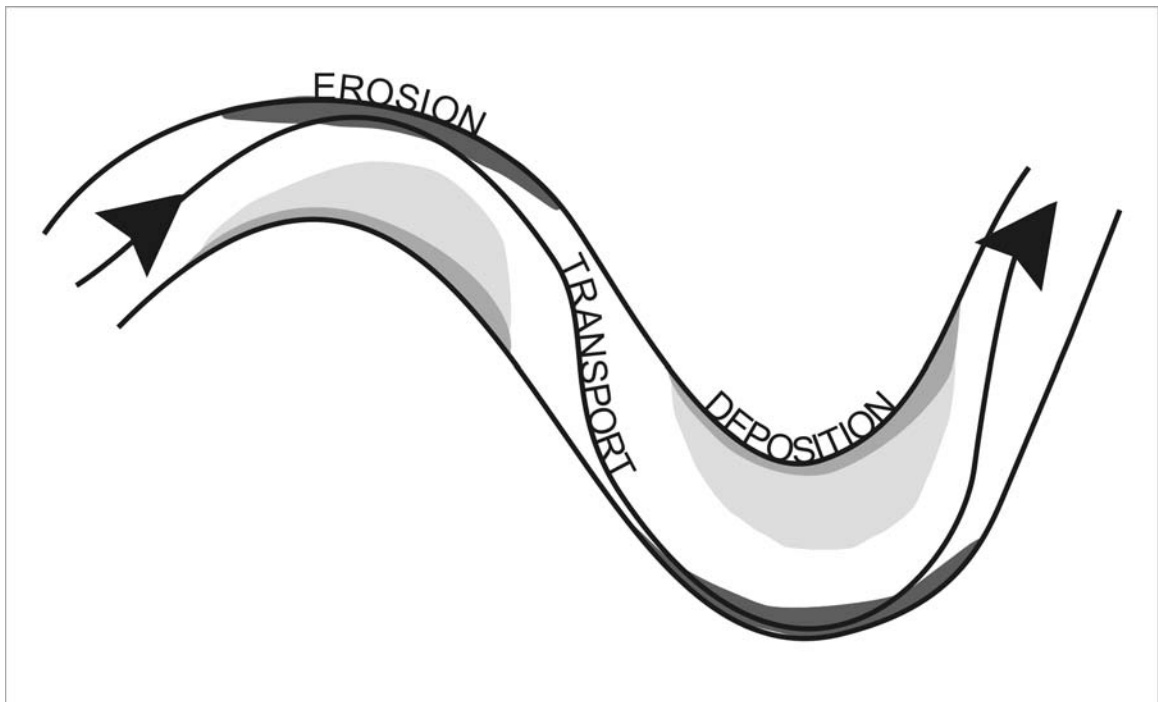


Figure 58. Characteristic longitudinal pattern of erosion, transport, and deposition (ETD) through a meander sequence.

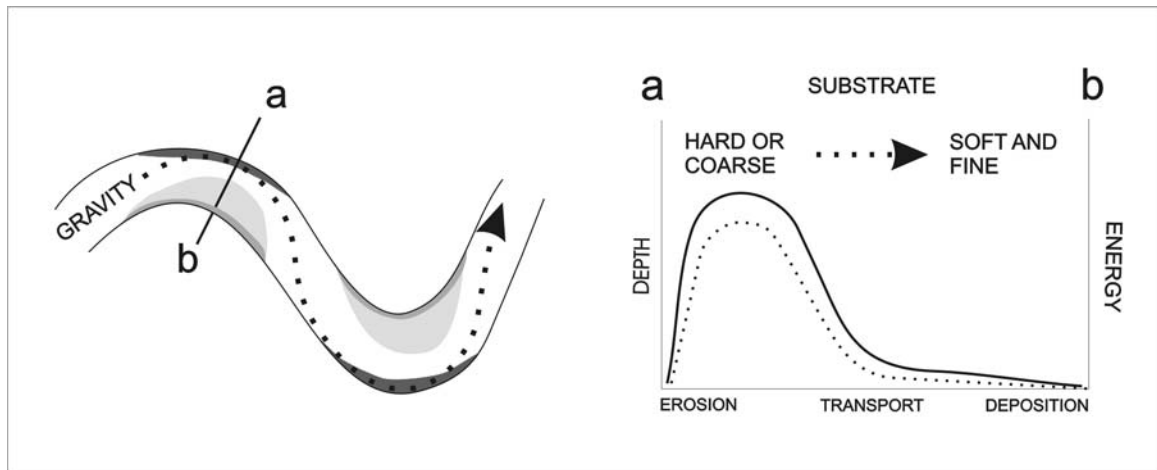


Figure 59. Distribution of depth, substrate, and energy with ETD for a typical cross-section.

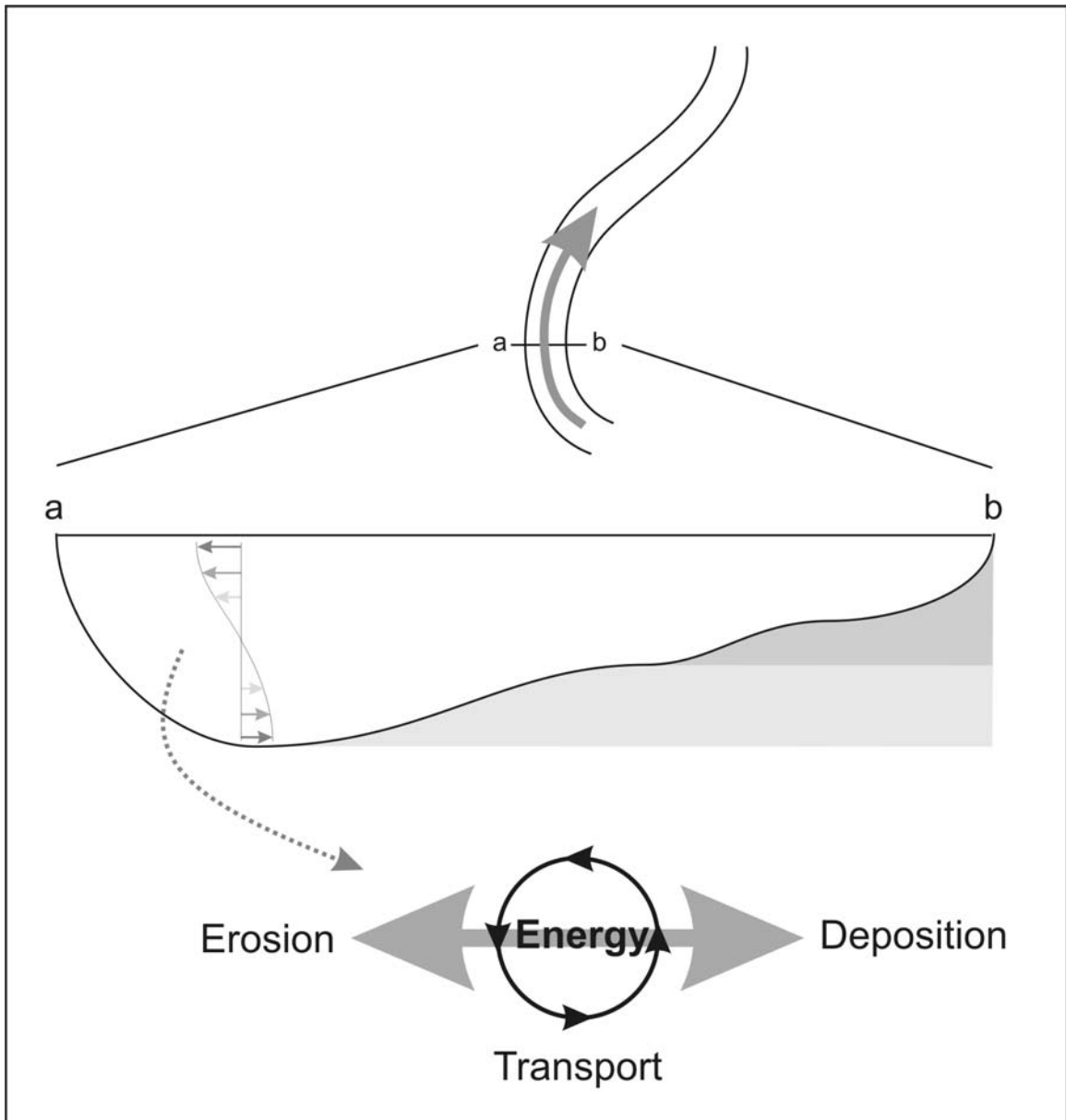


Figure 60. Represents the lateral or secondary flow characteristics of river bends that lead to ETD. Based on Einstein (1926) and Leopold and Wolman (1960).

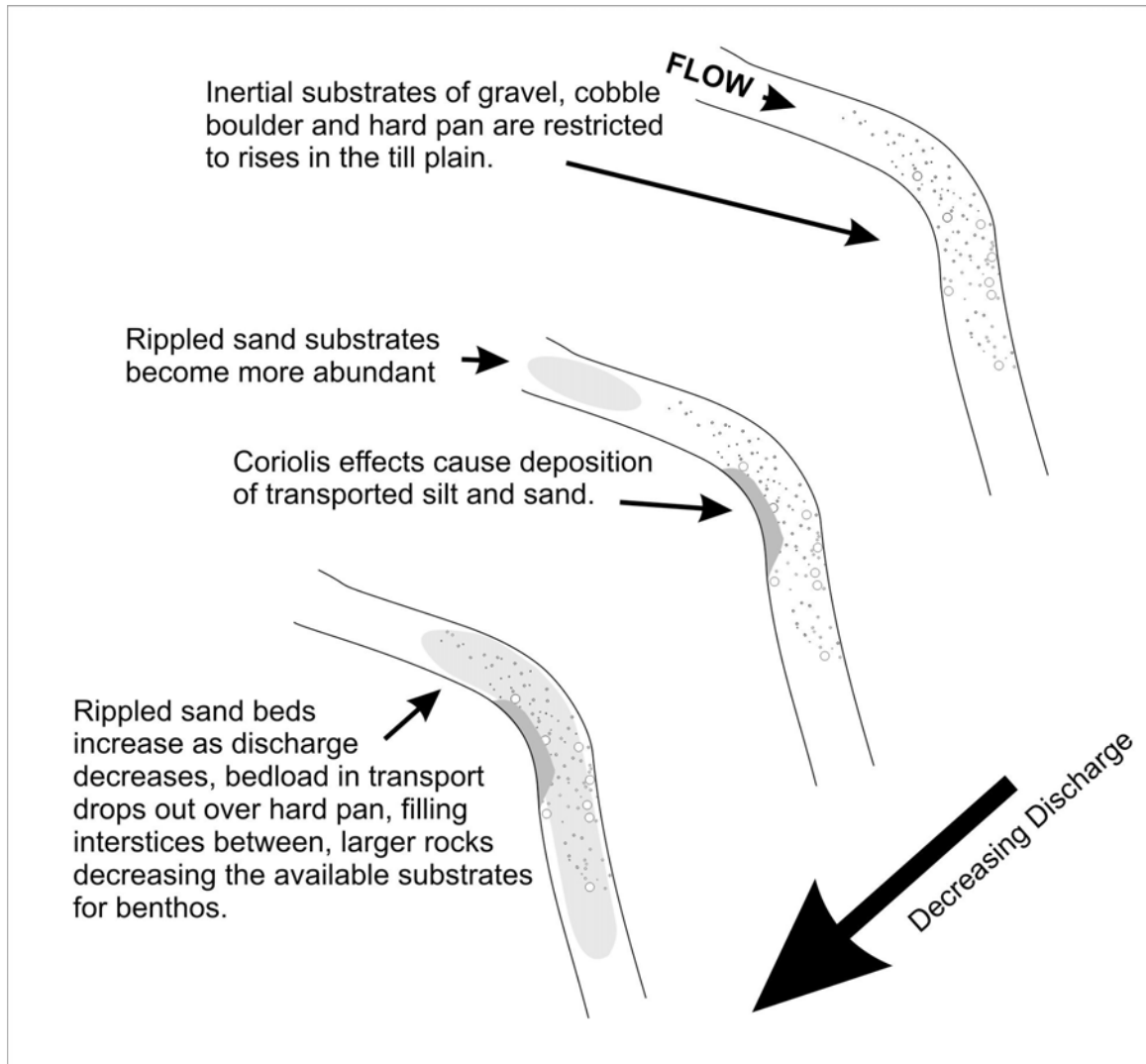


Figure 61. Development of discharge dependent bedload sand with discharge with comments on the subsidiary effects in interstitial benthos. Based on Jackson (1975) with field observation from Assiniboine River present study.

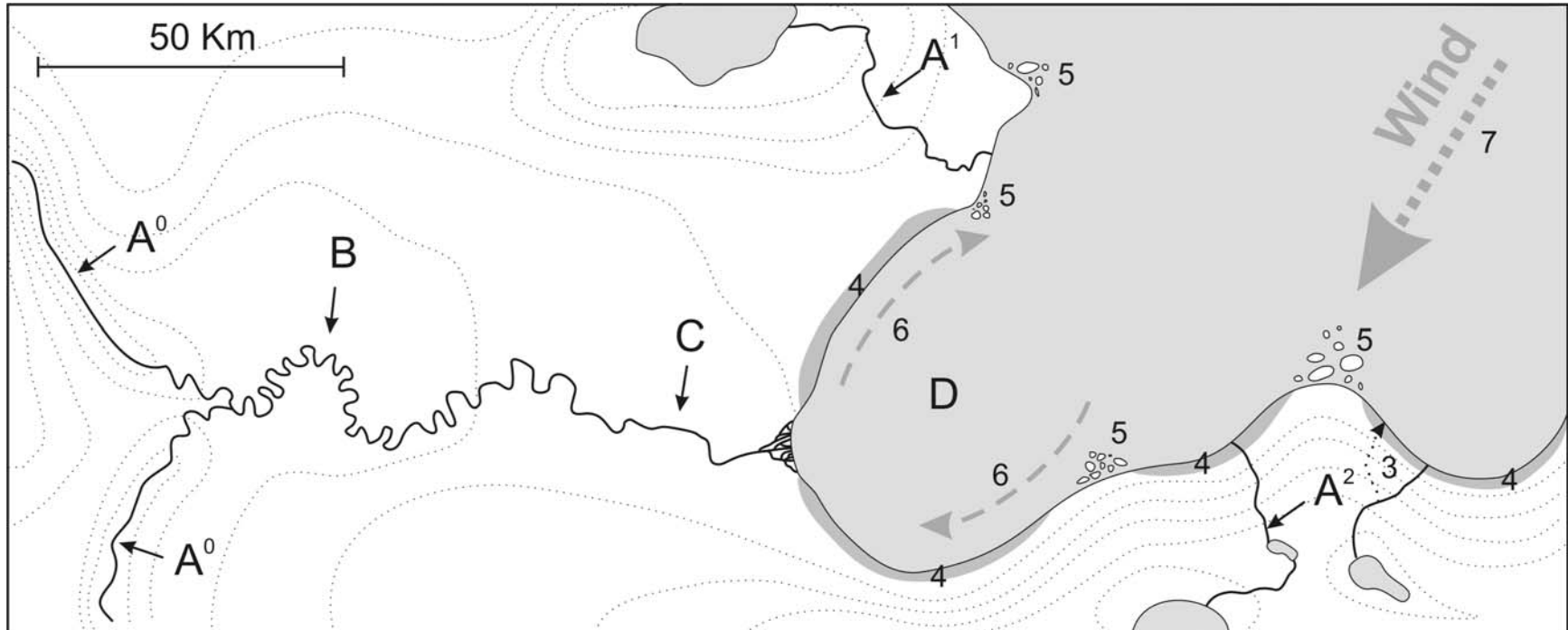


Figure 62. Stylized picture of southern Manitoba showing different watershed features: (A^0) Prairie ecozone headwater streams (A^1) headwater streams in a region of high relief; (A^2) Montane headwater streams; (3) Distributaries may have temporal component; (B) Medium sized streams of low slope in prairie ecozones; (C) Larger rivers in prairie ecozones; (D) Lake embayment with (4) sand-gravel beaches and (5) high energetic boulder points (6) longshore currents (7) wind energy from fetch.

TABLES

Table 1. Taxonomy of the 81 currently described and recognized species of Catostomidae of North America. Taxonomy is based on mtDNA, SSU and LSU rRNA gene sequences (after Harris and Mayden, 2001; Harris et al., 2002) including notes from Bart et al. (in review), as well as Personal Communications from Mark Clements Tulane University, LA and Robert Jenkins Roanoke College, VA. Although, certain species have not yet been formally described they are recognized by State agencies.

Family Catostomidae
Subfamily Myxocyprininae (Harris and Mayden, 2001)
<i>Myxocyprinus asiaticus</i> (Yangtze River, China)
Subfamily Ictiobinae
<i>Ictiobus bubalus</i> (Rafinesque)
<i>Ictiobus cyprinellus</i> (Valenciennes)
<i>Ictiobus labiosus</i> (Meek)
<i>Ictiobus meridionalis?</i> (Gunther) ¹
<i>Ictiobus niger</i> (Rafinesque)
<i>Carpionodes carpio</i> (Rafinesque)
<i>Carpionodes cyprinus</i> (Lesueur)
<i>Carpionodes elongatus</i> (Meek)
<i>Carpionodes velifer</i> (Rafinesque)
Subfamily Cycleptinae
<i>Cycleptus elongatus</i> (Lesueur)
<i>Cycleptus meridionalis</i> (Burr and Mayden)
Subfamily Catostominae
<i>incertae sedis</i> (Harris and Mayden, 2001; Harris et al., 2002)
<i>Erimyzon oblongus</i> (Mitchill)
<i>Erimyzon sucetta</i> (Lacépède)
<i>Erimyzon tenuis</i> (Agassiz)
<i>Minytrema melanops</i> (Rafinesque)

Tribe Catostomini

- "Catostomus" ardens* Jordan & Gilbert
- "Catostomus" bernardini* Girard
- "Catostomus" cahita* Siebert & Minckley
- "Catostomus" catostomus* (Forster)
- "Catostomus" clarkii* Baird & Girard
- "Catostomus" columbianus* (Eigenmann & Eigenmann)
- "Catostomus" commersoni* (Lacépède)
- "Catostomus" conchos* (Meek)
- "Catostomus" discobolus* Cope
- "Catostomus" fumeiventris* Miller
- "Catostomus" insignis* Baird & Girard
- "Catostomus" latipinnis* Baird & Girard
- "Catostomus" leopoldi* Siebert & Minckley
- "Catostomus" macrocheilus* Girard
- "Catostomus" microps* Rutter
- "Catostomus" nebuliferus* Garman
- "Catostomus" occidentalis* Ayres
- "Catostomus" platyrhynchus* (Cope)
- "Catostomus" plebeius* Baird & Girard
- "Catostomus" rimiculus* Gilbert & Snyder
- "Catostomus" santaanae* (Snyder)
- "Catostomus" snyderi* Gilbert
- "Catostomus" tahoensis* Gill & Jordan
- "Catostomus" warnerensis* Snyder
- "Catostomus" wigginsi* Herre & Brock
-

Tribe Catostomini continued...

Xyrauchen texanus (Abbott)

Chasmistes brevirostris Cope

Chasmistes cujus Cope

Chasmistes liorus Jordan

Chasmistes muriei Miller & Smith

Deltistes? luxatus (Cope)

Tribe Thoburniini (sensu Hubbs, 1930)

Hypentelium etowanum (Jordan)

Hypentelium nigricans (Lesueur)

Hypentelium roanokense Raney & Lachner

Thoburnia atripinnis (Bailey)

Thoburnia hamiltoni Raney & Lachner

Thoburnia rhothoeca (Thoburn)

Tribe Moxostomatini

"Moxostoma" anisurum (Rafinesque)

"Moxostoma" collapsum (Jenkins)

"Moxostoma" pappillosum (Cope)

"Moxostoma" carnatum (Cope)

"Moxostoma" sp. cf. macrolepidotum "sicklefin"

"Moxostoma" duquesnei (Lesueur)

"Moxostoma" erythrurum (Rafinesque)

"Moxostoma" sp. "Carolina redhorse"

"Moxostoma" lacerum (Jordan & Brayton)†

"Moxostoma" hubbsi Legendre

"Moxostoma" macrolepidotum (Lesueur)

Tribe Moxostomatini

"Moxostoma" breviceps (Cope)

"Moxostoma" pisolabrum Trautman and Martin

"Moxostoma" poecilurum (Jordan)

"Moxostoma" sp. cf. poecilurum "Apalachicola"

"Moxostoma" robustum (Cope)

"Moxostoma" valenciennesi Jordan

"Scartomyzon"? ariommus (Robins & Raney)

"Scartomyzon"? austrinus (Bean)

"Scartomyzon"? austrinus milleri (Robins and Raney)

"Scartomyzon" sp. cf. austrinus "Rio Juchipila"

"Scartomyzon" sp. cf. austrinus "Rio Conchos"

"Scartomyzon" sp. cf. lachneri

"Scartomyzon"? cervinus (Cope)

"Scartomyzon"? congestus (Baird & Girard)

"Scartomyzon"? albidus (Robins & Raney)

"Scartomyzon"? lachneri (Robins & Raney)

"Scartomyzon"? mascotae Regan

"Scartomyzon"? rupiscartes (Jordan & Jenkins)

Notes: Groups that may exhibit paraphyly or polyphyly are denoted in quotes; groups that may not merit distinction or have uncertain placement are noted by a "?"; 1 notes that *I. meridionalis* may not be different from *I. bubalus*.

Table 2. Habitat variable ranges used for eight categories of depth, velocity and substrate including the percent composition.

Category	Depth (m)		Velocity (m/s)		Substrate	
	Range	%	Range	%	Range	%
1	0-0.45	1.39	0-0.15	1.85	Clay	7.06
2	0.46-0.90	16.67	0.16-0.30	5.67	Silt	1.97
3	0.91-1.35	31.02	0.31-0.45	17.01	Silt-Sand	9.72
4	1.36-1.80	22.57	0.46-0.60	28.82	Sand	46.99
5	1.81-2.25	13.19	0.61-0.75	24.65	Gravel	13.31
6	2.26-2.70	8.80	0.76-0.90	16.32	Cobble	17.13
7	2.71-3.15	4.51	-.91-1.05	4.63	Boulder	1.74
8	3.15+	1.04	1.05+	1.04	Snag	2.08

Table 3. Meander geometry, depth and velocity comparison between ETD and TILL substrates.

Stream Character	ETD ($n=212$)	TILL ($n=60$)	Probability
Degrees in Bend	69.34 $\pm$ 37.88 (12-195)	64.80 $\pm$ 34.24 (17-183)	0.556 [†]
Bend Radius	501.13 $\pm$ 388.35 (59.07-2087.87)	469.54 $\pm$ 387.78 (100.33-1811.92)	0.529 [†]
Meander Arc Length	446.61 $\pm$ 204.33 (114.20-1114.03)	405.06 $\pm$ 194.35 (137.09-896.82)	0.126 [†]
River Width	65.78 $\pm$ 9.36 (46.35-103.53)	83.42 $\pm$ 15.89 (50.85-114.95)	<0.0001 [†]
River Depth [†]	1.60 $\pm$ 0.72 (0.23-5.5)	1.27 $\pm$ 0.50 (0.32-2.87)	<0.0001 [†]
River Velocity [†]	0.60 $\pm$ 0.20 (0-1.2)	0.57 $\pm$ 0.22 (0-1.33)	<0.007 [†]

[†] Mann-Whitney *U*-Test $\alpha=0.01$

[†] Values are based on habitat sampling numbers $n_{\text{ETD}} = 663$ and $n_{\text{TILL}} = 201$.

Table 4. Common, scientific, and abbreviated names and number captured for six catostomid species found in the Assiniboine River, MB.

Common Name	Scientific Name	Abbreviated Name	Number Captured
Quillback	<i>Carpionodes cyprinus</i> (Lesueur)	QB	513
Bigmouth Buffalo	<i>Ictiobus cyprinellus</i> (Valenciennes)	BB	46
White Sucker	<i>Catostomus commersoni</i> (Lacépède)	WS	325
Silver Redhorse	<i>Moxostoma anisurum</i> (Rafinesque)	SR	291
Golden Redhorse	<i>Moxostoma erythrurum</i> (Rafinesque)	GR	110
Shorthead Redhorse	<i>Moxostoma macrolepidotum</i> (Lesueur)	SHR	2072

Table 5. Total species abundance by large-scale substrate, mean $\pm$ SD for each substrate category and Mann-Whitney *U*-Test probabilities. Values in parentheses are the percentage of samples in which a given species occurred.

Species Abundance (n_{ETD} , n_{TILL})	ETD ($n=663$)	Till ($n=201$)	Probability
WS (107, 218)	0.16 $\pm$ 0.56 (10.81)	1.09 $\pm$ 2.31 (41.79)	<0.0001 ¹
SR (205, 85)	0.31 $\pm$ 0.73 (20.42)	0.42 $\pm$ 0.85 (27.36)	0.039 ^{1,NS}
GR (23, 87)	0.04 $\pm$ 0.25 (2.40)	0.43 $\pm$ 0.91 (25.37)	<0.0001 ¹
SHR (1052, 1020)	1.59 $\pm$ 2.48 (52.70)	5.08 $\pm$ 6.43 (77.11)	<0.0001 ¹
QB (459, 54)	0.69 $\pm$ 1.63 (32.13)	0.27 $\pm$ 0.69 (18.91)	<0.0001 ¹
BB (40, 6)	0.06 $\pm$ 0.59 (3.15)	0.03 $\pm$ 0.24 (1.99)	0.386 ^{1,NS}

¹ Mann-Whitney *U*-Test $\alpha=0.01$

^{NS} Not significant

Table 6. Niche breadth (*NB*), effective niche breadth (*ENB*), maximum niche breadth (*MNB*), and evenness, for six species of Catostomid fishes using a three-dimensional data based on depth, velocity and substrate.

	<i>n</i>	Niche Breadth	Effective Niche Breadth	Maximum Breadth	Evenness
WS	325	4.07	58.40	84	0.70
SR	290	4.15	63.57	88	0.72
GR	110	3.46	31.89	44	0.72
SHR	2072	4.39	80.96	151	0.54
QB	513	4.05	57.32	97	0.59
BB	46	2.65	14.14	24	0.59

Table 7. Species observed niche breadth (*NB*) values compared to three random models, Poisson (*RDVS*), Utilization (*IDVS*), and Actual (*ODVS*). Increased number of fish in the *ODVS* model approached observed and were considered not different when 10 of the 1000 iterations were greater than the observed, or 1%.

Species (<i>n</i> , <i>s</i> ¹)	Observed	Poisson	Utilization	Actual (%>Observed)
WS (325, 84)	4.07	5.40 ± 0.03 [†]	4.45 ± 0.06 [†]	3.93 ± 0.05 [‡] (0.1) 4.05 ± 0.02 ^{NS} (10.6)
SR (290, 88)	4.15	5.32 ± 0.03 [†]	4.45 ± 0.06 [†]	3.99 ± 0.05 [‡] (0) 4.13 ± 0.02 ^{NS} (14.6)
GR (110, 44)	3.46	4.56 ± 0.04 [†]	3.79 ± 0.10 [†]	3.25 ± 0.09 [‡] (0.3) 3.45 ± 0.02 ^{NS} (31.7)
SHR (2072, 151)	4.39	6.11 ± 0.01 [†]	4.77 ± 0.03 [†]	4.36 ± 0.02 ^{NS} (5.8) 4.38 ± 0.01 ^{NS} (21.1)
QB (513, 97)	4.05	5.67 ± 0.03 [†]	4.56 ± 0.05 [†]	3.95 ± 0.05 ^{NS} (1.3) 4.03 ± 0.02 ^{NS} (14.1)
BB (46, 24)	2.65	3.77 ± 0.04 [†]	3.35 ± 0.12 [†]	2.36 ± 0.18 ^{NS} (3.2) 2.64 ± 0.04 ^{NS} (36.5)

¹ *s* is the number of *jkl* combinations in the three-dimensional habitat array (p. MNB)

[†] Model produces significantly higher *NB* values than observed.

[‡] Model produces significantly lower *NB* values than observed.

^{NS} Model produces *NB* values not significantly different than observed.

Table 8. Species co-occurrence compared to randomized distributions. Row species are held in observed locations, while column species are randomized. Observed values are given above while values in parentheses are mean_{co-occurrence} ± SD for 100 randomizations.

	WS	SR	GR	SHR	QB	BB
WS <i>n</i> =325	156	59 [†] (44.43 ± 5.32)	32 [†] (18.05 ± 3.82)	132 [‡] (141.77 ± 3.84)	38 [‡] (69.96 ± 6.76)	9 [†] (8.02 ± 2.34)
SR <i>n</i> =290	59 59.49 ± 6.11 ^{NS}	191	22 22.05 ± 3.45 ^{NS}	144 173.67 ± 3.88 [‡]	76 85.63 ± 6.41 [‡]	11 9.35 ± 2.70 [†]
GR <i>n</i> =110	32 [†] (21.09 ± 3.94)	22 [†] (18.70 ± 3.30)	67	58 [‡] (61.27 ± 2.35)	19 [‡] (30.20 ± 4.25)	3 ^{NS} (3.56 ± 1.74)
SHR <i>n</i> =2072	132 [‡] (157.91 ± 7.59)	144 ^{NS} (143.99 ± 7.54)	58 [‡] (59.88 ± 4.81)	505	180 [‡] (225.40 ± 8.13)	23 [‡] (25.83 ± 3.54)
QB <i>n</i> =513	38 [‡] (78.21 ± 6.14)	76 [†] (71.44 ± 6.65)	19 [‡] (29.54 ± 4.43)	180 [‡] (228.67 ± 4.07)	251	15 [†] (12.71 ± 3.18)
BB <i>n</i> =46	9 [†] (7.64 ± 2.20)	11 [†] (7.52 ± 2.22)	3 ^{NS} (3.12 ± 1.57)	23 ^{NS} (22.62 ± 1.46)	15 [†] (11.44 ± 2.71)	25

^{NS} Observed co-occurrence is not different from random.

[†] Observed co-occurrence is higher than random.

[‡] Observed co-occurrence is lower than random.

Table 9. Species abundance compared to randomized distributions. Row species are held in observed locations, while column species are randomized. Observed values are given above while values in parentheses are mean_{abundance} ± SD for 100 randomizations.

	WS	SR	GR	SHR	QB	BB
WS (325, 156)	2.08	1.58 [†] (1.19 ± 0.07)	1.94 [†] (1.07 ± 0.07)	6.49 [†] (2.63 ± 0.11)	2.90 [†] (1.33 ± 0.07)	1.33 [†] (1.03 ± 0.06)
SR (290, 191)	1.58 [†] (1.20 ± 0.06)	1.52	1.41 [†] (1.06 ± 0.05)	4.90 [†] (2.65 ± 0.10)	2.07 [†] (1.34 ± 0.07)	1.91 [†] (1.03 ± 0.02)
GR (110, 67)	3.25 [†] (1.19 ± 0.10)	1.77 [†] (1.18 ± 0.10)	1.64	7.59 [†] (2.66 ± 0.17)	1.58 [†] (1.35 ± 0.11)	1.67 [†] (0.99 ± 0.24)
SHR (2072, 505)	2.23 [†] (1.20 ± 0.03)	1.52 [†] (1.18 ± 0.03)	1.72 [†] (1.07 ± 0.04)	4.10	2.12 [†] (1.33 ± 0.03)	1.91 [†] (1.02 ± 0.03)
QB (513, 251)	2.58 [†] (1.19 ± 0.05)	1.57 [†] (1.18 ± 0.05)	1.79 [†] (1.07 ± 0.04)	3.91 [†] (2.64 ± 0.09)	2.04	2.40 [†] (1.02 ± 0.04)
BB (46, 25)	4.22 [†] (1.20 ± 0.19)	1.64 [†] (1.16 ± 0.16)	2.00 [†] (0.97 ± 0.32)	4.00 [†] (2.66 ± 0.30)	3.60 [†] (1.34 ± 0.19)	1.84

^{NS} Observed mean abundance encountered is not different from random mean abundance.

[†] Observed mean abundance encountered is higher than random mean abundance.

[‡] Observed mean abundance encountered is lower than random.

Table 10. A summary of diet matrices for 385 fish stomachs anterior portion of the intestine.

Species (<i>n</i>)	% Fill	% Empty	Mean _{Richness} ± SD (Range)	Mean _{%Prevalence} ± SD (Range)
WS (71)	24.74	14.09	8.16 ± 3.55 (1-16)	24.74 ± 21.9 (1.6-73.8)
SR (64)	24.91	14.06	7.47 ± 3.26 (2-16)	24.91 ± 19.2 (1.8-69.1)
GR (61)	34.01	3.28	10.20 ± 3.19 (1-17)	34.01 ± 29.5 (1.7-96.6)
SHR (74)	20.44	9.46	6.74 ± 2.99 (1-14)	20.44 ± 21.8 (1.5-88.5)
QB (88)	14.00	23.86	3.78 ± 2.02 (1-8)	14.00 ± 15.4 (1.5-50.7)
BB (27)	20.82	37.04	2.71 ± 1.86 (1-6)	20.82 ± 18.5 (5.9-64.7)

Table 11. Mean Horn overlap values $\pm$ SD for all pair combinations, based on 33 identified food items. Values IN parentheses are the number of pair combinations.

	WS	SR	GR	SHR)	QB	BB
WS	0.33 $\pm$ 0.24 (1830)	-	-	-	-	-
SR	0.28 $\pm$ 0.22 (3355)	0.28 $\pm$ 0.22 (1485)	-	-	-	-
GR	0.35 $\pm$ 0.21 (3599)	0.31 $\pm$ 0.20 (3245)	0.53 $\pm$ 0.20 (1711)	-	-	-
SHR	0.26 $\pm$ 0.20 (4087)	0.23 $\pm$ 0.20 (3685)	0.43 $\pm$ 0.21 (3953)	0.46 $\pm$ 0.28 (2211)	-	-
QB	0.12 $\pm$ 0.16 (4087)	0.13 $\pm$ 0.18 (3685)	0.13 $\pm$ 0.16 (3953)	0.12 $\pm$ 0.18 (4489)	0.22 $\pm$ 0.28 (2211)	-
BB	0.05 $\pm$ 0.13 (1037)	0.03 $\pm$ 0.08 (935)	0.03 $\pm$ 0.08 (1003)	0.03 $\pm$ 0.09 (1139)	0.19 $\pm$ 0.32 (1139)	0.38 $\pm$ 0.41 (136)

Table 12. Mean M_{jk} , M_{kj} values $\pm$ SD for all pair combinations, based on 33 identified food items. N-values are the same as for Horn overlaps.

