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HABITAT AVAILABILITY AND ITS UTILIZATION BY 11 SPECIES OF FISH FROM THE ASSINIBOINE RIVER, MANITOBA, WITH SPECIAL REFERENCE TO HABITAT PROCESSES

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Physical habitat and fish occurrence data were collected over a 160-kilometre reach of the Assiniboine River, Manitoba, to elucidate the patterns of habitat use by fish species. The longitudinal distributions of substrates were determined largely by glacial till plain exposures and glacial Lake Agassiz deposits. The interaction between erosion, transport, and deposition created regular patterns of substrates of fine and coarse sediments, while discharge had subsidiary affects on sand substrates. The most frequent depth intervals were 0.61-1.80m and 0.81-2.00m in bank and channel habitats respectively. The most frequent velocities were 0.31-0.80m/s and 0.51-1.00m/s in bank and channel habitats respectively. Bank substrates tended to be equitably distributed, while sand and rippled-sand dominated channel substrates. Other noticeable differences were that clay, the transition of till plain exposures between deposition and transport states and submerged trees were more abundant in bank habitats. Depths increased 0.55-0.60m and velocity increased on average 10 cm/s for every 50m^3/s increase in discharge. Depth varied approximately 1.8m from the highest to lowest discharge (220-49m^3/s). Substrate area increased with increased discharge during this study only when the spring flood inundated riverbanks. We were unable to estimate weighted useable area (WUA) properly because we did not encounter discharges below 49m^3/s. Fish over-utilized depths of 0.21-1.60m and 0.61-1.20m in bank and channel habitats respectively. Fish occurrences, in relation to velocity, showed two distinct ranges (0-0.40m/s and 0.71-1.20m/s) were over-utilized in bank habitats, while in channel habitats, a narrow range of intermediate velocities were over-utilized (0.51-0.90m/s). Ten of the sixteen substrates were over-utilized by fish in bank habitats, while only three substrates (gravel-cobble, cobble-boulder, and sand-cobble) were over-utilized in channel habitats. Fish generally over-utilized coarser substrates of exposed glacial till plain, indicating that broad distributions are determined largely by large-scale geology. An exception was the quillback which utilized sandier substrates more frequently in channel habitats. Bank habitats had a greater variety of substrates than channel habitats, which we attributed to increased substrate heterogeneity and equitability of substrate distribution along banks as compared to the centre of channels.

Nous avons recueilli des données sur l'habitat physique et l'occurrence des poissons dans un tronçon de 160 km de la rivière Assiniboine, au Manitoba, pour mieux connaître les profils d'utilisation des habitats par les différentes espèces. Les distributions longitudinales des substrats étaient déterminées en bonne partie par la présence de plaines de till à découvert et de dépôts glaciaires du lac Agassiz. L'interaction entre l'érosion, le transport et le dépôt a produit des profils réguliers de substrats de sédiments fins et grossiers, tandis que le débit avait un effet secondaire sur les substrats de sable. Dans les habitats des bancs et des chenaux, les intervalles de profondeur les plus fréquents étaient 0,61-1,80 m et 0,81-2,00 m respectivement, et les vitesses, 0,31-0,80 m/s et 0,51-1,00 m/s respectivement. Les substrats des bancs étaient répartis assez également, alors que le sable et le sable ondulé dominaient dans les substrats des chenaux. Parmi les autres différences observables, nous avons noté que l'argile, la transition des plaines de till à découvert de la phase de dépôt à la phase de transport et les arbres submergés étaient plus abondants dans les habitats des bancs que dans les habitats des chenaux. Chaque fois que le débit augmentait de 50 m^3/s, les profondeurs augmentaient de 0,55-0,60 m, et la vitesse, de 10 cm/s en moyenne. La profondeur variait environ de 1,8 m entre le débit le plus fort et le débit le plus faible (220-49 m^3/s). Au cours de l'étude, c'est seulement après l'inondation des berges par les crues printanières que la superficie de substrats a augmenté avec le débit. Nous avons été incapables d'estimer adéquatement la superficie utilisable pondérée, car nous n'avons pas mesuré de débits inférieurs à 49 m^3/s. Les poissons surutilisaient les profondeurs de 0,21-1,60 m et de 0,61-1,20 m dans les habitats des bancs et des chenaux respectivement. Les occurrences des poissons ont montré que deux plages distinctes de vitesse (0-0,40 m/s et 0,71-1,20 m/s) étaient surutilisées dans les habitats des bancs. Dans les habitats des chenaux, par contre, seule une petite plage de vitesse intermédiaire était surutilisée (0,51-0,90 m/s). Dix des seize substrats étaient surutilisés par les poissons dans les habitats des bancs, tandis que seulement trois substrats (gravier-cailloux, cailloux-blocs et sable-gravier) l'étaient dans les habitats des chenaux. Les poissons surutilisaient généralement les substrats grossiers des plaines de till à découvert, ce qui indique que les grandes lignes des distributions sont habituellement déterminées par la géologie à grande échelle. La couette était l'exception : elle utilisait davantage les substrats sableux des habitats des chenaux. Les habitats des bancs présentaient une plus grande variété de substrats que les habitats des chenaux. Nous expliquons ce fait par l'hétérogénéité des substrats et l'uniformité de leur distribution le long des bancs comparativement au centre des chenaux.

INTRODUCTION

The Assiniboine River drainage is an important prairie drainage of about 153,000 km^2 in area in Saskatchewan, North Dakota and Manitoba. Much of the land in the drainage is in agricultural uses with concomitant large and growing water consumption. Due to increased water demands and a lack of knowledge on fish and fish habitat in the river, a study was undertaken to examine the habitat use by various species inhabiting the river. Presently the method of choice for determining in-stream flow requirements for fish by many jurisdictions is the instream flow incremental methodology (IFIM). IFIM is a set of software modules developed by Bovee and coworkers from the U.S. Fish and Wildlife Services (Bovee 1978) originally for use in small cold water streams of the western United States. Many U.S. states and some Canadian provinces have adopted IFIM as a standard for recommending minimum instream flows for fish.

Both local and regional processes affect flow patterns and substrate compositions in every river. The regional processes at work in the Assiniboine River are slope, the distribution of glacially derived alluvial and deltaic deposits (Rannie et al., 1989), and resistant till exposures (E. Nielsen MB Department of Energy and Mines, personal communication). The local processes of erosion, transport, and deposition determine substrates within these constraints. The radii of curvature of meanders and available substrate material, in concert with discharge, produce the substrate patterns observed at any particular time and reach of the river. In this study, we set out to determine the distribution of fish species in relation to the available habitats in a portion of the Assiniboine River. Our objective was to produce fish preference curves that would be suitable for use in IFIM and other fish habitat models, and to learn what processes were important in determining the distributions of substrate, depth, velocity, and the resident fish populations.

MATERIALS AND METHODS

STUDY SITE

The Assiniboine River can be characterized as a low-slope, turbid, prairie river. The river has an average slope over its 1866km length of 35cm/km. Downstream of a major dam and reservoir at Shellmouth, at about kilometre 896, the slope averages only 20cm/km (Andres and Thompson 1995). The final reach of the river, where this study took place, has an average slope of 17cm/km (Andres and Thompson 1995). The Assiniboine River has 49 species of fish, including many recreationally important species. The study area was a 162-kilometre-length of the river between the flood control dam at Portage la Prairie and the river's confluence with the Red River at Winnipeg (Figure 1). This reach of the river has a minimal non-agricultural riparian zone of thin gallery forest composed of peachleaf willow, green ash, elm, cottonwood, and to a lesser extent, basswood and burr oak.

SAMPLING

The river was stratified into sixteen 10-kilometre blocks for sampling. Within each 10-kilometre block, three one-kilometre sample sites were selected randomly at each of seven sampling periods. Each one-kilometre site was divided into three equal and sequential transects: the first along the right bank, the second in the center of the channel, and the third along the left bank (looking downstream) (Figure 2). Fish samples were collected using an electro-shocking boat (450 volts pulsed DC; 2.5-3.5 amperes) for 150 seconds drifting downstream. Fish were captured, placed in a holding tank, identified, measured for length and returned to the water after sampling. Fish, identified by sight were counted but not measured. Depth and substrate data were collected as habitat variables along the length of each transect, while velocities were measured only at the beginning of each transect. Depths were measured to the nearest cm using a graduated 5m-aluminum pole. Velocities were measured or estimated at 6/10 depth using a variety of methods including an electronic velocity meter, Pygmy meter, an Ottmeter, and occasionally, a floating orange. Surface velocities acquired using the floating orange were calibrated to velocity at 6/10 depth with the Ottmeter. Substrate particle size was assessed remotely using a 5-meter aluminum pole as sensor and categorized as one of 16 classes (Table 1).

PHYSICAL HABITAT VARIABLES

The effects of discharge on river depth and velocity were determined. The relationship of depth to discharge was determined by regression of data from the Lido Plage area cross sections (Steffler et al 1997). Centre station depths and velocities collected along the whole reach during 1996 were used in similar calculations to determine the relationship of average depth and velocity at centre stations to discharge on sample dates.

The substrate classes reported for the transects were simplified to the dominant substrates for each transect. Substrate assessments were verified using Ponar grabs and by visual checks of some reaches at a short-term low flow event (<15 m^3/s) in May 1997. Seven sampling runs were completed; August 1995, September 1995, and five consecutive monthly runs from May to September 1996. Both 1995 and 1996 were high flow years with return frequencies of about 25 and 20 years respectively (Figure 3) and few of our sampling periods had typical discharge for the time of year. Fish species utilization curves, which follow, are divided into bank and channel habitats.

ESTIMATES OF SUBSTRATE AREAS IN RELATION TO DISCHARGE

The total amounts of the various substrate classes in the river were determined by extrapolation from the frequencies of occurrence of the randomly obtained substrate identifications as the product of the mean width of the river, determined from digitized aerial photography, times the length of the reach (162 km). Width was measured from the digital file at each kilometre using AutoCAD software (Image taken in April 1988; average discharge 49 m^3/s). Bank transects arbitrarily were designated a width of five metres at our lowest flows (approximately 50 m^3/s) with the remainder of the river designated as channel or mid-river substrates. We believe this is a reasonable approximation of the width of bank substrates until we have accurate measured the distributions of substrates along the margins of the river accurately at different discharges. The increase in river width with discharge was determined by regression of measured widths at the different discharges obtained from 12 surveyed cross-sections taken between 42 and 43 kilometres from the confluence (Lido Plage area) output from the CDG2D model of Steffler et al (1997). Within the range of 25 to 150 m^3/s, the width increased about 5% for each 50 m^3/s increase in discharge in a very tight relationship (Figure 5). An average width of 14 cross-sections within that same kilometre taken from the digital file fell within the 95% confidence intervals of the regression. The increase in river width due to increasing discharge above 50 m^3/s was applied to bank substrates only because the channel substrates generally would be unaffected by increasing width, particularly at flows greater than 100 m^3/s above which the river starts to exceed bankfull stage. These data were used to generate areas of substrate classes in channel and bank transects at the range of flows encountered in our 1996 sampling runs to provide estimates of effects of discharge on substrate availability. The frequency histogram of width at 10-km intervals is roughly normally distributed and conceivably the distribution could weight the calculated areas in different river segments. However, areas of substrates calculated from width-distribution-weighted data fell within 95% confidence intervals of areas calculated from the unweighted mean width so the latter areas were used.

HABITAT UTILIZATION/AVAILABILITY HISTOGRAMS

Microhabitat utilization criteria derived from the IFIM are dependent upon the collection of species presence - absence data. An observation of a particular species at a particular location is considered an observation for each microhabitat variable measured. The utilization criteria are histograms of the frequencies of observations for that species over a range of microhabitat values for each measured variable (definitions after Peters et al., 1989).

Utilization is defined as:

U_{axi} = Total observations of species *i* for category *x* within a variable *a*. The percent utilization is calculated by dividing the observations of a species at a habitat category by the total number of times that habitat variable was sampled.

$$U_{axi} = (U_{axi}/\Sigma U_{axi})$$

Availability of habitats from among the conditions present in the river are important considerations for the calculation of habitat preferences. Availability histograms show the frequencies of occurrence of categories based on measurements taken at grid locations and are defined as:

A_{ax} = Frequency distribution of habitat categories x within a variable a. Percent availability is calculated by dividing the observations for a category by the sum of all category values present within a variable and multiplying by 100.

$$A_{ax} = (A_{ax}/\Sigma A_{ax})$$

Although the IFIM methodology has been employed by many researchers seeking criteria on which to base management strategies, we have taken a slightly modified approach due to the coarser nature of our sampling protocol. Instead of using only presence/absence data we used abundance-weighted data. We felt this was a more useful assessment because total biomass is a more likely target for management recommendations. The advantages and disadvantages of using abundance-weighted and unweighted preference curves are discussed by Aadland et al. (1989). Because of the complex effects of the interaction of regional and local processes, we divided the substrates into three categories: erosion, transport, and deposition. Within each category, the substrates were ranked according to particle size classes for development of utilization and availability curves. These adjustments were performed for comparison to the classical IFIM approach, as they may provide a better understanding of the relationship between physical habitat and lotic processes affecting the habitats. Considering that these processes are the main factors affecting the habitat variables, we feel this approach is warranted.