Mjk	WS	SR	GR	SHR	QB	BB
WS	0.43 ± 0.26	-	-	-	-	-
SR	0.41 ± 0.24	0.41 ± 0.25	-	-	-	-
GR	0.47 ± 0.24	0.39 ± 0.23	0.63 ± 0.20	-	-	-
SHR	0.42 ± 0.26	0.35 ± 0.25	0.56 ± 0.23	0.44 ± 0.25	-	-
QB	0.33 ± 0.28	0.28 ± 0.26	0.35 ± 0.29	0.25 ± 0.26	0.29 ± 0.29	-
BB	0.18 ± 0.27	0.13 ± 0.22	0.17 ± 0.26	0.12 ± 0.23	0.25 ± 0.34	0.44 ± 0.40
Mkj	WS	SR	GR	SHR	QB	BB
WS	0.43 ± 0.25	0.38 ± 0.23	0.53 ± 0.24	0.34 ± 0.21	0.17 ± 0.16	0.08 ± 0.15
SR	-	0.36 ± 0.21	0.50 ± 0.23	0.30 ± 0.20	0.16 ± 0.16	0.07 ± 0.11
GR	-	-	0.56 ± 0.21	0.38 ± 0.21	0.15 ± 0.15	0.06 ± 0.12
SHR	-	-	-	0.43 ± 0.26	0.15 ± 0.16	0.07 ± 0.12
QB	-	-	-	-	0.31 ± 0.31	0.21 ± 0.28
BB	-	-	-	-	-	0.34 ± 0.33

Table 13. Mean angle of M_{jk} versus M_{kj} scatter plots $\pm$ SD. Values in parentheses are the percentage of angles that are greater than the intra-specific mean of 45° . The same number of pairwise combinations used for the Horn overlaps given in Table 10 are used here.

	WS	SR	GR	SHR)	QB	BB
WS	45.0 $\pm$ 13.70 (50)	-	-	-	-	-
SR	40.28 $\pm$ 17.91 (35.17)	45.0 $\pm$ 17.13 (50)	-	-	-	-
GR	49.71 $\pm$ 16.63 (56.88)	54.61 $\pm$ 15.02 (69.40)	45.0 $\pm$ 13.86 (50)	-	-	-
SHR	36.51 $\pm$ 16.97 (27.23)	41.08 $\pm$ 16.25 (34.44)	31.85 $\pm$ 13.87 (16.44)	45.0 $\pm$ 15.76 (50)	-	-
QB	30.56 $\pm$ 15.08 (12.85)	35.0 $\pm$ 14.5 (16.99)	25.78 $\pm$ 11.01 (4.38)	37.67 $\pm$ 13.81 (19.63)	45.0 $\pm$ 13.70 (50)	-
BB	25.39 $\pm$ 16.66 (5.79)	28.05 $\pm$ 17.20 (5.13)	20.90 $\pm$ 14.82 (4.59)	31.01 $\pm$ 17.59 (5.44)	37.06 $\pm$ 15.35 (12.56)	45.0 $\pm$ 14.71 (50)

Table 14. Percentage of randomized Horn overlaps greater than observed for RA1, RA2, and RA3. Overlaps are based on mean prevalence of diet items by species.

	RA1	RA2	RA3
WS:SR	0	0	0
WS:GR	0	0	0
WS:SHR	0	0	0
SR:GR	0	0	0
SR:SHR	11	0	0
GR:SHR	0	0	0
WS:QB	25	4	5
SR:QB	48	8	10
GR:QB	67	16	17
SHR:QB	29	17	15
WS:BB	93	58	71
SR:BB	88	73	55
GR:BB	89	83	55
SHR:BB	76	77	44
QB:BB	13	0	1

Table 15. Percentage of randomized Horn overlaps greater than observed for RA1, RA2, and RA3. Overlaps are based on mean abundance values for each species.

	RA1	RA2	RA3
WS:SR	100	2	1
WS:GR	99	1	1
WS:SHR	100	0	0
SR:GR	100	8	6
SR:SHR	100	1	0
GR:SHR	5	0	0
WS:QB	100	14	12
SR:QB	100	44	60
GR:QB	100	47	42
SHR:QB	100	33	22
WS:BB	90	4	6
SR:BB	100	97	95
GR:BB	100	95	95
SHR:BB	100	96	93
QB:BB	14	0	2

Table 16. Summary of canonical variates analysis of PCoA feeding group scores (Figure 41). Chi-square statistics indicates significance for up to the first 2 canonical variates removed.

Variable	Among Group SSQ	Within Group SSQ	F-Ratio
1	6.11	0.01	587.90
2	1.96	0.02	81.32
3	2.54	0.01	179.03
4	0.62	0.03	21.17
Canonical Variate	Eigenvalue	Eigenvalue as Percentage	Canonical Correlation
1	7.14	70.37	0.94
2	1.81	17.78	0.80
3	1.20	11.84	0.74
Canonical Variates Removed	Chi Square	Degrees of Freedom	Wilks Lamba
Up to 0	1257.67 [†]	12	0.02
Up to 1	584.49 [†]	6	0.16
Up to 2	253.39 [†]	2	0.45

[†] Indicates values are significantly greater than chi-square statistic at given degrees of freedom.

Table 17. Summary of canonical variates analysis of PCoA benthic invertebrate group scores (Figure 43). Chi-square statistics indicates significance for up to the first 2 canonical variates removed.

Variable	Among Group SSQ	Within Group SSQ	F-Ratio
1	9.32	0.02	575.09
2	5.34	0.02	290.47
3	2.16	0.01	157.69
4	0.02	0.02	1.08
Canonical Variate	Eigenvalue	Eigenvalue as Percentage	Canonical Correlation
1	5.85	60.42	0.92
2	2.41	24.88	0.84
3	1.42	14.71	0.77
Canonical Variates Removed	Chi Square	Degrees of Freedom	Wilks Lamba
Up to 0	1363.70 [†]	12	0.02
Up to 1	713.49 [†]	6	0.12
Up to 2	299.15 [†]	2	0.41

[†] Indicates values are significantly greater than chi-square statistic at given degrees of freedom.

Table 18: Coefficient of Sympatry, Variance of $M_{jk}:M_{kj}$, number of watersheds and type of pattern for all sister pairs of Ictiobinae. Abbreviations are summarized below Table.

Species Pair	Coefficient of Sympatry	Variance (M_{jk} & M_{kj})	Number of Watersheds	Type of Distribution
<i>Cca:Ccy</i>	0.55	8.55×10^{-05}	821:964	Sympatric
<i>Cca:Cel</i>	0	0	821:149	Allopatric
<i>Cca:Cve</i>	0.62	0.07	821:502	Sympatric
<i>Ccy:Cve</i>	0.67	0.09	964:502	Sympatric
<i>Ibu:Icy</i>	0.72	0.02	826:653	Sympatric
<i>Ibu:Ila</i>	0	0	826:15	Allopatric
<i>Ibu:Ime</i>	0	0	826:52	Allopatric
<i>Ibu:Ini</i>	0.85	0.03	826:628	Sympatric
<i>Icy:Ila</i>	0	0	653:15	Allopatric
<i>Icy:Ime</i>	0	0	653:52	Allopatric
<i>Icy:Ini</i>	0.69	5.26×10^{-05}	653:628	Sympatric
<i>Ila:Ime</i>	0	0	15:52	Allopatric
<i>Ila:Ini</i>	0	0	15:628	Allopatric
<i>Ime:Ini</i>	0	0	52:628	Allopatric

Cca = *Carpoides carpio*, *Ccy* = *C. cyprinus*, *Cel* = *C. elongatus*, *Cve* = *C. velifer*, *Ibu* = *Ictiobus bubalus*, *Icy* = *I. cyprinellus*, *Ila* = *I. labiosus*, *Ime* = *I. meridionalis*, *Ini* = *I. niger*,

Table 19: Coefficient of Sympatry, Variance of $M_{jk}:M_{kj}$, number of watersheds and type of pattern for all sister pairs of *Moxostoma*. Abbreviations are summarized below Table.

Species Pair	Coefficient of Sympatry	Variance (M_{jk} & M_{kj})	Number of Watersheds	Type of Distribution
<i>Mhu:Mma</i>	1.0×10^{-3}	0.50	9:1218	Peripheral
<i>Mhu:Mbr</i>	0	0	9:110	Allopatric
<i>Mhu:Mpi</i>	0	0	9:113	Allopatric
<i>Mma:Mbr</i>	0.01	1.0×10^{-3}	1218:110	Parapatric
<i>Mma:Mpi</i>	0.04	0.04	1218:113	Parapatric
<i>Mbr:Mpi</i>	0	0	110:113	Allopatric
<i>Man:Mco</i>	0	0	726:66	Allopatric
<i>Man:Mpa</i>	0	0	726:22	Allopatric
<i>Mco:Mpa</i>	0.42	0.24	66:22	Sympatric
<i>Mer:"MCA"</i>	0	0	556:20	Allopatric

Mhu = *Moxostoma hubbsi*, *Mma* = *M. macrolepidotum*, *Mbr* = *M. breviceps*, *Mpi* = *M. pisolabrum*, *Man* = *M. anisurum*, *Mco* = *M. collapsum*, *Mpa* = *M. pappillosum*, *Mer* = *M. erythrurum*, "MCA" = *M. sp. "Carolina"*,

Table 20: Coefficient of Sympatry, Variance of $M_{jk}:M_{kj}$, number of watersheds and type of pattern for all sympatric catostomids from Assiniboine River, restricted to within feeding group comparisons. Abbreviations are summarized below Table.

Species Pair	Coefficient of Sympatry	Variance (M_{jk} & M_{kj})	Number of Watersheds	Type of Distribution
<i>Cco:Man</i>	0.46	0.03	2295:726	Sympatric
<i>Cco:Mer</i>	0.29	0.22	2295:556	Sympatric
<i>Cco:Mma</i>	0.69	0.20	2295:1218	Sympatric
<i>Man:Mer</i>	0.61	0.10	726:556	Sympatric
<i>Man:Mma</i>	0.56	0.02	726:1218	Sympatric
<i>Mer:Mma</i>	0.28	0.05	556:1218	Sympatric
<i>Cca:Icy</i>	0.69	0.04	964:653	Sympatric

Cco = *Catostomus commersoni*.

APPENDICES

Appendix 1. Raw catch data from 6 monthly sample periods with 144 samples each, excluding May 1996, for six catostomid species from 160km of the Assiniboine River, MB between Potage la Prairie Dam (160km) and Winnipeg (0km).

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
157.9	09.08.95	11:00	16	A1	0.19	1.35	0.63	5	0	0	0	0	4	0
157.6	09.08.95	11:15	16	A2	0.22	1.40	0.72	5	0	0	0	0	1	0
157.3	09.08.95	11:30	16	A3	0.20	1.66	0.68	5	0	0	0	0	1	0
154.9	09.08.95	11:45	16	B1	0.22	1.00	0.72	5	0	0	0	2	1	0
154.6	09.08.95	12:00	16	B2	0.21	1.83	0.72	4	0	0	0	1	0	0
154.3	09.08.95	12:15	16	B3	0.19	1.79	0.65	5	0	0	0	1	0	0
151.9	09.08.95	12:30	16	C1	0.18	1.25	0.59	6	0	1	0	1	0	0
151.6	09.08.95	12:45	16	C2	0.19	1.25	0.63	4	1	0	0	0	0	0
151.3	09.08.95	13:00	16	C3	0.20	0.83	0.64	4	1	1	0	1	0	0
147.9	11.08.95	10:30	15	A1	0.21	1.62	0.72	4	0	0	0	4	1	0
147.6	11.08.95	10:48	15	A2	0.16	1.05	0.54	4	0	0	0	0	1	0
147.3	11.08.95	11:00	15	A3	0.19	0.85	0.63	4	0	0	0	1	2	0
146.9	11.08.95	11:06	15	B1	0.19	1.45	0.65	4	0	0	0	2	0	0
146.6	11.08.95	11:15	15	B2	0.19	0.85	0.62	4	0	0	0	1	0	0
146.3	11.08.95	11:25	15	B3	0.25	1.35	0.82	4	0	0	0	0	10	0
141.9	11.08.95	11:35	15	C1	0.16	1.35	0.52	3	1	0	0	0	0	0
141.6	11.08.95	11:50	15	C2	0.20	1.65	0.66	4	0	0	0	0	0	0
141.3	11.08.95	12:00	15	C3	0.16	1.28	0.52	4	0	0	0	1	0	0
140.9	11.08.95	12:10	14	A1	0.15	1.93	0.50	3	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
140.6	11.08.95	12:20	14	A2	0.18	1.37	0.60	4	2	0	0	1	0	0
140.3	11.08.95	12:55	14	A3	0.18	1.10	0.60	4	0	0	0	1	0	0
134.9	11.08.95	13:03	14	B1	0.21	0.53	0.69	3	0	0	0	1	3	0
134.6	11.08.95	13:10	14	B2	0.15	1.25	0.50	4	0	1	0	0	0	0
134.3	11.08.95	13:20	14	B3	0.19	0.52	0.60	4	0	0	0	0	0	0
132.9	11.08.95	13:23	14	C1	0.20	1.37	0.67	4	0	0	0	0	0	0
132.6	11.08.95	13:36	14	C2	0.18	1.05	0.60	4	0	0	0	0	0	0
132.3	11.08.95	13:42	14	C3	0.07	2.04	0.23	4	0	1	0	0	0	0
126.9	11.08.95	15:20	13	A1	0.08	0.70	0.25	3	0	0	0	0	0	0
126.6	11.08.95	15:30	13	A2	0.18	1.58	0.60	4	0	0	0	0	1	0
126.3	11.08.95	15:40	13	A3	0.07	0.23	0.23	4	0	0	0	0	1	0
122.9	11.08.95	16:00	13	B1	0.12	0.98	0.38	3	0	0	0	0	0	0
122.6	11.08.95	16:07	13	B2	0.18	1.10	0.60	4	0	0	0	1	0	0
122.3	11.08.95	16:14	13	B3	0.18	1.20	0.60	4	0	0	0	0	1	0
121.9	11.08.95	16:18	13	C1	0.22	2.04	0.75	1	0	0	0	0	0	0
121.6	11.08.95	16:23	13	C2	0.18	1.27	0.60	4	0	0	0	2	0	0
121.3	11.08.95	16:30	13	C3	0.13	0.54	0.43	4	0	3	0	0	0	0
119.9	11.08.95	16:58	12	A1	0.12	0.98	0.40	4	0	2	0	0	1	0
119.6	11.08.95	17:05	12	A2	0.18	0.93	0.60	4	0	0	0	0	0	0
119.3	11.08.95	17:11	12	A3	0.13	1.48	0.43	4	0	0	0	3	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
115.9	11.08.95	17:17	12	B1	0.18	0.88	0.60	4	0	0	0	1	1	0
115.6	11.08.95	17:22	12	B2	0.18	1.24	0.60	4	0	0	0	0	0	0
115.3	11.08.95	17:30	12	B3	0.18	1.80	0.60	4	0	0	0	0	1	0
111.9	11.08.95	18:00	12	C1	0.19	0.59	0.60	4	0	0	0	0	1	0
111.6	11.08.95	18:08	12	C2	0.20	0.80	0.64	4	0	0	0	0	0	0
111.3	11.08.95	18:16	12	C3	0.11	1.30	0.37	4	0	0	0	3	0	0
109.9	11.08.95	18:25	11	A1	0.14	2.63	0.50	4	0	0	0	3	0	0
109.6	11.08.95	18:35	11	A2	0.18	2.28	0.64	4	0	0	0	0	0	0
109.3	11.08.95	18:45	11	A3	0.09	0.71	0.30	5	0	0	0	0	0	0
107.9	11.08.95	18:55	11	B1	0.18	1.40	0.60	4	0	0	0	1	1	0
107.6	11.08.95	19:00	11	B2	0.15	1.82	0.50	4	0	0	0	0	1	0
107.3	11.08.95	19:07	11	B3	0.14	1.73	0.46	5	1	0	0	1	0	0
106.9	11.08.95	19:15	11	C1	0.10	0.85	0.33	4	0	0	0	0	1	0
106.6	11.08.95	19:20	11	C2	0.18	0.93	0.60	4	0	0	0	0	0	0
106.3	11.08.95	19:25	11	C3	0.15	1.29	0.50	4	0	0	0	1	1	0
98.9	12.08.95	12:00	10	A1	0.00	1.55	0.00	2	0	0	0	1	0	0
98.6	12.08.95	12:15	10	A2	0.23	1.25	0.75	4	0	0	0	0	0	0
98.3	12.08.95	12:20	10	A3	0.11	1.19	0.37	4	2	1	0	0	2	0
97.9	12.08.95	12:30	10	B1	0.18	1.55	0.60	1	0	0	0	0	0	0
97.6	12.08.95	12:35	10	B2	0.15	1.10	0.50	4	0	0	0	0	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
97.3	12.08.95	12:45	10	B3	0.23	0.79	0.75	4	0	0	0	2	0	0
91.9	12.08.95	13:00	10	C1	0.10	1.50	0.33	3	0	1	0	1	1	0
91.6	12.08.95	13:10	10	C2	0.18	1.10	0.60	4	0	0	0	0	0	0
91.3	12.08.95	13:16	10	C3	0.22	1.48	0.75	5	0	1	0	4	0	0
87.9	12.08.95	13:46	9	A1	0.15	1.33	0.50	4	0	0	0	3	0	0
87.6	12.08.95	13:56	9	A2	0.15	1.09	0.50	4	0	0	0	0	1	0
87.3	12.08.95	14:02	9	A3	0.13	1.05	0.43	4	0	0	0	2	0	0
86.9	12.08.95	14:10	9	B1	0.17	3.00	0.60	1	0	0	0	0	0	0
86.6	12.08.95	14:15	9	B2	0.13	1.77	0.43	4	0	0	0	0	0	0
86.3	12.08.95	14:25	9	B3	0.15	1.40	0.50	4	0	0	0	1	0	0
85.9	12.08.95	14:30	9	C1	0.18	0.85	0.60	4	0	0	0	1	1	0
85.6	12.08.95	14:33	9	C2	0.18	1.40	0.60	4	0	0	0	0	0	0
85.3	12.08.95	14:40	9	C3	0.14	1.43	0.46	5	0	0	0	0	0	0
74.9	12.08.95	15:45	8	A1	0.26	1.21	0.85	6	2	1	1	6	1	0
74.6	12.08.95	15:56	8	A2	0.19	1.10	0.64	6	2	2	0	4	1	0
74.3	12.08.95	16:00	8	A3	0.18	0.80	0.60	6	1	2	1	8	0	0
73.9	12.08.95	16:06	8	B1	0.13	0.80	0.43	6	2	2	1	4	0	0
73.6	12.08.95	16:10	8	B2	0.23	0.90	0.75	5	0	0	0	1	0	0
73.3	12.08.95	16:15	8	B3	0.17	1.20	0.56	5	0	4	0	5	0	0
72.9	12.08.95	16:20	8	C1	0.07	1.99	0.23	3	0	0	0	1	2	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
72.6	12.08.95	16:24	8	C2	0.17	1.35	0.56	6	0	0	0	3	0	0
72.3	12.08.95	16:30	8	C3	0.14	1.30	0.46	5	0	0	0	2	0	0
70.9	12.08.95	16:50	7	A1	0.15	0.92	0.50	4	0	0	0	0	0	0
70.6	12.08.95	16:55	7	A2	0.18	1.10	0.60	4	0	0	0	0	1	0
70.3	12.08.95	17:00	7	A3	0.14	0.46	0.46	4	0	0	0	0	0	0
69.9	12.08.95	17:10	7	B1	0.00	1.15	0.00	1	0	0	0	1	0	0
69.6	12.08.95	17:15	7	B2	0.18	1.23	0.60	4	0	0	0	1	0	0
69.3	12.08.95	17:20	7	B3	0.17	2.54	0.60	5	0	0	0	0	0	0
63.9	12.08.95	17:35	7	C1	0.12	0.80	0.38	4	0	0	0	0	0	0
63.6	12.08.95	17:40	7	C2	0.17	2.50	0.60	5	0	0	0	0	0	0
63.3	12.08.95	17:45	7	C3	0.13	0.75	0.43	4	0	0	0	0	0	0
59.9	12.08.95	18:10	6	A1	0.15	0.95	0.50	4	0	1	0	1	0	0
59.6	12.08.95	18:15	6	A2	0.12	2.65	0.43	4	0	0	0	0	0	0
59.3	12.08.95	18:20	6	A3	0.15	1.55	0.50	4	0	1	0	1	0	0
54.9	12.08.95	18:40	6	B1	0.11	1.12	0.38	3	0	0	0	0	0	0
54.6	12.08.95	18:45	6	B2	0.18	1.84	0.60	4	0	0	0	0	0	0
54.3	12.08.95	18:50	6	B3	0.10	3.00	0.37	4	1	0	0	0	0	0
53.9	12.08.95	18:58	6	C1	0.12	2.26	0.43	4	0	0	0	0	0	0
53.6	12.08.95	19:03	6	C2	0.15	1.79	0.50	4	0	0	0	0	1	0
53.3	12.08.95	19:08	6	C3	0.15	0.85	0.50	4	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
47.9	13.08.95	9:50	5	A1	0.15	1.01	0.50	6	0	0	1	0	0	0
47.6	13.08.95	9:55	5	A2	0.18	1.70	0.60	4	0	0	0	0	0	0
47.3	13.08.95	10:00	5	A3	0.11	1.79	0.37	6	0	0	0	1	0	0
43.9	13.08.95	10:15	5	B1	0.13	1.09	0.43	4	1	1	0	1	0	0
43.6	13.08.95	10:20	5	B2	0.18	1.41	0.60	6	3	1	0	6	1	0
43.3	13.08.95	10:25	5	B3	0.13	0.64	0.43	4	0	0	0	0	1	0
41.9	13.08.95	10:45	5	C1	0.13	1.42	0.43	4	0	0	0	2	0	0
41.6	13.08.95	10:50	5	C2	0.15	1.47	0.50	4	0	0	0	0	0	0
41.3	13.08.95	10:55	5	C3	0.11	1.90	0.37	4	0	1	0	1	0	0
38.9	13.08.95	11:10	4	A1	0.18	1.58	0.60	6	0	0	0	0	0	0
38.6	13.08.95	11:15	4	A2	0.15	1.32	0.50	4	0	1	0	0	0	0
38.3	13.08.95	11:20	4	A3	0.12	2.29	0.43	6	0	0	0	0	0	0
35.9	13.08.95	11:38	4	B1	0.11	1.35	0.37	4	1	0	0	0	0	0
35.6	13.08.95	11:43	4	B2	0.14	2.75	0.50	4	0	0	0	0	0	0
35.3	13.08.95	11:48	4	B3	0.12	3.15	0.43	6	0	0	0	1	0	0
32.9	13.08.95	12:03	4	C1	0.10	1.13	0.33	1	1	0	1	0	0	0
32.6	13.08.95	12:08	4	C2	0.15	1.12	0.50	4	0	0	0	0	0	0
32.3	13.08.95	12:13	4	C3	0.11	1.42	0.38	4	0	0	0	0	0	0
28.9	13.08.95	12:35	3	A1	0.10	1.61	0.33	6	0	1	0	1	0	0
28.6	13.08.95	12:40	3	A2	0.13	1.81	0.43	4	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
28.3	13.08.95	12:45	3	A3	0.00	1.20	0.00	2	0	0	0	0	0	0
27.9	13.08.95	12:50	3	B1	0.11	1.30	0.37	2	0	0	0	0	0	0
27.6	13.08.95	12:55	3	B2	0.10	2.00	0.33	6	0	0	0	0	0	0
27.3	13.08.95	13:00	3	B3	0.14	2.30	0.50	5	0	0	1	0	0	0
24.9	13.08.95	13:15	3	C1	0.15	1.80	0.50	7	0	1	0	7	0	0
24.6	13.08.95	13:20	3	C2	0.12	2.06	0.43	4	0	0	0	0	0	0
24.3	13.08.95	13:25	3	C3	0.13	1.80	0.43	6	4	0	0	11	0	0
17.9	17.08.95	13:17	2	A1	0.15	0.67	0.47	6	1	0	2	8	0	0
17.6	17.08.95	13:22	2	A2	0.19	1.12	0.64	6	2	0	0	14	0	0
17.3	17.08.95	13:27	2	A3	0.13	0.84	0.42	6	0	0	1	7	0	0
15.9	17.08.95	13:55	2	B1	0.08	1.23	0.25	6	0	0	0	2	1	0
15.6	17.08.95	14:00	2	B2	0.08	1.71	0.28	6	1	0	1	0	0	0
15.3	17.08.95	14:05	2	B3	0.13	0.96	0.42	4	0	0	0	0	0	0
13.9	17.08.95	14:30	2	C1	0.16	1.15	0.52	6	0	0	3	5	0	0
13.6	17.08.95	14:35	2	C2	0.15	2.00	0.51	6	6	1	0	1	0	0
13.3	17.08.95	14:40	2	C3	0.16	1.00	0.52	6	1	0	0	2	0	0
10.9	17.08.95	15:10	1	A1	0.18	0.72	0.58	6	2	0	2	5	0	0
10.6	17.08.95	15:15	1	A2	0.25	0.65	0.81	6	4	0	0	20	0	0
10.3	17.08.95	15:20	1	A3	0.10	2.11	0.33	5	0	0	0	3	0	0
8.9	17.08.95	15:25	1	B1	0.10	0.80	0.32	5	1	0	3	3	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
8.6	17.08.95	15:30	1	B2	0.22	1.07	0.74	6	1	0	0	3	0	0
8.3	17.08.95	15:35	1	B3	0.16	1.40	0.54	6	0	0	1	2	0	0
6.9	17.08.95	16:20	1	C1	0.10	1.02	0.32	2	0	0	0	0	0	0
6.6	17.08.95	16:25	1	C2	0.09	2.50	0.30	4	0	0	0	0	0	0
6.3	17.08.95	16:30	1	C3	0.06	1.01	0.20	6	0	0	0	0	1	0
157.9	15.09.95	11:07	16	A1	0.15	1.45	0.51	5	1	0	0	4	2	0
157.6	15.09.95	11:12	16	A2	0.18	1.67	0.61	5	0	0	0	4	0	0
157.3	15.09.95	11:17	16	A3	0.16	1.80	0.53	1	0	0	0	2	7	1
153.9	15.09.95	12:08	16	B1	0.21	1.14	0.71	5	0	1	0	2	4	0
153.6	15.09.95	12:13	16	B2	0.25	0.79	0.80	4	0	0	0	0	0	0
153.3	15.09.95	12:18	16	B3	0.12	0.75	0.38	4	0	1	0	4	2	0
152.9	15.09.95	12:44	16	C1	0.14	3.75	0.51	4	0	0	0	0	6	0
152.6	15.09.95	12:49	16	C2	0.18	0.33	0.58	4	0	0	0	1	2	0
152.3	15.09.95	12:54	16	C3	0.18	1.05	0.59	4	0	0	0	5	4	0
147.9	15.09.95	13:34	15	A1	0.15	1.54	0.51	4	0	0	0	5	2	0
147.6	15.09.95	13:39	15	A2	0.21	0.80	0.68	4	0	0	0	0	4	0
147.3	15.09.95	13:44	15	A3	0.15	1.15	0.48	4	0	1	0	2	4	0
146.9	15.09.95	14:00	15	B1	0.21	1.61	0.72	4	0	0	0	5	3	0
146.6	15.09.95	14:05	15	B2	0.20	0.60	0.63	4	0	0	0	1	3	0
146.3	15.09.95	14:10	15	B3	0.18	0.78	0.58	4	0	0	0	1	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
142.9	15.09.95	15:01	15	C1	0.18	0.26	0.57	3	0	0	0	5	0	0
142.6	15.09.95	15:06	15	C2	0.20	0.50	0.63	4	0	0	0	1	0	0
142.3	15.09.95	15:11	15	C3	0.20	1.78	0.68	4	0	0	0	7	5	0
134.9	15.09.95	16:43	14	A1	0.13	0.36	0.40	3	0	0	0	0	4	0
134.6	15.09.95	16:48	14	A2	0.22	0.98	0.72	4	1	0	0	0	0	0
134.3	15.09.95	16:53	14	A3	0.07	0.58	0.24	4	0	0	0	0	0	0
133.9	15.09.95	17:05	14	B1	0.14	2.05	0.48	3	0	0	0	4	3	0
133.6	15.09.95	17:10	14	B2	0.18	0.82	0.58	4	0	0	0	2	0	0
133.3	15.09.95	17:15	14	B3	0.15	1.13	0.51	4	0	0	0	6	1	0
132.9	15.09.95	17:23	14	C1	0.22	0.77	0.72	4	0	0	0	5	0	0
132.6	15.09.95	17:28	14	C2	0.09	1.17	0.31	4	0	0	0	0	0	0
132.3	15.09.95	17:33	14	C3	0.12	1.35	0.41	4	0	0	0	1	5	0
128.9	15.09.95	18:07	13	A1	0.15	0.65	0.48	4	0	0	0	0	2	0
128.6	15.09.95	18:12	13	A2	0.23	1.30	0.76	4	0	0	0	0	0	0
128.3	15.09.95	18:17	13	A3	0.13	1.62	0.43	3	0	0	0	1	2	0
126.9	15.09.95	18:34	13	B1	0.11	1.20	0.36	3	0	0	0	1	0	0
126.6	15.09.95	18:39	13	B2	0.20	1.42	0.68	4	0	0	0	2	0	0
126.3	15.09.95	18:44	13	B3	0.08	0.28	0.26	3	0	0	0	7	0	0
122.9	15.09.95	19:10	13	C1	0.20	1.05	0.65	4	0	0	0	6	0	0
122.6	15.09.95	19:15	13	C2	0.18	0.90	0.58	4	1	0	0	1	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
122.3	15.09.95	19:20	13	C3	0.15	0.34	0.47	4	0	0	0	5	1	0
118.9	16.09.95	11:46	12	A1	0.17	2.27	0.60	4	0	0	0	1	0	0
118.6	16.09.95	11:51	12	A2	0.18	1.12	0.58	4	0	0	0	0	1	0
118.3	16.09.95	11:56	12	A3	0.17	1.85	0.58	4	0	0	0	0	1	0
116.9	16.09.95	12:16	12	B1	0.17	1.50	0.58	4	1	1	0	5	0	0
116.6	16.09.95	12:21	12	B2	0.19	1.20	0.63	4	0	0	0	0	0	0
116.3	16.09.95	12:26	12	B3	0.10	0.95	0.32	3	0	0	0	3	7	0
115.9	16.09.95	12:32	12	C1	0.16	1.39	0.53	5	0	1	0	2	1	0
115.6	16.09.95	12:37	12	C2	0.19	0.78	0.63	4	0	0	0	0	0	0
115.3	16.09.95	12:42	12	C3	0.13	0.75	0.42	4	0	0	0	1	0	0
109.9	16.09.95	13:05	11	A1	0.07	1.22	0.22	3	0	0	0	0	0	0
109.6	16.09.95	13:10	11	A2	0.12	2.70	0.43	1	0	0	0	0	0	0
109.3	16.09.95	13:15	11	A3	0.13	0.90	0.44	4	0	1	0	3	2	0
104.9	16.09.95	13:30	11	B1	0.18	0.30	0.56	3	0	0	0	2	1	0
104.6	16.09.95	13:35	11	B2	0.23	0.87	0.74	4	0	0	0	0	0	0
104.3	16.09.95	13:40	11	B3	0.14	0.90	0.45	3	0	3	0	0	2	0
101.9	16.09.95	13:53	11	C1	0.20	1.60	0.67	4	1	1	0	2	0	0
101.6	16.09.95	13:58	11	C2	0.21	1.32	0.71	4	0	0	0	0	0	0
101.3	16.09.95	14:03	11	C3	0.13	0.90	0.43	3	1	0	0	4	4	0
99.9	16.09.95	14:30	10	A1	0.23	1.10	0.77	4	0	1	0	1	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
99.6	16.09.95	14:35	10	A2	0.18	1.83	0.63	4	0	0	0	0	0	0
99.3	16.09.95	14:40	10	A3	0.20	1.25	0.68	6	0	0	0	3	1	0
94.9	16.09.95	15:06	10	B1	0.14	0.92	0.47	4	0	0	0	2	0	0
94.6	16.09.95	15:11	10	B2	0.22	1.10	0.71	4	0	1	0	0	1	0
94.3	16.09.95	15:16	10	B3	0.13	0.40	0.43	4	0	0	0	0	0	0
93.9	16.09.95	15:32	10	C1	0.17	1.87	0.58	4	0	1	0	1	0	0
93.6	16.09.95	15:37	10	C2	0.17	1.40	0.57	4	0	0	0	0	0	0
93.3	16.09.95	15:42	10	C3	0.15	0.85	0.48	4	0	0	0	3	0	0
87.9	16.09.95	16:00	9	A1	0.15	1.10	0.50	4	0	0	0	7	0	0
87.6	16.09.95	16:05	9	A2	0.20	1.10	0.65	4	0	0	0	0	0	0
87.3	16.09.95	16:10	9	A3	0.16	0.35	0.51	4	0	0	0	0	1	0
84.9	16.09.95	16:30	9	B1	0.11	1.20	0.35	3	0	0	0	7	0	0
84.6	16.09.95	16:35	9	B2	0.19	0.81	0.62	4	0	0	0	0	0	0
84.3	16.09.95	16:40	9	B3	0.18	1.15	0.61	6	1	0	0	0	0	0
83.9	16.09.95	16:50	9	C1	0.08	0.95	0.26	3	0	0	0	0	0	0
83.6	16.09.95	16:55	9	C2	0.18	1.15	0.61	4	0	0	0	1	0	0
83.3	16.09.95	17:00	9	C3	0.20	0.55	0.63	4	0	1	0	2	1	0
77.9	16.09.95	17:46	8	A1	0.13	0.45	0.43	4	0	0	0	0	0	0
77.6	16.09.95	17:51	8	A2	0.18	1.10	0.60	4	0	1	0	5	0	0
77.3	16.09.95	18:06	8	A3	0.09	0.38	0.28	3	0	1	0	7	2	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
74.9	16.09.95	18:11	8	B1	0.18	1.30	0.60	6	2	1	0	9	0	0
74.6	16.09.95	18:17	8	B2	0.24	0.98	0.78	6	1	0	0	16	0	0
74.3	16.09.95	18:22	8	B3	0.22	0.65	0.71	5	2	0	0	12	0	0
72.9	16.09.95	18:46	8	C1	0.07	1.55	0.22	1	0	0	0	0	0	0
72.6	16.09.95	18:51	8	C2	0.18	0.95	0.60	5	0	1	0	2	0	0
72.3	16.09.95	18:56	8	C3	0.13	1.18	0.44	4	0	0	0	9	0	0
66.9	17.09.95	9:57	7	A1	0.16	1.20	0.52	4	1	2	1	6	0	0
66.6	17.09.95	10:02	7	A2	0.21	1.13	0.70	4	0	1	0	0	0	0
66.3	17.09.95	10:07	7	A3	0.00	0.63	0.00	2	0	0	0	0	4	0
93.9	17.09.95	10:24	7	B1	0.12	2.02	0.42	6	1	0	0	1	0	0
63.6	17.09.95	10:29	7	B2	0.21	1.50	0.72	6	0	0	0	2	0	0
63.3	17.09.95	10:34	7	B3	0.17	0.55	0.54	4	0	0	0	1	0	0
62.9	17.09.95	10:42	7	C1	0.21	1.85	0.70	1	0	1	0	1	0	0
62.6	17.09.95	10:47	7	C2	0.25	0.80	0.80	4	0	1	0	0	0	0
62.3	17.09.95	10:52	7	C3	0.15	1.00	0.48	4	1	0	0	4	0	0
57.9	17.09.95	11:18	6	A1	0.23	0.70	0.74	4	0	1	0	0	0	0
57.6	17.09.95	11:23	6	A2	0.10	1.15	0.32	4	0	1	0	0	0	0
57.3	17.09.95	11:28	6	A3	0.19	0.65	0.63	4	0	0	0	4	1	0
53.9	17.09.95	11:43	6	B1	0.12	2.20	0.41	4	0	0	0	1	0	0
53.6	17.09.95	11:48	6	B2	0.19	1.53	0.64	4	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
53.3	17.09.95	11:53	6	B3	0.10	0.60	0.31	4	0	0	0	1	1	0
51.9	17.09.95	11:58	6	C1	0.15	0.93	0.48	4	1	0	0	0	0	0
51.6	17.09.95	12:12	6	C2	0.19	1.38	0.62	4	0	0	0	0	0	0
51.3	17.09.95	12:17	6	C3	0.19	1.22	0.62	5	0	0	0	2	0	0
48.9	17.09.95	12:53	5	A1	0.18	2.35	0.61	1	0	0	0	0	0	0
48.6	17.09.95	12:58	5	A2	0.12	2.48	0.43	4	0	0	0	0	0	0
48.3	17.09.95	13:03	5	A3	0.18	1.10	0.61	4	1	0	0	2	1	0
45.9	17.09.95	13:17	5	B1	0.23	2.40	0.80	1	0	0	0	1	0	0
45.6	17.09.95	13:22	5	B2	0.19	1.40	0.65	4	0	0	0	0	0	0
45.3	17.09.95	13:27	5	B3	0.15	2.40	0.52	1	0	0	0	1	0	0
42.9	17.09.95	13:43	5	C1	0.12	1.14	0.40	3	0	0	0	0	0	0
42.6	17.09.95	13:48	5	C2	0.16	1.33	0.54	6	0	1	0	0	0	0
42.3	17.09.95	13:53	5	C3	0.13	0.91	0.41	4	0	0	0	3	0	0
40.9	17.09.95	14:05	4	A1	0.12	1.28	0.41	4	0	0	0	1	0	0
40.6	17.09.95	14:10	4	A2	0.14	1.65	0.48	4	0	0	0	1	0	0
40.3	17.09.95	14:15	4	A3	0.18	1.05	0.58	4	0	0	0	5	0	0
34.9	17.09.95	14:32	4	B1	0.07	0.65	0.24	2	1	0	0	0	0	0
34.6	17.09.95	14:37	4	B2	0.10	2.40	0.34	4	1	1	0	0	0	0
34.3	17.09.95	14:42	4	B3	0.09	0.81	0.28	4	0	0	2	1	0	0
32.9	17.09.95	14:58	4	C1	0.12	0.82	0.38	3	0	0	0	1	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
32.6	17.09.95	15:03	4	C2	0.13	1.13	0.44	4	0	1	0	0	0	0
32.3	17.09.95	15:08	4	C3	0.12	1.25	0.40	4	0	2	0	1	0	0
28.9	17.09.95	15:30	3	A1	0.11	1.31	0.35	6	0	0	0	7	0	0
28.6	17.09.95	15:35	3	A2	0.10	1.25	0.34	6	1	0	0	2	0	0
28.3	17.09.95	15:40	3	A3	0.02	1.16	0.08	1	0	0	0	0	1	0
27.9	17.09.95	15:47	3	B1	0.05	0.94	0.18	1	0	0	0	0	1	0
27.6	17.09.95	15:52	3	B2	0.07	2.75	0.24	6	1	0	0	0	0	0
27.3	17.09.95	15:57	3	B3	0.09	1.60	0.32	6	0	0	0	0	0	0
23.9	17.09.95	16:16	3	C1	0.06	0.99	0.20	3	0	0	1	5	0	0
23.6	17.09.95	16:21	3	C2	0.16	1.26	0.52	6	1	0	0	15	0	0
23.3	17.09.95	16:26	3	C3	0.07	0.79	0.24	5	1	0	0	7	0	0
18.9	17.09.95	16:51	2	A1	0.02	1.01	0.06	5	4	0	0	19	0	0
18.6	17.09.95	16:56	2	A2	0.21	0.83	0.67	6	2	0	0	17	0	0
18.3	17.09.95	17:01	2	A3	0.09	0.96	0.28	5	0	0	1	4	0	0
15.9	17.09.95	17:22	2	B1	0.08	1.30	0.26	4	0	0	1	2	1	0
15.6	17.09.95	17:27	2	B2	0.05	1.70	0.17	5	0	0	0	1	0	0
15.3	17.09.95	17:32	2	B3	0.11	1.45	0.38	3	0	0	1	1	0	0
14.9	17.09.95	17:42	2	C1	0.06	0.70	0.21	5	0	0	0	4	5	0
14.6	17.09.95	17:47	2	C2	0.18	0.96	0.58	6	2	0	3	5	1	0
14.3	17.09.95	17:52	2	C3	0.15	0.55	0.48	4	0	0	0	4	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
10.9	17.09.95	18:15	1	A1	0.13	0.54	0.42	7	5	1	0	10	0	0
10.6	17.09.95	18:20	1	A2	0.24	0.65	0.78	7	2	1	0	10	0	0
10.3	17.09.95	18:25	1	A3	0.09	2.10	0.30	1	1	0	2	1	0	0
9.9	17.09.95	18:55	1	B1	0.17	0.98	0.55	5	1	1	0	3	0	0
9.6	17.09.95	19:00	1	B2	0.16	1.67	0.53	6	1	0	0	1	0	0
9.3	17.09.95	19:05	1	B3	0.06	0.95	0.21	3	2	3	0	0	0	0
8.9	17.09.95	19:29	1	C1	0.31	0.32	0.98	6	3	0	3	8	0	0
8.6	17.09.95	19:34	1	C2	0.25	0.90	0.83	6	0	0	0	0	0	0
8.3	17.09.95	19:39	1	C3	0.10	0.80	0.31	5	0	0	0	0	0	0
157.9	24.06.96	11:28	16	A1	0.22	1.93	0.77	5	1	0	0	6	21	0
157.6	24.06.96	11:33	16	A2	0.22	3.27	0.78	1	0	0	0	0	0	0
157.3	24.06.96	11:38	16	A3	0.24	3.87	0.89	6	0	0	0	1	1	0
156.9	24.06.96	11:50	16	B1	0.16	2.10	0.55	5	0	0	0	0	7	0
156.6	24.06.96	11:55	16	B2	0.16	2.33	0.55	4	0	0	0	0	0	0
156.3	24.06.96	12:00	16	B3	0.03	2.10	0.12	3	0	0	0	0	0	0
152.9	24.06.96	12:25	16	C1	0.35	2.27	1.20	6	0	0	0	0	5	0
152.6	24.06.96	12:30	16	C2	0.26	1.75	0.90	4	0	0	0	0	4	0
152.3	24.06.96	12:35	16	C3	0.21	2.90	0.75	5	2	2	0	0	1	1
148.9	24.06.96	13:35	15	A1	0.24	1.77	0.82	4	0	0	0	10	6	0
148.6	24.06.96	13:40	15	A2	0.34	2.73	1.20	4	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
148.3	24.06.96	13:45	15	A3	0.23	1.14	0.76	4	0	0	2	15	2	0
146.9	24.06.96	14:02	15	B1	0.26	2.10	0.88	4	0	0	0	2	2	0
146.6	24.06.96	14:07	15	B2	0.28	2.07	0.98	4	0	0	0	0	0	0
146.3	24.06.96	14:12	15	B3	0.13	2.50	0.44	4	1	0	0	8	2	0
145.9	24.06.96	14:20	15	C1	0.19	2.93	0.67	1	0	0	0	2	0	0
145.6	24.06.96	14:25	15	C2	0.26	2.43	0.91	4	0	0	0	0	0	0
145.3	24.06.96	14:30	15	C3	0.22	1.80	0.75	4	0	0	0	1	0	0
139.9	24.06.96	15:13	14	A1	0.23	1.33	0.78	4	0	3	0	8	2	0
139.6	24.06.96	15:18	14	A2	0.29	2.10	0.99	4	0	0	0	0	0	0
139.3	24.06.96	15:23	14	A3	0.15	2.47	0.53	4	0	0	0	0	0	0
137.9	24.06.96	15:40	14	B1	0.27	2.60	0.96	4	0	0	0	2	0	0
137.6	24.06.96	15:45	14	B2	0.24	1.93	0.81	4	0	0	0	0	0	0
137.3	24.06.96	15:50	14	B3	0.24	1.16	0.81	4	1	3	0	3	0	0
136.9	24.06.96	16:20	14	C1	0.28	1.90	0.95	1	0	2	0	3	0	0
136.6	24.06.96	16:25	14	C2	0.24	2.03	0.84	4	0	0	0	0	0	0
136.3	24.06.96	16:30	14	C3	0.17	2.13	0.58	4	1	1	0	2	1	0
129.9	24.06.96	17:10	13	A1	0.09	1.73	0.31	3	0	0	0	5	1	0
129.6	24.06.96	17:15	13	A2	0.26	2.00	0.91	4	0	0	0	0	0	0
129.3	24.06.96	17:20	13	A3	0.22	2.80	0.78	4	0	0	0	2	0	0
125.9	24.06.96	17:40	13	B1	0.21	2.40	0.72	4	0	0	0	3	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
125.6	24.06.96	17:45	13	B2	0.21	2.30	0.72	4	0	0	0	0	0	0
125.3	24.06.96	17:50	13	B3	0.16	1.76	0.56	4	1	1	0	5	0	0
123.9	24.06.96	18:25	13	C1	0.25	1.43	0.84	4	0	1	0	4	3	0
123.6	24.06.96	18:30	13	C2	0.25	3.30	0.90	4	0	0	0	0	0	0
123.3	24.06.96	18:35	13	C3	0.18	2.57	0.63	4	0	2	1	0	0	0
120.9	24.06.96	18:40	12	A1	0.25	1.57	0.84	4	1	1	0	7	8	0
120.6	24.06.96	18:45	12	A2	0.25	2.77	0.87	4	0	0	0	0	0	0
120.3	24.06.96	18:50	12	A3	0.16	3.18	0.59	5	0	0	0	2	0	0
115.9	24.06.96	10:25	12	B1	0.29	2.98	1.02	8	0	0	0	0	3	0
115.6	24.06.96	10:30	12	B2	0.29	2.53	1.02	4	0	0	0	0	0	0
115.3	24.06.96	10:35	12	B3	0.12	2.05	0.43	4	0	0	0	4	0	0
113.9	24.06.96	10:50	12	C1	0.21	2.10	0.72	4	1	0	0	2	0	0
113.6	24.06.96	10:55	12	C2	0.25	2.27	0.88	4	0	0	0	0	0	0
113.3	24.06.96	11:00	12	C3	0.23	1.95	0.79	4	0	2	0	10	3	0
108.9	25.06.96	11:25	11	A1	0.21	2.63	0.73	5	0	0	0	0	0	0
108.6	25.06.96	11:30	11	A2	0.23	2.48	0.80	4	0	0	0	0	0	0
108.3	25.06.96	11:35	11	A3	0.16	2.23	0.57	4	0	0	0	2	0	0
105.9	25.06.96	12:00	11	B1	0.16	2.87	0.57	5	0	0	0	8	0	0
105.6	25.06.96	12:05	11	B2	0.23	1.80	0.80	4	0	0	0	0	0	0
105.3	25.06.96	12:10	11	B3	0.19	2.73	0.67	4	0	1	0	1	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
104.9	25.06.96	12:15	11	C1	0.23	2.30	0.80	4	0	0	0	1	0	1
104.6	25.06.96	12:20	11	C2	0.29	2.23	1.00	4	0	0	0	0	0	0
104.3	25.06.96	12:25	11	C3	0.28	3.13	1.00	5	0	0	0	0	0	0
99.9	25.06.96	12:50	10	A1	0.20	1.60	0.67	3	0	4	0	14	0	0
99.6	25.06.96	12:55	10	A2	0.22	3.05	0.80	4	0	0	0	0	0	0
99.3	25.06.96	13:00	10	A3	0.19	2.05	0.67	1	0	0	0	0	1	0
93.9	25.06.96	13:15	10	B1	0.22	3.00	0.80	1	0	0	0	1	0	0
93.6	25.06.96	13:20	10	B2	0.28	2.70	1.00	4	0	0	0	0	0	0
93.3	25.06.96	13:25	10	B3	0.19	2.33	0.67	4	0	1	0	4	1	0
91.9	25.06.96	13:35	10	C1	0.14	2.80	0.50	1	0	1	1	0	0	0
91.6	25.06.96	13:40	10	C2	0.22	2.97	0.80	4	0	0	0	0	0	0
91.3	25.06.96	13:45	10	C3	0.28	3.03	1.00	6	0	1	0	1	1	0
88.9	25.06.96	14:05	9	A1	0.19	2.40	0.67	3	0	0	0	3	2	0
88.6	25.06.96	14:10	9	A2	0.28	3.18	1.00	5	0	0	0	0	0	0
88.3	25.06.96	14:15	9	A3	0.22	3.00	0.80	5	0	0	0	6	0	0
86.9	25.06.96	14:31	9	B1	0.28	2.67	1.00	6	1	2	0	3	1	0
86.6	25.06.96	14:36	9	B2	0.28	2.88	1.00	4	0	0	0	0	0	0
86.3	25.06.96	14:41	9	B3	0.15	1.93	0.50	3	0	0	0	3	2	0
82.9	25.06.96	15:10	9	C1	0.08	2.37	0.27	1	2	1	0	5	2	0
82.6	25.06.96	15:15	9	C2	0.23	2.17	0.80	4	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
82.3	25.06.96	15:20	9	C3	0.19	2.73	0.67	4	0	0	0	1	0	0
79.9	25.06.96	15:40	8	A1	0.13	1.42	0.44	2	1	0	0	3	0	0
79.6	25.06.96	15:45	8	A2	0.28	2.87	1.00	6	0	0	0	0	0	0
79.3	25.06.96	15:50	8	A3	0.17	1.60	0.57	3	0	0	0	8	0	1
78.9	25.06.96	16:00	8	B1	0.20	1.57	0.67	5	1	0	0	10	0	0
78.6	25.06.96	16:05	8	B2	0.30	2.70	1.07	4	0	0	0	0	0	0
78.3	25.06.96	16:10	8	B3	0.14	2.57	0.50	6	1	1	0	7	0	0
72.9	25.06.96	16:25	8	C1	0.00	1.80	0.00	3	0	2	0	2	1	1
72.6	25.06.96	16:30	8	C2	0.23	2.47	0.80	4	0	0	0	0	0	0
72.3	25.06.96	16:35	8	C3	0.13	2.23	0.44	3	0	0	0	2	0	0
68.9	25.06.96	17:00	7	A1	0.16	2.40	0.57	4	0	0	0	4	0	0
68.6	25.06.96	17:05	7	A2	0.23	2.43	0.80	4	0	0	0	0	0	0
68.3	25.06.96	17:10	7	A3	0.16	2.83	0.57	4	0	0	0	2	0	0
65.9	25.06.96	17:15	7	B1	0.23	2.41	0.80	5	0	0	0	0	0	0
65.6	25.06.96	17:20	7	B2	0.28	2.53	1.00	4	0	0	0	0	0	0
65.3	25.06.96	17:25	7	B3	0.14	2.43	0.50	3	0	0	0	2	0	0
61.9	25.06.96	17:35	7	C1	0.23	2.05	0.80	6	1	0	0	3	0	0
61.6	25.06.96	17:40	7	C2	0.27	3.80	1.00	5	0	0	0	0	0	0
61.3	25.06.96	17:45	7	C3	0.19	2.23	0.67	4	0	0	0	2	0	0
56.9	25.06.96	17:55	6	A1	0.19	2.53	0.67	1	0	0	0	1	0	1

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
56.6	25.06.96	18:00	6	A2	0.28	2.83	1.00	6	0	0	0	0	0	0
56.3	25.06.96	18:05	6	A3	0.08	2.33	0.27	3	0	0	0	1	0	0
54.9	25.06.96	18:20	6	B1	0.16	2.62	0.57	4	0	0	0	4	2	1
54.6	25.06.96	18:25	6	B2	0.24	3.90	0.89	5	0	0	0	0	0	0
54.3	25.06.96	18:30	6	B3	0.12	1.70	0.40	4	1	0	0	2	1	1
52.9	25.06.96	18:35	6	C1	0.13	1.23	0.44	2	1	0	0	1	5	1
52.6	25.06.96	18:40	6	C2	0.27	3.46	1.00	4	0	0	0	0	0	0
52.3	25.06.96	18:45	6	C3	0.07	2.93	0.25	3	0	0	0	0	0	0
46.9	26.06.96	10:20	5	A1	0.15	2.07	0.50	3	0	0	0	3	2	0
46.6	26.06.96	10:25	5	A2	0.23	2.63	0.80	4	0	0	0	0	0	0
46.3	26.06.96	10:30	5	A3	0.15	1.53	0.50	3	2	1	0	5	5	0
44.9	26.06.96	10:45	5	B1	0.17	2.03	0.57	3	2	0	0	7	0	0
44.6	26.06.96	10:50	5	B2	0.19	2.80	0.67	6	0	0	0	0	0	0
44.3	26.06.96	10:55	5	B3	0.05	1.57	0.16	6	0	0	0	3	3	0
41.9	26.06.96	11:00	5	C1	0.17	1.40	0.57	3	0	0	0	2	0	0
41.6	26.06.96	11:05	5	C2	0.23	2.63	0.80	4	0	0	0	0	0	0
41.3	26.06.96	11:10	5	C3	0.17	2.00	0.57	3	0	0	0	1	0	1
37.9	26.06.96	11:30	4	A1	0.20	1.73	0.67	1	1	0	0	1	0	0
37.6	26.06.96	11:35	4	A2	0.28	3.00	1.00	4	0	0	0	0	0	0
37.3	26.06.96	11:40	4	A3	0.16	3.15	0.57	6	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
35.9	26.06.96	12:00	4	B1	0.21	0.70	0.67	3	0	0	0	6	1	0
35.6	26.06.96	12:05	4	B2	0.18	3.40	0.67	5	0	0	0	0	0	0
35.3	26.06.96	12:10	4	B3	0.11	2.63	0.40	3	1	0	0	2	0	0
32.9	26.06.96	12:15	4	C1	0.20	1.50	0.67	1	0	0	0	3	1	0
32.6	26.06.96	12:20	4	C2	0.22	3.03	0.80	4	0	0	0	0	0	0
32.3	26.06.96	12:25	4	C3	0.14	0.80	0.44	4	0	0	0	3	0	0
29.9	26.06.96	12:30	3	A1	0.15	1.30	0.50	2	0	0	0	0	1	0
29.6	26.06.96	12:35	3	A2	0.22	3.07	0.80	5	0	0	0	0	0	0
29.3	26.06.96	12:40	3	A3	0.14	2.13	0.50	1	0	0	0	0	0	0
28.9	26.06.96	12:50	3	B1	0.15	1.43	0.50	1	1	0	0	3	0	0
28.6	26.06.96	12:55	3	B2	0.23	2.46	0.80	6	0	0	0	0	0	0
28.3	26.06.96	13:00	3	B3	0.20	1.87	0.67	4	0	0	0	4	1	0
22.9	26.06.96	13:10	3	C1	0.24	1.40	0.80	7	0	0	0	3	1	0
22.6	26.06.96	13:15	3	C2	0.20	1.76	0.67	6	0	0	0	1	0	0
22.3	26.06.96	13:20	3	C3	0.17	1.46	0.57	6	0	0	0	2	0	1
20.9	26.06.96	13:45	2	A1	0.24	1.07	0.80	5	22	2	3	30	4	3
20.6	26.06.96	14:10	2	A2	0.30	1.60	1.00	6	0	0	0	4	0	0
20.3	26.06.96	14:15	2	A3	0.12	1.33	0.40	6	1	1	1	11	0	1
17.9	26.06.96	14:30	2	B1	0.24	1.43	0.80	6	3	0	1	34	0	0
17.6	26.06.96	14:35	2	B2	0.19	2.30	0.67	6	0	0	0	8	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
17.3	26.06.96	14:40	2	B3	0.17	1.31	0.57	6	1	0	0	11	0	0
16.9	26.06.96	14:50	2	C1	0.24	1.23	0.80	5	1	0	0	5	0	0
16.6	26.06.96	14:55	2	C2	0.29	1.78	1.00	6	0	0	0	1	0	0
16.3	26.06.96	15:00	2	C3	0.24	1.60	0.80	5	2	1	1	4	0	0
10.9	26.06.96	15:45	1	A1	0.34	1.13	1.14	6	10	0	4	16	1	0
10.6	26.06.96	15:50	1	A2	0.39	1.63	1.33	6	1	0	0	1	0	0
10.3	26.06.96	15:55	1	A3	0.20	1.93	0.67	6	1	1	0	0	0	0
8.9	26.06.96	16:05	1	B1	0.20	1.50	0.67	6	4	0	5	10	0	0
8.6	26.06.96	16:10	1	B2	0.23	2.25	0.80	7	0	0	1	1	0	0
8.3	26.06.96	16:15	1	B3	0.20	1.10	0.67	7	3	4	0	11	3	0
3.9	26.06.96	16:40	1	C1	0.10	1.10	0.33	5	0	0	4	4	1	0
3.6	26.06.96	16:45	1	C2	0.20	5.50	0.80	1	0	0	0	0	0	0
3.3	26.06.96	16:50	1	C3	0.17	0.86	0.57	7	3	2	2	2	0	1
157.9	22.07.96	11:26	16	A1	0.20	1.50	0.67	5	3	0	0	2	6	0
157.6	22.07.96	11:31	16	A2	0.29	2.93	1.03	5	0	0	0	0	0	0
157.3	22.07.96	11:36	16	A3	0.16	2.67	0.57	1	0	1	0	2	3	1
152.9	22.07.96	12:25	16	B1	0.24	1.90	0.81	5	1	0	0	1	4	1
152.6	22.07.96	12:30	16	B2	0.24	0.63	0.76	4	0	0	0	0	0	0
152.3	22.07.96	12:35	16	B3	0.24	1.90	0.82	4	0	3	0	3	14	8
151.9	22.07.96	12:40	16	C1	0.09	0.98	0.29	5	6	1	0	4	8	2