SPECIES UTILIZATION SUMMARY

A summary of the utilization of the habitat variables by the 11 species is provided by using a minus (-) to mark under-utilization, a plus (+) to mark over-utilization and a zero (0) to mark not utilized. The number of species which over-utilized variable categories was summed across all species to elucidate key ranges of depth and velocity and key substrate categories. We tabulated these results for both bank and channel habitats; depth (Table 2), velocity, and substrate (Table 3).

SPECIES ABUNDANCE PATTERNS IN RELATION TO PROCESS

We examined further the relationships among fish occurrence and substrates by way of re-sampling of our data set using MATLAB 5.0 for Macintosh (Programming by Cory Gunter-Smith, Department of Engineering, University of Manitoba). Thirteen samples were taken from the fish species habitat dataset 500 times (with replacement) to provide estimates of abundance at the same sample size (thirteen samples were used because that was the largest number of samples where all substrates had been sampled — i.e., re-sampling was restricted to within observed data). The abundance matrices were sorted by substrate type in the three major categories of bank substrates and channel substrates (all of which would fall into erosion-transport-deposition categories depending on discharge) (Figure 37).

RESULTS

PHYSICAL HABITAT VARIABLES

The longitudinal distributions of substrate types in the Assiniboine River are affected largely by glacial deposits of till, former glacial Lake Agassiz bottom sediments, and deltaic deposits (Elson 1967), with gravel, cobble and boulder occurrences being restricted to areas where the river flows over rises in the glacial till-plain (E. Nielsen MB Dept. Energy and Mines personal communication). Long stretches of sandy substrates are dominant and locally interrupted as the river flows through meanders where the characteristic patterns of erosion, transport, and deposition (Figure 4) occur. Erosion is characteristic of deeper outside bends, while transport occurs through sandy runs. Deposition occurs on inside bends and along the margins of runs, with concomitant changes in depth and velocity. Downstream of the apices of inside bends, as a meander entered the next run, substrates of soft fine sand to silty sand and silt were often observed. The distributions of substrates also were affected by the degree of curvature of the meanders. Coarse sand was evident in scoured regions but was very discontinuous in distribution. Rippled sand substrates occurred in sand reaches as flow patterns under relatively stable discharge regimes produced standing waves in loose sand. Sand/gravel, and sand/cobble substrates occurred when bedload sand moved over exposed glacial till.

The average frequencies of occurrence of the sixteen classes we used to classify substrates in the study reach of the Assiniboine River are shown in Figure 6. Frequencies of occurrence of velocity and depth measurements in the river segment are shown in Figures 7 and 8. Regression of water surface elevations on discharge at Lido Plage cross sections indicated an increase of 0.60 m for each increase of 50 m^3/s in discharge in the range of 25 - 150 m^3/s (Figure 9). A similar analysis of depth and velocity measurements, on the whole, reach at discharges recorded on sample dates provided a similar relationship — about 0.55m increase in depth and about 10cm/s increase in velocity for each 50 m^3/s increase in discharge (Figures 10 and 11). Supporting evidence for these analyses comes from the stage:discharge curve for the Headingley gauging station. Water surface elevation increases approximately 0.41m for each 50 m^3/s increase in discharge in the same range of discharges (Figure 12) (data courtesy of Manitoba DNR, Water Resources Branch).

The expected range in depths, as predicted by the regression of depth on discharge at the Lido Plage site, indicates that we should have encountered about 1.9m variation in depth from our lowest (49 m^3/s) to highest (220 m^3/s) flows. The regression of the depths we measured during our 1996 sampling runs on discharge yielded a difference of 1.8m between the lowest and highest discharge. A similar calculation for the Headingley station provides a depth difference of 1.4m for this range of discharge. The Headingley site has a width of about 100m, which is considerably greater than the averages for the reach (71m) or the Lido Plage site (70m). The general correspondence of these data suggests that about half a metre change in depth for each 50 m^3/s change in discharge at within-bank range of flows is reasonable (i.e. from about 25 to 150 m^3/s).

ESTIMATES OF SUBSTRATE AREAS IN RELATION TO DISCHARGE

Table 4 shows the calculated areas in hectares of each of the substrate classes in riverbank and channel transects at the times and discharges in our 1996 sample periods. The areas of bank substrates in the earlier months were determined as incremental increases above that found at the approximately 50 m^3/s discharge in the August to October sample runs. These figures indicate the rather close fit of the normal river channel (i.e. below bankfull stage) to a U shape with most of the increase accruing at out-of-bank discharge conditions. Given the combined errors of all of the measurements and estimates used to arrive at these figures, it is reasonable to say that there is a significant increase in substrate area in this portion of the river only at out-of-bank discharge. The distribution of substrate types, and therefore areas of the various substrate types at normal in-bank flows, is discharge dependent. This is especially true of bank-related substrates where discharge related processes determined 1) the location of our substrate samples (on the river bank vs. within the channel, on an inside vs. outside bend or in a run); and 2) the effects of deposition on the availability of overlying small particle substrates. These two sampling-related effects are notable in the upper part of Table 4 as shifts among substrate types within the different classes with the only real increase in total area coming from the "riverbank" class at high flows. In the lower part of the table, no increase in total area would be expected, but significant changes in distribution of the classes occurred as discharge declined and stabilized following the spring flood (in 1996 a fairly large flood). The single biggest change was the development of rippled sand substrates at the expense of non-categorized sand substrates. A significant reduction in substrate areas covered by water would be expected only at very low flows — in the order of < 10 m^3/s (see cross sections in Steffler et al 1997). However, additional research and analyses of these and other data still are required to determine appropriate minimum depths covering the various substrate types to protect fish habitat — particularly shallow inside bend habitats. The limited range of discharges encountered in this study, combined with using average substrate condition for a transect, precludes calculation of weighted usable areas (WUA) for fish utilization of substrates.

HABITAT UTILIZATION / AVAILABILITY HISTOGRAMS

Five representatives of the family Catostomidae occurred in the Assiniboine River in sufficient numbers to determine habitat preferences: white sucker (*Catostomus commersoni*), golden redhorse (*Moxostoma erythrurum*), shorthead redhorse (*M. macrolepidotum*), silver redhorse (*M. anisurum*), and quillback (*Carpiodes cyprinus*). All members of the Catostomidae tended to utilize the shallower water in both bank and channel habitats (Figures 13A-20A; Figure 22A), with the exception of quillback, which tended towards intermediate depths in bank habitats (Figure 21A). Silver redhorse heavily over utilized the depth interval 3.81-4.00m, a result of capturing a single group of 10 spawning males at one location. The velocity utilization by the catostomids generally followed the availability for bank habitats (Figures 13B; 15B; 17B; 19B; 21B). Channel velocity utilization was less coherent with the availability due to patchy numbers and generally low abundance (Figures 14B; 16B; 18B; 20B). Shorthead redhorse were caught in high numbers and utilized velocities between 0.51 - 1.00 m/s (Figure 20B). All catostomids except for quillback utilized larger particle size substrates in bank habitats (Figures 13C; 15C; 17C; 19C) and heavily over utilized these substrates in channel habitats (Figures 14C; 16C; 18C; 20C). Quillback utilized the sand mixture substrates in bank habitats (Figure 21C) and heavily over utilized rippled-sand substrates in channel habitats (Figure 22C).

Carp (*Cyprinus carpio*: Family Cyprinidae) over utilized shallower water in both bank and channel habitats (Figures 23A; 24A). In bank habitats, carp utilization generally tracked the velocity availability (Figure 23B). The channel velocity utilization tended towards faster water 0.71 m/s – 1.00 m/s (Figure 24B). Carp over utilized larger particle sizes in bank habitats (Figure 23C) and heavily over utilized these substrates in channel habitats (Figure 24C).

Goldeye (*Hiodon alosoides*) and mooneye (*H. tergisus*) (Family Hiodontidae) utilized depths in bank habitats in relation to their availability (Figures 25A; 27A). In channel habitats, goldeye over utilized depths between 1.01m – 2.40m (Figure 26A). Mooneye over-utilized depths between 0.81m – 1.60m and heavily over utilized depths between 2.21m – 2.40m (Figure 28A). Again the variable and heavy over utilization in the Hiodontidae are caused by the combination of low occurrences and patchy abundance. Goldeye and mooneye velocity utilization generally tracked the availability in both bank and channel habitats (Figures 25B; 26B; 27B; 28B). Goldeye and mooneye in bank habitats generally utilized substrates in relation to their availability (Figures 25C; 27C). Substrate utilization by these two species in channel habitats was almost identical with both species over utilizing rippled-sand substrates (Figures 26C; 28C).

Both walleye (*Stizostedion vitreum*) and sauger (*S. canadense*) (Family Percidae) utilized shallower water in bank habitats, generally over utilizing water shallower than 1.20m (Figures 29A; 31A). Walleye generally utilized water shallower than 1.40m and depths between 1.81m – 2.00m in channel habitats (Figure 30A). Sauger generally utilized water shallower than 1.80m and heavily over utilized water depths between 0.61m – 0.80m and 1.01m – 1.20m (Figure 32A). Velocity utilization by these species generally followed availability in both bank and channel habitats (Figures 29B; 30B; 31B; 32B). Substrate utilization by walleye and sauger was very similar in bank habitats; both species over-utilized the larger erosion substrates of gravel-cobble (Figures 29C; 31C). In channel substrates both species utilized sand, coarse-sand, gravel-cobble, and cobble-boulder substrates (Figures 30C; 32C).

Freshwater drum (*Aplodinotus grunniens*: Family Sciaenidae) utilized shallower water in bank habitats (<1.70m) (Figure 33A). Numbers of freshwater drum were low in channel habitats (see Figure 34A; B; C). Velocity utilization by freshwater drum in bank habitats generally tracked availability (Figure 33B). Freshwater drum generally over-utilized silt, coarse-sand, silt-gravel, and sand-cobble (Figure 33C), and heavily over-utilized gravel, gravel-cobble, cobble-boulder, and riverbank substrates (Figure 33C).

Because the Assiniboine River was unusually high during all of sampling periods in this study, we were unable to collect fish preferences during average summer low flow conditions. This limited our ability to sample all life stages of the species encountered, and, as a result, our data refer to mainly adult or sub-adult fish. Length frequency histograms of the 11 species for which we have presented preference data are found in Figures 35 and 36.

SPECIES UTILIZATION SUMMARY

Summary data of over, under and non-utilized depth intervals shows that at least 45.5% and 72.7% of the 11 species over utilized depths between 0.21m and 1.60m and between 0.61m and 1.60m in bank and channel habitats, respectively (Table 2). Similar ranges were found in channel habitats — 0.61m-0.80m and 1.01m-1.20m (Table 2). Another main observation in this summary is the large number of non-utilized depth intervals in channel habitats compared to bank habitats. Depths greater than 2.81m in channel habitats were never utilized by any of the 11 species (Table 2). In bank habitats, the majority of the 11 species either under-utilized or did not utilize depths greater than 2.81m. However, there are a few instances of over-utilization, one of which was the spawning group of male silver redhorses mentioned previously (3.81m-4.00m).

Summary data for over, under and non-utilized velocity intervals shows that at least 45.5% of the species over-utilized velocity intervals of 0m/s to 0.40m/s and 0.71m/s to 1.20m/s (Table 3). In contrast to depth utilization, most of the over-utilization of the species occurred in the single velocity range of 0.51m/s to 0.90m/s, which corresponds to intermediate bank velocities, but encompasses most channel velocities as well. More precisely, in both bank and channel habitats the velocity intervals most frequently over-utilized were those which fell above or below the most frequently measured velocities (0.41m/s-0.60m/s in bank habitats) and (0.71m/s-0.80m/s in channel habitats).

Summary data for over, under and non-utilized substrate categories shows that in both bank and channel habitats, the over-utilized substrates were never the most frequently occurring substrates (Table 3). Among erosion substrates in bank habitats, clay was under-utilized by all species in bank habitats and never utilized in channel habitats (Table 3). Bank habitat erosion substrates, with the exception of submerged trees, were heavily over-utilized (Table 3). Submerged trees were under-utilized by all species except goldeye and sauger. Only gravel-cobble, cobble-boulder, and sand-cobble were over-utilized in channel habitats (Table 3). Only sand and hard-sand, among transport substrates in bank habitats, were under-utilized by the majority of the species. Rippled-sand, sand-gravel, and sand-cobble were over-utilized by at least 45.5% of the species in bank habitats (Table 4). Only sand-cobble was over-utilized by 45.5% of the species in channel transport habitats. Silt-gravel, silt, and riverbank were over-utilized in bank habitats — silt-gravel being over-utilized by 10 of the 11 species.