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
151.6	22.07.96	12:45	16	C2	0.25	1.70	0.84	4	0	0	0	0	1	0
151.3	22.07.96	12:50	16	C3	0.22	1.80	0.76	5	0	2	0	4	8	0
150.9	22.07.96	12:55	15	A1	0.17	1.36	0.57	5	0	3	0	9	0	0
150.6	22.07.96	13:00	15	A2	0.26	1.85	0.89	4	0	0	0	0	0	0
150.3	22.07.96	13:05	15	A3	0.29	1.93	0.98	5	0	0	0	1	0	0
148.9	22.07.96	13:45	15	B1	0.19	2.20	0.67	1	0	0	0	3	0	0
148.6	22.07.96	13:50	15	B2	0.26	1.97	0.89	4	0	0	0	0	0	0
148.3	22.07.96	13:55	15	B3	0.14	1.17	0.45	4	0	0	0	4	3	0
143.9	22.07.96	14:25	15	C1	0.13	2.07	0.45	4	0	0	0	2	1	1
143.6	22.07.96	14:30	15	C2	0.29	1.60	0.98	4	0	0	0	0	0	0
143.3	22.07.96	14:35	15	C3	0.23	2.17	0.79	4	0	1	0	5	0	1
139.9	22.07.96	14:40	14	A1	0.21	0.74	0.68	4	0	1	0	1	2	0
139.6	22.07.96	14:45	14	A2	0.20	1.36	0.67	4	0	0	0	0	0	0
139.3	22.07.96	14:50	14	A3	0.19	2.43	0.67	1	0	2	0	0	0	0
138.9	22.07.96	15:05	14	B1	0.11	1.15	0.35	4	0	0	0	2	0	0
138.6	22.07.96	15:10	14	B2	0.23	1.10	0.76	4	0	0	0	0	0	0
138.3	22.07.96	15:15	14	B3	0.17	1.30	0.55	4	0	1	0	3	2	0
132.9	22.07.96	15:41	14	C1	0.18	2.50	0.62	4	0	0	0	3	0	0
132.6	22.07.96	15:46	14	C2	0.25	1.70	0.84	4	0	0	0	0	0	0
132.3	22.07.96	15:51	14	C3	0.20	1.60	0.67	4	0	0	0	3	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
130.9	22.07.96	16:04	13	A1	0.15	1.20	0.50	3	0	3	0	5	4	0
130.6	22.07.96	16:09	13	A2	0.24	1.21	0.79	4	0	0	0	0	0	0
130.3	22.07.96	16:14	13	A3	0.19	1.63	0.65	4	0	1	0	0	2	0
126.9	22.07.96	16:48	13	B1	0.19	1.70	0.63	8	0	0	0	2	0	0
126.6	22.07.96	16:53	13	B2	0.27	1.90	0.94	4	0	0	0	0	0	0
126.3	22.07.96	16:58	13	B3	0.20	1.76	0.67	4	0	0	0	1	0	0
124.9	22.07.96	17:03	13	C1	0.15	2.10	0.53	1	0	0	0	1	0	0
124.6	22.07.96	17:08	13	C2	0.27	2.17	0.94	4	0	0	0	0	0	0
124.3	22.07.96	17:13	13	C3	0.13	1.20	0.43	4	0	1	0	2	1	0
120.9	22.07.96	17:35	12	A1	0.22	1.23	0.74	4	0	2	0	3	1	1
120.6	22.07.96	17:40	12	A2	0.25	2.10	0.86	4	0	0	0	0	0	0
120.3	22.07.96	17:45	12	A3	0.07	2.47	0.26	1	0	2	0	6	0	0
119.9	22.07.96	17:50	12	B1	0.12	1.35	0.41	4	0	0	0	0	0	0
119.6	22.07.96	17:55	12	B2	0.24	1.53	0.82	4	0	0	0	0	0	0
119.3	22.07.96	18:00	12	B3	0.19	1.13	0.62	4	0	0	0	8	0	0
115.9	22.07.96	18:05	12	C1	0.25	1.93	0.86	6	0	2	0	1	0	0
115.6	22.07.96	18:10	12	C2	0.26	1.67	0.89	4	0	0	0	0	0	0
115.3	22.07.96	18:15	12	C3	0.14	1.27	0.48	4	0	1	0	5	0	0
106.9	23.07.96	11:05	11	A1	0.21	1.43	0.71	4	0	0	0	4	0	0
106.6	23.07.96	11:10	11	A2	0.28	1.14	0.94	4	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
106.3	23.07.96	11:15	11	A3	0.12	1.17	0.41	3	0	0	0	4	0	0
105.9	23.07.96	11:23	11	B1	0.17	1.40	0.57	8	0	1	0	5	0	0
105.6	23.07.96	11:28	11	B2	0.25	1.43	0.84	4	0	0	0	0	0	0
105.3	23.07.96	11:33	11	B3	0.24	1.80	0.82	4	0	0	0	3	0	0
101.9	23.07.96	11:45	11	C1	0.18	0.77	0.60	4	0	2	0	6	1	0
101.6	23.07.96	11:50	11	C2	0.32	2.33	1.13	4	0	0	0	1	0	0
101.3	23.07.96	11:55	11	C3	0.12	1.03	0.41	3	0	0	0	3	3	0
100.9	23.07.96	12:15	10	A1	0.15	1.90	0.53	1	0	0	0	0	1	0
100.6	23.07.96	12:20	10	A2	0.25	1.30	0.84	4	0	0	0	0	0	0
100.3	23.07.96	12:25	10	A3	0.22	1.56	0.74	1	0	0	0	0	1	0
95.9	23.07.96	12:35	10	B1	0.23	1.40	0.76	3	0	0	0	1	1	0
95.6	23.07.96	12:40	10	B2	0.21	2.10	0.71	4	0	0	0	0	0	0
95.3	23.07.96	12:45	10	B3	0.29	1.97	1.01	6	0	0	0	1	0	0
94.9	23.07.96	12:52	10	C1	0.21	1.33	0.71	3	0	1	0	2	0	0
94.6	23.07.96	12:57	10	C2	0.25	1.60	0.84	4	0	0	0	0	0	0
94.3	23.07.96	13:02	10	C3	0.21	1.17	0.70	4	1	0	0	7	0	0
87.9	23.07.96	14:12	9	A1	0.23	2.20	0.79	1	0	0	0	3	0	0
87.6	23.07.96	14:17	9	A2	0.21	2.13	0.74	5	0	0	0	0	0	0
87.3	23.07.96	14:22	9	A3	0.09	1.70	0.32	3	1	3	0	4	1	0
84.9	23.07.96	14:40	9	B1	0.14	1.43	0.48	3	1	0	0	4	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
84.6	23.07.96	14:45	9	B2	0.22	2.07	0.76	5	0	0	0	0	0	0
84.3	23.07.96	14:50	9	B3	0.11	1.97	0.38	7	2	0	0	4	0	0
81.9	23.07.96	15:11	9	C1	0.17	1.40	0.57	6	0	3	0	6	1	0
81.6	23.07.96	15:16	9	C2	0.23	2.37	0.79	6	0	0	0	0	0	0
81.3	23.07.96	15:21	9	C3	0.21	1.87	0.71	1	0	0	0	1	1	0
75.9	23.07.96	15:35	8	A1	0.23	1.27	0.76	8	0	0	0	2	1	0
75.6	23.07.96	15:40	8	A2	0.22	1.20	0.74	4	0	0	0	0	0	0
75.3	23.07.96	15:45	8	A3	0.17	1.16	0.57	5	0	1	0	3	0	0
74.9	23.07.96	15:55	8	B1	0.27	1.27	0.89	6	0	3	1	6	1	0
74.6	23.07.96	16:00	8	B2	0.32	1.53	1.07	4	1	0	0	1	0	0
74.3	23.07.96	16:05	8	B3	0.21	1.53	0.71	5	0	1	0	5	2	0
71.9	23.07.96	16:20	8	C1	0.15	1.97	0.53	1	0	0	0	1	2	0
71.6	23.07.96	16:25	8	C2	0.26	1.87	0.89	4	0	0	0	0	0	0
71.3	23.07.96	16:30	8	C3	0.18	1.83	0.60	1	0	0	0	5	1	0
67.9	23.07.96	16:43	7	A1	0.13	2.53	0.46	8	0	0	0	0	0	0
67.6	23.07.96	16:48	7	A2	0.22	1.67	0.76	4	0	0	0	0	0	0
67.3	23.07.96	16:53	7	A3	0.15	1.70	0.52	3	0	0	0	1	0	0
64.9	23.07.96	17:02	7	B1	0.22	1.36	0.72	4	0	1	0	0	1	0
64.6	23.07.96	17:07	7	B2	0.24	1.97	0.81	4	0	0	0	1	0	0
64.3	23.07.96	17:12	7	B3	0.20	2.96	0.71	1	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
61.9	23.07.96	17:40	7	C1	0.20	1.46	0.68	4	1	0	0	10	0	0
61.6	23.07.96	17:45	7	C2	0.26	2.76	0.93	5	0	0	0	0	0	0
61.3	23.07.96	17:50	7	C3	0.11	1.80	0.38	4	2	2	0	11	0	0
60.9	23.07.96	17:55	6	A1	0.24	2.90	0.86	1	0	0	0	2	0	0
60.6	23.07.96	18:00	6	A2	0.22	2.60	0.77	5	0	0	0	0	0	0
60.3	23.07.96	18:05	6	A3	0.21	2.46	0.72	5	0	0	0	1	0	0
57.9	23.07.96	18:10	6	B1	0.16	1.25	0.52	4	1	1	0	2	0	0
57.6	23.07.96	18:15	6	B2	0.22	1.70	0.76	4	0	0	0	0	0	0
57.3	23.07.96	18:20	6	B3	0.16	1.07	0.53	3	0	1	1	2	0	0
51.9	23.07.96	18:37	6	C1	0.21	1.37	0.71	1	0	1	0	3	1	0
51.6	23.07.96	18:42	6	C2	0.21	3.23	0.75	5	0	0	0	0	0	0
51.3	23.07.96	18:47	6	C3	0.20	1.65	0.67	3	0	1	0	6	0	0
48.9	24.07.96	19:10	5	A1	0.15	2.86	0.55	1	0	0	0	0	0	0
48.6	24.07.96	19:15	5	A2	0.22	3.00	0.77	4	0	0	0	0	0	0
48.3	24.07.96	19:20	5	A3	0.18	2.00	0.63	3	0	0	0	2	1	0
47.9	24.07.96	19:16	5	B1	0.20	2.00	0.68	7	0	0	1	1	1	0
47.6	24.07.96	19:21	5	B2	0.29	2.03	0.99	4	0	0	0	0	0	0
47.3	24.07.96	19:26	5	B3	0.17	1.90	0.58	3	0	0	0	0	0	0
43.9	24.07.96	10:15	5	C1	0.13	1.13	0.43	2	0	0	0	1	1	0
43.6	24.07.96	10:20	5	C2	0.20	1.76	0.68	6	0	2	0	0	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
43.3	24.07.96	10:25	5	C3	0.23	1.76	0.77	4	0	1	0	5	0	0
38.9	24.07.96	10:45	4	A1	0.20	1.80	0.67	1	0	0	1	1	1	0
38.6	24.07.96	10:50	4	A2	0.20	1.73	0.68	4	0	0	0	0	0	0
38.3	24.07.96	10:55	4	A3	0.20	2.53	0.70	1	1	0	0	0	0	0
35.9	24.07.96	11:06	4	B1	0.19	0.66	0.60	3	2	0	0	1	0	0
35.6	24.07.96	11:11	4	B2	0.20	3.10	0.72	4	0	0	0	0	0	0
35.3	24.07.96	11:16	4	B3	0.17	1.96	0.60	1	0	0	0	1	0	0
33.9	24.07.96	11:25	4	C1	0.22	1.60	0.75	6	1	1	0	1	0	0
33.6	24.07.96	11:30	4	C2	0.19	2.63	0.67	6	0	0	0	0	0	0
33.3	24.07.96	11:35	4	C3	0.07	1.16	0.23	2	0	0	0	1	0	0
28.9	24.07.96	11:45	3	A1	0.15	1.13	0.50	2	0	1	0	1	0	0
28.6	24.07.96	11:50	3	A2	0.18	1.90	0.63	5	2	0	0	1	0	0
28.3	24.07.96	11:55	3	A3	0.15	1.43	0.49	4	0	2	1	3	1	0
25.9	24.07.96	12:11	3	B1	0.12	1.13	0.39	6	0	0	0	1	0	0
25.6	24.07.96	12:16	3	B2	0.20	2.16	0.68	6	2	5	1	4	0	0
25.3	24.07.96	12:21	3	B3	0.17	1.16	0.57	6	0	0	0	2	0	0
21.9	24.07.96	12:35	3	C1	0.18	1.10	0.60	5	0	0	0	2	0	0
21.6	24.07.96	12:40	3	C2	0.21	1.20	0.71	7	0	0	0	16	0	0
21.3	24.07.96	12:45	3	C3	0.27	0.96	0.88	6	2	1	0	7	0	0
19.9	24.07.96	13:55	2	A1	0.12	0.93	0.39	6	0	0	0	6	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
19.6	24.07.96	14:00	2	A2	0.30	1.16	0.99	6	7	1	0	20	0	0
19.3	24.07.96	14:05	2	A3	0.23	1.03	0.76	5	4	0	0	7	0	0
12.9	24.07.96	14:30	2	B1	0.15	0.76	0.48	6	4	3	2	14	0	0
12.6	24.07.96	14:35	2	B2	0.25	1.27	0.84	7	3	0	0	25	0	0
12.3	24.07.96	14:40	2	B3	0.30	0.80	0.99	6	5	1	3	18	0	0
11.9	24.07.96	15:06	2	C1	0.32	1.00	1.05	5	3	0	2	12	0	0
11.6	24.07.96	15:11	2	C2	0.24	1.43	0.81	6	2	0	0	4	0	0
11.3	24.07.96	15:16	2	C3	0.12	0.73	0.39	6	5	0	0	17	1	0
10.9	24.07.96	15:25	1	A1	0.24	0.86	0.77	7	13	0	1	19	0	0
10.6	24.07.96	15:30	1	A2	0.34	1.07	1.11	6	3	2	0	13	1	0
10.3	24.07.96	15:35	1	A3	0.15	2.06	0.52	5	4	1	0	1	0	0
9.9	24.07.96	15:50	1	B1	0.24	1.36	0.79	5	0	0	2	4	0	0
9.6	24.07.96	15:55	1	B2	0.19	1.34	0.63	6	0	0	0	2	0	0
9.3	24.07.96	16:00	1	B3	0.14	1.27	0.45	3	0	1	1	2	3	0
1.9	24.07.96	16:30	1	C1	0.07	1.30	0.24	6	3	1	0	2	0	0
1.6	24.07.96	16:35	1	C2	0.14	4.30	0.52	3	0	0	0	0	0	0
1.3	24.07.96	16:40	1	C3	0.09	2.93	0.31	6	4	0	0	2	0	0
156.9	26.08.96	10:54	16	A1	0.12	1.03	0.41	5	0	0	0	6	0	0
156.6	26.08.96	10:59	16	A2	0.25	1.33	0.82	5	0	0	0	1	4	0
156.3	26.08.96	11:04	16	A3	0.14	1.27	0.48	5	0	0	0	10	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
155.9	26.08.96	11:14	16	B1	0.13	2.13	0.44	1	0	0	0	1	1	12
155.6	26.08.96	11:19	16	B2	0.17	1.88	0.58	5	0	0	0	0	1	0
155.3	26.08.96	11:24	16	B3	0.00	1.03	0.00	1	0	2	0	0	2	0
151.9	26.08.96	11:41	16	C1	0.20	1.20	0.67	4	0	0	0	7	3	0
151.6	26.08.96	11:46	16	C2	0.26	1.40	0.86	4	0	0	0	0	0	0
151.3	26.08.96	11:51	16	C3	0.22	1.08	0.72	5	0	0	0	0	1	0
145.9	26.08.96	12:10	15	A1	0.27	1.63	0.91	4	0	1	0	0	0	0
145.6	26.08.96	12:15	15	A2	0.24	1.28	0.80	4	1	0	0	0	8	0
145.3	26.08.96	12:20	15	A3	0.22	1.27	0.72	4	0	0	0	4	1	0
144.9	26.08.96	12:25	15	B1	0.22	1.80	0.75	1	0	1	0	3	0	0
144.6	26.08.96	12:30	15	B2	0.24	1.13	0.79	4	0	0	0	2	1	0
144.3	26.08.96	12:35	15	B3	0.20	0.90	0.65	4	0	0	0	0	1	0
142.9	26.08.96	12:54	15	C1	0.16	0.76	0.52	4	0	0	0	1	5	0
142.6	26.08.96	12:59	15	C2	0.26	1.40	0.88	4	0	0	0	1	3	0
142.3	26.08.96	13:04	15	C3	0.21	0.93	0.68	4	0	0	0	6	5	0
137.9	26.08.96	13:15	14	A1	0.18	2.26	0.63	8	0	0	0	1	0	0
137.6	26.08.96	13:20	14	A2	0.19	0.80	0.63	4	0	0	0	0	1	0
137.3	26.08.96	13:25	14	A3	0.25	0.88	0.82	4	0	0	0	3	1	0
135.9	26.08.96	13:55	14	B1	0.20	1.05	0.67	4	0	1	0	0	2	0
135.6	26.08.96	14:00	14	B2	0.25	1.20	0.84	4	0	0	0	1	2	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
135.3	26.08.96	14:05	14	B3	0.17	1.37	0.58	4	0	0	0	2	0	0
134.9	26.08.96	14:15	14	C1	0.17	1.28	0.55	4	0	0	0	0	1	0
134.6	26.08.96	14:20	14	C2	0.22	1.06	0.72	4	0	0	0	0	3	0
134.3	26.08.96	14:25	14	C3	0.17	0.82	0.55	4	0	0	0	0	0	0
130.9	26.08.96	14:53	13	A1	0.19	1.28	0.63	5	0	1	0	1	1	0
130.6	26.08.96	14:58	13	A2	0.25	1.86	0.84	4	0	0	0	0	3	0
130.3	26.08.96	15:03	13	A3	0.15	1.42	0.50	8	0	0	0	7	2	0
129.9	26.08.96	15:08	13	B1	0.22	0.96	0.72	4	0	0	0	3	2	0
129.6	26.08.96	15:13	13	B2	0.25	1.13	0.82	4	1	0	0	0	0	0
129.3	26.08.96	15:18	13	B3	0.23	1.13	0.75	4	0	0	0	2	0	0
126.9	26.08.96	15:28	13	C1	0.17	2.33	0.60	1	0	0	0	1	0	0
126.6	26.08.96	15:33	13	C2	0.27	1.38	0.89	4	0	0	0	1	1	0
126.3	26.08.96	15:38	13	C3	0.17	1.56	0.58	4	0	0	0	0	0	0
118.9	26.08.96	15:58	12	A1	0.18	2.07	0.63	1	0	0	0	2	0	0
118.6	26.08.96	16:03	12	A2	0.22	1.47	0.74	4	0	0	0	1	0	0
118.3	26.08.96	16:08	12	A3	0.17	2.00	0.57	1	0	0	0	3	0	0
117.9	26.08.96	16:16	12	B1	0.00	1.20	0.00	4	0	1	0	0	1	0
117.6	26.08.96	16:21	12	B2	0.23	1.23	0.75	4	0	0	0	0	0	0
117.3	26.08.96	16:26	12	B3	0.22	2.10	0.77	1	2	1	0	0	0	0
113.9	26.08.96	16:43	12	C1	0.25	0.72	0.82	4	0	1	0	2	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
113.6	26.08.96	16:48	12	C2	0.23	1.33	0.76	4	0	0	0	0	0	0
113.3	26.08.96	16:53	12	C3	0.21	0.87	0.67	3	0	1	0	1	2	0
110.9	27.08.96	11:43	11	A1	0.24	0.93	0.79	4	0	1	0	1	1	0
110.6	27.08.96	11:48	11	A2	0.25	1.10	0.84	4	0	0	0	0	1	0
110.3	27.08.96	11:53	11	A3	0.22	1.87	0.74	1	0	0	0	1	0	0
109.9	27.08.96	11:50	11	B1	0.05	0.73	0.17	4	0	0	0	1	2	0
109.6	27.08.96	11:55	11	B2	0.20	2.33	0.68	4	0	0	0	0	0	0
109.3	27.08.96	12:00	11	B3	0.11	1.13	0.36	4	1	0	0	2	1	0
108.9	27.08.96	12:08	11	C1	0.17	1.73	0.58	5	1	2	0	1	1	0
108.6	27.08.96	12:13	11	C2	0.19	1.33	0.65	4	0	0	0	1	0	0
108.3	27.08.96	12:18	11	C3	0.18	0.96	0.58	4	0	1	2	6	0	0
98.9	27.08.96	13:34	10	A1	0.26	1.46	0.88	1	0	1	0	6	2	0
98.6	27.08.96	13:39	10	A2	0.26	1.57	0.88	4	0	0	0	1	1	0
98.3	27.08.96	13:44	10	A3	0.16	0.66	0.53	4	0	1	0	4	1	0
97.9	27.08.96	13:51	10	B1	0.18	0.97	0.58	4	0	1	0	2	0	0
97.6	27.08.96	13:56	10	B2	0.20	2.17	0.68	4	1	0	0	0	0	0
97.3	27.08.96	14:01	10	B3	0.13	2.26	0.46	6	2	0	0	6	0	0
91.9	27.08.96	14:18	10	C1	0.24	2.17	0.84	1	0	0	0	2	0	0
91.6	27.08.96	14:23	10	C2	0.25	1.16	0.82	4	0	0	0	0	0	0
91.3	27.08.96	14:28	10	C3	0.09	1.76	0.31	6	0	0	0	1	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
85.9	27.08.96	14:47	9	A1	0.18	0.80	0.60	4	3	0	0	6	1	0
85.6	27.08.96	14:52	9	A2	0.23	2.23	0.81	4	0	0	0	0	2	0
85.3	27.08.96	14:57	9	A3	0.14	1.90	0.48	3	0	0	0	0	0	0
84.9	27.08.96	15:14	9	B1	0.14	1.30	0.46	4	0	0	0	3	2	0
84.6	27.08.96	15:19	9	B2	0.21	1.30	0.71	4	0	0	0	0	0	0
84.3	27.08.96	15:24	9	B3	0.14	1.93	0.48	6	0	2	0	2	0	0
81.9	27.08.96	15:34	9	C1	0.19	0.80	0.63	4	0	1	0	0	0	0
81.6	27.08.96	15:39	9	C2	0.21	1.83	0.72	4	0	1	0	0	0	0
81.3	27.08.96	15:44	9	C3	0.14	1.70	0.48	5	0	1	0	0	0	0
79.9	27.08.96	15:55	8	A1	0.18	0.87	0.60	8	0	0	0	1	1	0
79.6	27.08.96	16:01	8	A2	0.20	1.60	0.67	6	1	1	0	5	0	0
79.3	27.08.96	16:06	8	A3	0.16	1.07	0.52	4	0	2	0	9	1	0
77.9	27.08.96	16:14	8	B1	0.16	0.76	0.53	4	0	4	0	0	1	0
77.6	27.08.96	16:19	8	B2	0.20	1.23	0.67	4	0	0	0	0	0	0
77.3	27.08.96	16:24	8	B3	0.16	1.66	0.55	5	0	1	0	2	0	1
75.9	27.08.96	16:32	8	C1	0.20	0.70	0.65	6	0	0	0	4	1	0
75.6	27.08.96	16:37	8	C2	0.21	1.00	0.70	6	0	0	0	0	0	0
75.3	27.08.96	16:42	8	C3	0.19	0.70	0.63	5	0	0	0	13	0	0
69.9	27.08.96	16:57	7	A1	0.12	1.76	0.41	8	0	0	0	1	0	0
69.6	27.08.96	17:02	7	A2	0.22	2.03	0.75	4	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
69.3	27.08.96	17:07	7	A3	0.17	1.56	0.58	5	1	5	0	4	0	0
68.9	27.08.96	17:22	7	B1	0.22	0.98	0.71	4	1	0	0	2	0	0
68.6	27.08.96	17:27	7	B2	0.24	0.90	0.79	4	0	1	0	0	0	0
68.3	27.08.96	17:32	7	B3	0.33	0.85	1.08	5	0	0	0	0	0	0
63.9	27.08.96	17:44	7	C1	0.13	1.37	0.43	6	1	2	0	1	0	0
63.6	27.08.96	17:49	7	C2	0.26	1.33	0.86	5	0	0	0	0	1	0
63.3	27.08.96	17:54	7	C3	0.16	0.86	0.52	4	0	1	0	0	0	0
60.9	27.08.96	18:09	6	A1	0.16	2.26	0.57	5	0	0	0	0	0	0
60.6	27.08.96	18:14	6	A2	0.20	1.53	0.68	4	0	0	0	0	0	0
60.3	27.08.96	18:19	6	A3	0.11	2.28	0.39	3	0	0	0	1	0	0
55.9	27.08.96	18:23	6	B1	0.17	1.37	0.57	5	1	0	0	0	0	0
55.6	27.08.96	18:28	6	B2	0.18	1.80	0.60	4	0	0	0	0	0	0
55.3	27.08.96	18:33	6	B3	0.20	1.30	0.68	6	0	2	0	3	0	0
54.9	27.08.96	18:36	6	C1	0.13	1.43	0.43	3	0	1	0	1	0	0
54.6	27.08.96	18:41	6	C2	0.19	2.40	0.65	5	0	0	0	0	0	0
54.3	27.08.96	18:46	6	C3	0.16	1.23	0.53	4	0	0	0	0	0	0
47.9	27.08.96	19:00	5	A1	0.21	1.53	0.72	5	0	2	0	1	0	0
47.6	27.08.96	19:05	5	A2	0.22	1.76	0.74	4	0	0	0	0	0	0
47.3	27.08.96	19:10	5	A3	0.11	2.03	0.38	1	0	0	0	3	1	0
46.9	27.08.96	19:14	5	B1	0.18	1.00	0.58	3	0	3	0	0	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
46.6	27.08.96	19:19	5	B2	0.20	1.53	0.68	4	0	0	0	0	0	0
46.3	27.08.96	19:24	5	B3	0.19	1.57	0.63	6	0	0	0	5	1	0
43.9	27.08.96	19:37	5	C1	0.13	1.23	0.43	6	0	0	0	1	0	0
43.6	27.08.96	19:42	5	C2	0.19	1.53	0.65	6	1	0	0	7	0	0
43.3	27.08.96	19:47	5	C3	0.22	1.00	0.72	3	0	0	0	0	0	0
37.9	28.08.96	10:40	4	A1	0.16	1.03	0.52	3	0	0	0	1	0	0
37.6	28.08.96	10:45	4	A2	0.16	1.48	0.53	4	0	1	0	0	1	0
37.3	28.08.96	10:50	4	A3	0.15	2.00	0.53	6	0	0	0	1	0	0
36.9	28.08.96	10:53	4	B1	0.11	1.20	0.38	3	0	0	0	2	0	0
36.6	28.08.96	10:58	4	B2	0.14	1.86	0.48	4	0	0	0	0	0	0
36.3	28.08.96	11:03	4	B3	0.07	0.80	0.22	3	0	0	0	0	1	0
31.9	28.08.96	11:14	4	C1	0.12	1.60	0.41	2	0	1	0	0	0	0
31.6	28.08.96	11:19	4	C2	0.17	2.60	0.60	5	0	0	0	0	0	0
31.3	28.08.96	11:24	4	C3	0.11	2.43	0.39	5	0	6	0	0	0	0
30.9	28.08.96	11:29	3	A1	0.11	0.90	0.35	3	0	0	0	0	0	0
30.6	28.08.96	11:34	3	A2	0.13	2.00	0.43	3	0	0	0	0	0	0
30.3	28.08.96	11:39	3	A3	0.08	1.37	0.26	6	0	0	0	0	0	1
29.9	28.08.96	11:44	3	B1	0.09	1.07	0.29	8	0	0	0	0	0	0
29.6	28.08.96	11:49	3	B2	0.12	2.30	0.43	5	0	0	0	0	0	0
29.3	28.08.96	11:54	3	B3	0.12	1.23	0.39	5	0	3	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
25.9	28.08.96	12:20	3	C1	0.10	0.66	0.32	6	0	3	0	5	1	0
25.6	28.08.96	12:25	3	C2	0.17	1.17	0.55	6	0	0	2	10	0	0
25.3	28.08.96	12:30	3	C3	0.07	0.90	0.24	6	0	0	0	13	0	0
16.9	28.08.96	12:58	2	A1	0.14	0.75	0.46	7	6	3	0	25	0	0
16.6	28.08.96	13:03	2	A2	0.26	1.10	0.86	6	0	1	1	39	0	0
16.3	28.08.96	13:08	2	A3	0.11	0.80	0.36	6	1	1	0	3	0	0
14.9	28.08.96	13:20	2	B1	0.10	1.03	0.32	5	0	0	0	6	0	0
14.6	28.08.96	13:25	2	B2	0.13	1.43	0.43	5	0	0	0	0	0	0
14.3	28.08.96	13:30	2	B3	0.07	0.90	0.22	6	0	0	1	0	0	0
13.9	28.08.96	13:33	2	C1	0.19	0.80	0.62	6	1	0	0	8	0	0
13.6	28.08.96	13:38	2	C2	0.17	1.57	0.58	6	0	0	0	3	0	0
13.3	28.08.96	13:43	2	C3	0.18	0.93	0.60	6	0	0	0	1	0	0
9.9	28.08.96	14:21	1	A1	0.18	1.06	0.58	5	1	1	0	5	0	0
9.6	28.08.96	14:26	1	A2	0.16	1.70	0.55	5	0	0	0	4	0	0
9.3	28.08.96	14:31	1	A3	0.05	1.00	0.18	3	0	0	0	0	0	0
7.9	28.08.96	14:53	1	B1	0.31	0.46	0.99	6	1	2	2	4	1	0
7.6	28.08.96	14:58	1	B2	0.25	1.06	0.84	6	3	0	2	5	0	0
7.3	28.08.96	15:03	1	B3	0.08	0.80	0.27	8	0	1	0	0	2	0
1.9	28.08.96	15:27	1	C1	0.04	1.06	0.14	2	0	0	0	0	0	0
1.6	28.08.96	15:32	1	C2	0.09	4.63	0.34	6	0	0	0	0	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
1.3	28.08.96	15:37	1	C3	0.09	1.56	0.31	6	0	0	0	1	1	0
157.9	30.09.96	11:10	16	A1	0.12	1.03	0.38	5	3	1	0	2	2	0
157.6	30.09.96	11:15	16	A2	0.21	2.37	0.74	5	0	0	0	0	0	0
157.3	30.09.96	11:20	16	A3	0.15	2.07	0.53	5	0	4	0	4	0	0
153.9	30.09.96	11:33	16	B1	0.15	0.77	0.50	5	0	0	0	3	0	0
153.6	30.09.96	11:38	16	B2	0.24	1.33	0.79	4	0	0	0	2	0	0
153.3	30.09.96	11:43	16	B3	0.23	0.77	0.76	5	0	0	0	3	0	0
151.9	30.09.96	12:07	16	C1	0.12	0.97	0.40	4	3	0	0	4	1	0
151.6	30.09.96	12:12	16	C2	0.23	1.20	0.76	4	0	0	0	0	0	0
151.3	30.09.96	12:17	16	C3	0.24	0.78	0.79	4	0	0	0	2	0	0
147.9	30.09.96	12:45	15	A1	0.17	1.38	0.57	4	0	0	0	6	0	0
147.6	30.09.96	12:50	15	A2	0.23	1.07	0.76	4	0	0	0	0	1	0
147.3	30.09.96	12:55	15	A3	0.11	0.60	0.36	3	1	0	1	1	3	0
143.9	30.09.96	13:13	15	B1	0.13	1.50	0.45	4	0	0	0	1	1	0
143.6	30.09.96	13:18	15	B2	0.26	0.93	0.84	4	0	0	0	0	0	0
143.3	30.09.96	13:23	15	B3	0.20	1.38	0.67	4	0	0	0	6	1	0
142.9	30.09.96	13:29	15	C1	0.19	0.80	0.63	4	0	0	0	3	1	0
142.6	30.09.96	13:34	15	C2	0.23	0.98	0.76	4	0	0	0	0	2	0
142.3	30.09.96	13:39	15	C3	0.25	1.03	0.82	5	0	1	0	4	0	0
140.9	30.09.96	14:00	14	A1	0.23	1.20	0.76	4	0	3	0	3	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
140.6	30.09.96	14:05	14	A2	0.23	0.77	0.76	4	0	1	0	0	0	0
140.3	30.09.96	14:10	14	A3	0.24	1.23	0.79	8	0	3	0	3	0	0
134.9	30.09.96	15:10	14	B1	0.18	0.73	0.60	4	0	0	0	1	2	0
134.6	30.09.96	15:15	14	B2	0.13	1.60	0.45	4	0	1	0	0	1	0
134.3	30.09.96	15:20	14	B3	0.00	1.00	0.00	3	0	0	0	1	0	0
131.9	30.09.96	15:27	14	C1	0.25	0.57	0.79	3	0	0	0	0	1	0
131.6	30.09.96	15:32	14	C2	0.23	1.80	0.79	4	0	0	0	0	0	0
131.3	30.09.96	15:37	14	C3	0.09	1.60	0.31	3	0	0	0	5	4	0
129.9	30.09.96	15:50	13	A1	0.00	0.85	0.00	3	0	0	0	1	2	0
129.6	30.09.96	15:55	13	A2	0.19	1.00	0.63	4	0	0	0	0	0	0
129.3	30.09.96	16:00	13	A3	0.17	1.17	0.57	4	0	1	0	1	0	0
127.9	30.09.96	16:12	13	B1	0.18	1.77	0.62	4	0	0	0	0	1	0
127.6	30.09.96	16:17	13	B2	0.24	1.13	0.79	4	0	0	0	0	0	0
127.3	30.09.96	16:22	13	B3	0.14	1.68	0.48	4	0	0	0	0	0	0
121.9	30.09.96	16:53	13	C1	0.20	1.38	0.67	8	0	1	0	2	0	0
121.6	30.09.96	16:58	13	C2	0.23	0.87	0.76	4	0	0	0	0	0	0
121.3	30.09.96	17:03	13	C3	0.20	1.22	0.67	8	0	0	0	1	0	0
119.9	30.09.96	17:08	12	A1	0.04	1.47	0.14	3	0	1	0	3	2	0
119.6	30.09.96	17:13	12	A2	0.25	0.90	0.82	4	0	0	0	1	0	0
119.3	30.09.96	17:18	12	A3	0.21	0.80	0.67	4	0	0	0	2	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
118.9	30.09.96	17:27	12	B1	0.14	1.43	0.46	4	0	0	0	1	1	0
118.6	30.09.96	17:31	12	B2	0.20	0.90	0.67	4	0	0	0	0	0	0
118.3	30.09.96	17:35	12	B3	0.18	1.53	0.60	8	0	0	0	6	1	0
116.9	30.09.96	17:39	12	C1	0.11	0.93	0.36	4	0	0	0	5	0	0
116.6	30.09.96	17:44	12	C2	0.17	0.97	0.57	4	0	0	0	1	0	0
116.3	30.09.96	17:49	12	C3	0.16	0.72	0.53	4	0	0	0	0	0	0
107.9	01.10.96	9:28	11	A1	0.22	2.10	0.76	4	0	0	0	2	1	0
107.6	01.10.96	9:33	11	A2	0.27	1.47	0.91	4	0	0	0	0	1	0
107.3	01.10.96	9:38	11	A3	0.16	1.25	0.52	5	0	0	0	3	0	0
105.9	01.10.96	9:49	11	B1	0.18	0.87	0.58	4	0	1	0	9	2	0
105.6	01.10.96	9:54	11	B2	0.22	1.03	0.71	4	0	0	0	0	0	0
105.3	01.10.96	9:59	11	B3	0.20	0.97	0.67	4	0	0	0	1	1	0
103.9	01.10.96	10:08	11	C1	0.17	2.03	0.58	5	0	0	0	0	0	0
103.6	01.10.96	10:13	11	C2	0.25	1.40	0.82	4	0	0	0	0	0	0
103.3	01.10.96	10:18	11	C3	0.22	0.87	0.71	4	0	0	0	25	0	0
100.9	01.10.96	10:31	10	A1	0.22	1.70	0.74	5	0	2	1	3	0	0
100.6	01.10.96	10:36	10	A2	0.18	0.88	0.60	4	0	0	0	0	0	0
100.3	01.10.96	10:41	10	A3	0.22	1.15	0.74	4	0	0	0	2	0	0
98.9	01.10.96	10:58	10	B1	0.22	1.58	0.74	8	0	0	0	5	1	0
98.6	01.10.96	11:03	10	B2	0.28	1.28	0.93	4	0	0	0	1	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
98.3	01.10.96	11:08	10	B3	0.05	0.88	0.15	3	0	0	1	9	3	0
92.9	01.10.96	11:28	10	C1	0.19	0.73	0.62	4	0	0	0	3	2	0
92.6	01.10.96	11:33	10	C2	0.20	0.90	0.67	4	0	0	0	0	0	0
92.3	01.10.96	11:38	10	C3	0.23	1.28	0.76	4	0	0	0	7	0	0
87.9	01.10.96	12:05	9	A1	0.22	1.37	0.74	5	0	0	0	0	0	0
87.6	01.10.96	12:10	9	A2	0.22	1.23	0.72	4	0	0	0	0	0	0
87.3	01.10.96	12:15	9	A3	0.19	1.08	0.62	4	0	0	0	1	1	0
84.9	01.10.96	12:19	9	B1	0.15	1.20	0.50	5	0	2	0	2	1	0
84.6	01.10.96	12:24	9	B2	0.19	0.92	0.62	4	0	0	0	0	0	0
84.3	01.10.96	12:29	9	B3	0.18	1.57	0.60	6	0	0	0	0	0	0
81.9	02.10.96	10:14	9	C1	0.14	0.97	0.46	4	0	0	0	1	0	0
81.6	02.10.96	10:19	9	C2	0.19	1.47	0.65	4	0	0	0	0	0	0
81.3	02.10.96	10:24	9	C3	0.15	1.22	0.50	1	0	0	0	0	0	0
74.9	02.10.96	10:42	8	A1	0.20	1.17	0.67	6	1	1	0	9	0	0
74.6	02.10.96	10:47	8	A2	0.22	0.87	0.72	6	0	0	0	0	0	0
74.3	02.10.96	10:52	8	A3	0.13	0.75	0.41	6	0	1	2	16	2	0
73.9	02.10.96	11:11	8	B1	0.19	0.77	0.63	6	0	0	0	4	0	0
73.6	02.10.96	11:16	8	B2	0.23	0.88	0.76	6	0	0	0	0	0	0
73.3	02.10.96	11:21	8	B3	0.25	1.10	0.82	6	0	0	0	1	0	0
72.9	02.10.96	11:25	8	C1	0.21	0.80	0.67	6	0	0	0	4	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
72.6	02.10.96	11:30	8	C2	0.17	1.37	0.57	5	0	1	0	0	0	0
72.3	02.10.96	11:35	8	C3	0.09	1.42	0.31	6	0	2	0	8	2	0
69.9	02.10.96	12:01	7	A1	0.07	1.57	0.24	5	0	1	0	4	0	0
69.6	02.10.96	12:06	7	A2	0.21	2.07	0.72	6	0	0	0	1	0	0
69.3	02.10.96	12:11	7	A3	0.22	1.80	0.76	5	0	0	0	1	0	0
64.9	02.10.96	12:30	7	B1	0.20	0.65	0.65	4	0	0	0	1	2	0
64.6	02.10.96	12:35	7	B2	0.22	1.30	0.72	4	0	0	0	0	0	0
64.3	02.10.96	12:40	7	B3	0.14	2.27	0.50	1	0	0	0	1	0	0
63.9	02.10.96	12:45	7	C1	0.15	1.02	0.48	3	0	0	0	1	0	0
63.6	02.10.96	12:50	7	C2	0.18	2.25	0.63	4	0	0	0	0	0	0
63.3	02.10.96	12:55	7	C3	0.11	0.93	0.35	3	0	1	0	4	0	0
60.9	02.10.96	13:13	6	A1	0.16	1.25	0.53	4	0	0	0	14	1	0
60.6	02.10.96	13:18	6	A2	0.22	1.40	0.74	4	0	0	0	0	0	0
60.3	02.10.96	13:23	6	A3	0.14	2.17	0.50	1	0	0	0	0	0	0
53.9	02.10.96	13:45	6	B1	0.16	2.37	0.55	4	0	0	0	1	0	0
53.6	02.10.96	13:50	6	B2	0.14	1.97	0.48	4	0	0	0	0	0	0
53.3	02.10.96	13:55	6	B3	0.13	2.35	0.46	3	0	0	0	0	0	0
52.9	02.10.96	14:00	6	C1	0.15	0.97	0.50	4	0	1	0	2	0	0
52.6	02.10.96	14:05	6	C2	0.21	1.68	0.72	4	0	0	0	0	0	0
52.3	02.10.96	14:10	6	C3	0.06	1.77	0.22	3	0	0	0	7	1	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
50.9	02.10.96	14:19	5	A1	0.21	2.13	0.71	1	0	0	0	1	0	0
50.6	02.10.96	14:24	5	A2	0.19	1.60	0.65	4	0	0	0	0	0	0
50.3	02.10.96	14:29	5	A3	0.16	1.87	0.55	8	0	0	0	0	0	0
44.9	02.10.96	14:47	5	B1	0.14	1.87	0.48	6	0	0	0	1	0	0
44.6	02.10.96	14:52	5	B2	0.22	2.00	0.74	4	0	0	0	0	0	0
44.3	02.10.96	14:57	5	B3	0.11	1.18	0.36	6	0	0	1	3	1	0
42.9	02.10.96	15:10	5	C1	0.13	0.78	0.43	4	1	0	0	5	1	0
42.6	02.10.96	15:15	5	C2	0.17	1.07	0.57	4	0	0	0	0	0	0
42.3	02.10.96	15:20	5	C3	0.18	1.07	0.60	6	0	0	3	3	1	0
40.9	03.10.96	10:00	4	A1	0.16	0.87	0.53	4	0	0	0	1	0	0
40.6	03.10.96	10:05	4	A2	0.19	1.60	0.65	6	0	0	0	0	1	0
40.3	03.10.96	10:10	4	A3	0.21	1.18	0.68	4	1	0	0	4	0	0
39.9	03.10.96	10:19	4	B1	0.16	1.22	0.53	6	1	0	0	2	1	1
39.6	03.10.96	10:24	4	B2	0.23	1.67	0.79	5	0	0	0	0	0	0
39.3	03.10.96	10:29	4	B3	0.16	0.97	0.53	4	0	1	0	0	0	0
33.9	03.10.96	10:48	4	C1	0.13	0.93	0.41	5	1	1	0	1	0	0
33.6	03.10.96	10:53	4	C2	0.20	1.30	0.65	6	0	0	0	0	0	0
33.3	03.10.96	10:58	4	C3	0.17	1.00	0.56	3	0	0	0	2	0	0
26.9	03.10.96	11:23	3	A1	0.12	0.97	0.38	4	0	0	0	14	0	0
26.6	03.10.96	11:28	3	A2	0.09	1.30	0.31	4	0	0	0	2	0	0

Appendix 1 continued...

KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
26.3	03.10.96	11:33	3	A3	0.12	0.80	0.40	6	1	0	0	5	0	0
24.9	03.10.96	11:52	3	B1	0.11	0.90	0.35	5	0	0	1	11	0	0
24.6	03.10.96	11:57	3	B2	0.15	1.80	0.52	6	0	0	1	1	0	0
24.3	03.10.96	12:02	3	B3	0.16	1.03	0.52	6	0	1	0	9	0	0
21.9	03.10.96	12:28	3	C1	0.11	0.78	0.36	5	2	0	1	16	0	0
21.6	03.10.96	12:33	3	C2	0.15	0.90	0.50	6	0	0	0	2	0	0
21.3	03.10.96	12:38	3	C3	0.22	0.83	0.72	6	7	0	0	12	0	0
14.9	03.10.96	13:23	2	A1	0.15	0.73	0.50	5	0	0	1	9	1	0
14.6	03.10.96	13:28	2	A2	0.11	1.52	0.36	6	0	0	0	0	0	0
14.3	03.10.96	13:33	2	A3	0.13	0.85	0.43	6	2	0	1	3	0	0
13.9	03.10.96	13:41	2	B1	0.16	0.80	0.52	6	3	0	1	5	0	0
13.6	03.10.96	13:46	2	B2	0.16	1.55	0.53	6	0	0	1	0	0	0
13.3	03.10.96	13:51	2	B3	0.22	0.87	0.72	6	1	0	5	2	0	0
12.9	03.10.96	14:03	2	C1	0.12	0.80	0.40	6	1	0	2	0	0	0
12.6	03.10.96	14:08	2	C2	0.25	1.00	0.81	7	0	0	0	2	0	0
12.3	03.10.96	14:13	2	C3	0.22	0.47	0.71	6	0	1	0	3	1	0
6.9	03.10.96	14:58	1	A1	0.14	0.92	0.45	2	4	0	0	1	0	0
6.6	03.10.96	15:03	1	A2	0.11	2.17	0.38	7	0	0	0	0	0	0
6.3	03.10.96	15:08	1	A3	0.08	1.23	0.26	8	0	0	0	0	0	0
5.9	03.10.96	15:18	1	B1	0.08	1.67	0.26	2	0	0	0	1	0	0

Appendix 1 continued...