SPECIES ABUNDANCE PATTERNS IN RELATION TO PROCESS

Organization of the substrates into local process categories of erosion, transport, and deposition shows that the highest numbers of fish occur over erosion substrates (Table 3). There are many relationships both biotic and abiotic, which are responsible for the observed patterns of fish and habitat. Perhaps one of the most important things to consider concerning riverine habitats is that there are dynamic aspects to certain substrates, which are directly related to discharge. The main point brought out by this analysis, is that coarse substrates always are the most important whether along a bank or in the center of the channel (Figure 37). These same substrates continue to be important even when combined with deposition of sand or silt but only when associated with the stream bank. Sand, in combination with gravel or cobble in centre channel locations, continued to support low species diversity and abundance, although sand-cobble was over-utilized by 45.5% of the species in channel habitats (Table 3). Gravel substrates along banks apparently increase in importance when overlain by silt, perhaps because of colonization of organic rich silt deposits by burrowing insect larvae. The single most important substrate was gravel-cobble probably because this would be the single most complex substrate in terms of surface area and availability of interstitial spaces for benthic invertebrate colonization.

DISCUSSION

Generally fish over-utilized water shallower than 1.60 metres in bank habitats and water between 0.61-1.60 metres in channel habitats. Depths over 3.00 metres in bank habitats were either under-utilized or not utilized at all by most species, while generally water deeper than 2.41 metres in channel habitats was not utilized.

Fish tended toward bimodal velocity usage in bank habitats, over-utilizing water slower than 0.40 m/s, and velocities in the range of 0.71-1.20 m/s. In contrast, fish over-utilized the mid-range velocities of 0.51-0.90 m/s in the channel habitats. Generally, the fastest waters in both bank and channel habitats were not used, while many fish did not use slower water in channel habitats. Four of the six erosion substrates were over-utilized in bank habitats: coarse-sand, gravel, gravel-cobble, and cobble-boulder, with clay and trees being under-utilized. Three of the five transport substrates were over-utilized in bank habitats: rippled-sand, sand-gravel, and sand-cobble, with sand and hard-sand being strongly under-utilized. Three of the five deposition substrates were over-utilized in bank habitats: silt, silt-gravel, and riverbank, while silt-cobble and silt-sand were under-utilized. Only three substrates were over-utilized in the channel habitats: gravel-cobble, cobble-boulder, and sand-cobble, while the remaining substrates generally were under-utilized by most species.

Four general principles arise from the results of this report. The first is that the processes which are responsible for generating habitat patterns create more heterogeneity along bank habitats than they do in channel habitats. Second, channel habitats are very barren compared to bank habitats (lower abundance, lower richness). Third, larger particle sizes of gravel-cobble-boulder are always over-utilized whether they occur in bank or channel habitats. The increased productivity of larger substrate surface areas also has been found for benthic invertebrates (see McCoy and Bell, 1991 and citations therein). Finally, shallow fluvial habitats (marginal habitats of silt deposition; point bars) can contribute significantly to the local biodiversity. Thorp and Delong (1994) found similar lateral trends in abundance and richness for benthic invertebrates in streams.

Spatial distributions of species are highly variable, often varying considerably among streams (Angermeier 1987; Angermeier and Smogor 1995). In addition, a species' relative occurrence with respect to particular habitats is strongly related to a species' overall abundance in the stream. The continuity of a species' distribution in relation to habitat in any given study generally is related to the scale of the sampling design (Angermeier and Smogor 1995) and specifically related to the small scale spatial distribution of both species and habitat variables (Williams 1996). Two discrete till plain exposures separated by approximately 40 kilometres of river showed high abundance of individual catches in channel habitats while the relatively long stretches of sand and rippled-sand substrates in channel habitats — both above and between till plain exposures — yielded consistently low abundance and richness. This indicates that although the continuity of the sand and rippled-sand substrates in channel habitats maintains long distance cohesiveness, the influence of particle size has a greater influence on species abundance, regardless of the spatial discontinuity between the discrete exposures. Gorman and Karr (1978) and Schlosser (1982) found species diversity to be positively correlated with habitat complexity, a trend supported in this study for both physical particle size in bank and channel habitats as well as substrate heterogeneity in bank versus channel habitats. Although depth has been noted as an important habitat variable (Sheldon 1968; Evans and Noble 1979), we found substrate the major influence on both species abundance and richness in the Assiniboine River. Some researchers have used the guild approach (Balon 1975; Gorman 1988; Aadland 1993) to rationalize broader scale distributions of fish in relation to stream parameters. There are advantages to this approach, as the relationships may be more broadly applicable among streams in different ecozones and of basin size. However, our data are not currently amenable to this approach.

There are many other theoretical paradigms in stream ecology (Vannote et al. 1980; Junk et al. 1989; Thorp and Delong 1991; Ward 1998) that have a place in relating fish occurrence to habitat. Since the introduction of the river continuum concept (RCC) (Vannote et al. 1980), the flood pulse concept (FPC) (Junk et al. 1989), and the riverine productivity model (RPM) (Thorp and Delong 1994) there has been an increased awareness of geomorphology as a constraining factor on aquatic habitats and their contained communities (Busch and Sly 1992; Ward 1998). There are a number of factors which specifically are responsible for generating habitat patterns and the distribution of habitat variables, both longitudinally and laterally as well as temporally (Vannote et al 1980; Thorp and Delong 1994; Junk et al 1989). Geomorphology can be defined as watershed geology and slope of landform. In the Assiniboine River basin, glacial till plains and glacial Lake Agassiz deltaic deposits are responsible for the spatial pattern of substrates at larger scales. Slope and geology affect meander sinuosity, having direct implications on the physical energetics and subsidiary effects on substrates and microhabitat distribution (Franzin et al. unpublished). The radius of curvature of a meander has direct effects on the degree of erosion and transport and the amount of the transported silts and sands that are deposited as point bars. The substrate patterns through a meander sequence are dependent largely on the local substrate composition. Discharge has direct effects on certain substrates — rippled-sand substrates are in motion and as they move over rises in the till plain, sand fills the spaces between cobbles, changing habitat quality for macroinvertebrates that may be consumed by fish. This may in part explain the reduced abundance in sand-cobble substrates compared to gravel-cobble and cobble-boulder substrates. Certain habitats, such as point bars (utilized by walleye, sauger, goldeye, mooneye, quillback, silver redhorse and smaller cyprinids) require further investigation due to the influence of discharge on shallow fluvial habitats — point bars become exposed and often go dry at low discharges. The potential for different trophic interactions in these habitats may have a great influence in fine sedimentary streams, where erosion, transport, and deposition are primary structuring forces.

SUMMARY

When we began this study, we had little data about the distribution and abundance of fish species inhabiting the Assiniboine River itself, despite considerable information about its tributary streams. Therefore, we deliberately chose to carry out an extensive sampling program over the whole reach of the river between Winnipeg and Portage la Prairie. Since one of the goals of the study was to produce preference curves for the main resident fishes, we decided to use a stratified random sampling design which would yield unbiased data on both reach-wide fish distributions over the open-water season as well as information on fish occurrence in relation to physical habitats. We also needed the distributions of the habitats themselves, about which we knew only a little. We were largely successful in achieving both goals, although the habitat data is not as detailed as we would have liked and cannot be directly translated into a substrate map of the river bottom. That substrate map is required to accurately model the distributions of fish in relation to substrate. *The data we have gathered on the distribution of substrates and fish use of them suggests strongly that the discrete sections of larger particle substrates are restricted enough and utilized sufficiently, even by non-spawning fish, to be considered critical habitats.*

We still lack detailed cross sectional data on depths and velocities at a large number of sites which are necessary to model accurately the effects of differing discharge on these parameters at any one site. A further complication to modeling is the fact that the substrate at any one site changes with discharge as a result of transition of the site among the hydraulic states of erosion, transport, and deposition. Work is proceeding to address these shortcomings in our data. In the interim, we do have a lot more data to work with in the immediate future than was previously available. A copy of the data used in this report is available on disk upon request by contacting Dr. W. G. Franzin.

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Table 1: 16 substrate classes in bank habitats and 11 classes in channel habitats, from the Assiniboine River, divided into local categories, and regional processes.

Bank Habitats		
Substrate Class	Local Category	Distribution and Regional Process
Clay	Erosion	Outside bends
Trees	Erosion	Large radius bends
Coarse-Sand	Erosion	Scoured zones
Gravel	Erosion	May be of till-plain origin or hydraulic sorting
Gravel-Cobble	Erosion	Restricted to regions of shallow till-plain exposures
Cobble-Boulder	Erosion	Restricted to regions of shallow till-plain exposures
Sand	Transport	Glacial Lake Agassiz derived
Hard-Sand	Transport	Discontinuous
Rippled-Sand	Transport	Small ripples formed by hydrology
Sand-Gravel	Transport	Created by combined effects of till-plain distribution and bedload transport
Sand-Cobble	Transport	Created by combined effects of till-plain distribution and bedload transport
Silt	Deposition	Marginal, deposited in low velocity areas and at river edge
Silt-Sand	Deposition	Created by mixing of deposited silt and sand on inside bends and at margins
Silt-Gravel	Deposition	Created by combined effects of till-plain distribution and silt deposition
Silt-Cobble	Deposition	Created by combined effects of till-plain distribution and silt deposition
Inundated Riverbank	Deposition	Caused by out of bank conditions during spring flooding

Channel Habitats		
Substrate Class	Local Category	Regional Process
Clay	Erosion	Outside bends
Coarse-Sand	Erosion	Scoured zones very discontinuous
Gravel	Erosion	May be of till-plain origin or hydraulic sorting
Gravel-Cobble	Erosion	Restricted to regions of shallow till-plain exposures
Cobble-Boulder	Erosion	Restricted to regions of shallow till-plain exposures
Sand	Transport	Glacial lake Agassiz derived
Hard-Sand	Transport	Glacial Lake Agassiz derived, discontinuous
Rippled-Sand	Transport	Large ripples of bedload transport
Sand-Gravel	Transport	Created by combined effects of till-plain distribution and bedload transport
Sand-Cobble	Transport	Created by combined effects of till-plain distribution and bedload transport
Silt-Sand	Deposition	Created by mixing of deposited silt and sand on inside bends, included here due to the lateral extent of certain bends
Silt-Gravel	Deposition	Created by combined effects of till-plain distribution and silt deposition
Silt-Cobble	Deposition	Created by combined effects of till-plain distribution and silt deposition

Intervals	Availability	WS	SR	GR	SH	QB	C	GE	ME	W	S	FD	ALL	Availability	WS	SR	GR	SH	QB	C	GE	ME	W	S	FD	ALL
0.21-0.40	0.0149	-	-	+	+	+	-	-	+	+	+	+	**7**	0.0030	0	0	0	-	+	0	0	0	+	+	0	3
0.41-0.60	0.0238	+	+	+	-	+	-	-	+	-	+	0	**6**	0.0060	0	0	0	-	+	+	0	+	+	0	0	4
0.61-0.80	0.0967	+	-	+	+	+	+	+	+	+	+	+	**10**	0.0298	+	+	0	+	+	+	0	0	+	+	+	**8**
0.81-1.00	0.1190	+	-	+	+	-	+	-	+	+	+	+	**8**	0.0893	+	-	+	+	-	+	-	+	0	+	0	**6**
1.01-1.20	0.1280	+	+	+	+	+	+	+	+	+	+	+	**11**	0.1220	+	+	+	+	+	+	+	+	-	+	+	**10**
1.21-1.40	0.1161	-	+	-	-	+	+	-	+	-	-	+	**5**	0.1310	+	-	0	+	+	0	-	-	-	-	+	4
1.41-1.60	0.0878	-	+	+	+	+	-	+	+	-	-	-	**6**	0.0863	+	+	-	+	+	+	+	+	0	0	0	**7**
1.61-1.80	0.0729	-	+	-	+	+	-	-	-	-	-	-	3	0.0833	-	-	+	-	+	0	+	-	0	-	0	3
1.81-2.00	0.0551	-	-	-	-	+	-	+	+	+	-	-	4	0.0655	+	-	0	-	+	-	+	0	+	0	0	4
2.01-2.20	0.0595	-	-	-	-	-	-	+	-	-	-	+	2	0.0506	-	+	+	-	0	+	0	0	0	0	0	3
2.21-2.40	0.0521	-	-	-	-	-	-	-	-	0	-	-	0	0.0476	-	-	+	-	-	0	+	+	0	0	0	3
2.41-2.60	0.0342	-	+	-	-	-	-	-	-	-	-	0	1	0.0417	0	-	0	-	0	+	0	0	0	0	0	1
2.61-2.80	0.0313	-	+	-	-	-	-	-	-	-	-	-	1	0.0476	-	0	0	-	0	0	-	0	0	0	0	0
2.81-3.00	0.0313	+	-	0	-	-	-	-	-	-	-	-	1	0.0506	0	0	0	0	0	0	0	0	0	0	0	0
3.01-3.20	0.0268	-	-	0	-	-	-	-	-	-	-	0	0	0.0357	0	0	0	0	0	0	0	0	0	0	0	0
3.21-3.40	0.0134	0	0	0	-	-	0	-	+	-	0	-	1	0.0327	0	0	0	0	0	0	0	0	0	0	0	0
3.41-3.60	0.0074	0	0	0	-	-	0	-	-	+	0	0	1	0.0119	0	0	0	0	0	0	0	0	0	0	0	0
3.61-3.80	0.0104	0	-	0	-	+	-	0	0	0	-	+	2	0.0208	0	0	0	0	0	0	0	0	0	0	0	0
3.81-4.00	0.0074	0	+	0	-	-	-	-	-	0	0	0	1	0.0149	0	0	0	0	0	0	0	0	0	0	0	0
4.01-4.20	0.0060	0	-	0	-	0	0	0	0	0	-	0	0	0.0149	0	0	0	0	0	0	0	0	0	0	0	0
4.21-4.40	0.0015	+	0	0	0	+	0	0	0	0	0	0	2	0.0030	0	0	0	0	0	0	0	0	0	0	0	0
4.41-4.60	0.0030	0	0	0	0	0	0	-	+	0	0	0	1	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4.60+	0.0015	0	0	0	+	0	+	0	0	0	0	0	2	0.0119	0	0	0	0	0	0	0	0	0	0	0	0

WS = *Catostomus commersoni*, SR = *Moxostoma anisurum*, GR = *Moxostoma erythrurum*, SH = *Moxostoma macrolepidotum*, QB = *Carpiodes cyprinus, C = Cyprinus carpio*, GE = *Hiodon alosoides*, ME = *Hiodon tergisus*, W = *Stizostedion vitreum*, S = *Stizostedion canadense*,
FD = Aplodinotus grunniens. ALL = The number of the 11 species which over utilized the particular interval, numbers in bold highlight intervals that at least 45.5% of the species were over utilizing.
NA = Indicates categories which were not available to be sampled.

Table 3: Shows the under (-), over (+), and non (0) utilization of velocity and substrate individually and combined.

Velocity	Bank	Utilization												Channel	Utilization											
Intervals	Availability	WS	SR	GR	SH	QB	C	GE	ME	W	S	FD	ALL	Availability	WS	SR	GR	SH	QB	C	GE	ME	W	S	FD	ALL
0-0.10	0.0179	-	+	0	-	+	-	+	-	-	+	+	**5**	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.11-0.20	0.0164	0	-	+	-	+	-	+	-	+	-	+	**5**	0.0030	0	0	0	-	0	0	+	0	0	+	0	2
0.21-0.30	0.0580	+	-	+	-	-	+	+	+	+	+	+	**8**	0.0089	+	0	+	0	0	0	0	0	0	0	0	2
0.31-0.40	0.1146	+	-	+	-	-	+	-	+	+	+	+	**7**	0.0298	+	+	0	-	0	0	+	+	0	0	0	4
0.41-0.50	0.1920	-	-	-	-	-	-	-	-	+	+	+	3	0.0744	0	+	0	-	-	-	-	0	0	+	0	2
0.51-0.60	0.1964	-	+	-	-	-	+	-	+	-	-	+	4	0.1339	+	+	+	+	+	+	+	-	+	+	+	**10**
0.61-0.70	0.1429	-	-	-	-	+	-	-	-	-	-	-	1	0.1637	+	+	-	+	-	-	+	+	+	-	0	**6**
0.71-0.80	0.1518	+	+	+	+	+	-	+	-	+	+	+	**9**	0.2530	-	-	-	-	-	-	-	-	-	-	+	1
0.81-0.90	0.0417	-	+	-	+	+	+	+	+	+	-	+	**8**	0.1280	+	-	+	+	+	+	+	+	-	+	0	**8**
0.91-1.00	0.0491	+	+	+	+	-	-	+	+	-	-	-	**6**	0.1518	-	-	0	-	-	+	-	0	0	-	0	1
1.01-1.10	0.0119	-	+	+	-	-	-	-	-	0	-	0	2	0.0298	-	-	0	-	0	0	0	0	0	0	0	0
1.11-1.20	0.0045	+	0	+	+	+	+	0	0	+	+	+	**8**	0.0208	+	+	0	+	-	0	0	0	0	0	0	3
1.21-1.30	0.0015	0	0	0	-	+	0	0	0	0	0	0	1	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.30+	0.0015	0	0	0	+	0	0	0	0	0	0	0	1	0.0030	+	0	0	-	0	0	0	0	0	0	0	1

Substrate	Bank	Utilization												Channel	Utilization											
Categories	Availability	WS	SR	GR	SH	QB	C	GE	ME	W	S	FD	ALL	Availability	WS	SR	GR	SH	QB	C	GE	ME	W	S	FD	ALL
Clay	0.1116	-	-	-	-	-	-	-	-	-	-	-	0	0.0208	0	0	0	0	0	0	0	0	0	0	0	0
Silt	0.0417	-	-	-	-	-	+	+	+	+	+	+	**6**	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Silt-Sand	0.1354	-	-	-	-	+	-	-	+	-	-	-	2	0.0060	0	0	0	0	0	0	0	0	0	0	0	0
Sand	0.1399	-	-	-	-	+	-	-	+	-	-	-	2	0.2381	-	+	0	-	-	-	-	-	+	+	0	3
Hard-Sand	0.0298	-	-	0	-	-	-	-	-	-	-	-	0	0.0149	0	0	0	0	0	0	+	+	0	0	0	2
Rippled-Sand	0.1176	-	+	-	+	+	-	+	+	-	+	-	**6**	0.3988	-	-	0	-	+	-	+	+	-	0	-	3
Coarse-Sand	0.0313	-	+	-	+	+	+	+	-	+	-	+	**7**	0.0089	0	0	0	-	+	0	0	0	+	+	0	3
Gravel	0.0714	+	+	+	+	-	-	+	-	-	-	+	**6**	0.0179	0	0	0	-	+	0	+	0	0	0	0	2
Silt-Gravel	0.0193	+	-	+	+	+	+	+	+	+	+	+	**10**	0.0030	0	0	0	-	0	0	+	0	0	+	0	2
Sand-Gravel	0.0551	+	+	-	+	+	+	-	+	+	+	-	**8**	0.0744	0	-	0	-	-	-	+	+	+	0	0	3
Gravel-Cobble	0.0744	+	+	+	+	-	+	-	+	+	+	+	**9**	0.0833	+	+	+	+	-	+	-	0	+	+	+	**8**
Cobble-Boulde	0.0432	+	+	+	+	-	+	-	+	+	-	+	**8**	0.0417	+	+	+	+	-	+	-	+	+	+	+	**9**
Silt-Cobble	0.0223	+	-	-	-	-	+	-	-	-	-	0	2	0.0030	0	0	0	0	0	0	0	0	0	0	0	0
Sand-Cobble	0.0357	+	-	+	+	-	+	-	-	-	-	+	**5**	0.0893	+	+	+	+	-	+	-	-	0	-	0	**5**
Riverbank	0.0253	+	+	+	+	-	+	-	-	+	-	+	**7**	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trees	0.0461	-	-	-	-	-	-	+	-	-	+	0	2	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4. Discharge:Substrate Area Relationship for Bank and Centre Stations in the Assiniboine River between Portage la Prairie and Winnipeg. Area of substrate in hectares.

Bank Stations					
Sample Date		May-96	Jun-96	Jul-96	Aug/Sept/Oct 96
Substrate	Q	220cms	150cms	81cms	49cms Average
Clay		157.84	223.26	157.95	109.69
Silt-Detritus		19.73	148.84	140.40	67.50
Silty Sand		295.95	186.05	122.85	118.13
Silt-Gravel		157.84	93.02	52.65	177.19
Silty Clay		98.65	37.21	17.55	33.75
Soft Sand		19.73	0.00	0.00	16.88
Sand		394.61	576.75	526.50	67.50
Rippled Sand		0.00	18.60	105.30	556.88
Hard&Coarse Sand		177.57	74.42	70.20	50.63
Sand-Gravel		138.11	74.42	122.85	160.31
Sand-Cobble		59.19	37.21	0.00	33.75
Gravel		39.46	18.60	17.55	50.63
Gravel-Cobble		138.11	223.26	280.80	151.88
Cobble		39.46	37.21	35.10	25.31
Boulders		0.00	18.60	35.10	0.00
Riverbank		157.84	18.60	0.00	0.00
Total		1894.11	1786.05	1684.80	1620.00

Centre Stations						
Sample Date		`May 96	`Jun 96	`Jul 96	`Aug 96	`Sep/Oct 96
Substrate	Q	220 cms	150 cms	81 cms	54 cms	44 cms
Clay		206.08	206.08	0.00	0.00	0.00
Silt-Detritus		0.00	0.00	206.08	0.00	0.00
Silty Sand		0.00	206.08	0.00	206.08	0.00
Silt-Gravel		206.08	0.00	206.08	206.08	206.08
Silty Clay		0.00	0.00	0.00	412.17	206.08
Soft Sand		412.17	0.00	0.00	0.00	0.00
Sand		5564.25	5152.08	1442.58	412.17	618.25
Rippled Sand		412.17	1442.58	4739.92	6594.67	6388.58
Hard&Coarse Sand		206.08	0.00	0.00	0.00	0.00
Sand-Gravel		412.17	412.17	618.25	618.25	824.33
Sand-Cobble		412.17	206.08	206.08	206.08	618.25
Gravel		0.00	0.00	206.08	206.08	0.00
Gravel-Cobble		1442.58	1442.58	2060.83	1030.42	824.33
Cobble		618.25	412.17	206.08	0.00	206.08
Boulders		0.00	412.17	0.00	0.00	0.00
Totals		9892.00	9892.00	9892.00	9892.00	9892.00

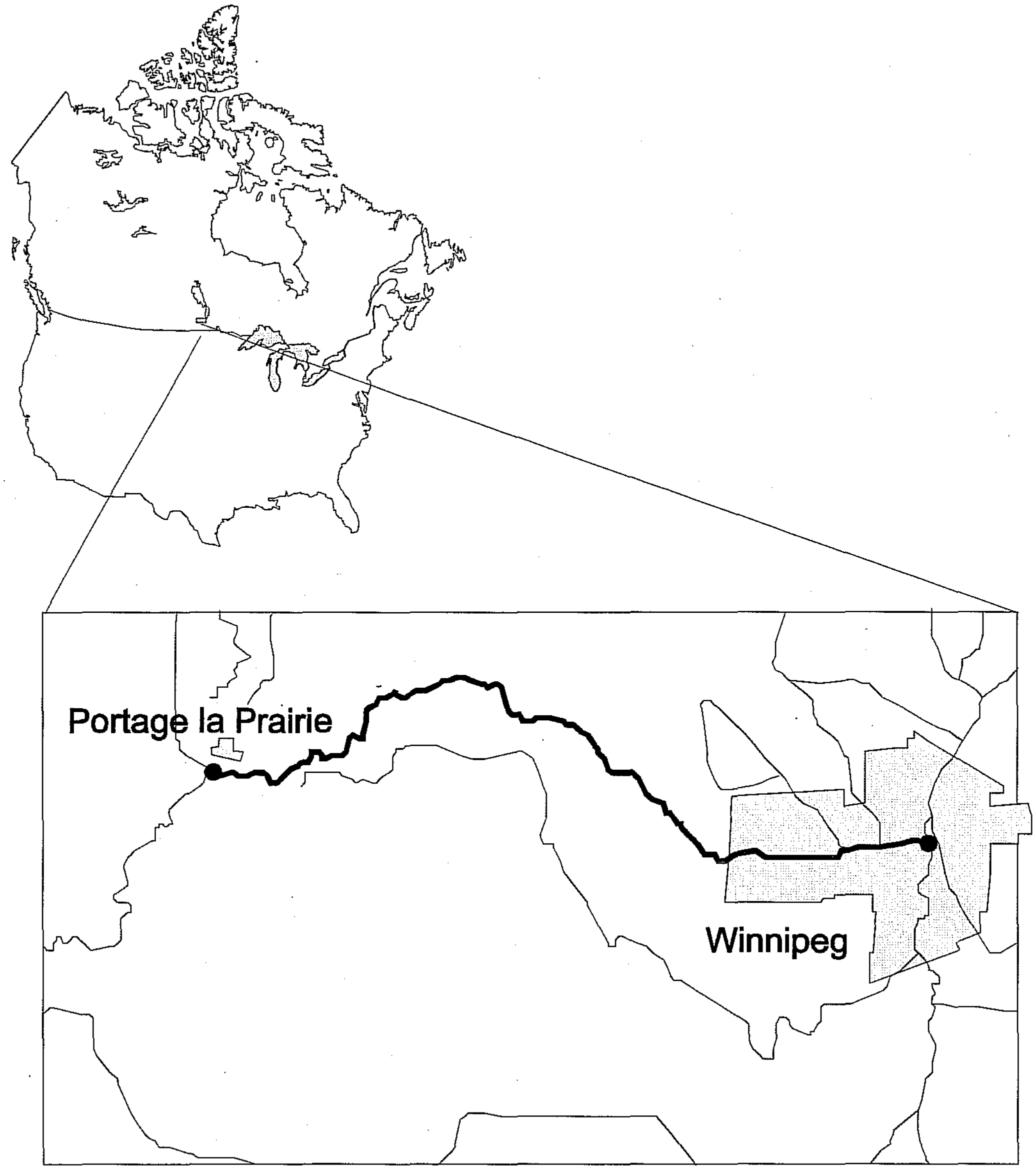


Figure 1: Study site is a 160 km reach of the Assiniboine River, between Portage la Prairie Dam and the confluence with the Red River at Winnipeg.