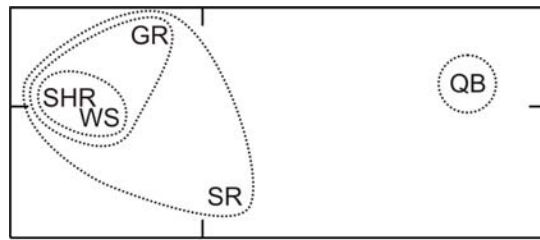
KM	Date	Time	Reach ¹	Sample ²	Froude	Depth	Velocity	Substrate ³	WS	SR	GR	SHR	QB	BB
5.6	03.10.96	15:23	1	B2	0.12	3.40	0.45	4	0	0	0	0	0	0
5.3	03.10.96	15:28	1	B3	0.08	1.02	0.27	2	0	0	0	0	0	0
2.9	03.10.96	15:39	1	C1	0.00	0.87	0.00	6	0	1	0	0	0	0
2.6	03.10.96	15:44	1	C2	0.10	3.27	0.35	6	0	0	0	0	0	0
2.3	03.10.96	15:49	1	C3	0.06	2.17	0.21	6	3	1	0	0	0	0

¹ Reach is the 10km block within which the sample was collected e.g. Reach 16 is 160km to 151km, Reach 15 in 150km to 141km etc.

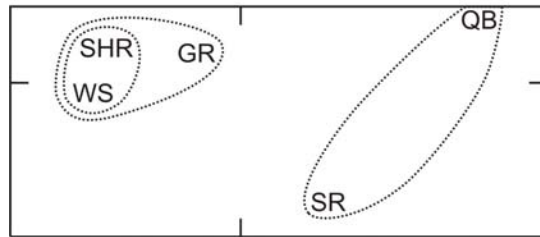
² Sample letter refers to the replicate and numbers to left bank, channel, and right bank samples e.g. A1 is replicate A left bank, A2 is replicate A channel, and A3 is replicate A right bank etc.

³ Substrate categories are defined as: 1-Clay, 2-Silt, 3-Silt-Sand, 4-Sand, 5-Gravel, 6-Cobble, 7-Boulder, and 8-Trees (or Snag).

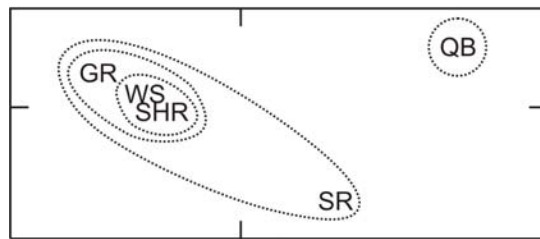
Appendix 2. PCoA ordinations based on co-occurrence from six sampling periods pooled for analyses.



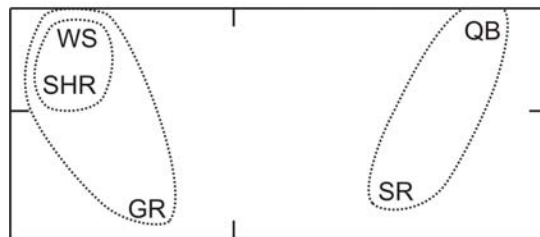
August 1995
 Axis 1 = 36.62%
 Axis 2 = 27.42%
 Axis 3 = 23.46%
 Axis 4 = 12.49%
 Cophenetic Correlation = 0.97



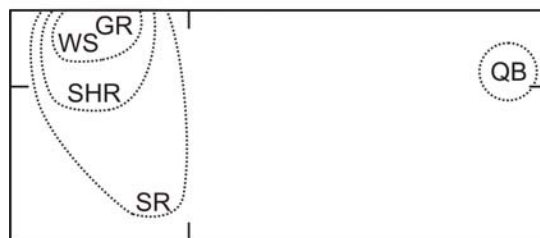
September 1995
 Axis 1 = 36.89%
 Axis 2 = 28.20%
 Axis 3 = 24.66%
 Axis 4 = 10.25%
 Cophenetic Correlation = 0.97



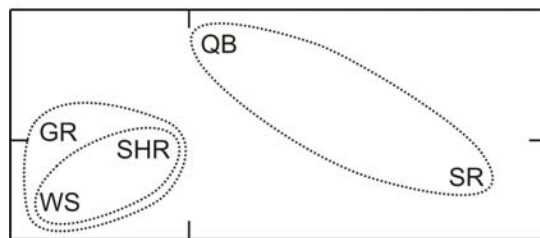
June 1996
 Axis 1 = 39.62%
 Axis 2 = 30.96%
 Axis 3 = 18.12%
 Axis 4 = 11.29%
 Cophenetic Correlation = 0.97



July 1996
 Axis 1 = 43.84%
 Axis 2 = 25.83%
 Axis 3 = 19.85%
 Axis 4 = 10.48%
 Cophenetic Correlation = 0.96

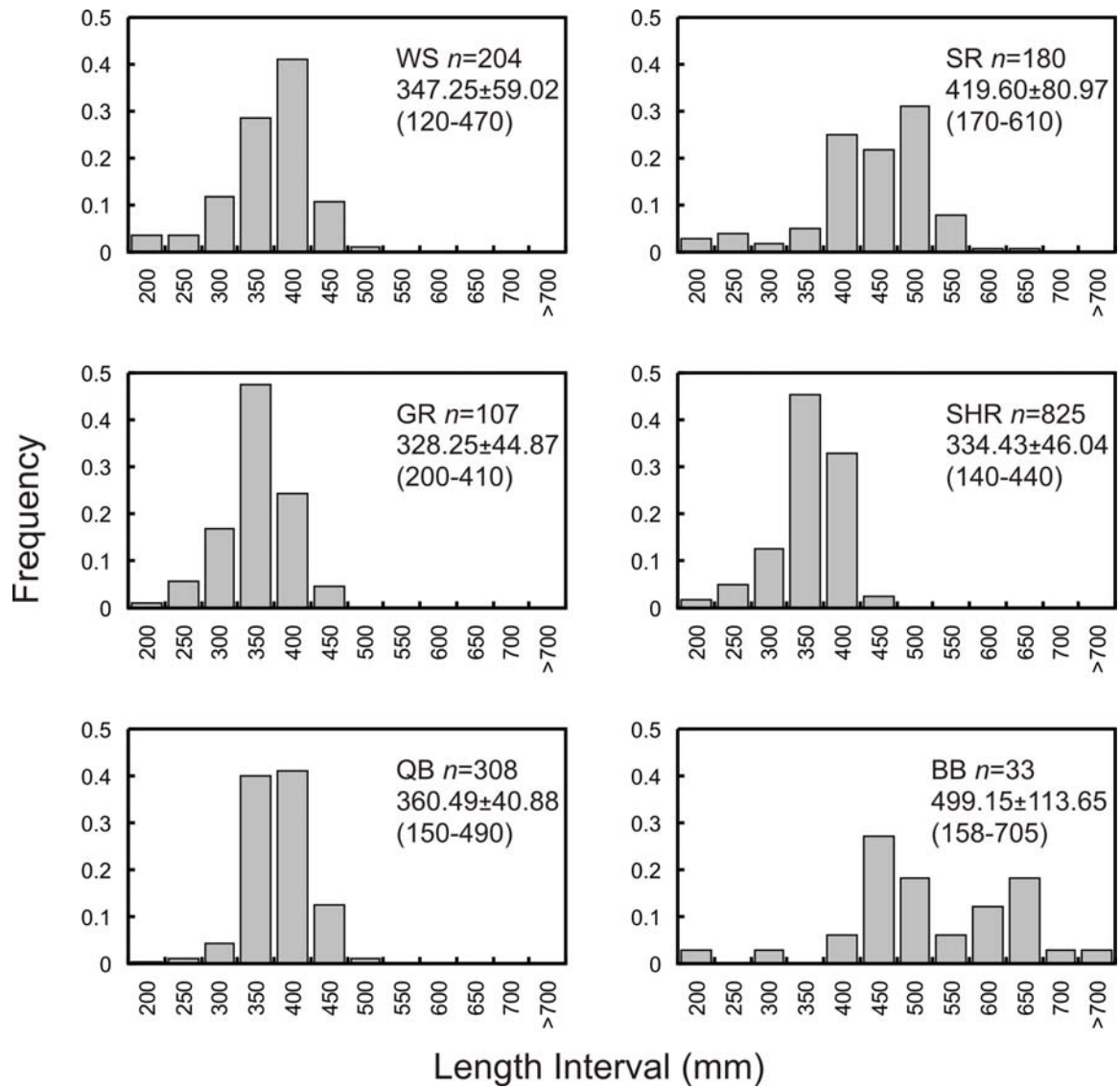


August 1996
 Axis 1 = 34.34%
 Axis 2 = 27.54%
 Axis 3 = 21.93%
 Axis 4 = 16.19%
 Cophenetic Correlation = 0.97



September 1996
 Axis 1 = 29.03%
 Axis 2 = 27.30%
 Axis 3 = 22.79%
 Axis 4 = 20.88%
 Cophenetic Correlation = 0.78

Appendix 3. Length frequency histograms for six catostomid species, Values are sample size (*n*), mean $\pm$ SD, and range in parentheses.



Appendix 4. Visual basic script and VBA macros used for analyses.

```
Sub ThreeDimensional_Niche()

Randomize
Dim data(864, 9) 'raw samples uncategorized
Dim data2(864, 9) 'data samples categorized
Dim dep(864, 1)
Dim vel(864, 1)
Dim subs(864, 1)

Dim raw1(8, 8, 8) 'set array to actual size
Dim raw2(8, 8, 8) 'set array to actual size
Dim raw3(8, 8, 8) 'set array to actual size
Dim raw4(8, 8, 8) 'set array to actual size
Dim raw5(8, 8, 8) 'set array to actual size
Dim raw6(8, 8, 8) 'set array to actual size
Dim raw7(8, 8, 8) 'set array to actual size

Dim j As Integer
Dim k As Integer
Dim l As Integer
Dim x As Integer
Dim y As Integer
Dim z As Integer

'read in raw categorized data
Worksheets(2).Select
For j = 1 To 864
For k = 1 To 9

Cells(j, k) = data2(j, k)

Next k
Next j

'counts number of observed fish
ws = 0: sr = 0: gr = 0: shr = 0: qb = 0: bb = 0
For j = 1 To 864
For k = 4 To 9

Select Case k

Case Is = 4
ws = ws + data2(j, k)

Case Is = 5
sr = sr + data2(j, k)

Case Is = 6
gr = gr + data2(j, k)

Case Is = 7
shr = shr + data2(j, k)

Case Is = 8
qb = qb + data2(j, k)

Case Is = 9
bb = bb + data2(j, k)

End Select


```

```

Next k
Next j

For j = 1 To 864
For k = 4 To 9

x = data2(j, 1)
y = data2(j, 2)
z = data2(j, 3)

Select Case k

Case Is = 4
If data2(j, k) = 0 Then raw1(x, y, z) = raw1(x, y, z) + 0 Else raw1(x, y, z) = raw1(x, y, z) + data2(j, k) / ws

Case Is = 5
If data2(j, k) = 0 Then raw2(x, y, z) = raw2(x, y, z) + 0 Else raw2(x, y, z) = raw2(x, y, z) + data2(j, k) / sr

Case Is = 6
If data2(j, k) = 0 Then raw3(x, y, z) = raw3(x, y, z) + 0 Else raw3(x, y, z) = raw3(x, y, z) + data2(j, k) / gr

Case Is = 7
If data2(j, k) = 0 Then raw4(x, y, z) = raw4(x, y, z) + 0 Else raw4(x, y, z) = raw4(x, y, z) + data2(j, k) / shr

Case Is = 8
If data2(j, k) = 0 Then raw5(x, y, z) = raw5(x, y, z) + 0 Else raw5(x, y, z) = raw5(x, y, z) + data2(j, k) / qb

Case Is = 9
If data2(j, k) = 0 Then raw6(x, y, z) = raw6(x, y, z) + 0 Else raw6(x, y, z) = raw6(x, y, z) + data2(j, k) / bb

End Select

Next k
Next j

sum1 = 0: sum2 = 0: sum3 = 0: sum4 = 0: sum5 = 0: sum6 = 0
sum11 = 0: sum12 = 0: sum13 = 0: sum14 = 0: sum15 = 0: sum16 = 0
sum21 = 0

For j = 1 To 8
For k = 1 To 8
For l = 1 To 8

'calculates total entropy based on availability
If raw1(j, k, l) = 0 Then sum1 = sum1 + 0 Else sum1 = sum1 + -(raw1(j, k, l) * (Log(raw1(j, k, l))))
If raw2(j, k, l) = 0 Then sum2 = sum2 + 0 Else sum2 = sum2 + -(raw2(j, k, l) * (Log(raw2(j, k, l))))
If raw3(j, k, l) = 0 Then sum3 = sum3 + 0 Else sum3 = sum3 + -(raw3(j, k, l) * (Log(raw3(j, k, l))))
If raw4(j, k, l) = 0 Then sum4 = sum4 + 0 Else sum4 = sum4 + -(raw4(j, k, l) * (Log(raw4(j, k, l))))
If raw5(j, k, l) = 0 Then sum5 = sum5 + 0 Else sum5 = sum5 + -(raw5(j, k, l) * (Log(raw5(j, k, l))))
If raw6(j, k, l) = 0 Then sum6 = sum6 + 0 Else sum6 = sum6 + -(raw6(j, k, l) * (Log(raw6(j, k, l))))

'calculates occurrence or Hmax for cube
If raw1(j, k, l) = 0 Then sum11 = sum11 + 0 Else sum11 = sum11 + 1
If raw2(j, k, l) = 0 Then sum12 = sum12 + 0 Else sum12 = sum12 + 1
If raw3(j, k, l) = 0 Then sum13 = sum13 + 0 Else sum13 = sum13 + 1
If raw4(j, k, l) = 0 Then sum14 = sum14 + 0 Else sum14 = sum14 + 1
If raw5(j, k, l) = 0 Then sum15 = sum15 + 0 Else sum15 = sum15 + 1
If raw6(j, k, l) = 0 Then sum16 = sum16 + 0 Else sum16 = sum16 + 1

Next l
Next k

```

Next j

'Calculates Horns Index

```
ssum3 = 0: ssum5 = 0: ssum7 = 0: ssum9 = 0
ssum31 = 0: ssum51 = 0: ssum71 = 0: ssum91 = 0
ssum32 = 0: ssum52 = 0: ssum72 = 0: ssum92 = 0
ssum33 = 0: ssum53 = 0: ssum73 = 0: ssum93 = 0
ssum34 = 0: ssum54 = 0: ssum74 = 0: ssum94 = 0
ssum35 = 0: ssum55 = 0: ssum75 = 0: ssum95 = 0
ssum36 = 0: ssum56 = 0: ssum76 = 0: ssum96 = 0
ssum37 = 0: ssum57 = 0: ssum77 = 0: ssum97 = 0
ssum38 = 0: ssum58 = 0: ssum78 = 0: ssum98 = 0
ssum39 = 0: ssum59 = 0: ssum79 = 0: ssum99 = 0
ssum40 = 0: ssum60 = 0: ssum80 = 0: ssum100 = 0
ssum41 = 0: ssum61 = 0: ssum81 = 0: ssum101 = 0
ssum42 = 0: ssum62 = 0: ssum82 = 0: ssum102 = 0
ssum43 = 0: ssum63 = 0: ssum83 = 0: ssum103 = 0
ssum44 = 0: ssum64 = 0: ssum84 = 0: ssum104 = 0
```

For j = 1 To 8

For k = 1 To 8

For l = 1 To 8

wsh = raw1(j, k, l)

srh = raw2(j, k, l)

grh = raw3(j, k, l)

shrh = raw4(j, k, l)

qbh = raw5(j, k, l)

bbh = raw6(j, k, l)

If wsh > 0 Or srh > 0 Then

ssum3 = ssum3 + ((wsh + srh) * Log(wsh + srh))

Elseif wsh = 0 Or srh = 0 Then

ssum3 = ssum3 + 0

End If

If wsh > 0 Or grh > 0 Then

ssum31 = ssum31 + ((wsh + grh) * Log(wsh + grh))

Elseif wsh = 0 Or grh = 0 Then

ssum31 = ssum31 + 0

End If

If wsh > 0 Or shrh > 0 Then

ssum32 = ssum32 + ((wsh + shrh) * Log(wsh + shrh))

Elseif wsh = 0 Or shrh = 0 Then

ssum32 = ssum32 + 0

End If

If wsh > 0 Or qbh > 0 Then

ssum33 = ssum33 + ((wsh + qbh) * Log(wsh + qbh))

Elseif wsh = 0 Or qbh = 0 Then

ssum33 = ssum33 + 0

End If

If wsh > 0 Or bbh > 0 Then

ssum34 = ssum34 + ((wsh + bbh) * Log(wsh + bbh))

Elseif wsh = 0 Or bbh = 0 Then

ssum34 = ssum34 + 0

End If

If srh > 0 Or grh > 0 Then

ssum35 = ssum35 + ((srh + grh) * Log(srh + grh))

Elseif srh = 0 Or grh = 0 Then

ssum35 = ssum35 + 0

End If

If srh > 0 Or shrh > 0 Then

ssum36 = ssum36 + ((srh + shrh) * Log(srh + shrh))

```

Elseif srh = 0 Or shrh = 0 Then
ssum36 = ssum36 + 0
End If
If srh > 0 Or qbh > 0 Then
ssum37 = ssum37 + ((srh + qbh) * Log(srh + qbh))
Elseif srh = 0 Or qbh = 0 Then
ssum37 = ssum37 + 0
End If
If srh > 0 Or bbh > 0 Then
ssum38 = ssum38 + ((srh + bbh) * Log(srh + bbh))
Elseif srh = 0 Or bbh = 0 Then
ssum38 = ssum38 + 0
End If
If grh > 0 Or shrh > 0 Then
ssum39 = ssum39 + ((grh + shrh) * Log(grh + shrh))
Elseif grh = 0 Or shrh = 0 Then
ssum39 = ssum39 + 0
End If
If grh > 0 Or qbh > 0 Then
ssum40 = ssum40 + ((grh + qbh) * Log(grh + qbh))
Elseif grh = 0 Or qbh = 0 Then
ssum40 = ssum40 + 0
End If
If grh > 0 Or bbh > 0 Then
ssum41 = ssum41 + ((grh + bbh) * Log(grh + bbh))
Elseif grh = 0 Or bbh = 0 Then
ssum41 = ssum41 + 0
End If
If shrh > 0 Or qbh > 0 Then
ssum42 = ssum42 + ((shrh + qbh) * Log(shrh + qbh))
Elseif shrh = 0 Or qbh = 0 Then
ssum42 = ssum42 + 0
End If
If shrh > 0 Or bbh > 0 Then
ssum43 = ssum43 + ((shrh + bbh) * Log(shrh + bbh))
Elseif shrh = 0 Or bbh = 0 Then
ssum43 = ssum43 + 0
End If
If qbh > 0 Or bbh > 0 Then
ssum44 = ssum44 + ((qbh + bbh) * Log(qbh + bbh))
Elseif qbh = 0 Or bbh = 0 Then
ssum44 = ssum44 + 0
End If

If wsh > 0 Then
ssum5 = ssum5 + (wsh * Log(wsh))
Elseif wsh = 0 Then
ssum5 = ssum5 + 0
End If
If srh > 0 Then
ssum51 = ssum51 + (srh * Log(srh))
Elseif srh = 0 Then
ssum51 = ssum51 + 0
End If
If grh > 0 Then
ssum52 = ssum52 + (grh * Log(grh))
Elseif grh = 0 Then
ssum52 = ssum52 + 0
End If
If shrh > 0 Then
ssum53 = ssum53 + (shrh * Log(shrh))
Elseif shrh = 0 Then

```

```

ssum53 = ssum53 + 0
End If
If qbh > 0 Then
ssum54 = ssum54 + (qbh * Log(qbh))
Elseif qbh = 0 Then
ssum54 = ssum54 + 0
End If
If bbh > 0 Then
ssum55 = ssum55 + (bbh * Log(bbh))
Elseif bbh = 0 Then
ssum55 = ssum55 + 0
End If

Next l
Next k
Next j

ssum9 = ssum9 + ((ssum3 - ssum5 - ssum51) / (2 * Log(2)))
ssum91 = ssum91 + ((ssum31 - ssum5 - ssum52) / (2 * Log(2)))
ssum92 = ssum92 + ((ssum32 - ssum5 - ssum53) / (2 * Log(2)))
ssum93 = ssum93 + ((ssum33 - ssum5 - ssum54) / (2 * Log(2)))
ssum94 = ssum94 + ((ssum34 - ssum5 - ssum55) / (2 * Log(2)))
ssum95 = ssum95 + ((ssum35 - ssum51 - ssum52) / (2 * Log(2)))
ssum96 = ssum96 + ((ssum36 - ssum51 - ssum53) / (2 * Log(2)))
ssum97 = ssum97 + ((ssum37 - ssum51 - ssum54) / (2 * Log(2)))
ssum98 = ssum98 + ((ssum38 - ssum51 - ssum55) / (2 * Log(2)))
ssum99 = ssum99 + ((ssum39 - ssum52 - ssum53) / (2 * Log(2)))
ssum100 = ssum100 + ((ssum40 - ssum52 - ssum54) / (2 * Log(2)))
ssum101 = ssum101 + ((ssum41 - ssum52 - ssum55) / (2 * Log(2)))
ssum102 = ssum102 + ((ssum42 - ssum53 - ssum54) / (2 * Log(2)))
ssum103 = ssum103 + ((ssum43 - ssum53 - ssum55) / (2 * Log(2)))
ssum104 = ssum104 + ((ssum44 - ssum54 - ssum55) / (2 * Log(2)))

Worksheets(6).Select
Cells(1, 1) = "observations"
Cells(2, 1) = ws
Cells(3, 1) = sr
Cells(4, 1) = gr
Cells(5, 1) = shr
Cells(6, 1) = qb
Cells(7, 1) = bb

Cells(1, 2) = "totalentropy"
Cells(2, 2) = sum1
Cells(3, 2) = sum2
Cells(4, 2) = sum3
Cells(5, 2) = sum4
Cells(6, 2) = sum5
Cells(7, 2) = sum6

Cells(1, 3) = "maximumentropy"
Cells(2, 3) = Log(sum11)
Cells(3, 3) = Log(sum12)
Cells(4, 3) = Log(sum13)
Cells(5, 3) = Log(sum14)
Cells(6, 3) = Log(sum15)
Cells(7, 3) = Log(sum16)

Cells(2, 8) = "ws"
Cells(3, 8) = "sr"
Cells(4, 8) = "gr"
Cells(5, 8) = "shr"

```

Cells(6, 8) = "qb"
Cells(7, 8) = "bb"

Cells(1, 9) = "ws"
Cells(2, 9) = 1
Cells(3, 9) = ssum9
Cells(4, 9) = ssum91
Cells(5, 9) = ssum92
Cells(6, 9) = ssum93
Cells(7, 9) = ssum94
Cells(1, 10) = "sr"
Cells(3, 10) = 1
Cells(4, 10) = ssum95
Cells(5, 10) = ssum96
Cells(6, 10) = ssum97
Cells(7, 10) = ssum98
Cells(1, 11) = "gr"
Cells(4, 11) = 1
Cells(5, 11) = ssum99
Cells(6, 11) = ssum100
Cells(7, 11) = ssum101
Cells(1, 12) = "shr"
Cells(5, 12) = 1
Cells(6, 12) = ssum102
Cells(7, 12) = ssum103
Cells(1, 13) = "qb"
Cells(6, 13) = 1
Cells(7, 13) = ssum104
Cells(1, 14) = "bb"
Cells(7, 14) = 1

End Sub

```

Sub RDVS()

Worksheets(7).Select
Randomize
Dim x As Integer
Dim y As Integer
Dim z As Integer
Dim raw1(8, 8, 8)
Dim data2(5000, 3)
n = 46 'changes with n-value of species

For lupe = 1 To 1000

For j = 1 To n
For k = 1 To 3
Select Case k
Case Is = 1
x = Int((8 - 1 + 1) * Rnd + 1)
data2(j, k) = x
Case Is = 2
y = Int((8 - 1 + 1) * Rnd + 1)
data2(j, k) = y
Case Is = 3
z = Int((8 - 1 + 1) * Rnd + 1)
data2(j, k) = z
End Select
Next k
Next j

For j = 1 To 8
For k = 1 To 8
For l = 1 To 8
raw1(j, k, l) = 0
Next l
Next k
Next j

For fish = 1 To n
a = data2(fish, 1)
b = data2(fish, 2)
c = data2(fish, 3)
raw1(a, b, c) = raw1(a, b, c) + 1
Next fish

Sum = 0
For j = 1 To 8
For k = 1 To 8
For l = 1 To 8
If raw1(j, k, l) = 0 Then Sum = Sum + 0 Else Sum = Sum + -((raw1(j, k, l) / n) * (Log(raw1(j, k, l) / n)))
Next l
Next k
Next j

Cells(lupe + 1, 7) = Sum

Next lupe

Cells(1, 7) = "RDVS"

End Sub

```

```

Sub IDVS()

Worksheets(7).Select
Randomize
Dim data2(3000, 3) 'data samples categorized
Dim dep(3000, 1)
Dim vel(3000, 1)
Dim subs(3000, 1)
Dim calc(1000, 2)
Dim raw1(8, 8, 8) 'set array to actual size
Dim raw2(8, 8, 8) 'set array to actual size
Dim j As Integer
Dim k As Integer
Dim l As Integer
Dim x As Integer
Dim y As Integer
Dim z As Integer
Dim a As Single
Dim b As Single
Dim c As Single
n = 46

For lupe = 1 To 1000

For j = 1 To n
For k = 1 To 3
Column = k
Select Case Column
Case Is = 1
a = Rnd
Select Case a
'Case 0 To 0.023391813
'data2(j, k) = 1
Case 0 To 0.02173913
data2(j, k) = 2
Case 0.02173913 To 0.217391304
data2(j, k) = 3
Case 0.217391304 To 0.369565217
data2(j, k) = 4
Case 0.369565217 To 0.891304348
data2(j, k) = 5
Case 0.891304348 To 0.97826087
data2(j, k) = 6
Case 0.97826087 To 1#
data2(j, k) = 7
'Case 0.986354776 To 1#
'data2(j, k) = 8
End Select
Case Is = 2
b = Rnd
Select Case b
Case 0 To 0.02173913
data2(j, k) = 1
Case 0.02173913 To 0.086956522
data2(j, k) = 2
Case 0.086956522 To 0.434782609
data2(j, k) = 3
Case 0.434782609 To 0.630434783
data2(j, k) = 4
Case 0.630434783 To 0.695652174
data2(j, k) = 5
Case 0.695652174 To 0.972709552

```

```

data2(j, k) = 6
Case 0.972709552 To 1#
data2(j, k) = 7
'Case 0.986354776 To 1#
'data2(j, k) = 8
End Select
Case Is = 3
c = Rnd
Select Case c
Case 0 To 0.326086957
data2(j, k) = 1
Case 0.326086957 To 0.347826087
data2(j, k) = 2
Case 0.347826087 To 0.413043478
data2(j, k) = 3
Case 0.413043478 To 0.717391304
data2(j, k) = 4
Case 0.717391304 To 0.891304348
data2(j, k) = 5
Case 0.891304348 To 0.97826087
data2(j, k) = 6
Case 0.97826087 To 1#
data2(j, k) = 7
'Case 0.978557505 To 1#
'data2(j, k) = 8
End Select
End Select
Next k
Next j

'clears raw1
For j = 1 To 8
For k = 1 To 8
For l = 1 To 8
raw1(j, k, l) = 0
Next l
Next k
Next j

For fish = 1 To n
x = data2(fish, 1)
y = data2(fish, 2)
z = data2(fish, 3)
raw1(x, y, z) = raw1(x, y, z) + 1
Next fish

Worksheets(7).Select
Sum = 0
For j = 1 To 8
For k = 1 To 8
For l = 1 To 8
If raw1(j, k, l) = 0 Then Sum = Sum + 0 Else Sum = Sum + -((raw1(j, k, l) / n) * (Log(raw1(j, k, l) / n)))
Next l
Next k
Next j
Cells(lupe + 1, 13) = Sum

Next lupe

Cells(1, 13) = "IDVS"

End Sub

```

```

Sub ODVS()

Randomize
Dim data(864, 9) 'raw samples uncategorized
Dim data2(864, 9) 'data samples categorized
Dim dep(864, 1)
Dim vel(864, 1)
Dim subs(864, 1)
Dim calc(512, 4)
Dim raw1(8, 8, 8) 'set array to actual size
Dim raw2(8, 8, 8) 'set array to actual size
Dim raw3(8, 8, 8) 'set array to actual size
Dim raw4(8, 8, 8) 'set array to actual size
Dim raw5(8, 8, 8) 'set array to actual size
Dim raw6(8, 8, 8) 'set array to actual size
Dim raw7(8, 8, 8) 'set array to actual size
Dim j As Integer
Dim k As Integer
Dim l As Integer
Dim x As Integer
Dim y As Integer
Dim z As Integer
n = 1000

'read in categorized data
Worksheets(2).Select
For j = 1 To 864
For k = 1 To 9
data(j, k) = Cells(j, k)
Next k
Next j

'counts number of observed fish
ws = 0: sr = 0: gr = 0: shr = 0: qb = 0: bb = 0
For j = 1 To 864
For k = 4 To 9
Select Case k
Case Is = 4
ws = ws + data(j, k)
Case Is = 5
sr = sr + data(j, k)
Case Is = 6
gr = gr + data(j, k)
Case Is = 7
shr = shr + data(j, k)
Case Is = 8
qb = qb + data(j, k)
Case Is = 9
bb = bb + data(j, k)
End Select
Next k
Next j

For j = 1 To 864
For k = 4 To 9
x = data(j, 1)
y = data(j, 2)
z = data(j, 3)
Select Case k
'builds species specific raw arrays
Case Is = 4
If data(j, k) = 0 Then raw1(x, y, z) = raw1(x, y, z) + 0 Else raw1(x, y, z) = raw1(x, y, z) + data(j, k) / ws

```

```

Case ls = 5
If data(j, k) = 0 Then raw2(x, y, z) = raw2(x, y, z) + 0 Else raw2(x, y, z) = raw2(x, y, z) + data(j, k) / sr
Case ls = 6
If data(j, k) = 0 Then raw3(x, y, z) = raw3(x, y, z) + 0 Else raw3(x, y, z) = raw3(x, y, z) + data(j, k) / gr
Case ls = 7
If data(j, k) = 0 Then raw4(x, y, z) = raw4(x, y, z) + 0 Else raw4(x, y, z) = raw4(x, y, z) + data(j, k) / shr
Case ls = 8
If data(j, k) = 0 Then raw5(x, y, z) = raw5(x, y, z) + 0 Else raw5(x, y, z) = raw5(x, y, z) + data(j, k) / qb
Case ls = 9
If data(j, k) = 0 Then raw6(x, y, z) = raw6(x, y, z) + 0 Else raw6(x, y, z) = raw6(x, y, z) + data(j, k) / bb
End Select
Next k
Next j

```

```

counter = 0
For j = 1 To 8
For k = 1 To 8
For l = 1 To 8
counter = counter + 1
calc(counter, 1) = j
calc(counter, 2) = k
calc(counter, 3) = l
calc(counter, 4) = raw6(j, k, l)
Next l
Next k
Next j

```

```

Worksheets(8).Select
'extracts only relevant data
counter1 = 0
For j = 1 To counter
Select Case calc(j, 4)
Case ls > 0
counter1 = counter1 + 1
Cells(counter1, 1) = calc(j, 1)
Cells(counter1, 2) = calc(j, 2)
Cells(counter1, 3) = calc(j, 3)
Cells(counter1, 4) = calc(j, 4)
End Select
Next j

```

```

Dim calc1(1000, 6)
For j = 1 To 1000
For k = 1 To 6
calc1(j, k) = Cells(j, k)
Next k
Next j

```

```

For lupe = 1 To 1000
Dim calc2(1000, 3)
For fish = 1 To n
xyz = Rnd
For j = 1 To 1000
Select Case xyz
Case calc1(j, 5) To calc1(j, 6)
calc2(fish, 1) = calc1(j, 1)
calc2(fish, 2) = calc1(j, 2)
calc2(fish, 3) = calc1(j, 3)
End Select
Next j
Next fish

```

```

Dim test(8, 8, 8)
'clears test
For j = 1 To 8
For k = 1 To 8
For l = 1 To 8
test(j, k, l) = 0
Next l
Next k
Next j

For j = 1 To n
x = calc2(j, 1)
y = calc2(j, 2)
z = calc2(j, 3)
Sum = 0
test(x, y, z) = test(x, y, z) + 1
Next j

For j = 1 To 8
For k = 1 To 8
For l = 1 To 8
If test(j, k, l) = 0 Then Sum = Sum + 0 Else Sum = Sum + -((test(j, k, l) / n) * (Log(test(j, k, l) / n)))
Next l
Next k
Next j
Cells(lupe + 1, 19) = Sum
Next lupe

Cells(1, 19) = "ADVS"

End Sub

```

```

Sub Co_occurrence()

Worksheets(2).Select

Dim raw(864, 9)

For j = 1 To 864
For k = 1 To 9

raw(j, k) = Cells(j, k)

Next k
Next j

Dim calc(864, 9)
Dim calc3(864, 6)
counter = 0
counter2 = 0

For j = 1 To 864

Select Case raw(j, 6)

Case Is > 0
counter = counter + 1
If raw(j, 4) > 0 Then calc(counter, 1) = 1 Else calc(counter, 1) = 0
If raw(j, 5) > 0 Then calc(counter, 2) = 1 Else calc(counter, 2) = 0
If raw(j, 7) > 0 Then calc(counter, 4) = 1 Else calc(counter, 4) = 0
If raw(j, 8) > 0 Then calc(counter, 5) = 1 Else calc(counter, 5) = 0
If raw(j, 9) > 0 Then calc(counter, 6) = 1 Else calc(counter, 6) = 0
calc(counter, 3) = 1
calc(counter, 7) = raw(j, 1)
calc(counter, 8) = raw(j, 2)
calc(counter, 9) = raw(j, 3)

If raw(j, 4) > 0 Then calc3(counter, 1) = raw(j, 4) Else calc3(counter, 1) = 0
If raw(j, 5) > 0 Then calc3(counter, 2) = raw(j, 5) Else calc3(counter, 2) = 0
If raw(j, 7) > 0 Then calc3(counter, 4) = raw(j, 7) Else calc3(counter, 4) = 0
If raw(j, 8) > 0 Then calc3(counter, 5) = raw(j, 8) Else calc3(counter, 5) = 0
If raw(j, 9) > 0 Then calc3(counter, 6) = raw(j, 9) Else calc3(counter, 6) = 0
calc3(counter, 3) = raw(j, 6)
'calc(counter, 7) = raw(j, 1)
'calc(counter, 8) = raw(j, 2)
'calc(counter, 9) = raw(j, 3)

End Select

Next j

Worksheets(10).Select
For j = 1 To counter
For k = 1 To 6

Cells(j, k) = calc(j, k)
Cells(j, k + 20) = calc3(j, k)

Next k
Next j

End Sub