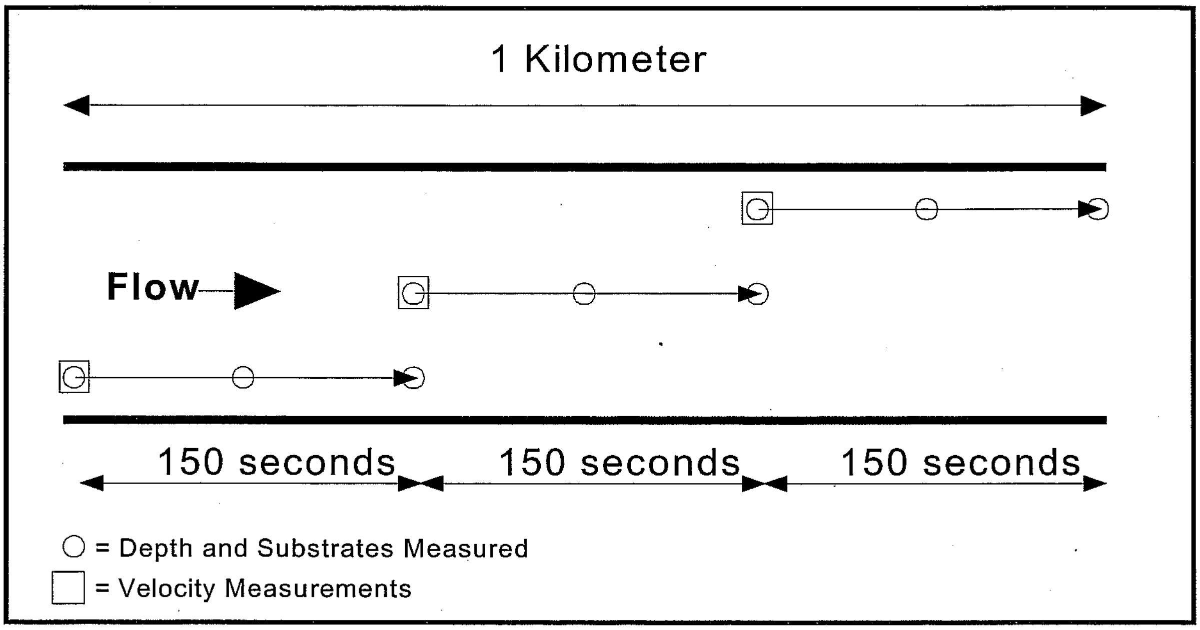


Figure 2: Sampling protocol used in the collection of fish occurrences, depths, velocities, and substrates.

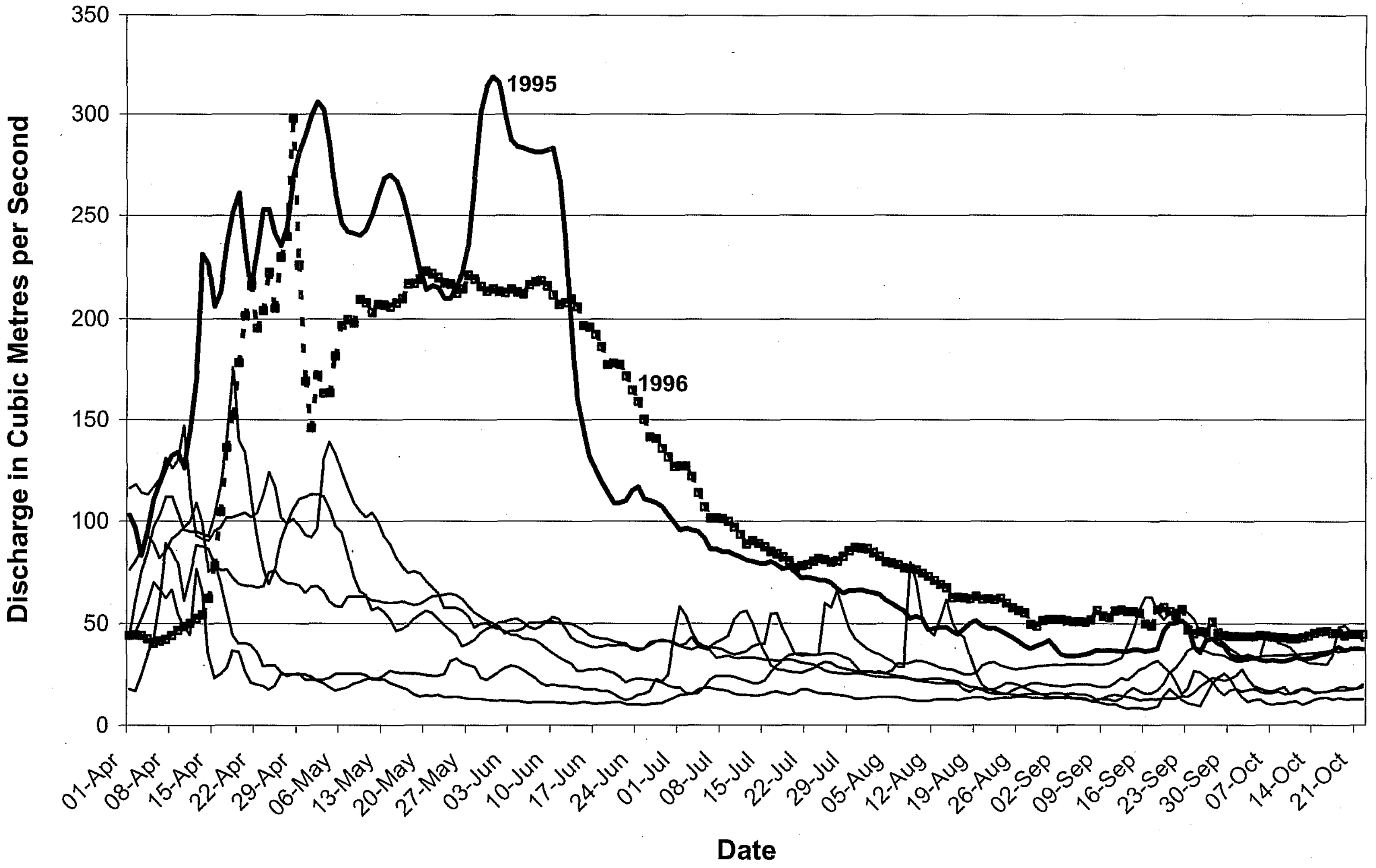


Figure 3: Assiniboine River discharge at Headingley between April 1 and October 22 for the period 1990 to 1996.

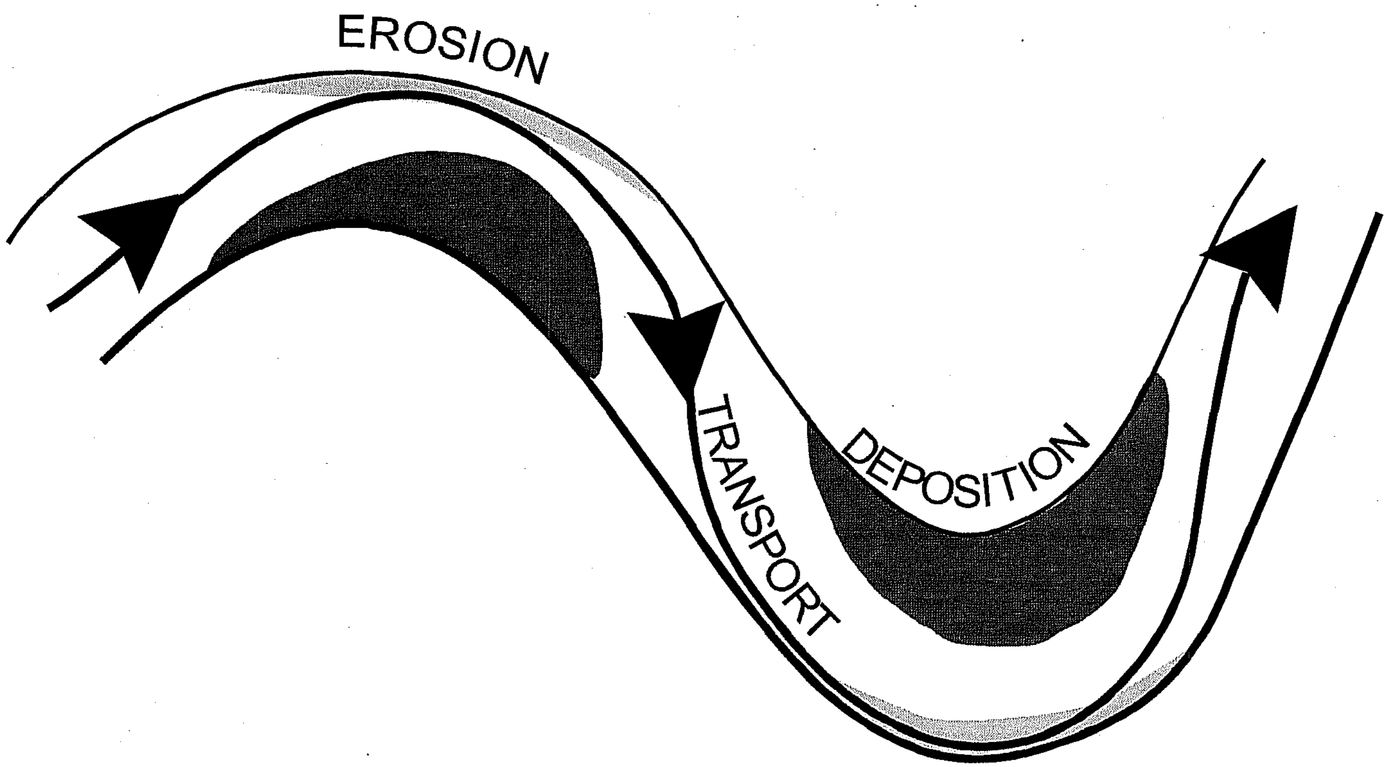


Figure 4: Distribution of erosion , transport and deposition through a typical meander sequence.

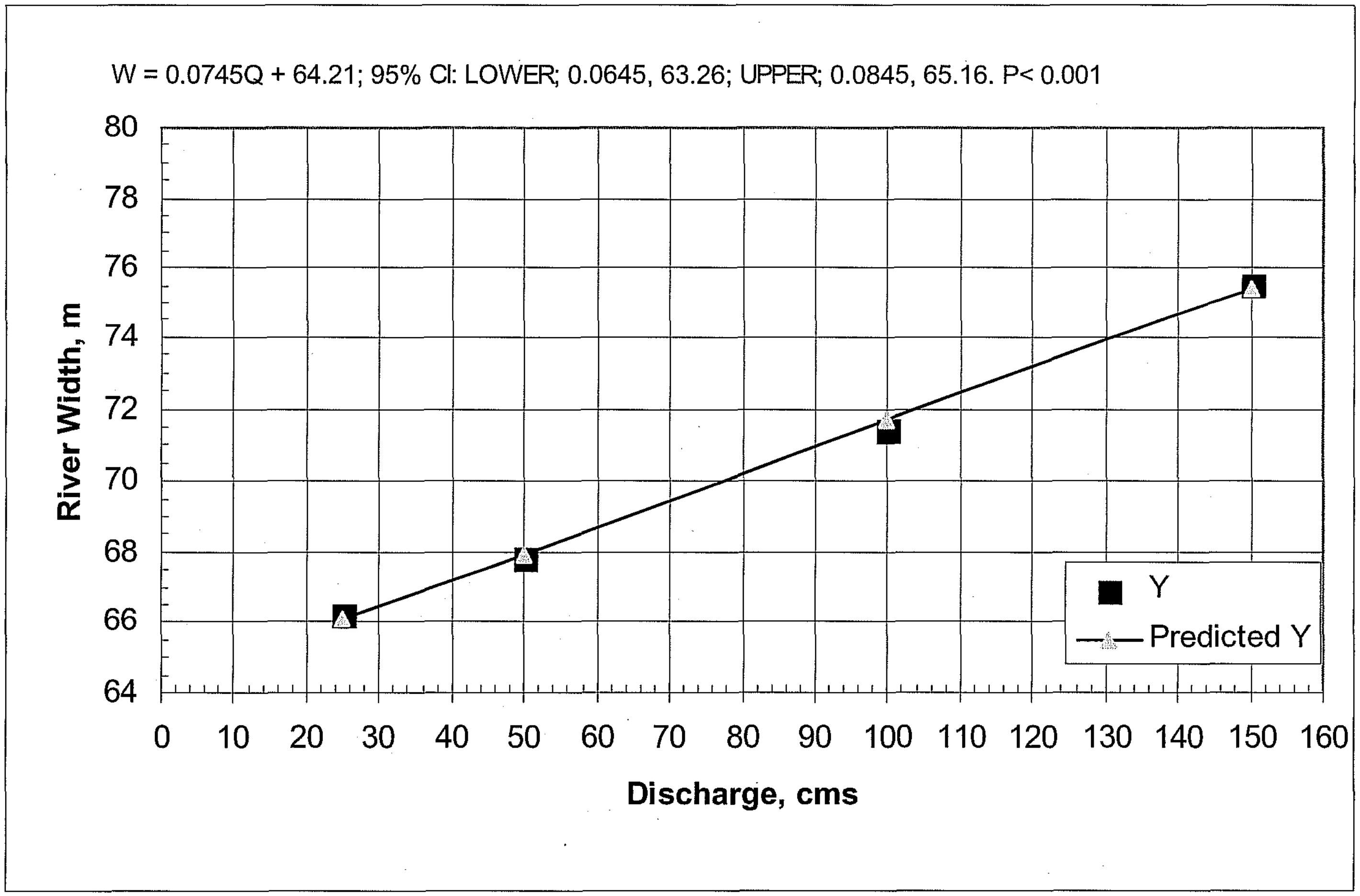


Figure 5: Regression of modeled river width in relation to discharge from averages taken on 12 measured cross-sections at the Lido Plage site (Km 42-43).