```

```
Sub Random_Co_occurrence()
```

```
Worksheets(2).Select
```

```
Randomize
```

```
Dim raw(864, 4)  
Dim raw2(864, 5)
```

```
For j = 1 To 864  
For k = 1 To 4
```

```
raw(j, k) = Cells(j, k)
```

```
Next k  
Next j
```

```
For lupe = 1 To 100
```

```
For j = 1 To 864  
For k = 1 To 5
```

```
raw2(j, k) = 0
```

```
Next k  
Next j
```

```
'For j = 1 To 864  
For k = 1 To 5  
Select Case k
```

```
Case Is = 1  
For Count = 1 To 290  
x = Int((864 - 1 + 1) * Rnd + 1)  
raw2(x, k) = raw2(x, k) + 1  
Next Count
```

```
Case Is = 2  
For Count = 1 To 110  
x = Int((864 - 1 + 1) * Rnd + 1)  
raw2(x, k) = raw2(x, k) + 1  
Next Count
```

```
Case Is = 3  
For Count = 1 To 2072  
x = Int((864 - 1 + 1) * Rnd + 1)  
raw2(x, k) = raw2(x, k) + 1  
Next Count
```

```
Case Is = 4  
For Count = 1 To 513  
x = Int((864 - 1 + 1) * Rnd + 1)  
raw2(x, k) = raw2(x, k) + 1  
Next Count
```

```
Case Is = 5  
For Count = 1 To 46  
x = Int((864 - 1 + 1) * Rnd + 1)  
raw2(x, k) = raw2(x, k) + 1  
Next Count
```

```
End Select
```

```

Next k
'Next j

Dim calc2(1000, 6)

Dim calc(864, 6)
counter = 0
For j = 1 To 864

    Column = raw(j, 4)
    Select Case Column

        Case Is > 0
            counter = counter + 1
            If raw2(j, 1) > 0 Then calc(counter, 2) = 1 Else calc(counter, 2) = 0
            If raw2(j, 2) > 0 Then calc(counter, 3) = 1 Else calc(counter, 3) = 0
            If raw2(j, 3) > 0 Then calc(counter, 4) = 1 Else calc(counter, 4) = 0
            If raw2(j, 4) > 0 Then calc(counter, 5) = 1 Else calc(counter, 5) = 0
            If raw2(j, 5) > 0 Then calc(counter, 6) = 1 Else calc(counter, 6) = 0
            calc(counter, 1) = 1
            'calc(counter, 7) = raw(j, 1)
            'calc(counter, 8) = raw(j, 2)
            'calc(counter, 9) = raw(j, 3)

    End Select

Next j

Dim calc4(1000, 6)

Dim calc3(864, 6)
counter = 0
For j = 1 To 864

    Column = raw(j, 4)
    Select Case Column

        Case Is > 0
            counter = counter + 1
            If raw2(j, 1) > 0 Then calc3(counter, 2) = raw2(j, 1) Else calc3(counter, 2) = 0
            If raw2(j, 2) > 0 Then calc3(counter, 3) = raw2(j, 2) Else calc3(counter, 3) = 0
            If raw2(j, 3) > 0 Then calc3(counter, 4) = raw2(j, 3) Else calc3(counter, 4) = 0
            If raw2(j, 4) > 0 Then calc3(counter, 5) = raw2(j, 4) Else calc3(counter, 5) = 0
            If raw2(j, 5) > 0 Then calc3(counter, 6) = raw2(j, 5) Else calc3(counter, 6) = 0
            calc3(counter, 1) = raw(j, 4)
            'calc(counter, 7) = raw(j, 1)
            'calc(counter, 8) = raw(j, 2)
            'calc(counter, 9) = raw(j, 3)

    End Select

Next j

For j = 1 To 864
    For k = 1 To 6

        calc2(lupe, k) = calc2(lupe, k) + calc(j, k)
        calc4(lupe, k) = calc4(lupe, k) + calc3(j, k)

    Next k

```

```

Next j

Next lupe

Worksheets(11).Select
For j = 1 To 100
For k = 1 To 6

Cells(j, k) = calc2(j, k)
Cells(j, k + 20) = calc4(j, k)

Next k
Next j

Worksheets(17).Select

For j = 1 To 864
For k = 1 To 5

Cells(j, k) = raw2(j, k)

Next k
Next j

End Sub

```

```

Sub Diversity_()

Worksheets(1).Select

Randomize

m = 71
n = 33

Dim calc(71, 33) 'must be an m by n array
Dim calc1(71, 33) 'must be an m by n array
Dim calc3(1000, 71) 'must have m columns stores richness
Dim calc4(1000, 2) 'mean and variance storage
Dim calc5(71, 33) 'must be an m by n array
Dim calc6(1000, 71) 'must have m columns stores row H
Dim calc7(1000, 71) 'must have m columns stores column H
Dim calc8(1000, 71) 'must have m columns stores H1+2
Dim calc9(1000, 71) 'must have m columns stores H12
Dim calc10(1000, 71) 'must have m columns stores eH
Dim calc11(1000, 2) 'row H mean and variance
Dim calc12(1000, 2) 'column H mean and variance
Dim calc13(1000, 2) 'H1+2 mean and variance
Dim calc14(1000, 2) 'H12 mean and variance
Dim calc15(1000, 2) 'eH mean and variance

'Reads in data
For r = 1 To m
For c = 1 To n
calc(r, c) = Cells(r + 5, c)
Next c
Next r

'Sets limit at which to stop
For strap = 1 To 71 'step 2
Cells(1, 10) = strap
'Number of iterations
For lupe = 1 To 1000
Count = 0
Cells(1, 11) = lupe
'Random draw of rows
For t = 1 To strap
x = Rnd
'x = Abs(Now() * 100000 - Int(Now() * 100000))
Row = Int((m - 1 + 1) * x + 1)

'Stores drawn row(s)
For Column = 1 To n
calc1(t, Column) = calc(Row, Column)

Next Column
Next t

'need to standardize matrix to proportions and f..=1
sum10 = 0
For j = 1 To strap
For k = 1 To n
sum10 = sum10 + calc1(j, k)
Next k
Next j

For j = 1 To strap
For k = 1 To n

```

```

If sum10 = 0 Then calc5(j, k) = 0 Else calc5(j, k) = calc1(j, k) / sum10

Next k
Next j

'Richness
Sum = 0
For p = 1 To n
  counter = 0

  For q = 1 To strap
    If calc5(q, p) > 0 Then counter = counter + 1 Else counter = counter + 0
  Next q

  If counter > 0 Then Sum = Sum + 1 Else Sum = Sum + 0

Next p

calc3(lupe, strap) = Sum

'Shannon's H'

'counts the number of non-zero rows and non-zero columns
sum20 = 0: sum70 = 0
For k = 1 To strap
  For l = 1 To n
    If calc5(k, l) > 0 Then sum20 = sum20 + 1 Else sum20 = sum20 + 0
  Next l
Next k

If sum20 = 0 Then sum70 = 0 Else sum70 = Log(sum20)

'calculates Shannon's H for rows
sum11 = 0
For d = 1 To strap
  sum12 = 0
  For e = 1 To n
    sum12 = calc5(d, e) + sum12
  Next e
  If sum12 = 0 Then sum11 = sum11 + 0 Else sum11 = (sum12 * Log(sum12)) + sum11
Next d
calc6(lupe, strap) = -sum11
'Cells(1, 7) = calc11(1, 1)

'calculates Shannon's H for columns
sum15 = 0
For d = 1 To n
  sum13 = 0
  For e = 1 To strap
    sum13 = calc5(e, d) + sum13
  Next e
  If sum13 = 0 Then sum15 = sum15 + 0 Else sum15 = (sum13 * Log(sum13)) + sum15
Next d
calc7(lupe, strap) = -sum15
'Cells(1, 8) = calc11(1, 2)
calc10(lupe, strap) = Exp(-sum15) 'calculates eH

'Mutual entropy
sum16 = 0: sum17 = 0
calc8(lupe, strap) = sum70 'Log(-sum20) 'Joint entropy

```

```

sum17 = ((calc6(lupe, strap) + calc7(lupe, strap)) - calc8(lupe, strap))
calc9(lupe, strap) = sum17
'Cells(1, 9) = calc11(1, 3)
'Cells(1, 10) = calc11(1, 4)

```

Next lupe

Next strap

Worksheets(3).Select

```

For s = 1 To m
sum1 = 0: sum3 = 0: sum30 = 0: Sum31 = 0: sum32 = 0: sum33 = 0: sum34 = 0
sum40 = 0: sum41 = 0: sum42 = 0: sum43 = 0: sum44 = 0
For l = 1 To 1000
sum1 = sum1 + calc3(l, s)
sum30 = sum30 + calc6(l, s)
Sum31 = Sum31 + calc7(l, s)
sum32 = sum32 + calc10(l, s)
sum33 = sum33 + calc8(l, s)
sum34 = sum34 + calc9(l, s)
Next l

```

```

sum3 = sum1 / 1000
sum40 = sum30 / 1000
sum41 = Sum31 / 1000
sum42 = sum32 / 1000
sum43 = sum33 / 1000
sum44 = sum34 / 1000
calc4(s, 1) = sum3
calc11(s, 1) = sum40
calc12(s, 1) = sum41
calc13(s, 1) = sum42
calc14(s, 1) = sum43
calc15(s, 1) = sum44

```

Next s

```

sum2 = 0: sum50 = 0: sum51 = 0: sum52 = 0: sum53 = 0: sum54 = 0
For s = 1 To m
For l = 1 To 1000
sum2 = (calc3(l, s) - calc4(s, 1)) ^ 2
sum50 = (calc6(l, s) - calc11(s, 1)) ^ 2
sum51 = (calc7(l, s) - calc12(s, 1)) ^ 2
sum52 = (calc10(l, s) - calc13(s, 1)) ^ 2
sum53 = (calc8(l, s) - calc14(s, 1)) ^ 2
sum54 = (calc9(l, s) - calc15(s, 1)) ^ 2

```

Next l

```

Var = 0: Var1 = 0: Var2 = 0: Var3 = 0: Var4 = 0: Var5 = 0
Var = sum2 / 999
Var1 = sum50 / 999
Var2 = sum51 / 999
Var3 = sum52 / 999
Var4 = sum53 / 999
Var5 = sum54 / 999

```

```

calc4(s, 2) = Var
calc11(s, 2) = Var1
calc12(s, 2) = Var2
calc13(s, 2) = Var3
calc14(s, 2) = Var4

```

```
calc15(s, 2) = Var5
```

```
Next s
```

```
For s = 1 To m
```

```
Cells(s, 1) = calc4(s, 1)
```

```
Cells(s, 2) = calc4(s, 2)
```

```
Cells(s, 3) = calc11(s, 1)
```

```
Cells(s, 4) = calc11(s, 2)
```

```
Cells(s, 5) = calc12(s, 1)
```

```
Cells(s, 6) = calc12(s, 2)
```

```
Cells(s, 7) = calc13(s, 1)
```

```
Cells(s, 8) = calc13(s, 2)
```

```
Cells(s, 9) = calc14(s, 1)
```

```
Cells(s, 10) = calc14(s, 2)
```

```
Cells(s, 11) = calc15(s, 1)
```

```
Cells(s, 12) = calc15(s, 2)
```

```
Next s
```

```
End Sub
```

```

Sub diet_overlap()

Dim raw1(326, 35)
Dim sympatry As Double
Dim share As Integer
Dim unshare1 As Integer
Dim total1 As Integer
Dim horn1(326, 35)
Dim xjk As Double
Dim yjk As Double
Dim pij As Double
Dim pik As Double
Dim pij2 As Double
Dim pik2 As Double
Dim mjk As Double
Dim mkj As Double
Dim data(326, 326)
Dim sorted(52975, 6)

m = 326
n = 35

Worksheets(2).Select
'Reads in the distributions
For j = 1 To m
For k = 1 To n

raw1(j, k) = Cells(j + 1, k + 6)

Next k
Next j

'Set rows for Horn's
For counter = 1 To 326
For j = 1 To 326

sum3 = 0: sum5 = 0: sum50 = 0: sum51 = 0

For k = 3 To 35

xjk = raw1(counter, k)
yjk = raw1(j, k)

If xjk > 0 Or yjk > 0 Then
sum3 = sum3 + ((xjk + yjk) * Log(xjk + yjk))
Elseif xjk = 0 Or yjk = 0 Then
sum3 = sum3 + 0
End If

If xjk > 0 Then
sum5 = sum5 + (xjk * Log(xjk))
Elseif xjk = 0 Then
sum5 = sum5 + 0
End If

If yjk > 0 Then
sum50 = sum50 + (yjk * Log(yjk))
Elseif yjk = 0 Then
sum50 = sum50 + 0
End If

Next k

Next j

```

```

sum51 = sum51 + ((sum3 - sum5 - sum50) / (2 * Log(2)))
data(j, counter) = sum51

Next j

Next counter

'calculates overall substrate similarity

counter3 = 0
For counter2 = 1 To 326
For j = 1 To 326

Select Case j

Case Is > counter2
counter3 = counter3 + 1

suma = 0: sumb = 0: sumc = 0: sumd = 0: sume = 0

sub1j = raw1(counter2, 1)
sub2j = raw1(counter2, 2)
sub1k = raw1(j, 1)
sub2k = raw1(j, 2)

If sub1j = sub1k Then suma = suma + 1000 Else suma = suma + 0
If sub2j = sub2k Then sumd = sumd + 100 Else sumd = sumd + 0
If sub1j = sub2k Then sumb = sumb + 10 Else sumb = sumb + 0
If sub2j = sub1k Then sumc = sumc + 1 Else sumc = sumc + 0
sume = suma + sumb + sumc + sumd

sorted(counter3, 1) = counter3
sorted(counter3, 2) = suma
sorted(counter3, 3) = sumd
sorted(counter3, 4) = sumc
sorted(counter3, 5) = sumb
sorted(counter3, 6) = sume

End Select

Next j

Next counter2

Worksheets(3).Select

Dim sorted2(326, 326)
For j = 1 To 326
For k = 1 To 326

Row = j
Select Case Row

Case 1 To 67
Select Case k
Case 1 To 67
sorted2(j, k) = 1
End Select

Case 68 To 128
Select Case k

```

```
Case 1 To 67
sorted2(j, k) = 2
Case 68 To 128
sorted2(j, k) = 3
End Select
```

```
Case 129 To 145
Select Case k
Case 1 To 67
sorted2(j, k) = 4
Case 68 To 128
sorted2(j, k) = 5
Case 129 To 145
sorted2(j, k) = 6
End Select
```

```
Case 146 To 200
Select Case k
Case 1 To 67
sorted2(j, k) = 7
Case 68 To 128
sorted2(j, k) = 8
Case 129 To 145
sorted2(j, k) = 9
Case 146 To 200
sorted2(j, k) = 10
End Select
```

```
Case 201 To 259
Select Case k
Case 1 To 67
sorted2(j, k) = 11
Case 68 To 128
sorted2(j, k) = 12
Case 129 To 145
sorted2(j, k) = 13
Case 146 To 200
sorted2(j, k) = 14
Case 201 To 259
sorted2(j, k) = 15
End Select
```

```
Case 260 To 326
Select Case k
Case 1 To 67
sorted2(j, k) = 16
Case 68 To 128
sorted2(j, k) = 17
Case 129 To 145
sorted2(j, k) = 18
Case 146 To 200
sorted2(j, k) = 19
Case 201 To 259
sorted2(j, k) = 20
Case 260 To 326
sorted2(j, k) = 21
End Select
```

```
End Select
```

```
Next k
Next j
```

```

For j = 1 To 326
For k = 1 To 326

If j = k Then data(j, k) = ""
'If j = k Then sorted(j, k) = ""
If j = k Then sorted2(j, k) = ""
If k > j Then data(j, k) = ""
'If k > j Then sorted(j, k) = ""
If k > j Then sorted2(j, k) = ""

Next k
Next j

Dim data2(52975, 9)
counter = 0
For j = 1 To 326
For k = 1 To 326

Select Case data(j, k)

Case Is <> ""
counter = counter + 1
data2(counter, 1) = counter
data2(counter, 2) = sorted(counter, 1)
data2(counter, 3) = sorted(counter, 2)
data2(counter, 4) = sorted(counter, 3)
data2(counter, 5) = sorted(counter, 4)
data2(counter, 6) = sorted(counter, 5)
data2(counter, 7) = sorted(counter, 6)
data2(counter, 8) = sorted2(j, k)
data2(counter, 9) = data(j, k)

End Select

Next k
Next j

For j = 1 To 52975
For k = 1 To 9

Cells(j, k) = data2(j, k)

Next k
Next j

Dim data3(326, 326)
Dim data5(326, 326)
Dim sorted3(326, 326)
Worksheets(7).Select
'Calculates MacArthur and Levins Mjk and Mkj
counter2 = 0
For counter = 1 To 326
For j = 1 To 326

sumpijpk = 0: sumpij2 = 0: sumpik2 = 0: mjk = 0: mkj = 0

Select Case j

Case Is >= counter

For k = 3 To 35

```

```

    pij = raw1(counter, k)
    pik = raw1(j, k)
    pij2 = raw1(counter, k) ^ 2
    pik2 = raw1(j, k) ^ 2
    sumpijpik = sumpijpik + (pij * pik)
    sumpij2 = sumpij2 + pij ^ 2
    sumpik2 = sumpik2 + pik ^ 2

Next k

End Select

If sumpijpik = 0 Then mjk = mjk + 0 Else mjk = sumpijpik / sumpij2
If sumpijpik = 0 Then mkj = mkj + 0 Else mkj = sumpijpik / sumpik2
data3(j, counter) = mjk
data5(j, counter) = mkj
counter2 = counter2 + 1
sorted3(j, counter) = counter2

Next j

Next counter

For j = 1 To 326
For k = 1 To 326

    If j = k Then data3(j, k) = ""
    If j = k Then sorted2(j, k) = ""
    If k > j Then data3(j, k) = ""
    If k > j Then sorted2(j, k) = ""

Next k
Next j

Dim data4(52975, 4)
counter = 0
For j = 1 To 326
For k = 1 To 326

    Select Case sorted2(j, k)

        Case Is <> ""
            counter = counter + 1
            data4(counter, 1) = counter
            data4(counter, 2) = sorted2(j, k)
            data4(counter, 3) = data3(j, k)
            data4(counter, 4) = data5(j, k)
        End Select

Next k
Next j

For j = 1 To 52975
For k = 1 To 4

    Cells(j, k) = data4(j, k)

Next k
Next j

End Sub

```

```

Sub MacArthur_Levins()

Dim raw1(326, 33)
Dim sympatry As Double
Dim share As Integer
Dim unshare1 As Integer
Dim total1 As Integer
Dim horn1(326, 33)
Dim xjk As Double
Dim yjk As Double
Dim pij As Double
Dim pik As Double
Dim pij2 As Double
Dim pik2 As Double
Dim mjk As Double
Dim mkj As Double
Dim data(326, 326)
Dim sorted(52975, 6)

m = 326
n = 33

Worksheets(2).Select
'Reads in the distributions
For j = 1 To m
For k = 1 To n

raw1(j, k) = Cells(j + 1, k + 8)

Next k
Next j

Dim sorted2(326, 326)
For j = 1 To 326
For k = 1 To 326

Row = j
Select Case Row

Case 1 To 67
Select Case k
Case 1 To 67
sorted2(j, k) = 1
End Select

Case 68 To 128
Select Case k
Case 1 To 67
sorted2(j, k) = 2
Case 68 To 128
sorted2(j, k) = 3
End Select

Case 129 To 145
Select Case k
Case 1 To 67
sorted2(j, k) = 4
Case 68 To 128
sorted2(j, k) = 5
Case 129 To 145
sorted2(j, k) = 6
End Select

```

```

Case 146 To 200
Select Case k
Case 1 To 67
sorted2(j, k) = 7
Case 68 To 128
sorted2(j, k) = 8
Case 129 To 145
sorted2(j, k) = 9
Case 146 To 200
sorted2(j, k) = 10
End Select

```

```

Case 201 To 259
Select Case k
Case 1 To 67
sorted2(j, k) = 11
Case 68 To 128
sorted2(j, k) = 12
Case 129 To 145
sorted2(j, k) = 13
Case 146 To 200
sorted2(j, k) = 14
Case 201 To 259
sorted2(j, k) = 15
End Select

```

```

Case 260 To 326
Select Case k
Case 1 To 67
sorted2(j, k) = 16
Case 68 To 128
sorted2(j, k) = 17
Case 129 To 145
sorted2(j, k) = 18
Case 146 To 200
sorted2(j, k) = 19
Case 201 To 259
sorted2(j, k) = 20
Case 260 To 326
sorted2(j, k) = 21
End Select

```

```

End Select

```

```

Next k
Next j

```

```

Dim data3(326, 326)
Dim data5(326, 326)
Dim sorted3(326, 326)
Worksheets(7).Select
'Calculates MacArthur and Levins Mjk and Mkj
counter2 = 0
For counter = 1 To 326
For j = 1 To 326

```

```

sumpijpik = 0: sumpij2 = 0: sumpik2 = 0: mjk = 0: mkj = 0

```

```

Select Case j

```

```

Case Is >= counter

```

```

For k = 1 To 33

    pij = raw1(counter, k)
    pik = raw1(j, k)
    pij2 = raw1(counter, k) ^ 2
    pik2 = raw1(j, k) ^ 2
    If pij = 0 Or pik = 0 Then sumpijpik = sumpijpik + 0 Else sumpijpik = sumpijpik + (pij * pik)
    If pij = 0 Then sumpij2 = sumpij2 + 0 Else sumpij2 = sumpij2 + pij2
    If pik = 0 Then sumpik2 = sumpik2 + 0 Else sumpik2 = sumpik2 + pik2

Next k

End Select

If sumpijpik = 0 Then mjk = mjk + 0 Else mjk = sumpijpik / sumpij2
If sumpik2 = 0 Then mkj = mkj + 0 Else mkj = sumpijpik / sumpik2
data3(j, counter) = mjk
data5(j, counter) = mkj
counter2 = counter2 + 1
sorted3(j, counter) = counter2

Next j

Next counter

For j = 1 To 326
For k = 1 To 326

    If j = k Then data3(j, k) = ""
    If j = k Then sorted2(j, k) = ""
    If k > j Then data3(j, k) = ""
    If k > j Then sorted2(j, k) = ""

Next k
Next j

Dim data4(52975, 6)
counter = 0
For j = 1 To 326
For k = 1 To 326

    Select Case sorted2(j, k)

        Case Is <> ""
            counter = counter + 1
            data4(counter, 1) = counter
            data4(counter, 2) = sorted2(j, k)
            data4(counter, 3) = j
            data4(counter, 4) = k
            data4(counter, 5) = data3(j, k)
            data4(counter, 6) = data5(j, k)
        End Select

Next k
Next j

For j = 1 To 52975
For k = 1 To 6

    Cells(j, k) = data4(j, k)

```

Next k
Next j

End Sub

```

Sub Overlap_Abundance()

Randomize
Dim raw1(6, 33)
Dim sympatry As Double
Dim share As Integer
Dim unshare1 As Integer
Dim total1 As Integer
Dim horn1(6, 33)
Dim xjk As Double
Dim yjk As Double
Dim pij As Double
Dim pik As Double
Dim pij2 As Double
Dim pik2 As Double
Dim mjk As Double
Dim mkj As Double
Dim data(6, 6)
Dim sorted(21, 6)

m = 6
n = 33

Worksheets(1).Select
'Reads in the distributions
For j = 1 To m
For k = 1 To n

raw1(j, k) = Cells(j + 1, k + 1)

Next k
Next j

'sets row totals for porportion=1
ws = 0: sr = 0: gr = 0: shr = 0: qb = 0: bb = 0
For j = 1 To 6
For k = 1 To 33

Select Case j

Case Is = 1
ws = ws + raw1(j, k)
Case Is = 2
sr = sr + raw1(j, k)
Case Is = 3
gr = gr + raw1(j, k)
Case Is = 4
shr = shr + raw1(j, k)
Case Is = 5
qb = qb + raw1(j, k)
Case Is = 6
bb = bb + raw1(j, k)
End Select

Next k
Next j

'sets matrix row total to 1
Dim raw2(6, 33)
For j = 1 To 6
For k = 1 To 33

```

```

Select Case j

Case Is = 1
raw2(j, k) = raw2(j, k) + raw1(j, k) / ws
Case Is = 2
raw2(j, k) = raw2(j, k) + raw1(j, k) / sr
Case Is = 3
raw2(j, k) = raw2(j, k) + raw1(j, k) / gr
Case Is = 4
raw2(j, k) = raw2(j, k) + raw1(j, k) / shr
Case Is = 5
raw2(j, k) = raw2(j, k) + raw1(j, k) / qb
Case Is = 6
raw2(j, k) = raw2(j, k) + raw1(j, k) / bb
End Select

Next k
Next j

'Set rows for Horn's
For counter = 1 To 6
For j = 1 To 6

sum3 = 0: sum5 = 0: sum50 = 0: sum51 = 0

For k = 1 To 33

xjk = raw2(counter, k)
yjk = raw2(j, k)

If xjk > 0 Or yjk > 0 Then
sum3 = sum3 + ((xjk + yjk) * Log(xjk + yjk))
Elseif xjk = 0 Or yjk = 0 Then
sum3 = sum3 + 0
End If

If xjk > 0 Then
sum5 = sum5 + (xjk * Log(xjk))
Elseif xjk = 0 Then
sum5 = sum5 + 0
End If

If yjk > 0 Then
sum50 = sum50 + (yjk * Log(yjk))
Elseif yjk = 0 Then
sum50 = sum50 + 0
End If

Next k

sum51 = sum51 + ((sum3 - sum5 - sum50) / (2 * Log(2)))
data(j, counter) = sum51

Next j

Next counter

Dim data3(6, 6)
Dim data5(6, 6)
Dim sorted3(6, 6)
Worksheets(3).Select

```

```

'Calculates MacArthur and Levins Mjk and Mkj
counter2 = 0
For counter = 1 To 6
  For j = 1 To 6

    sumpijpik = 0: sumpij2 = 0: sumpik2 = 0: mjk = 0: mkj = 0

    Select Case j

      Case Is >= counter

        For k = 1 To 33

          pij = raw2(counter, k)
          pik = raw2(j, k)
          pij2 = raw2(counter, k) ^ 2
          pik2 = raw2(j, k) ^ 2
          sumpijpik = sumpijpik + (pij * pik)
          sumpij2 = sumpij2 + pij ^ 2
          sumpik2 = sumpik2 + pik ^ 2

        Next k

      End Select

      If sumpijpik = 0 Then mjk = mjk + 0 Else mjk = sumpijpik / sumpij2
      If sumpijpik = 0 Then mkj = mkj + 0 Else mkj = sumpijpik / sumpik2
      data3(j, counter) = mjk
      data5(j, counter) = mkj
      counter2 = counter2 + 1
      sorted3(j, counter) = counter2

    Next j

  Next counter

  Dim data4(21, 4)
  counter = 0
  For j = 1 To 6
    For k = 1 To 6

      Select Case k

        Case Is <= j
          counter = counter + 1
          data4(counter, 1) = counter
          data4(counter, 2) = data(j, k)
          data4(counter, 3) = data3(j, k)
          data4(counter, 4) = data5(j, k)
        End Select

      Next k
    Next j

    For j = 1 To 21
      For k = 1 To 4

        Cells(j, k + 10) = data4(j, k)

      Next k
    Next j
  
```

End Sub

```

Sub RA1_Abundance()

Randomize
Dim raw1(6, 33)
Dim raw1A(6, 33)
Dim sympatry As Double
Dim share As Integer
Dim unshare1 As Integer
Dim total1 As Integer
Dim horn1(6, 33)
Dim xjk As Double
Dim yjk As Double
Dim pij As Double
Dim pik As Double
Dim pij2 As Double
Dim pik2 As Double
Dim mjk As Double
Dim mkj As Double
Dim dataa(6, 6)
Dim sorteda(21, 6)

m = 6
n = 33

For lupe = 1 To 100

Worksheets(2).Select
'Reads in the distributions
For j = 1 To m
For k = 1 To n

raw1(j, k) = Cells(j + 1, k + 1)
raw1A(j, k) = Cells(j + 1, k + 1)

Next k
Next j

'sets up raw1c(6,33) random shuffle of existing proportions keeping zeroes same
For j = 1 To 6
For k = 33 To 1 Step -1

Select Case raw1(j, k)

Case Is <> 0
1 u = Rnd()
draw = Int(((k) - 1 + 1) * u + 1)

If raw1A(j, draw) = 0 Then GoTo 1 Else GoTo 2
2 temp = raw1A(j, draw)
raw1A(j, draw) = raw1A(j, k)
raw1A(j, k) = temp

Case Is = 0
draw = k
temp = raw1A(j, draw)
raw1A(j, draw) = raw1A(j, k)
raw1A(j, k) = temp

End Select

Next k
Next j

```

```
'sets row totals for porportion=1
ws = 0: sr = 0: gr = 0: shr = 0: qb = 0: bb = 0
ws1a = 0: sr1a = 0: gr1a = 0: shr1a = 0: qb1a = 0: bb1a = 0
For j = 1 To 6
For k = 1 To 33
```

```
Select Case j
```

```
Case Is = 1
ws1a = ws1a + raw1A(j, k)
Case Is = 2
sr1a = sr1a + raw1A(j, k)
Case Is = 3
gr1a = gr1a + raw1A(j, k)
Case Is = 4
shr1a = shr1a + raw1A(j, k)
Case Is = 5
qb1a = qb1a + raw1A(j, k)
Case Is = 6
bb1a = bb1a + raw1A(j, k)
End Select
```

```
Next k
```

```
Next j
```

```
'sets matrix row total to 1
```

```
Dim raw2(6, 33)
```

```
Dim raw2A(6, 33)
```

```
For j = 1 To 6
```

```
For k = 1 To 33
```

```
Select Case j
```

```
Case Is = 1
raw2A(j, k) = raw1A(j, k) / ws1a
Case Is = 2
raw2A(j, k) = raw1A(j, k) / sr1a
Case Is = 3
raw2A(j, k) = raw1A(j, k) / gr1a
Case Is = 4
raw2A(j, k) = raw1A(j, k) / shr1a
Case Is = 5
raw2A(j, k) = raw1A(j, k) / qb1a
Case Is = 6
raw2A(j, k) = raw1A(j, k) / bb1a
End Select
```

```
Next k
```

```
Next j
```

```
'Set rows for Horn's
```

```
For counter = 1 To 6
```

```
For j = 1 To 6
```

```
sum3a = 0: sum5a = 0: sum50a = 0: sum51a = 0
```

```
Select Case j
```

```
Case Is >= counter
```

```

For k = 1 To 33

xjka = raw2A(counter, k)
yjka = raw2A(j, k)

If xjka > 0 Or yjka > 0 Then
sum3a = sum3a + ((xjka + yjka) * Log(xjka + yjka))
Elseif xjka = 0 Or yjka = 0 Then
sum3a = sum3a + 0
End If

If xjka > 0 Then
sum5a = sum5a + (xjka * Log(xjka))
Elseif xjka = 0 Then
sum5a = sum5a + 0
End If

If yjka > 0 Then
sum50a = sum50a + (yjka * Log(yjka))
Elseif yjka = 0 Then
sum50a = sum50a + 0
End If

Next k

End Select

sum51a = sum51a + ((sum3a - sum5a - sum50a) / (2 * Log(2)))
dataa(j, counter) = sum51a

Next j

Next counter

Dim data3a(6, 6)
Dim data5a(6, 6)
Dim sorted3a(6, 6)

'Calculates MacArthur and Levins Mjk and Mkj
counter2 = 0
For counter = 1 To 6
For j = 1 To 6

sumpijpika = 0: sumpij2a = 0: sumpik2a = 0: mjka = 0: mkja = 0

Select Case j

Case Is >= counter

For k = 1 To 33

pija = raw2A(counter, k)
pika = raw2A(j, k)
pij2a = raw2A(counter, k) ^ 2
pik2a = raw2A(j, k) ^ 2
sumpijpika = sumpijpika + (pija * pika)
sumpij2a = sumpij2a + pij2a
sumpik2a = sumpik2a + pik2a

Next k

```

```

End Select

If sumpijpika = 0 Then mjka = mjka + 0 Else mjka = sumpijpika / sumpij2a
If sumpijpika = 0 Then mkja = mkja + 0 Else mkja = sumpijpika / sumpik2a
data3a(j, counter) = mjka
data5a(j, counter) = mkja
counter2 = counter2 + 1
sorted3a(j, counter) = counter2

Next j

Next counter

Dim data4A(21, 4)
Dim meana1(100, 21)
Dim meanb1(100, 21)
Dim meanc1(100, 21)

counter = 0
For j = 1 To 6
For k = 1 To 6

Select Case k

Case Is <= j
counter = counter + 1
meana1(lupe, counter) = dataa(j, k)
meanb1(lupe, counter) = data3a(j, k)
meanc1(lupe, counter) = data5a(j, k)
End Select

Next k
Next j

Next lupe

sum01 = 0: sum02 = 0: sum03 = 0: sum04 = 0: sum05 = 0: sum06 = 0: sum07 = 0
sum08 = 0: sum09 = 0: sum10 = 0: sum11 = 0: sum12 = 0: sum13 = 0: sum14 = 0
sum15 = 0: sum16 = 0: sum17 = 0: sum18 = 0: sum19 = 0: sum20 = 0: sum21 = 0

Dim total(9, 21)

For j = 1 To 100
For k = 1 To 21

total(1, k) = total(1, k) + meana1(j, k) / 100
total(2, k) = total(2, k) + meanb1(j, k) / 100
total(3, k) = total(3, k) + meanc1(j, k) / 100

Next k
Next j

Worksheets(9).Select

For j = 1 To 9
For k = 1 To 21

Cells(j, k + 10) = total(j, k)

Next k
Next j

```

```
Worksheets(10).Select  
  
For j = 1 To 100  
For k = 1 To 21  
  
Cells(j, k) = meana1(j, k)  
  
Next k  
Next j  
  
End Sub
```

```

Sub RA2_Abundance()

Randomize
Dim raw1(6, 33)
Dim raw1A(6, 33)
Dim raw1B(6, 33)
Dim raw1C(6, 33)
Dim sympatry As Double
Dim share As Integer
Dim unshare1 As Integer
Dim total1 As Integer
Dim horn1(6, 33)
Dim xjk As Double
Dim yjk As Double
Dim pij As Double
Dim pik As Double
Dim pij2 As Double
Dim pik2 As Double
Dim mjk As Double
Dim mkj As Double
Dim dataa(6, 6)
Dim datab(6, 6)
Dim datac(6, 6)
Dim sorteda(21, 6)
Dim sortedb(21, 6)
Dim sortedc(21, 6)

m = 6
n = 33

For lupe = 1 To 100

Worksheets(1).Select
'Reads in the distributions
For j = 1 To m
For k = 1 To n

raw1(j, k) = Cells(j + 1, k + 1)
raw1A(j, k) = Cells(j + 1, k + 1)
raw1B(j, k) = Cells(j + 1, k + 1)
raw1C(j, k) = Cells(j + 1, k + 1)

Next k
Next j

'sets up raw1A(6,33) random shuffle of existing proportions shifting zeroes
For j = 1 To 6
For k = 33 To 1 Step -1

u = Rnd()
draw = Int(((k) - 1 + 1) * u + 1)

temp = raw1A(j, draw)
raw1A(j, draw) = raw1A(j, k)
raw1A(j, k) = temp

Next k
Next j

'sets up raw1b(6,33) random electivity keeping zeroes in same location
For j = 1 To 6
For k = 1 To 33

```

```

If raw1(j, k) > 0 Then raw1B(j, k) = Rnd Else raw1B(j, k) = 0

Next k
Next j

'sets up raw1c(6,33) random shuffle of existing electivities keeping zeroes same
For j = 1 To 6
For k = 33 To 1 Step -1

Select Case raw1(j, k)

Case Is <> 0
1 u = Rnd()
draw = Int(((k) - 1 + 1) * u + 1)

If raw1C(j, draw) = 0 Then GoTo 1 Else GoTo 2
2 temp = raw1C(j, draw)
raw1C(j, draw) = raw1C(j, k)
raw1C(j, k) = temp

Case Is = 0
draw = k
temp = raw1C(j, draw)
raw1C(j, draw) = raw1C(j, k)
raw1C(j, k) = temp

End Select

Next k
Next j

'sets row totals for porportion=1
ws = 0: sr = 0: gr = 0: shr = 0: qb = 0: bb = 0
ws1a = 0: sr1a = 0: gr1a = 0: shr1a = 0: qb1a = 0: bb1a = 0
ws1b = 0: sr1b = 0: gr1b = 0: shr1b = 0: qb1b = 0: bb1b = 0
ws1c = 0: sr1c = 0: gr1c = 0: shr1c = 0: qb1c = 0: bb1c = 0
For j = 1 To 6
For k = 1 To 33

Select Case j

Case Is = 1
ws1a = ws1a + raw1A(j, k)
ws1b = ws1b + raw1B(j, k)
ws1c = ws1c + raw1C(j, k)
Case Is = 2
sr1a = sr1a + raw1A(j, k)
sr1b = sr1b + raw1B(j, k)
sr1c = sr1c + raw1C(j, k)
Case Is = 3
gr1a = gr1a + raw1A(j, k)
gr1b = gr1b + raw1B(j, k)
gr1c = gr1c + raw1C(j, k)
Case Is = 4
shr1a = shr1a + raw1A(j, k)
shr1b = shr1b + raw1B(j, k)
shr1c = shr1c + raw1C(j, k)
Case Is = 5
qb1a = qb1a + raw1A(j, k)
qb1b = qb1b + raw1B(j, k)
qb1c = qb1c + raw1C(j, k)

```

```

Case Is = 6
bb1a = bb1a + raw1A(j, k)
bb1b = bb1b + raw1B(j, k)
bb1c = bb1c + raw1C(j, k)
End Select

Next k
Next j

'sets matrix row total to 1
Dim raw2(6, 33)
Dim raw2A(6, 33)
Dim raw2B(6, 33)
Dim raw2C(6, 33)

For j = 1 To 6
For k = 1 To 33

Select Case j

Case Is = 1
raw2A(j, k) = raw2A(j, k) + raw1A(j, k) / ws1a
raw2B(j, k) = raw2B(j, k) + raw1B(j, k) / ws1b
raw2C(j, k) = raw2C(j, k) + raw1C(j, k) / ws1c
Case Is = 2
raw2A(j, k) = raw2A(j, k) + raw1A(j, k) / sr1a
raw2B(j, k) = raw2B(j, k) + raw1B(j, k) / sr1b
raw2C(j, k) = raw2C(j, k) + raw1C(j, k) / sr1c
Case Is = 3
raw2A(j, k) = raw2A(j, k) + raw1A(j, k) / gr1a
raw2B(j, k) = raw2B(j, k) + raw1B(j, k) / gr1b
raw2C(j, k) = raw2C(j, k) + raw1C(j, k) / gr1c
Case Is = 4
raw2A(j, k) = raw2A(j, k) + raw1A(j, k) / shr1a
raw2B(j, k) = raw2B(j, k) + raw1B(j, k) / shr1b
raw2C(j, k) = raw2C(j, k) + raw1C(j, k) / shr1c
Case Is = 5
raw2A(j, k) = raw2A(j, k) + raw1A(j, k) / qb1a
raw2B(j, k) = raw2B(j, k) + raw1B(j, k) / qb1b
raw2C(j, k) = raw2C(j, k) + raw1C(j, k) / qb1c
Case Is = 6
raw2A(j, k) = raw2A(j, k) + raw1A(j, k) / bb1a
raw2B(j, k) = raw2B(j, k) + raw1B(j, k) / bb1b
raw2C(j, k) = raw2C(j, k) + raw1C(j, k) / bb1c
End Select

Next k
Next j

'Set rows for Horn's
For counter = 1 To 6
For j = 1 To 6

sum3a = 0: sum5a = 0: sum50a = 0: sum51a = 0
sum3b = 0: sum5b = 0: sum50b = 0: sum51b = 0
sum3c = 0: sum5c = 0: sum50c = 0: sum51c = 0

Select Case j

Case Is >= counter

For k = 1 To 33

```

```

xjka = raw2A(counter, k)
xjkb = raw2B(counter, k)
xjkc = raw2C(counter, k)
yjka = raw2A(j, k)
yjkb = raw2B(j, k)
yjkc = raw2C(j, k)

If xjka > 0 Or yjka > 0 Then
sum3a = sum3a + ((xjka + yjka) * Log(xjka + yjka))
Elseif xjka = 0 Or yjka = 0 Then
sum3a = sum3a + 0
End If

If xjkb > 0 Or yjkb > 0 Then
sum3b = sum3b + ((xjkb + yjkb) * Log(xjkb + yjkb))
Elseif xjkb = 0 Or yjkb = 0 Then
sum3b = sum3b + 0
End If

If xjkc > 0 Or yjkc > 0 Then
sum3c = sum3c + ((xjkc + yjkc) * Log(xjkc + yjkc))
Elseif xjkc = 0 Or yjkc = 0 Then
sum3c = sum3c + 0
End If

If xjka > 0 Then
sum5a = sum5a + (xjka * Log(xjka))
Elseif xjka = 0 Then
sum5a = sum5a + 0
End If

If xjkb > 0 Then
sum5b = sum5b + (xjkb * Log(xjkb))
Elseif xjkb = 0 Then
sum5b = sum5b + 0
End If

If xjkc > 0 Then
sum5c = sum5c + (xjkc * Log(xjkc))
Elseif xjkc = 0 Then
sum5c = sum5c + 0
End If

If yjka > 0 Then
sum50a = sum50a + (yjka * Log(yjka))
Elseif yjka = 0 Then
sum50a = sum50a + 0
End If

If yjkb > 0 Then
sum50b = sum50b + (yjkb * Log(yjkb))
Elseif yjkb = 0 Then
sum50b = sum50b + 0
End If

If yjkc > 0 Then
sum50c = sum50c + (yjkc * Log(yjkc))
Elseif yjkc = 0 Then
sum50c = sum50c + 0
End If

```

Next k

End Select

sum51a = sum51a + ((sum3a - sum5a - sum50a) / (2 * Log(2)))
dataa(j, counter) = sum51a

sum51b = sum51b + ((sum3b - sum5b - sum50b) / (2 * Log(2)))
datab(j, counter) = sum51b

sum51c = sum51c + ((sum3c - sum5c - sum50c) / (2 * Log(2)))
datac(j, counter) = sum51c

Next j

Next counter

Dim data3a(6, 6)
Dim data3b(6, 6)
Dim data3c(6, 6)
Dim data5a(6, 6)
Dim data5b(6, 6)
Dim data5c(6, 6)
Dim sorted3a(6, 6)
Dim sorted3b(6, 6)
Dim sorted3c(6, 6)

'Calculates MacArthur and Levins Mjk and Mkj

counter2 = 0

For counter = 1 To 6

For j = 1 To 6

sumpijpika = 0: sumpij2a = 0: sumpik2a = 0: mjka = 0: mkja = 0
sumpijpikb = 0: sumpij2b = 0: sumpik2b = 0: mjkb = 0: mkjb = 0
sumpijpikc = 0: sumpij2c = 0: sumpik2c = 0: mjkc = 0: mkjc = 0

Select Case j

Case Is >= counter

For k = 1 To 33

pija = raw2A(counter, k)
pijb = raw2B(counter, k)
pijc = raw2C(counter, k)
pika = raw2A(j, k)
pikb = raw2B(j, k)
pikc = raw2C(j, k)
pij2a = raw2A(counter, k) ^ 2
pij2b = raw2B(counter, k) ^ 2
pij2c = raw2C(counter, k) ^ 2
pik2a = raw2A(j, k) ^ 2
pik2b = raw2B(j, k) ^ 2
pik2c = raw2C(j, k) ^ 2
sumpijpika = sumpijpika + (pija * pika)
sumpijpikb = sumpijpikb + (pijb * pikb)
sumpijpikc = sumpijpikc + (pijc * pikc)
sumpij2a = sumpij2a + pija ^ 2
sumpij2b = sumpij2b + pijb ^ 2
sumpij2c = sumpij2c + pijc ^ 2
sumpij2a = sumpij2a + pika ^ 2

```
sumpik2b = sumpik2b + pikb ^ 2
sumpik2c = sumpik2c + pikc ^ 2
```

```
Next k
```

```
End Select
```

```
If sumpijpika = 0 Then mjka = mjka + 0 Else mjka = sumpijpika / sumpij2a
If sumpijpikb = 0 Then mjkb = mjkb + 0 Else mjkb = sumpijpikb / sumpij2b
If sumpijpikc = 0 Then mjkc = mjkc + 0 Else mjkc = sumpijpikc / sumpij2c
If sumpijpika = 0 Then mkja = mkja + 0 Else mkja = sumpijpika / sumpik2a
If sumpijpikb = 0 Then mkjb = mkjb + 0 Else mkjb = sumpijpikb / sumpik2b
If sumpijpikc = 0 Then mkjc = mkjc + 0 Else mkjc = sumpijpikc / sumpik2c
data3a(j, counter) = mjka
data3b(j, counter) = mjkb
data3c(j, counter) = mjkc
data5a(j, counter) = mkja
data5b(j, counter) = mkjb
data5c(j, counter) = mkjc
counter2 = counter2 + 1
sorted3a(j, counter) = counter2
sorted3b(j, counter) = counter2
sorted3c(j, counter) = counter2
```

```
Next j
```

```
Next counter
```

```
Dim data4A(21, 4)
Dim data4B(21, 4)
Dim data4C(21, 4)
Dim meana1(100, 21)
Dim meana2(100, 21)
Dim meana3(100, 21)
Dim meanb1(100, 21)
Dim meanb2(100, 21)
Dim meanb3(100, 21)
Dim meanc1(100, 21)
Dim meanc2(100, 21)
Dim meanc3(100, 21)
```

```
counter = 0
For j = 1 To 6
For k = 1 To 6
```

```
Select Case k
```

```
Case Is <= j
counter = counter + 1
meana1(lupe, counter) = dataa(j, k)
meanb1(lupe, counter) = datab(j, k)
meanc1(lupe, counter) = datac(j, k)
meana2(lupe, counter) = data3a(j, k)
meanb2(lupe, counter) = data3b(j, k)
meanc2(lupe, counter) = data3c(j, k)
meana3(lupe, counter) = data5a(j, k)
meanb3(lupe, counter) = data5b(j, k)
meanc3(lupe, counter) = data5c(j, k)
End Select
```

```
Next k
```

```
Next j
```

Next lupe

sum01 = 0: sum02 = 0: sum03 = 0: sum04 = 0: sum05 = 0: sum06 = 0: sum07 = 0
sum08 = 0: sum09 = 0: sum10 = 0: sum11 = 0: sum12 = 0: sum13 = 0: sum14 = 0
sum15 = 0: sum16 = 0: sum17 = 0: sum18 = 0: sum19 = 0: sum20 = 0: sum21 = 0

Dim total(9, 21)

For j = 1 To 100
For k = 1 To 21

total(1, k) = total(1, k) + meana1(j, k) / 100
total(2, k) = total(2, k) + meanb1(j, k) / 100
total(3, k) = total(3, k) + meanc1(j, k) / 100

total(4, k) = total(4, k) + meana2(j, k) / 100
total(5, k) = total(5, k) + meanb2(j, k) / 100
total(6, k) = total(6, k) + meanc2(j, k) / 100

total(7, k) = total(7, k) + meana3(j, k) / 100
total(8, k) = total(8, k) + meanb3(j, k) / 100
total(9, k) = total(9, k) + meanc3(j, k) / 100

Next k
Next j

Worksheets(4).Select

For j = 1 To 9
For k = 1 To 21

Cells(j, k + 10) = total(j, k)

Next k
Next j

End Sub

```

Sub RA3_Abundance()

Randomize
Dim raw1(6, 33)
Dim raw1A(6, 33)
Dim sympatry As Double
Dim share As Integer
Dim unshare1 As Integer
Dim total1 As Integer
Dim horn1(6, 33)
Dim xjk As Double
Dim yjk As Double
Dim pij As Double
Dim pik As Double
Dim pij2 As Double
Dim pik2 As Double
Dim mjk As Double
Dim mkj As Double
Dim dataa(6, 6)
Dim sorteda(21, 6)

m = 6
n = 33

For lupe = 1 To 100

Worksheets(2).Select
'Reads in the distributions
For j = 1 To m
For k = 1 To n

raw1(j, k) = Cells(j + 1, k + 1)
raw1A(j, k) = Cells(j + 1, k + 1)

Next k
Next j

'sets up raw1b(6,33) random proportions keeping zeroes in same location
For j = 1 To 6
For k = 1 To 33

If raw1(j, k) > 0 Then raw1A(j, k) = Rnd Else raw1A(j, k) = 0

Next k
Next j

'sets row totals for porportion=1
ws = 0: sr = 0: gr = 0: shr = 0: qb = 0: bb = 0
ws1a = 0: sr1a = 0: gr1a = 0: shr1a = 0: qb1a = 0: bb1a = 0
For j = 1 To 6
For k = 1 To 33

Select Case j

Case Is = 1
ws1a = ws1a + raw1A(j, k)
Case Is = 2
sr1a = sr1a + raw1A(j, k)
Case Is = 3
gr1a = gr1a + raw1A(j, k)
Case Is = 4
shr1a = shr1a + raw1A(j, k)

```

```

Case ls = 5
qb1a = qb1a + raw1A(j, k)
Case ls = 6
bb1a = bb1a + raw1A(j, k)
End Select

Next k
Next j

'sets matrix row total to 1
Dim raw2(6, 33)
Dim raw2A(6, 33)

For j = 1 To 6
For k = 1 To 33

Select Case j

Case ls = 1
raw2A(j, k) = raw1A(j, k) / ws1a
Case ls = 2
raw2A(j, k) = raw1A(j, k) / sr1a
Case ls = 3
raw2A(j, k) = raw1A(j, k) / gr1a
Case ls = 4
raw2A(j, k) = raw1A(j, k) / shr1a
Case ls = 5
raw2A(j, k) = raw1A(j, k) / qb1a
Case ls = 6
raw2A(j, k) = raw1A(j, k) / bb1a
End Select

Next k
Next j

'Set rows for Horn's
For counter = 1 To 6
For j = 1 To 6

sum3a = 0: sum5a = 0: sum50a = 0: sum51a = 0

Select Case j

Case ls >= counter

For k = 1 To 33

xjka = raw2A(counter, k)
yjka = raw2A(j, k)

If xjka > 0 Or yjka > 0 Then
sum3a = sum3a + ((xjka + yjka) * Log(xjka + yjka))
Elseif xjka = 0 Or yjka = 0 Then
sum3a = sum3a + 0
End If

If xjka > 0 Then
sum5a = sum5a + (xjka * Log(xjka))
Elseif xjka = 0 Then
sum5a = sum5a + 0
End If

```

```

If yjka > 0 Then
sum50a = sum50a + (yjka * Log(yjka))
Elseif yjka = 0 Then
sum50a = sum50a + 0
End If

Next k

End Select

sum51a = sum51a + ((sum3a - sum5a - sum50a) / (2 * Log(2)))
dataa(j, counter) = sum51a

Next j

Next counter

Dim data3a(6, 6)
Dim data5a(6, 6)
Dim sorted3a(6, 6)

'Calculates MacArthur and Levins Mjk and Mkj
counter2 = 0
For counter = 1 To 6
For j = 1 To 6

sumpijpika = 0: sumpij2a = 0: sumpik2a = 0: mjka = 0: mkja = 0

Select Case j

Case Is >= counter

For k = 1 To 33

pija = raw2A(counter, k)
pika = raw2A(j, k)
pij2a = raw2A(counter, k) ^ 2
pik2a = raw2A(j, k) ^ 2
sumpijpika = sumpijpika + (pija * pika)
sumpij2a = sumpij2a + pij2a
sumpik2a = sumpik2a + pik2a

Next k

End Select

If sumpijpika = 0 Then mjka = mjka + 0 Else mjka = sumpijpika / sumpij2a
If sumpijpika = 0 Then mkja = mkja + 0 Else mkja = sumpik2a / sumpik2a
data3a(j, counter) = mjka
data5a(j, counter) = mkja
counter2 = counter2 + 1
sorted3a(j, counter) = counter2

Next j

Next counter

Dim data4A(21, 4)
Dim meana1(100, 21)
Dim meanb1(100, 21)
Dim meanc1(100, 21)

```

```

counter = 0
For j = 1 To 6
For k = 1 To 6

Select Case k

Case Is <= j
counter = counter + 1
meana1(lupe, counter) = dataa(j, k)
meanb1(lupe, counter) = data3a(j, k)
meanc1(lupe, counter) = data5a(j, k)
End Select

Next k
Next j

Next lupe

sum01 = 0: sum02 = 0: sum03 = 0: sum04 = 0: sum05 = 0: sum06 = 0: sum07 = 0
sum08 = 0: sum09 = 0: sum10 = 0: sum11 = 0: sum12 = 0: sum13 = 0: sum14 = 0
sum15 = 0: sum16 = 0: sum17 = 0: sum18 = 0: sum19 = 0: sum20 = 0: sum21 = 0

Dim total(9, 21)

For j = 1 To 100
For k = 1 To 21

total(1, k) = total(1, k) + meana1(j, k) / 100
total(2, k) = total(2, k) + meanb1(j, k) / 100
total(3, k) = total(3, k) + meanc1(j, k) / 100

Next k
Next j

Worksheets(9).Select

For j = 1 To 9
For k = 1 To 21

Cells(j + 8, k + 10) = total(j, k)

Next k
Next j

Worksheets(10).Select

For j = 1 To 100
For k = 1 To 21

Cells(j, k) = meana1(j, k)

Next k
Next j

End Sub

```

```

Private Sub Command1_Click()

Dim dMyDouble As Double
Dim dElement As Double
dMyDouble = (Picture1.Width * Picture1.Height)
Dim aMyArray()

For x = 0 To Picture1.Width

For y = 0 To Picture1.Height
dElement = dElement + 1
ReDim Preserve aMyArray(0 To dElement - 1)
aMyArray(dElement - 1) = Picture1.Point(x, y)
'sPoint = sPoint & "," & Picture1.Point(x, y)
Next y
dElement = dElement + 1
ReDim Preserve aMyArray(0 To dElement - 1)
aMyArray(dElement - 1) = vbCrLf
Next x


sPoint = Join(aMyArray, ",")
sPoint = Mid$(sPoint, 2) 'trims the first "," off so we don't need an if statement in the loop slowing us down
sPoint = Replace$(sPoint, vbCrLf & ",", vbCrLf)

Open "c:\MyCSV.csv" For Output As #1
Print #1, sPoint;
Close #1

MsgBox "Done"

End Sub

```

```

Sub Extract()

Dim raw(279, 250)
Dim x As Integer
Dim y As Integer

Row = 279
Col = 250

Worksheets(1).Select

For x = 1 To Row
For y = 1 To Col
If Cells(x, y) = 0 Then raw(x, y) = 1 Else raw(x, y) = ""
Next y
Next x

Worksheets(3).Select

For x = 1 To Row
For y = 1 To Col
Cells(x, y) = raw(x, y)
Next y
Next x

End Sub

```

```

Sub overlap1()

Dim raw1(279, 250)
Dim raw2(279, 250)
Dim sympatry As Double
Dim share As Integer
Dim unshare1 As Integer
Dim unshare2 As Integer
Dim total1 As Integer
Dim total2 As Integer
Dim horn1(279, 250)
Dim horn2(279, 250)
Dim xjk As Double
Dim yjk As Double
Dim pij As Double
Dim pik As Double
Dim pij2 As Double
Dim pik2 As Double
Dim mjk As Double
Dim mkj As Double

m = 279
n = 250

'Reads in the distributions
'must change the name of the workbooks
Windows("macrolepidotum.xls").Activate
Worksheets(3).Select
For j = 1 To m
For k = 1 To n
raw1(j, k) = Cells(j, k)
Next k
Next j

Windows("commersoni.xls").Activate
Worksheets(3).Select
For j = 1 To m
For k = 1 To n
raw2(j, k) = Cells(j, k)
Next k
Next j

'Calculates the shared cells
share = 0: total1 = 0: total2 = 0: unshare1 = 0: unshare2 = 0
For j = 1 To m
For k = 1 To n
If raw1(j, k) = 1 And raw2(j, k) = 1 Then share = share + 1
total1 = total1 + raw1(j, k)
total2 = total2 + raw2(j, k)
If raw1(j, k) = 1 And raw2(j, k) <> 1 Then unshare1 = unshare1 + 1 Else unshare1 = unshare1 + 0
If raw2(j, k) = 1 And raw1(j, k) <> 1 Then unshare2 = unshare2 + 1 Else unshare2 = unshare2 + 0
Next k
Next j

sympatry = (share + share) / (total1 + total2)

f..=1
For j = 1 To m
For k = 1 To n
horn1(j, k) = raw1(j, k) / total1
horn2(j, k) = raw2(j, k) / total2
Next k

```

```

Next j

'Calculates Horn's
sum51 = 0
For j = 1 To m
For k = 1 To n
sum3 = 0: sum5 = 0: sum50 = 0
xjk = horn1(j, k)
yjk = horn2(j, k)

If xjk > 0 Or yjk > 0 Then
sum3 = sum3 + ((xjk + yjk) * Log(xjk + yjk))
ElseIf xjk = 0 Or yjk = 0 Then
sum3 = sum3 + 0
End If

If xjk > 0 Then
sum5 = sum5 + (xjk * Log(xjk))
ElseIf xjk = 0 Then
sum5 = sum5 + 0
End If

If yjk > 0 Then
sum50 = sum50 + (yjk * Log(yjk))
ElseIf yjk = 0 Then
sum50 = sum50 + 0
End If

sum51 = sum51 + ((sum3 - sum5 - sum50) / (2 * Log(2)))

Next k
Next j

'Calculates MacArthur and Levins Mjk and Mkj
sumpijpik = 0: sumpij2 = 0: sumpik2 = 0
For j = 1 To m
For k = 1 To n
pij = horn1(j, k)
pik = horn2(j, k)
pij2 = horn1(j, k) ^ 2
pik2 = horn2(j, k) ^ 2
sumpijpik = sumpijpik + (pij * pik)
sumpij2 = sumpij2 + pij ^ 2
sumpik2 = sumpik2 + pik ^ 2
Next k
Next j

mjk = sumpijpik / sumpij2
mkj = sumpik2 / sumpik2

Windows("biogeo_macro.xls").Activate
Worksheets(2).Select
Cells(1, 1) = sum51 'horn's index
Cells(3, 2) = sympatry
Cells(2, 2) = share
Cells(2, 3) = total1
Cells(2, 4) = total2
Cells(3, 3) = unshare1
Cells(3, 4) = unshare2
Cells(2, 5) = mjk
Cells(3, 5) = mkj
End Sub

```

Appendix 5. Raw stomach content data from six catostomid species from 160km of the Assiniboine River, MB between Potage la Prairie Dam (160km) and Winnipeg (0km) captured between 1995 and 2001.

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaeniinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
QB	1	1	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	
QB	1	95	8	-	-	1	-	-	-	-	1	-	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	1	96	8	-	-	-	-	-	-	-	-	-	4	19	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	1	96	7	-	-	-	-	-	-	-	-	-	8	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	47	
QB	1	96	6	-	-	-	-	-	-	-	263	-	-	-	-	-	-	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	1	96	9	-	-	-	-	1	-	-	-	-	45	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67	-	-	-	
QB	1	96	5	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	793	-	-	
QB	2	1	7	-	-	-	-	-	-	-	6	-	-	-	-	-	7	2	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	
QB	2	95	8	2	-	-	-	-	-	-	1	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	37	42	-	-	
QB	2	95	9	-	-	-	-	-	-	-	760	-	-	-	-	-	-	1	-	152	-	-	-	-	-	-	-	-	3	-	-	-	72	-	-	-
QB	2	96	5	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	2	96	8	-	-	-	-	-	-	-	6	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	
QB	2	96	7	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61	
QB	2	96	6	-	-	-	-	-	-	-	403	-	-	-	-	-	-	62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	3	1	7	-	-	-	-	-	-	-	-	6	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	68	-	-	
QB	3	95	9	-	-	-	-	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	103	-	-	-	
QB	3	96	7	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	8	
QB	3	96	8	57	-	4	-	3	1	-	-	-	-	3	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	3	96	5	-	-	-	-	-	-	-	34	4	10	2	-	-	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	-	-
QB	3	96	9	-	-	1	-	-	-	-	-	-	-	1	5	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	203	-	-	-
QB	3	96	6	-	-	-	-	-	-	-	514	-	-	-	-	-	-	73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	4	1	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	89	-	-	

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
QB	4	95	9	-	-	-	-	-	-	-	-	11	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	4	96	8	-	-	-	-	-	-	-	-	-	1	-	1	-	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	4	96	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	137	
QB	4	96	9	5	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	570	-	-	-	
QB	5	1	7	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	256	1126	-	-	
QB	5	95	9	-	-	3	-	-	-	-	1	-	10	-	2	-	-	5	-	-	-	-	-	-	-	-	1	-	-	-	-	-	33	-	-	
QB	5	96	9	5	-	-	-	-	-	-	-	-	2	-	7	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	62	-	-		
QB	5	96	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	131	-	-		
QB	5	96	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78	
QB	5	96	5	-	-	-	-	-	-	-	104	-	14	-	32	-	-	56	-	-	-	-	-	-	-	-	2	-	-	-	-	5	-	-		
QB	6	1	7	1	-	-	-	-	-	-	4	1	-	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	4	28	-	5	
QB	6	95	9	-	-	4	-	-	-	-	112	14	14	-	-	-	-	11	-	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	6	96	8	1	-	-	-	-	-	-	-	-	-	1	14	-	-	3	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-		
QB	6	96	7	-	-	1	-	-	-	-	5	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	156	-	-		
QB	6	96	6	-	-	-	-	-	-	-	112	-	-	-	-	-	-	69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	6	96	9	-	-	-	-	-	-	-	45	-	-	-	75	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	
QB	7	1	7	-	-	-	-	-	-	-	1	4	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	189	-	259	
QB	7	95	9	2	-	-	-	-	-	-	-	376	-	-	47	-	-	1	-	-	-	-	-	-	1	-	5	-	-	-	-	71	-	-	-	
QB	7	96	6	-	-	-	-	-	-	-	5	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	7	96	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37	
QB	7	96	8	-	-	-	-	-	-	-	68	-	4	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
QB	8	1	7	-	-	-	-	-	-	-	1	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	37	
QB	8	95	9	-	-	1	-	-	-	-	34	-	-	-	-	-	-	9	-	17	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
QB	8	96	8	1	-	-	-	-	-	-	-	-	3	-	4	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	8	96	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	156
QB	9	1	7	-	-	-	-	-	-	-	1	2	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	13	12	-	61	
QB	9	95	9	2	-	-	-	-	-	-	60	-	-	-	1	-	30	158	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	9	96	8	-	-	-	-	-	-	-	46	-	-	-	3	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	9	96	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	62	
QB	10	0	7	-	-	-	-	-	-	-	1	4	-	2	-	-	11	-	-	1	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-
QB	10	95	9	-	-	-	-	-	-	-	56	28	-	-	1	28	-	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	10	96	9	3	-	-	-	-	-	-	-	-	2	-	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	10	96	8	-	-	-	-	-	-	-	72	3	-	-	-	-	-	8	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
QB	11	1	7	-	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	11	95	9	-	-	-	-	-	-	-	33	-	10	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
QB	11	96	7	-	-	-	-	-	-	-	102	-	6	-	6	-	-	78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	13	1	7	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	14	1	7	2	-	-	-	-	-	-	7	2	-	2	24	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
QB	16	1	7	1	-	-	-	-	-	-	5	-	-	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
QB	18	1	7	12	-	-	-	1	-	-	-	-	-	1	-	-	2	4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	35	-	-	-
QB	21	1	7	10	-	-	-	1	-	-	1	-	-	-	1	-	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QB	23	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-
QB	24	0	7	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
QB	26	1	7	-	-	-	-	3	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
QB	27	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-
WS	1	95	8	3	-	26	-	26	10	1	-	-	-	3	-	-	-	1	-	-	2	5	-	-	-	-	13	1	-	-	4	-	-	-	-	-

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
WS	1	95	9	3	-	9	-	2	4	-	-	-	-	6	9	-	-	3	-	-	-	-	-	-	-	4	254	-	-	-	3	-	-	-	-	-
WS	1	96	6	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WS	1	96	8	-	-	2	-	-	3	-	-	-	1	3	22	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
WS	1	96	5	-	-	-	-	-	2	-	-	-	5	5	25	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	1	-	-	
WS	1	96	9	-	-	-	-	-	-	-	6	-	-	38	8	-	-	-	-	-	-	-	-	-	-	-	78	-	-	-	9	-	-	-	-	
WS	2	95	8	1	-	1	-	1	-	-	42	-	-	3	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-	-	-	
WS	2	95	9	11	17	9	-	4	6	-	-	-	-	12	3	-	-	2	-	-	1	-	-	-	4	3	60	-	-	-	2	-	-	-	-	
WS	2	96	8	10	-	-	1	-	-	-	-	-	-	2	2	-	-	1	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	
WS	2	96	5	-	-	-	-	-	-	-	2	-	-	6	3	-	-	-	-	-	4	-	-	-	-	-	-	1	-	-	2	-	-	-	-	
WS	2	96	6	-	1	-	-	-	-	-	-	-	-	3	-	-	-	2	1	-	-	2	-	38	-	-	1	-	-	-	-	-	-	-	-	
WS	2	96	9	25	-	31	-	12	52	9	-	-	-	47	2	-	-	2	-	6	-	1	5	-	-	36	28	-	-	-	-	-	-	-	1	-
WS	3	0	8	-	-	11	-	-	-	-	1	-	-	-	-	-	2	-	1	-	-	3	-	6	-	-	2	-	-	-	-	-	-	-	-	
WS	3	95	8	5	-	57	1	12	3	-	2	-	-	17	8	-	-	7	-	-	-	3	-	-	-	5	92	-	-	-	-	-	-	-	-	
WS	3	95	9	4	98	5	-	2	3	-	-	-	-	42	6	-	-	1	-	-	-	-	-	-	1	-	51	-	-	-	2	-	-	-	-	
WS	3	96	5	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	
WS	3	96	7	1	-	-	-	6	-	-	2	-	-	5	3	-	-	1	-	-	-	72	-	-	-	-	-	-	-	-	-	-	-	-	-	
WS	3	96	8	47	1	-	3	1	14	2	3	-	-	6	14	-	-	3	-	1	-	-	-	-	1	-	3	-	-	-	-	-	-	-	-	
WS	3	96	9	17	1	9	-	16	14	5	7	-	5	6	5	-	-	-	-	16	-	3	-	4	1	15	-	-	6	-	-	-	-	-	-	
WS	4	0	8	11	2	-	-	12	2	-	12	-	-	1	-	-	3	-	-	-	-	-	-	7	-	-	31	-	-	1	-	-	-	-	-	
WS	4	95	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-	-	-	-	-	-	-	
WS	4	95	8	5	-	64	-	15	2	4	-	-	-	30	-	-	-	3	-	4	-	7	1	-	1	2	12	-	-	3	-	62	-	-	-	
WS	4	96	7	-	-	1	-	-	1	-	2	-	-	1	1	-	-	1	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	
WS	4	96	8	-	-	5	-	7	9	1	2	-	-	10	13	-	-	2	-	-	-	3	-	-	-	5	-	-	-	-	-	-	-	-	-	

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
WS	4	96	9	43	1	31	-	4	14	-	-	-	-	18	4	-	-	2	-	-	-	-	-	3	1	9	29	-	-	-	1	-	-	-	1	-
WS	4	96	5	-	-	-	-	-	-	-	-	-	2	-	4	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	4	103	18	32	-	-
WS	5	0	8	2	-	-	-	-	2	-	2	-	-	3	-	-	-	-	-	-	-	-	-	1	-	-	47	-	-	-	-	-	-	-	-	-
WS	5	95	8	13	-	17	-	-	5	-	3	-	-	10	1	-	-	4	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-
WS	5	96	5	3	-	-	-	-	2	-	-	-	1	4	3	-	-	-	-	-	-	-	-	-	2	2	5	-	-	-	-	-	-	-	-	-
WS	5	96	8	4	1	8	2	3	-	-	1	-	2	2	4	-	-	2	-	-	-	-	-	4	-	-	3	-	-	-	-	-	-	-	-	-
WS	5	96	9	16	-	3	-	-	15	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	4	19	-	-	-	-	-	-	-	-	-
WS	6	0	8	6	-	-	-	-	5	-	2	-	-	3	-	-	3	-	-	-	-	-	-	24	-	-	27	-	-	-	-	-	-	-	-	-
WS	6	96	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	
WS	6	96	5	-	-	-	-	-	3	1	-	-	-	2	3	-	1	1	-	-	12	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
WS	6	96	8	6	-	-	-	-	3	-	-	-	2	3	6	-	-	3	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-
WS	6	96	7	4	-	-	-	1	1	-	1	-	-	2	-	-	-	-	-	-	-	4	-	1	2	-	126	-	-	-	-	-	-	-	-	-
WS	7	1	8	2	-	-	3	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	-	-
WS	7	96	9	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	10	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
WS	7	96	7	9	-	-	-	1	-	-	1	-	-	2	-	-	-	-	-	-	-	5	-	1	-	-	23	-	-	-	-	-	-	-	-	-
WS	7	96	8	7	-	-	-	1	5	-	6	-	1	1	23	-	-	10	-	-	-	-	-	1	1	-	19	-	-	-	-	-	-	-	-	-
WS	8	1	8	-	-	-	-	-	2	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
WS	8	96	9	1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	17	-	
WS	8	96	7	17	-	2	4	10	3	6	1	-	-	-	-	-	-	2	-	-	-	71	-	-	-	-	13	-	-	-	-	-	-	-	-	-
WS	9	1	8	6	-	-	-	-	9	-	2	-	-	-	-	-	8	2	1	5	-	-	-	23	-	-	3	-	-	-	-	-	-	-	-	-
WS	9	96	8	7	-	1	-	-	1	-	2	-	-	1	5	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-
WS	9	96	7	1	2	1	-	1	1	1	1	-	-	2	1	-	-	-	-	-	-	3	-	-	-	-	19	-	-	-	-	-	-	-	-	-
WS	9	96	9	5	-	13	-	1	2	-	-	-	-	-	-	-	-	1	-	-	-	-	6	13	7	-	-	-	-	-	-	-	-	-	-	-