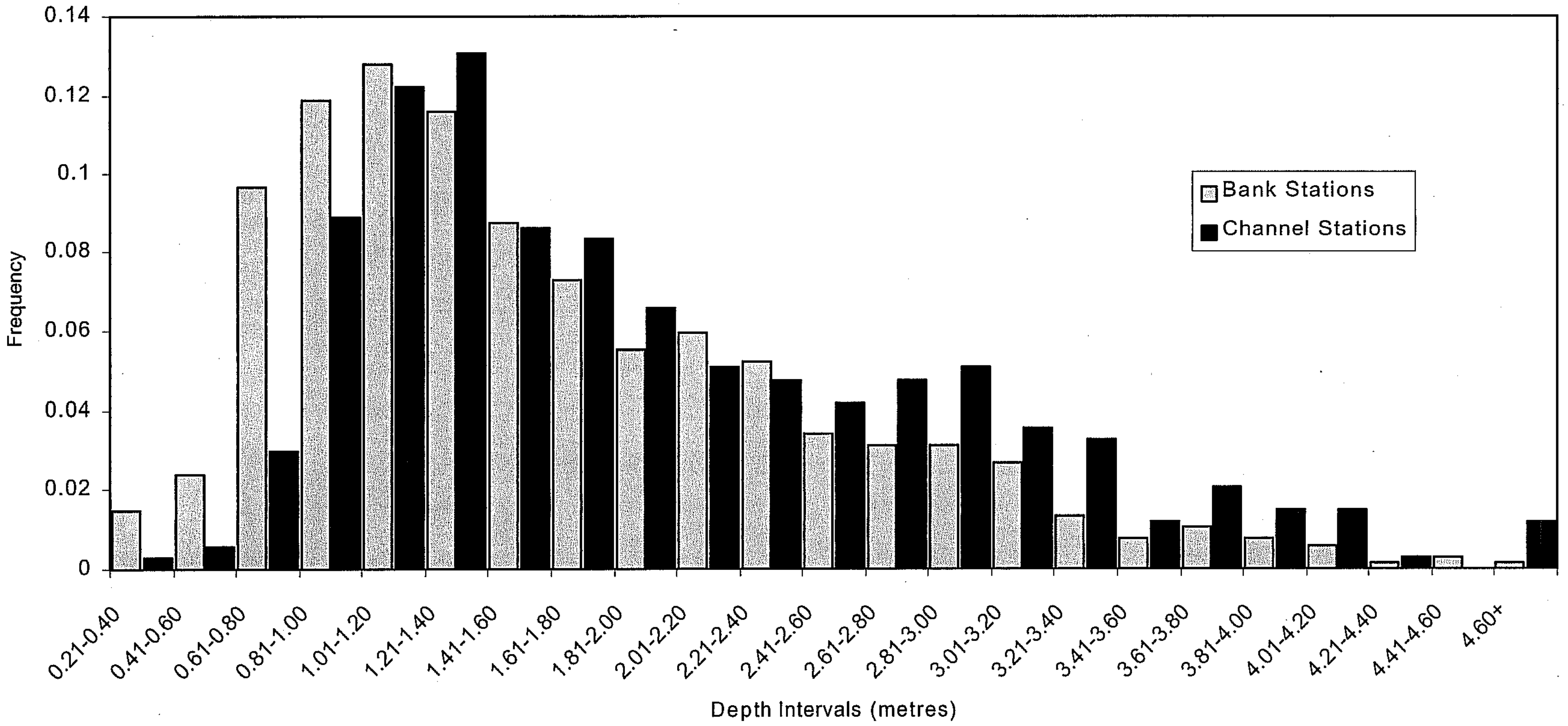


Figure 6: Frequency of depth intervals in the Assiniboine River sampled in 1995 and 1996; averages for all seven runs.

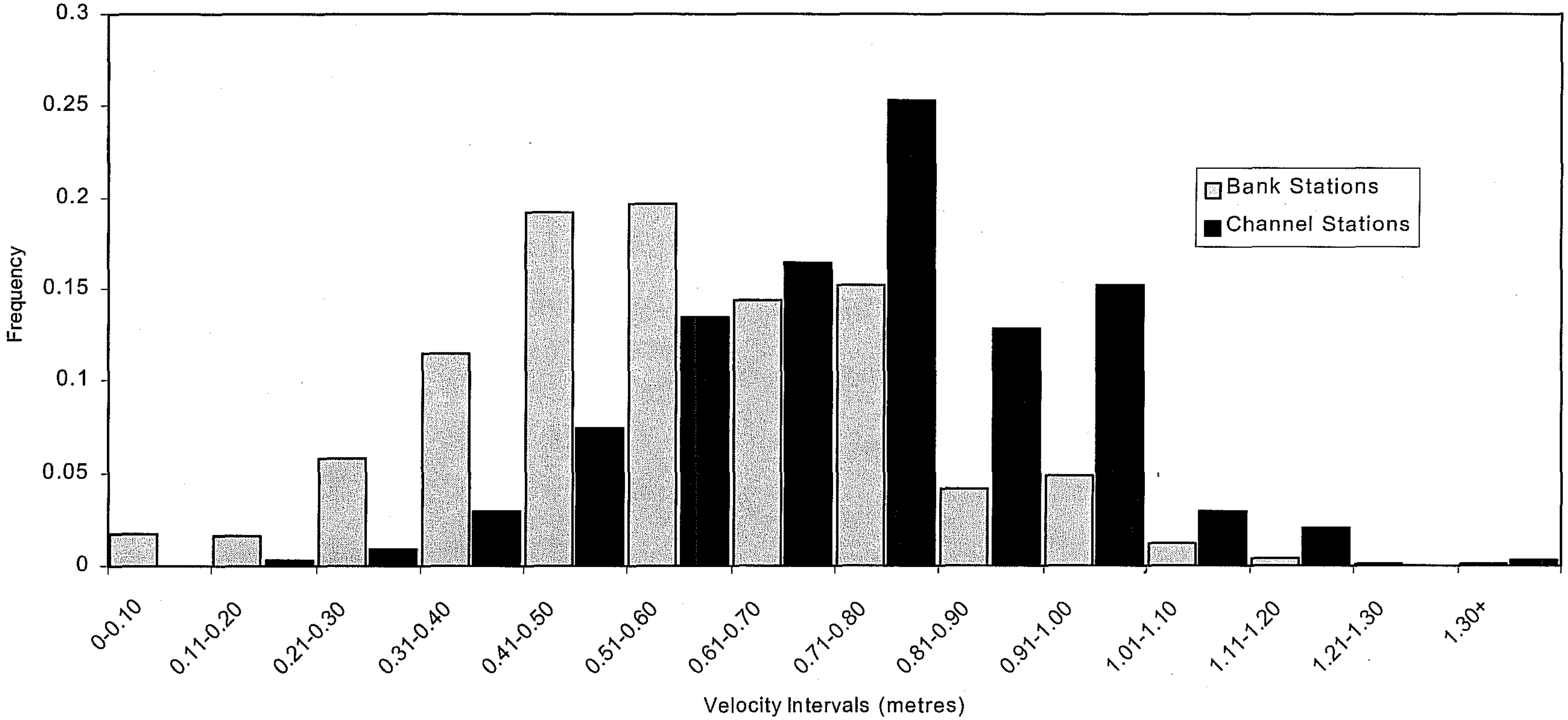


Figure 7: Frequency of velocity intervals in the Assiniboine River sampled in 1995 and 1996; averages for all seven runs.

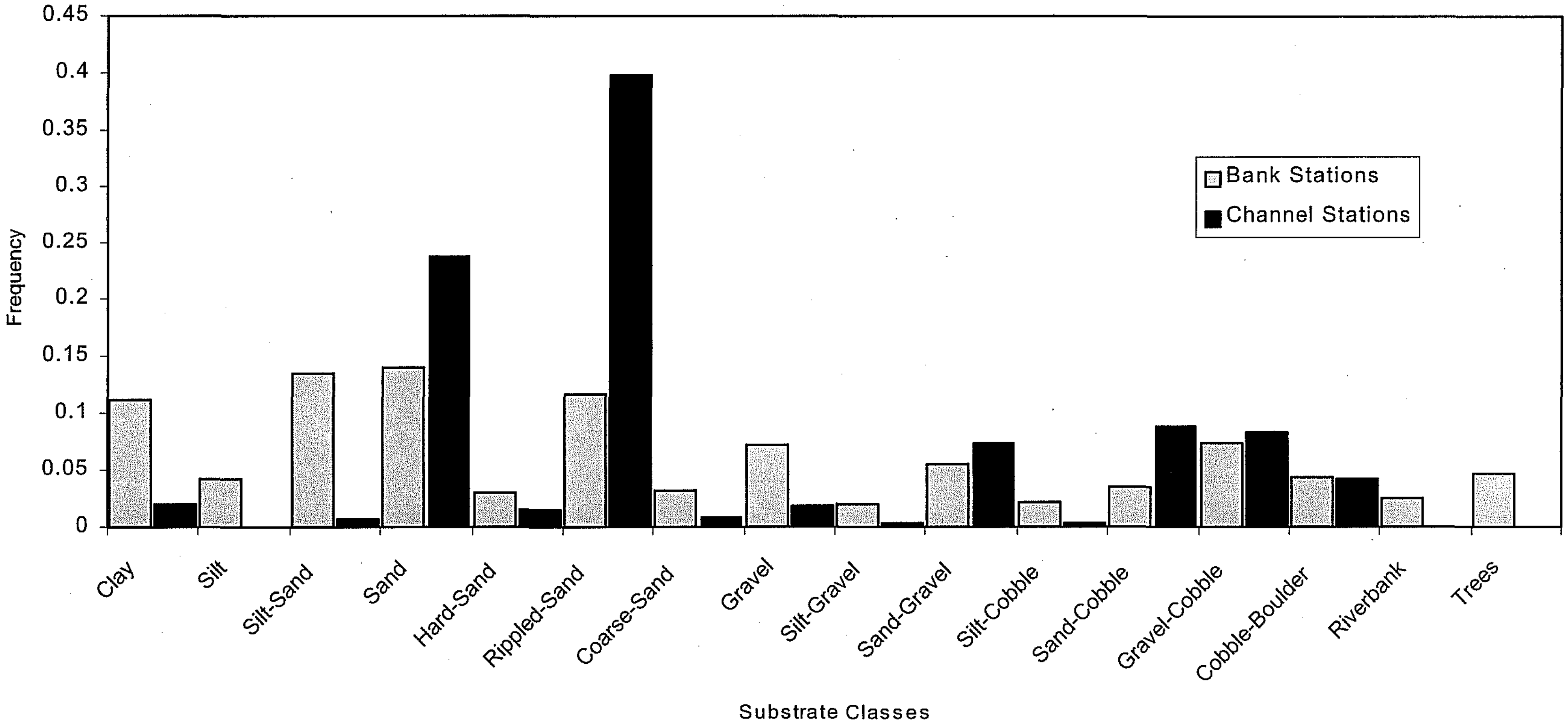


Figure 8: Frequency of substrate classes in the Assiniboine River sampled in 1995 and 1996; averages of all seven runs.

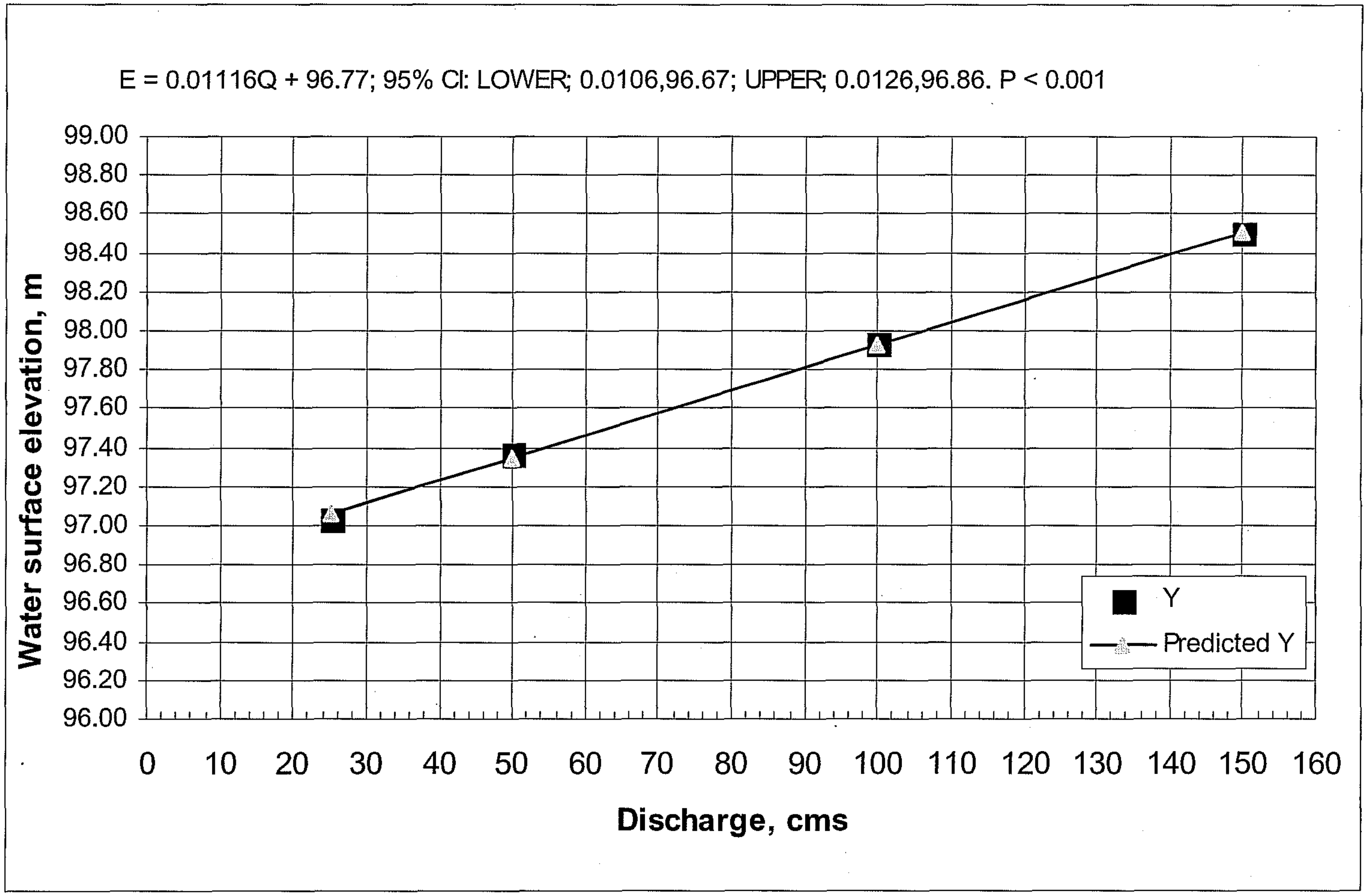


Figure 9: Regression of modeled water surface elevation in relation to discharge from averages taken on 12 measured cross-sections at the Lido Plage site (Km 42-43).

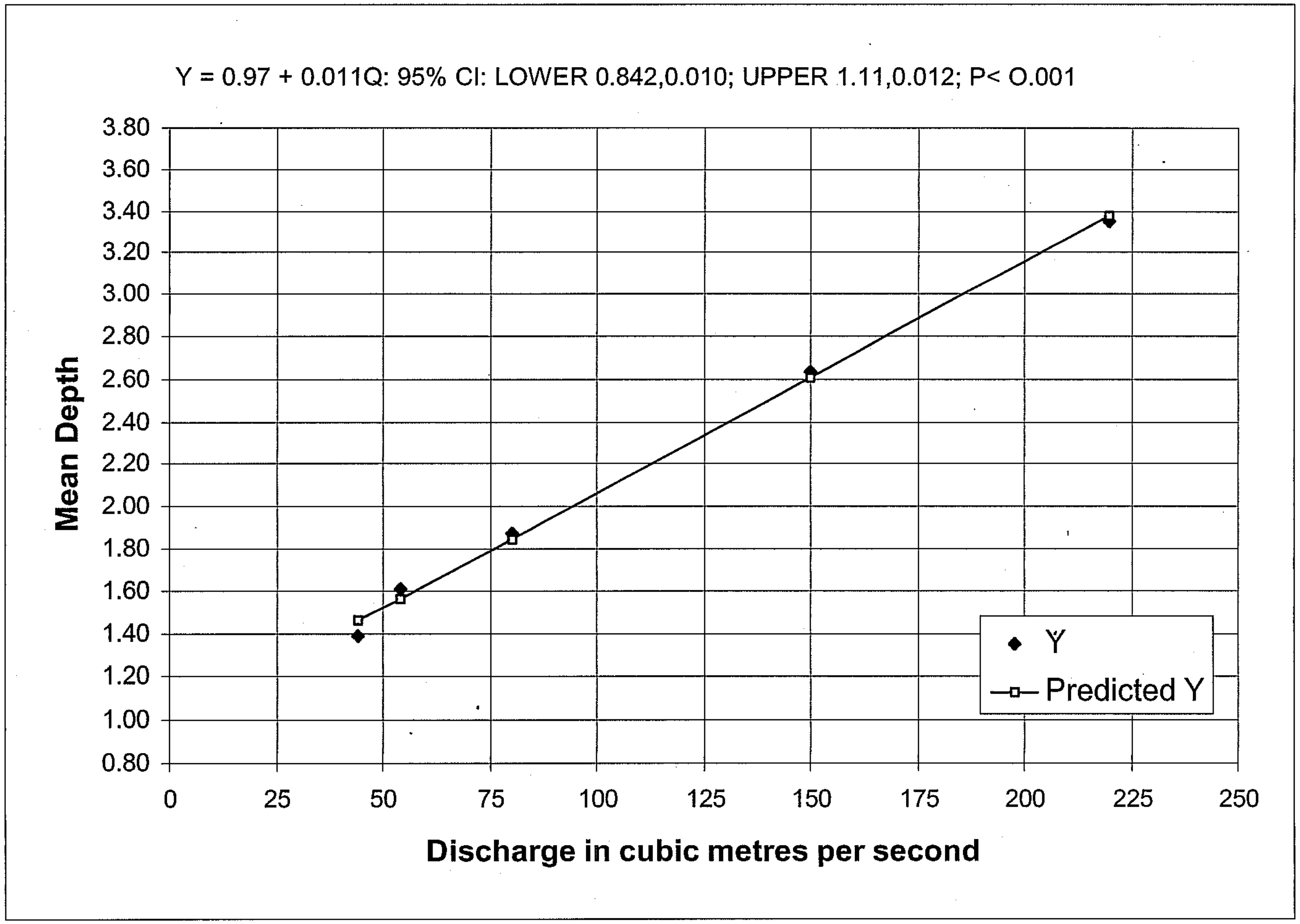


Figure 10: Regression of means of depth measurements made at centre stations in the Assiniboine River between Portage la Prairie and Winnipeg in 1996.

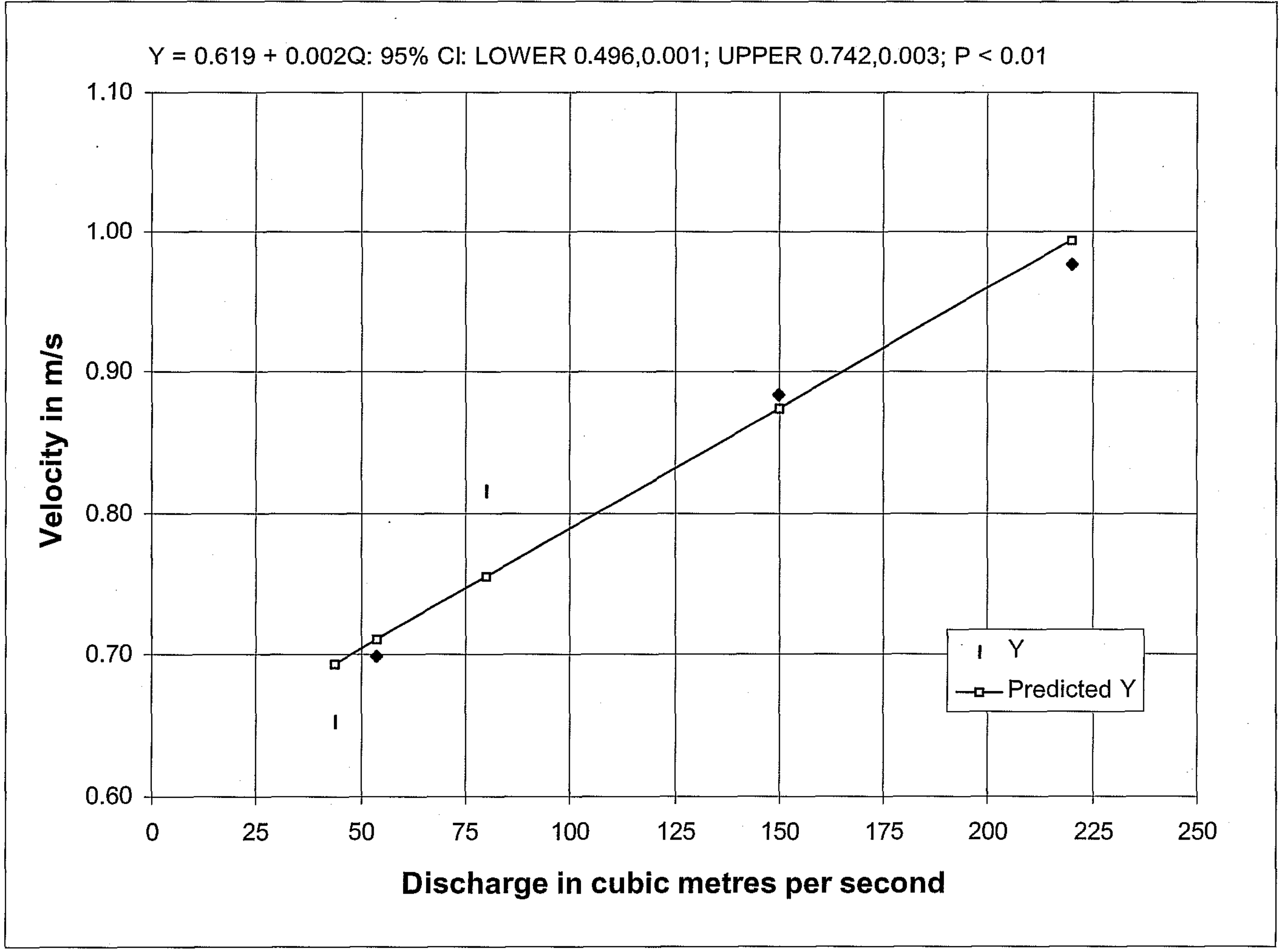
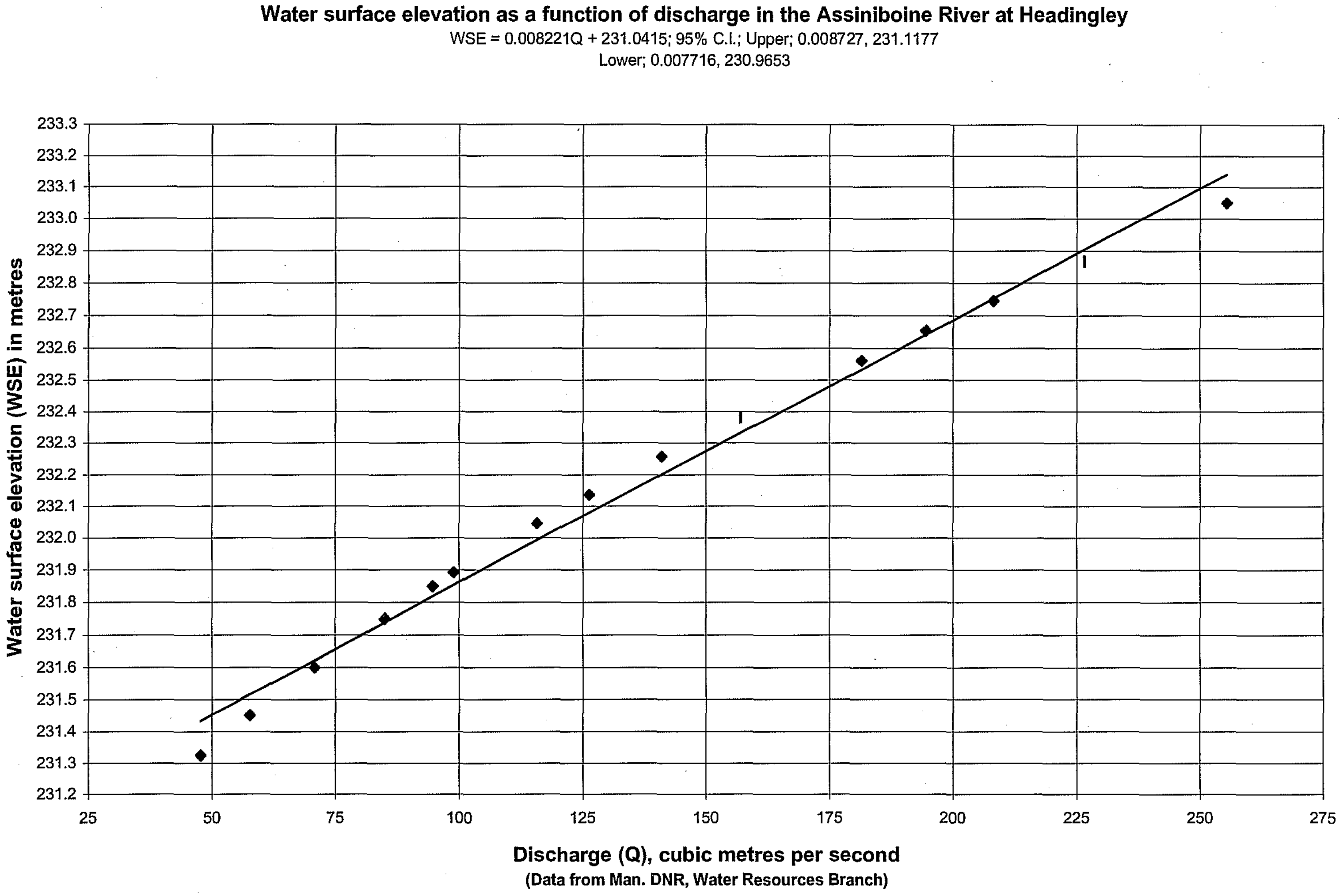


Figure 11: Regression of means of velocity measurements made at centre stations in the Assiniboine River between Portage la Prairie and Winnipeg in 1996.