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaidiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera	
WS	10	1	8	-	-	-	-	-	-	-	-	1	-	-	-	-	11	5	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	
WS	10	96	7	2	-	5	4	-	2	-	-	-	-	3	3	-	-	-	-	1	-	2	5	3	1	1	5	-	-	-	-	-	-	-	-	-	
WS	11	1	8	4	-	-	-	-	1	-	16	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	
WS	11	96	7	2	-	5	-	-	3	-	1	-	-	2	5	-	-	-	-	-	-	2	-	10	-	-	6	1	-	-	-	-	-	-	-	-	
WS	12	1	8	9	3	-	-	12	11	-	1	-	-	-	-	-	5	-	-	-	-	-	-	5	-	-	101	-	-	-	2	-	-	-	-	-	
WS	13	1	8	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	73	19	-	1690	
WS	15	1	8	-	-	-	-	-	-	-	5	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	53	-	-	-	-	-	-	-	-	-	
WS	16	1	8	2	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	
WS	17	0	8	4	-	-	-	16	-	-	92	4	-	8	-	-	16	5	-	1	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	
WS	18	0	8	-	-	-	-	9	-	-	23	2	2	12	-	-	1	6	-	-	-	-	1	16	-	4	-	2	1	-	-	-	-	-	-	-	-
WS	19	0	8	-	-	-	-	1	-	-	3	-	-	1	-	1	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-
WS	20	0	8	3	-	-	-	-	-	-	24	3	-	9	-	-	4	-	-	2	-	-	3	-	-	-	43	-	1	-	-	-	-	-	-	-	
WS	21	0	8	2	-	-	-	6	2	1	20	5	6	5	-	-	13	3	-	-	-	-	1	1	-	2	32	1	-	-	-	-	-	-	-	-	
WS	22	0	8	12	-	-	-	-	-	-	42	5	1	21	-	-	24	1	-	-	-	-	-	3	2	-	62	-	-	-	-	-	-	-	-	-	
BB	1	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	571		
BB	1	0	5	-	-	-	-	-	-	-	2	-	-	-	6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53	2384	9	-	
BB	1	96	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	
BB	1	96	6	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	2	-	2	
BB	1	96	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	27	-	-	93
BB	2	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	5	
BB	2	96	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	47	
BB	3	96	7	5	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1078	
BB	4	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaidiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
BB	4	96	5	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	2057	-	39	
BB	5	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	303	
BB	6	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	458	
BB	7	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	473	
BB	8	0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	629	
BB	10	1	7	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
BB	11	1	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	
BB	13	0	7	1	-	6	-	-	-	-	1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	538	-	-	-
SR	1	0	8	3	-	2	1	12	-	-	27	-	-	-	-	-	-	1	-	-	-	157	-	-	-	-	9	-	-	-	-	-	-	-	-	-
SR	1	95	9	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	
SR	1	95	8	5	-	67	9	40	5	-	-	-	-	3	19	-	-	11	-	-	-	7	-	-	1	-	14	-	2	-	18	-	-	-	-	-
SR	1	96	7	5	-	6	-	-	-	-	-	-	-	2	42	-	-	7	1	-	-	17	1	2	-	-	-	-	4	-	-	-	-	-	-	
SR	1	96	9	55	-	17	2	11	48	-	-	-	-	1	2	-	-	-	-	1	-	-	1	1	1	7	8	1	1	-	8	-	-	-	-	
SR	1	96	5	39	-	-	-	16	6	-	-	-	146	219	293	-	-	4	-	-	-	-	1	2	1	6	20	3	1	-	-	-	-	-	-	
SR	2	0	8	8	-	-	4	1	-	-	12	-	-	5	-	-	1	-	-	-	-	136	-	-	-	-	3	-	-	-	-	-	-	-	-	-
SR	2	95	9	-	-	-	-	1	-	-	-	-	2	1	5	-	-	-	-	-	-	-	-	-	1	-	4	-	3	-	32	-	7	-	-	-
SR	2	95	8	8	-	88	1	37	8	2	-	-	-	7	8	-	-	5	-	1	-	8	-	-	-	1	20	-	-	-	1	-	-	-	-	-
SR	2	96	7	1	-	2	-	-	-	-	1	-	-	1	1	1	-	2	-	-	-	20	5	-	-	-	2	-	-	-	-	-	-	-	-	-
SR	2	96	6	-	-	-	-	-	-	-	-	-	-	4	28	-	-	23	-	-	-	1	-	1	2	-	-	-	-	-	-	-	-	-	-	-
SR	3	1	8	7	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR	3	96	9	3	-	-	-	6	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	12	-	-	-	-	-	-	-	-	
SR	3	96	7	4	-	5	-	2	-	4	-	-	-	1	-	-	-	-	-	-	-	16	-	-	-	-	-	-	1	-	-	-	-	-	-	-
SR	3	96	8	-	-	1	-	7	-	-	-	-	-	-	21	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthocladinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
SR	3	96	6	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	1	106	-	2	-	-	-	-	1	-	-	-	-	-	-	-
SR	3	96	5	3	-	-	-	111	3	2	-	-	-	2	2	-	-	-	1	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-
SR	4	95	8	17	-	81	7	15	15	-	-	-	-	4	7	-	-	3	-	2	-	2	1	-	14	9	5	-	1	-	32	-	-	-	-	-
SR	4	96	9	3	-	2	-	-	-	-	-	-	-	-	29	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-
SR	4	96	8	-	-	2	-	-	-	-	-	-	30	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	5	-	1	-	-	-	-	-
SR	4	96	6	-	-	-	-	-	2	-	-	-	-	1	1	1	-	3	1	-	-	79	-	8	-	-	-	-	-	-	-	-	-	-	-	-
SR	5	1	8	1	-	-	1	-	-	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	1	-	-	-	-	-
SR	5	95	8	28	3	36	-	3	3	-	-	-	-	5	18	-	-	-	-	-	-	1	-	-	-	-	93	1	-	-	-	-	-	-	-	-
SR	5	96	9	7	-	-	-	-	3	-	-	-	-	15	16	-	-	-	-	-	10	-	-	6	7	-	-	-	-	-	-	-	-	-	-	-
SR	5	96	8	-	-	-	-	2	-	-	-	-	-	-	66	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR	5	96	7	-	-	2	-	-	-	-	-	-	46	-	-	-	-	35	-	-	-	5	-	1	-	-	-	-	3	-	-	-	-	-	-	-
SR	5	96	6	-	-	-	-	-	-	-	-	-	82	-	-	-	3	30	-	-	-	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-
SR	6	1	8	14	-	-	-	6	5	-	-	-	-	13	-	-	-	1	-	-	-	-	21	-	-	-	17	-	-	-	5	-	-	-	-	-
SR	6	96	9	6	-	-	-	-	2	-	-	-	4	5	9	-	-	-	-	-	2	-	2	-	-	2	-	1	-	-	-	-	-	-	1	-
SR	6	96	6	4	-	-	-	-	3	-	-	-	-	9	4	2	1	7	1	1	1	43	-	62	-	2	-	-	-	-	-	-	-	-	-	-
SR	7	1	8	2	-	-	1	1	-	-	2	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-
SR	7	96	7	12	-	-	-	1	5	1	-	-	-	3	2	-	-	-	-	-	-	43	-	-	-	-	7	-	-	-	-	-	-	-	-	-
SR	7	96	6	-	-	-	-	-	3	-	-	-	1	2	22	-	3	10	-	-	-	71	-	1	-	-	-	-	-	-	-	-	-	-	-	-
SR	7	96	8	-	-	-	-	10	-	-	-	-	-	1	73	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR	7	96	9	-	-	-	-	-	-	-	53	-	41	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR	8	96	9	1	-	-	-	-	-	-	4	-	14	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	-	-	-	-
SR	8	96	7	-	-	-	-	-	-	-	-	-	-	-	28	-	-	-	-	-	-	1	-	-	-	-	5	-	-	-	-	-	-	-	-	-
SR	8	96	8	26	-	12	-	6	3	-	-	-	-	5	12	-	-	3	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera	
SR	8	96	6	-	-	-	-	-	4	-	-	-	27	1	5	-	-	8	-	-	-	-	-	5	-	-	-	-	1	-	-	-	-	-	-	-	
SR	9	1	8	4	-	-	-	2	3	-	6	-	-	-	-	-	4	2	-	-	-	-	7	-	-	-	12	-	-	-	7	-	-	-	-	-	
SR	9	96	9	9	-	-	-	-	1	-	-	-	-	6	-	-	-	-	-	-	7	-	-	2	-	4	-	-	-	-	-	-	-	-	-	-	
SR	9	96	8	1	-	1	-	2	1	-	-	-	-	6	17	-	-	2	-	1	-	-	1	-	-	10	-	-	-	-	-	-	-	-	-	-	
SR	9	96	6	2	-	-	-	-	-	-	-	-	-	-	23	-	-	9	1	-	1	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	
SR	10	1	8	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	1	-	-	-	-	-	
SR	10	96	9	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	5	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	
SR	10	96	6	-	-	-	-	-	-	-	-	-	1	2	3	1	-	-	-	-	-	130	1	21	-	-	-	3	-	-	-	-	-	-	-	-	-
SR	11	1	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	1	-	-	-	-	-	
SR	12	1	8	14	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-	2	-	7	-	-	-	1	-	1	-	1	-	
SR	13	1	8	-	-	-	-	-	-	-	24	-	-	3	-	-	1	4	-	-	-	-	-	-	1	1	3	-	3	-	-	-	-	-	-	-	
SR	14	1	8	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	
SR	15	1	8	2	-	-	-	1	-	-	2	-	-	3	8	-	4	2	-	-	1	-	3	-	-	-	-	-	1	-	-	-	-	-	-	-	
SR	17	1	8	1	-	-	-	5	-	-	9	-	-	5	1	-	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	
SR	18	0	8	-	-	-	-	1	-	-	-	-	-	1	1	-	-	2	-	-	-	-	4	-	-	-	7	-	-	-	-	-	-	-	-	-	
SR	18	0	8	6	1	-	-	11	-	-	12	4	-	2	-	-	6	-	-	-	-	-	1	-	-	-	2	1	-	-	-	-	-	-	-	-	
SR	18	0	8	2	-	-	-	-	-	-	27	1	-	43	-	-	-	15	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	-	
GR	1	0	8	3	-	24	1	2	2	-	2	-	-	3	-	-	2	1	-	-	-	3	-	2	-	-	1	-	-	-	-	-	-	-	-	-	
GR	1	95	8	19	-	136	2	41	5	-	7	-	-	102	60	-	-	-	-	-	-	-	-	1	2	-	-	-	1	-	2	-	-	-	-	-	
GR	1	96	5	7	-	-	-	12	26	-	9	-	-	17	-	-	-	2	-	-	-	-	-	-	3	34	7	-	-	-	-	-	-	-	-	-	
GR	1	96	7	18	-	37	2	8	19	-	-	-	-	16	-	-	-	-	-	1	-	-	-	14	5	-	4	1	-	-	2	-	-	-	-	-	
GR	1	96	8	62	7	-	-	6	19	-	27	-	-	14	17	-	-	11	-	-	-	-	-	-	1	-	7	1	-	-	-	-	-	-	-	-	
GR	1	96	9	46	-	26	1	4	51	-	2	-	1	40	4	-	-	-	-	2	-	-	-	1	-	21	4	-	-	1	-	-	-	-	-	-	

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthocladinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
GR 1	96	6	32	-	-	-	5	1	-	243	-	-	81	-	-	-	4	-	1	-	-	9	-	-	-	5	-	-	-	-	-	-	-	-	-	-
GR 2	0	8	3	-	78	12	16	-	-	8	2	-	18	12	-	6	8	5	3	-	3	-	5	1	-	-	1	-	-	-	-	-	-	-	1	-
GR 2	95	9	41	4	102	1	1	6	-	-	-	-	43	1	-	-	1	-	-	-	-	-	-	-	-	5	-	-	-	3	1	-	-	-	-	
GR 2	95	8	23	2	154	6	9	14	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1	-	3	-	-	-	-	-	-	-	-	-	
GR 2	96	9	25	1	-	-	2	19	1	1	-	-	1	6	1	-	-	-	-	4	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	
GR 2	96	7	16	-	15	6	27	7	2	-	-	-	12	-	-	-	1	-	-	-	5	-	11	3	11	2	-	3	-	3	-	-	-	-	-	
GR 2	96	8	41	3	-	-	2	43	-	47	-	-	3	23	-	-	8	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-	-	-	-	
GR 2	96	5	3	-	-	-	31	2	8	15	-	5	5	40	-	-	1	2	20	-	-	-	-	-	8	-	3	-	-	-	-	1	11	-	-	
GR 2	96	6	51	1	-	1	3	12	-	152	-	-	114	38	-	-	3	-	-	-	1	1	1	-	-	3	2	-	-	-	-	-	-	1	-	
GR 3	1	8	24	-	-	-	4	9	-	5	-	-	7	-	-	1	1	-	-	-	-	-	11	-	-	12	-	-	-	2	-	-	-	-	-	
GR 3	95	9	21	-	142	6	5	6	-	30	-	-	45	-	-	-	2	-	-	-	-	-	-	-	-	3	2	-	-	4	-	-	-	-	-	
GR 3	95	8	-	-	-	-	-	-	-	-	-	-	-	163	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
GR 3	96	6	14	-	-	-	8	28	-	1	-	-	-	5	-	-	-	-	1	-	-	-	24	-	1	-	-	-	-	-	-	-	-	-	-	
GR 3	96	5	-	1	-	-	-	-	1	30	-	3	3	33	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	6	-	-	-		
GR 3	96	9	33	3	6	-	4	22	-	3	-	-	12	2	-	-	-	-	1	-	2	-	-	-	33	1	-	1	-	3	-	-	-	-		
GR 3	96	7	85	-	2	3	4	23	1	2	-	-	17	-	-	-	-	-	-	-	16	1	6	2	-	10	-	-	-	-	-	-	-	-	-	
GR 3	96	8	51	6	-	-	3	18	-	36	-	-	-	22	-	-	13	-	2	-	-	-	1	-	-	3	-	-	-	1	-	-	-	-	-	
GR 4	1	8	22	-	-	-	1	3	-	3	-	-	1	-	-	-	-	1	-	-	-	-	2	-	-	2	-	-	-	1	-	-	-	-	-	
GR 4	95	9	17	-	83	2	2	5	-	26	-	-	26	-	-	-	3	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	
GR 4	96	9	15	-	-	-	2	4	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	-	-	-	-	
GR 4	96	8	15	-	13	4	1	4	-	2	-	-	3	17	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	
GR 4	96	7	17	-	147	31	2	3	-	4	-	-	17	4	-	-	4	-	-	-	1	-	6	3	-	-	2	-	-	-	-	-	-	-	-	
GR 5	1	8	18	-	1	-	12	37	-	12	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	5	-	-	-	-	-	

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera	
GR 5 95 9 12	5	95	9	12	-	6	-	10	38	-	-	-	-	5	2	-	-	-	-	-	-	-	-	-	-	33	-	2	-	-	3	-	-	-	-	-	
GR 5 96 9 34	5	96	9	34	-	-	-	3	9	-	-	-	-	2	-	-	-	-	-	5	-	-	-	-	-	3	-	-	-	-	2	-	-	-	-	-	
GR 5 96 7 47	5	96	7	47	1	1	2	14	26	3	2	-	-	17	3	-	-	1	-	2	-	5	-	4	2	-	9	-	-	-	-	-	-	-	-	-	
GR 5 96 8 49	5	96	8	49	2	47	2	12	16	5	25	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	-	-	
GR 6 1 8 5	6	1	8	5	-	2	-	10	1	-	10	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	7	-	-	-	36	-	-	-	-	-	
GR 6 96 9 11	6	96	9	11	-	-	-	-	8	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	
GR 6 96 7 57	6	96	7	57	-	7	-	6	20	1	-	-	-	14	-	-	-	2	-	1	-	7	-	1	-	-	5	-	-	-	-	-	-	-	-	-	-
GR 6 96 8 8	6	96	8	8	-	48	2	33	22	13	2	-	-	3	4	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-
GR 7 1 8 32	7	1	8	32	1	-	-	7	-	-	3	1	-	14	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-
GR 7 96 7 7	7	96	7	7	-	2	4	-	5	1	-	-	-	1	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
GR 7 96 9 37	7	96	9	37	2	14	1	10	29	2	-	-	-	8	2	-	-	-	-	-	-	3	-	-	-	17	2	-	1	-	1	-	-	-	-	-	-
GR 8 1 8 12	8	1	8	12	1	1	1	13	29	-	9	-	-	7	-	-	-	5	-	-	-	-	-	-	-	-	23	-	-	-	5	-	-	-	-	-	-
GR 8 96 7 8	8	96	7	8	-	1	1	6	2	2	-	-	-	-	13	-	-	-	-	-	-	8	-	4	1	3	7	2	1	-	-	-	-	-	-	-	-
GR 8 96 9 47	8	96	9	47	-	9	-	10	7	-	-	-	-	8	1	-	-	-	-	-	-	-	-	-	-	16	-	1	1	-	20	-	-	-	-	-	-
GR 9 1 8 29	9	1	8	29	-	-	-	5	48	-	7	-	-	9	-	-	-	2	-	-	-	-	-	-	2	-	8	-	-	-	12	-	-	-	-	-	-
GR 9 96 7 13	9	96	7	13	-	41	11	1	2	1	12	-	-	7	6	-	-	-	1	6	-	2	-	3	1	6	-	-	-	-	-	-	-	-	-	-	-
GR 10 1 8 9	10	1	8	9	-	1	-	8	25	-	5	-	-	6	-	-	-	3	-	1	-	-	-	-	-	-	12	-	-	-	7	-	-	-	-	-	-
GR 11 1 8 49	11	1	8	49	5	-	-	13	61	-	2	-	-	23	-	-	1	1	-	-	-	-	-	-	-	-	42	-	-	-	1	-	-	-	-	-	-
GR 12 1 8 26	12	1	8	26	1	-	7	10	28	-	8	-	-	14	-	-	1	-	-	-	-	-	-	-	-	-	7	-	-	-	13	-	-	-	-	-	-
GR 13 1 8 11	13	1	8	11	-	1	4	5	30	-	-	-	-	33	-	-	-	2	-	-	-	-	-	-	-	-	8	-	-	-	50	-	-	-	-	-	-
GR 14 1 8 2	14	1	8	2	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-
GR 15 1 8 1	15	1	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GR 16 1 8 17	16	1	8	17	3	1	12	2	-	-	1	-	-	17	-	1	-	-	-	-	-	-	-	-	-	-	18	-	-	-	5	-	-	-	-	-	-

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera	
GR 17	1	8	42	-	-	-	1	54	-	23	-	-	17	-	-	-	4	-	-	-	-	-	7	-	-	12	-	-	-	-	7	-	-	-	-	-	
GR 18	1	8	6	-	1	-	5	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	3	-	-	2	-	-	-	-	-	-	-	-	-	-	
GR 19	1	8	26	-	2	-	4	10	-	9	-	-	14	-	-	1	3	-	-	-	-	-	-	-	-	5	-	-	-	-	8	-	-	-	-	-	
GR 20	1	8	23	-	-	-	3	-	-	15	-	-	3	-	-	26	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
GR 21	0	8	2	-	34	-	3	2	-	21	4	-	7	1	-	5	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
GR X	96	9	42	-	18	-	9	54	1	1	-	-	17	10	-	-	-	-	-	-	-	-	-	-	-	14	16	-	1	-	-	-	-	-	-	-	
GR Y	96	6	26	-	1	-	7	10	-	-	-	-	115	277	-	-	6	-	46	-	-	-	8	15	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 1	95	8	74	17	15	-	2	2	1	2	-	-	-	19	-	-	2	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 1	96	9	72	-	-	-	-	9	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 1	96	5	70	-	-	-	1	2	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	2	-	-	-	-	-	-	-	-	-	-
SHR 1	96	7	7	-	40	31	-	-	-	5	-	-	9	-	-	-	-	-	-	2	-	2	-	1	1	-	-	-	2	-	-	-	-	-	-	-	-
SHR 1	96	6	21	-	-	-	-	17	-	38	-	-	6	-	-	-	2	2	-	-	-	-	26	3	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 1	96	8	126	-	5	1	-	4	-	94	-	-	-	-	-	-	3	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 2	1	8	61	8	-	-	-	-	-	2	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-
SHR 2	95	8	2	-	-	-	-	-	-	2	-	-	-	29	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
SHR 2	96	9	1	-	-	-	-	4	-	-	-	-	-	2	-	-	-	-	-	25	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
SHR 2	96	5	57	-	-	-	-	-	-	13	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-	-
SHR 2	96	6	49	2	-	-	-	2	-	22	28	-	-	-	-	-	-	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 2	96	7	89	-	4	1	-	-	-	12	-	-	2	-	-	-	-	-	-	-	-	1	-	2	-	-	15	-	1	-	-	-	-	-	-	-	-
SHR 2	96	8	75	2	18	1	-	5	-	118	-	-	-	-	-	-	-	-	-	-	-	-	-	16	-	-	-	1	-	-	-	-	-	-	-	-	-
SHR 3	1	8	63	2	-	-	-	-	-	2	-	-	1	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 3	95	8	41	1	1	1	1	-	-	13	-	-	-	-	-	-	1	2	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 3	96	5	2	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthocladinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
SHR 3	96	9	28	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	7	-	-	-	-	-	-	-	-	-	-	
SHR 3	96	7	24	-	15	8	1	8	1	1	-	-	-	-	-	-	-	-	-	3	-	-	-	5	1	1	-	-	-	-	-	-	-	-	-	-
SHR 3	96	8	26	-	2	-	-	5	-	-	-	-	-	1	79	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-
SHR 4	1	8	68	1	-	-	-	-	-	-	8	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 4	95	8	23	-	50	4	1	1	-	5	-	-	-	-	-	-	-	3	-	-	1	-	-	2	-	1	82	2	-	-	-	-	-	-	-	-
SHR 4	96	7	31	1	-	-	1	1	2	12	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 4	96	9	85	-	-	-	-	14	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	13	4	-	-	-	-	-	-	-	-	-	-
SHR 4	96	8	35	-	-	1	-	6	-	-	-	-	-	3	78	-	-	4	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
SHR 5	1	8	168	-	-	-	2	-	-	2	-	-	-	-	-	-	9	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 5	95	8	13	-	15	3	19	3	-	7	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	1	-	-	-	-	-	-	-	-	-	-
SHR 5	96	9	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 5	96	8	23	-	-	-	-	2	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
SHR 5	96	7	211	2	-	-	2	3	1	39	-	-	-	-	-	-	-	-	2	-	1	-	2	2	2	2	2	-	2	-	-	-	-	-	-	-
SHR 6	0	8	35	1	-	-	7	-	-	36	-	-	13	-	-	10	1	-	1	-	-	-	-	-	15	-	1	-	-	-	-	-	-	-	-	-
SHR 6	95	8	28	2	24	3	10	59	1	4	-	-	-	-	-	-	-	-	-	-	4	-	-	1	3	2	-	-	-	7	-	-	-	-	-	-
SHR 6	96	7	3	-	1	1	-	8	-	3	-	-	2	-	-	-	-	-	-	-	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-
SHR 6	96	8	29	4	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 6	96	9	47	-	-	-	-	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2	11	-	-	-	-	-	-	-	-	-
SHR 7	0	8	24	2	-	-	1	-	-	10	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-
SHR 7	95	8	58	-	88	31	13	7	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	7	1	2	-	-	-	-	-	-	-	-	-
SHR 7	96	9	38	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	3	-	-	-	-	-	-	-	-	-	-	-
SHR 7	96	8	8	1	2	-	2	2	-	23	-	-	-	4	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 7	96	7	14	-	5	-	-	1	-	3	-	-	9	142	-	-	20	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthoclaadiinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera	
SHR 8 0 8 36	6	-	-	4	-	-	20	-	-	3	-	-	-	3	-	1	-	-	-	-	-	-	-	-	1	4	1	-	-	-	-	-	-	-	-		
SHR 8 95 8 28	6	20	6	1	10	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	
SHR 8 96 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 8 96 9 20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	1	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-	
SHR 8 96 7 38	1	1	-	8	-	5	-	-	58	-	-	-	3	-	-	-	-	3	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 9 0 8	-	-	-	-	-	-	-	-	3	-	-	2	-	-	-	-	-	-	-	-	-	-	9	-	-	4	-	-	-	-	-	-	-	-	-	-	-
SHR 9 95 8 51	13	45	1	3	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 9 96 9 8	-	-	-	-	4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	
SHR 9 96 7	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	2	-	-	-	-	-	8	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHR 10 0 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	
SHR 10 95 8 48	3	9	5	-	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	-	-	-	
SHR 10 96 7	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SHR 10 96 9 14	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	
SHR 11 0 8	-	-	-	-	-	-	-	-	-	6	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	22	-	7	-	-	-	-	-	-	-	-	
SHR 11 96 7 56	-	1	-	2	-	3	-	-	1	2	-	-	-	-	1	-	-	-	-	1	-	-	1	3	2	-	-	-	-	-	-	-	-	-	-	-	
SHR 12 96 7 29	1	1	-	1	-	-	6	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	
SHR 13 0 8 19	1	-	1	-	-	8	-	-	6	-	-	7	1	-	1	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	
SHR 13 96 7 9	-	6	1	25	3	3	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	8	-	-	-	-	-	-	-	-	-	-	-	
SHR 14 0 8 30	7	-	-	-	-	10	-	-	5	-	-	4	-	-	-	-	-	1	2	-	-	-	2	-	-	1	5	-	-	-	-	-	-	-	-	-	
SHR 15 0 8 14	-	-	-	1	-	-	6	-	-	4	-	-	2	-	2	-	-	2	-	2	-	-	-	-	7	-	1	-	-	-	-	-	-	-	-	-	
SHR 16 0 8 2	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	1	-	-	-	-	-	-	-	-	-	
SHR 17 0 8 1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	5	-	-	-	-	-	-	-	-	-	-	-	
SHR 18 0 8 11	3	-	-	1	1	-	6	-	-	2	-	-	3	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	

Appendix 5 Continued...

Species	Number	Year	Month	Hydropsychidae	Trichoptera_Pupae	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Tipulidae	ChironomidaeA	ChironomidaeB	Ceratopogonidae	Tanypodinae	Axarus	ChironomidaeI	ChironomidaeJ	Orthocladinae	Simuliidae_Pupae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentridae	Plecoptera	Sphaeriidae	Coleoptera	Gomphiidae	Acara_Mites	Gastropoda	Nematodes	Ostracoda	Copepoda	Corixidae	Cladocera
SHR 19	0	8	13	-	-	-	-	-	-	-	3	-	-	2	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
SHR 20	0	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	12	-	1	-	-	-	-	-	-	-	-	-
SHR 22	0	8	15	-	-	-	3	5	-	-	1	-	1	5	2	-	6	3	3	-	-	-	-	9	7	10	-	1	-	-	-	-	-	-	-	-
SHR 23	0	8	45	6	-	-	-	-	-	-	12	-	-	-	-	-	-	1	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
SHR 24	0	8	57	-	-	-	6	-	-	-	5	-	-	21	-	-	2	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 6. Raw benthic invertebrate data collected from the DFO Lido Plage IFIM study site on the Assiniboine River, MB.

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	ChironomidaeI	ChironomidaeJ	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle								
1	1	A	19	7	1	4	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-									
1	1	A	25	9	1	4	4	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	2	11	1	-	-	-	-	-	-	-	-	-	-	-	-								
1	1	B	19	7	1	4	4	-	-	-	-	-	-	-	1	-	3	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	1	-	-	-							
1	1	B	25	9	1	4	4	-	-	-	-	-	-	-	2	1	-	1	-	-	-	-	-	-	-	-	-	-	11	1	-	-	-	-	-	1	18	3	-	-	-	-	-	-	-	-	-	-	-	-	-							
1	1	C	19	7	1	4	4	-	-	-	-	-	-	-	8	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-								
1	1	C	25	9	1	4	4	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	1	-	-	-	-	7	-	-	-	-	-	-	-	2	35	7	-	-	-	-	-	-	-	-	-	-	-	-								
1	1	D	19	7	1	4	4	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-								
1	1	D	25	9	1	4	4	-	-	-	-	-	-	-	23	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
1	1	E	19	7	1	4	4	-	1	-	-	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
1	1	E	25	9	1	4	4	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
1	2	A	19	7	1	4	4	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
1	2	A	25	9	1	4	4	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
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Appendix 6 Continued...

[illegible]

Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	ChironomidaeI	ChironomidaeJ	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	ChironomidaeI	ChironomidaeJ	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	ChironomidaeI	ChironomidaeJ	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle						
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Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	Chironomidae i	Chironomidae j	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle																																																																																																																																																																																																																																																																																																																																																																																																			
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Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	ChironomidaeI	ChironomidaeJ	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle								
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Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	ChironomidaeI	ChironomidaeJ	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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Appendix 6 Continued...

[illegible]

Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	Chironomidae i	Chironomidae j	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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Appendix 6 Continued...

[illegible]

Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	ChironomidaeI	ChironomidaeJ	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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9	2	B	25	9	1	4	4	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	Chironomidae i	Chironomidae j	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle									
9	5	B	25	9	1	6	6	-	2	-	-	6	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	5	1	-	-	-	-	-	-	14	7	-	-	-	-	-	-	-	-	-	-	-							
9	5	C	25	9	1	6	6	3	3	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-							
9	5	D	25	9	1	6	6	-	-	-	2	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-							
9	5	E	25	9	1	4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	2	-	-	-	-	-	-	2	1	-	-	-	1	-	-	-	1	-	-	-	-							
10	1	A	19	7	1	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
10	1	A	25	9	1	3	3	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	16	-	-	1	-	-	-	-	-	-	-	-	-	-							
10	1	B	19	7	1	4	4	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-							
10	1	B	25	9	1	3	3	-	-	-	-	1	-	-	40	-	-	-	-	-	-	-	-	1	12	-	-	-	-	1	-	-	2	-	-	-	-	-	21	-	-	-	-	1	-	-	-	-	-	-	-	-							
10	1	C	19	7	1	4	4	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
10	1	C	25	9	1	4	4	-	-	-	-	1	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
10	1	D	19	7	1	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
10	1	D	25	9	1	4	4	-	-	-	-	1	-	40	-	-	8	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
10	1	E	19	7	1	4	4	-	-	-	-	-	-	41	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
10	1	E	25	9	1	4	4	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
10	2	A	19	7	1	4	4	1	1	-	4	6	-	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	2	-	6	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
10	2	A	25	9	1	4	4	-	-	-	-	-	-	-	2	-	3	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	7	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-					
10	2	B	19	7	1	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
10	2	B	25	9	1	4	4	-	-	-	-	2	-	17	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-				
10	2	C	19	7	1	4	4	-	-	-	1	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
10	2	C	25	9	1	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
10	2	D	19	7	1	4	4	1	-	-	1	3	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
10	2	D	25	9	1	4	4	-	-	-	-	-	-	-	3	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10	2	E	19	7	1	4	4	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10	2	E	25	9	1	4	4	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 6 Continued...

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Appendix 6 Continued...

Cross-Section	Transect	Sample	Day	Month	Year	Substrate_1	Substrate_2	Hydropsyche	Caenidae	Tricorythodae	Elmidae	Heptageniidae	Axarus	Tipulidae	Chironomid a	Chironomid b	Ceratopogonidae	Tanypodinae	Chironomid e	Chironomid f	Chironomid g	Chironomid h	Chironomidae i	Chironomidae j	Orthocladinae	Empididae	Hexagenia	Ephoron	Polymitarcyidae	Isonychia	Brachycentris	Plecoptera	Sphaeriidae	Coleoptera 1	Gomphiidae	Amphipoda	Gastropoda	Nematoda	Ostracoda	Copepoda	Acara_Mites	Corixidae	Cladocera	limpets	Adult_Diptera	Adult_Mayflies	Oligochaeta	Curculionidae	Cnidaria_Hydra	Water_Beetle											
10	5	C	19	7	1	6	5	1	2	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	11	-	1	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-									
10	5	C	25	9	1	6	6	2	-	-	1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-									
10	5	D	19	7	1	6	6	1	1	-	1	4	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-									
10	5	D	25	9	1	1	5	2	10	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	2	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-									
10	5	E	19	7	1	6	6	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-									
10	5	E	25	9	1	1	5	3	7	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	1	-	1	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-								
12	1	A	19	7	1	2	1	1	3	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	2	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
12	1	B	19	7	1	2	1	-	11	3	-	2	4	-	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-						
12	1	C	19	7	1	2	1	-	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	45	-	-	-	-	-	1	-	6	-	54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
12	1	D	19	7	1	1	1	-	4	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1	-	-	-	20	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-						
12	1	E	19	7	1	1	2	-	7	-	-	-	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	3	-	-	4	-	-	-	2	-	76	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-						
12	2	A	19	7	1	5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
12	2	B	19	7	1	4	5	-	-	-	-	-	-	-	3	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
12	2	C	19	7	1	5	4	2	1	1	2	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
12	2	D	19	7	1	4	5	1	-	-	-	-	-	-	3	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
12	2	D	25	9	1	4	4	-	-	-	-	-	-	-	24	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
12	2	E	19	7	1	4	5	3	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
12	3	A	19	7	1	4	4	-	-	-	-	-	-	-	3	-	-	-	-	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
12	3	B	19	7	1	4	4	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	3	C	19	7	1	4	4	-	-	-	-	-	-	-	4	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-									

Appendix 6 Continued...

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