Water surface elevation as a function of discharge in the Assiniboine River at Headingley

WSE = 0.008221Q + 231.0415; 95% C.I.; Upper; 0.008727, 231.1177
Lower; 0.007716, 230.9653

(Data from Man. DNR, Water Resources Branch)

Figure 12: Water surface elevation as a function of discharge in the Assiniboine River at Headingley.

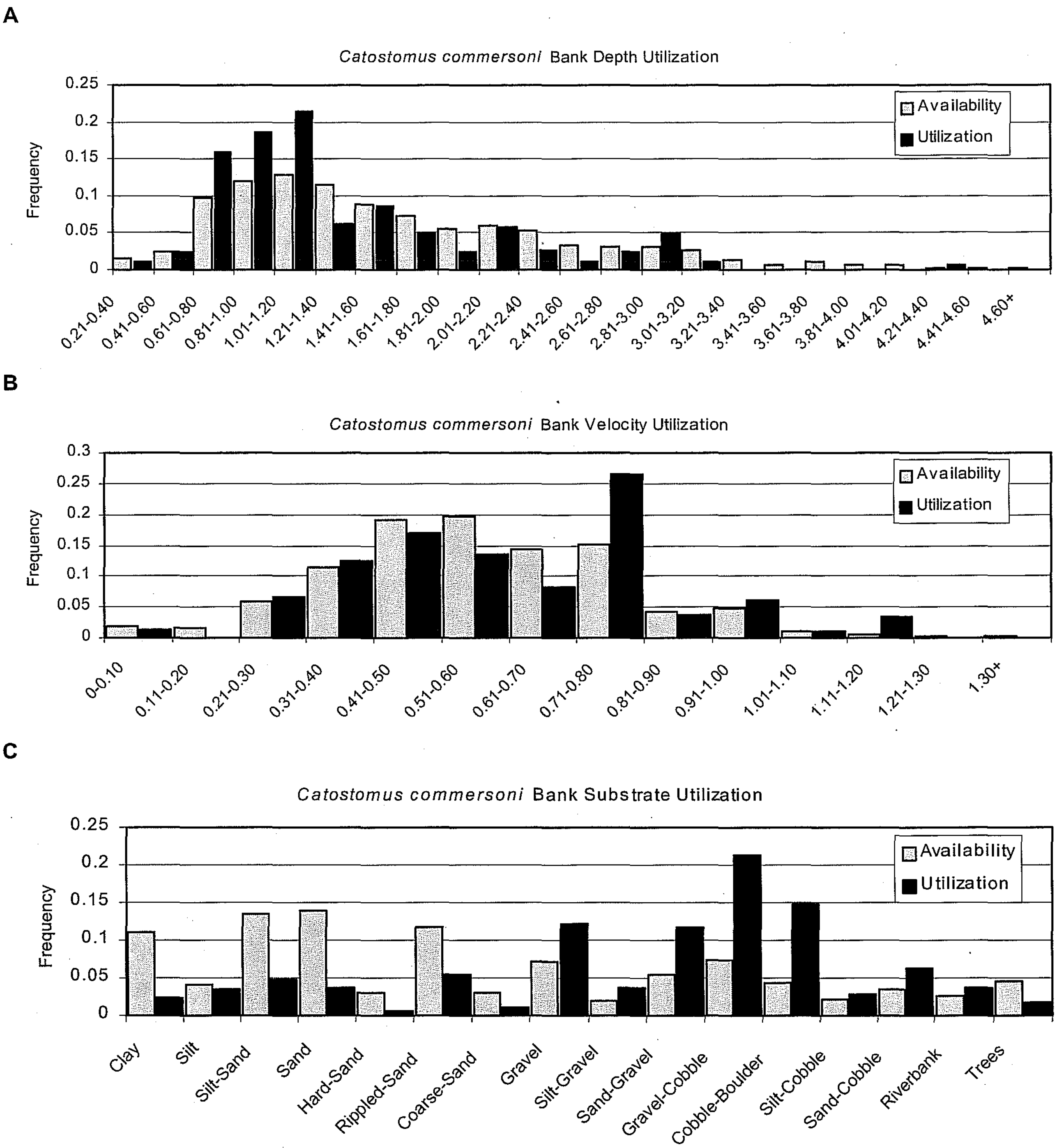


Figure 13: (A) Depth, (B) velocity and (C) substrate utilization for the white sucker (*Catostomus commersoni*) in bank habitats (n=290).

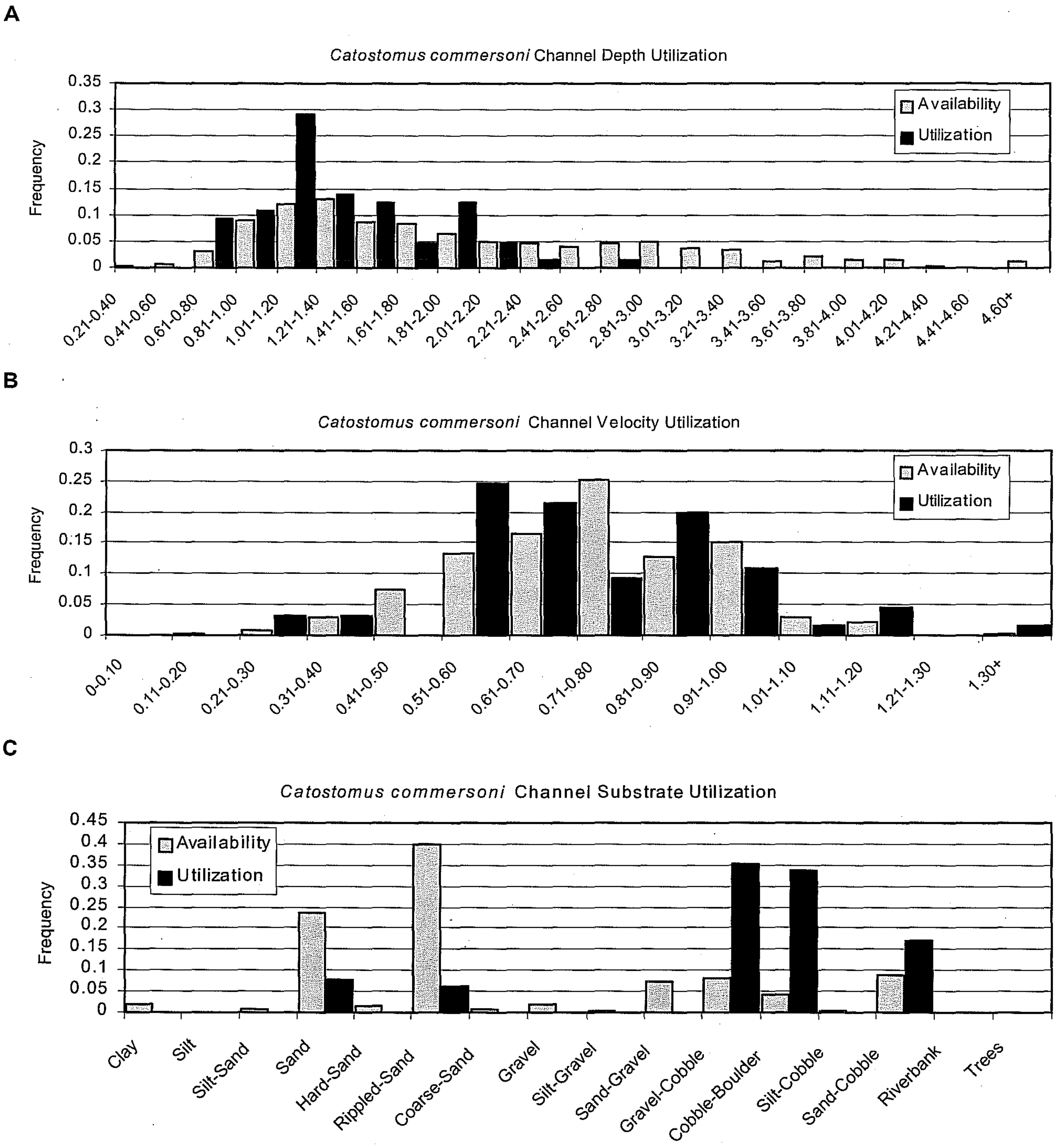


Figure 14: (A) Depth, (B) velocity and (C) substrate utilization for the white sucker (*Catostomus commersoni*) in channel habitats (n=65).

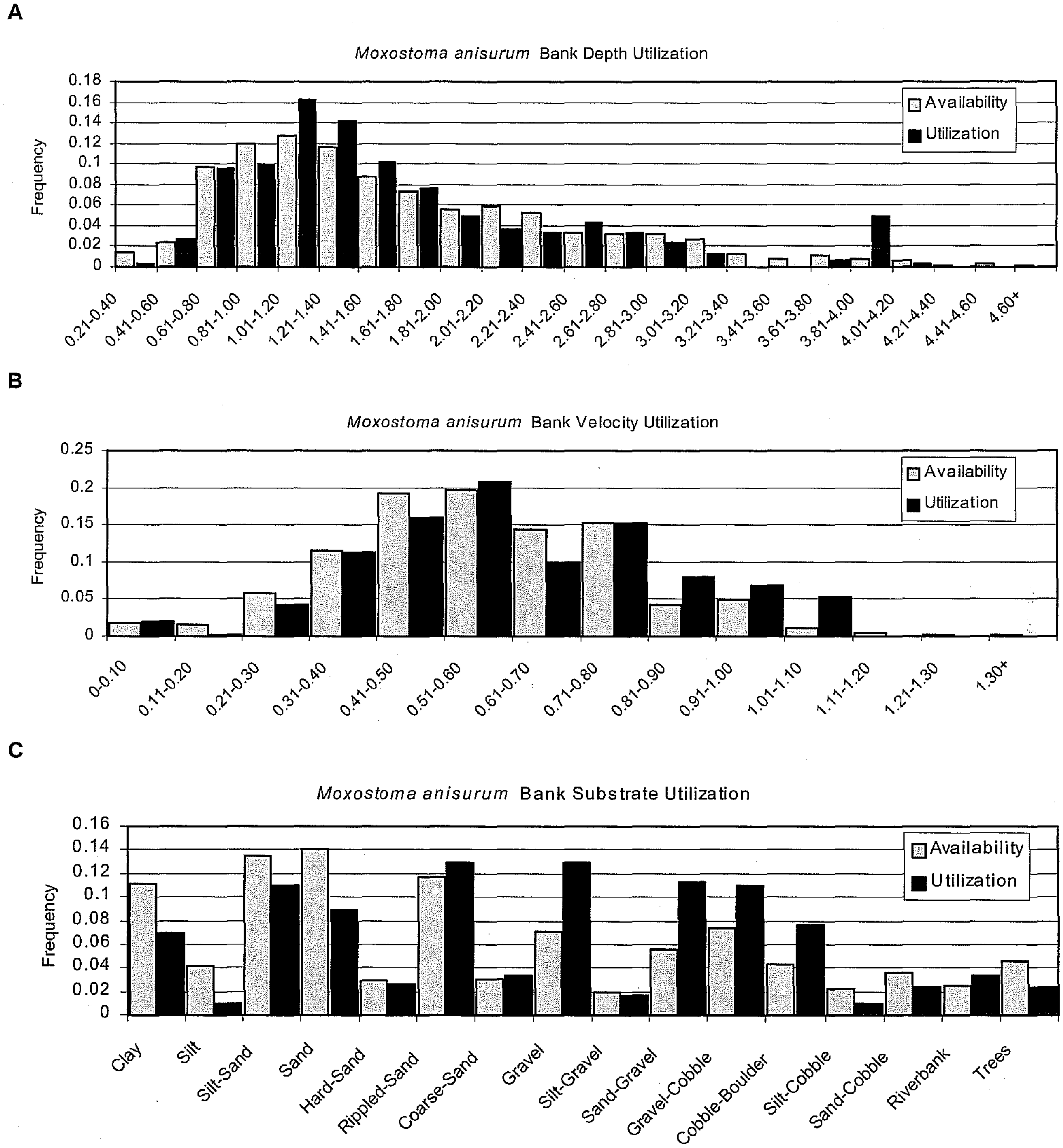


Figure 15: (A) Depth, (B) velocity and (C) substrate utilization for the silver redhorse (*Moxostoma anisurum*) in bank habitats (n=302).

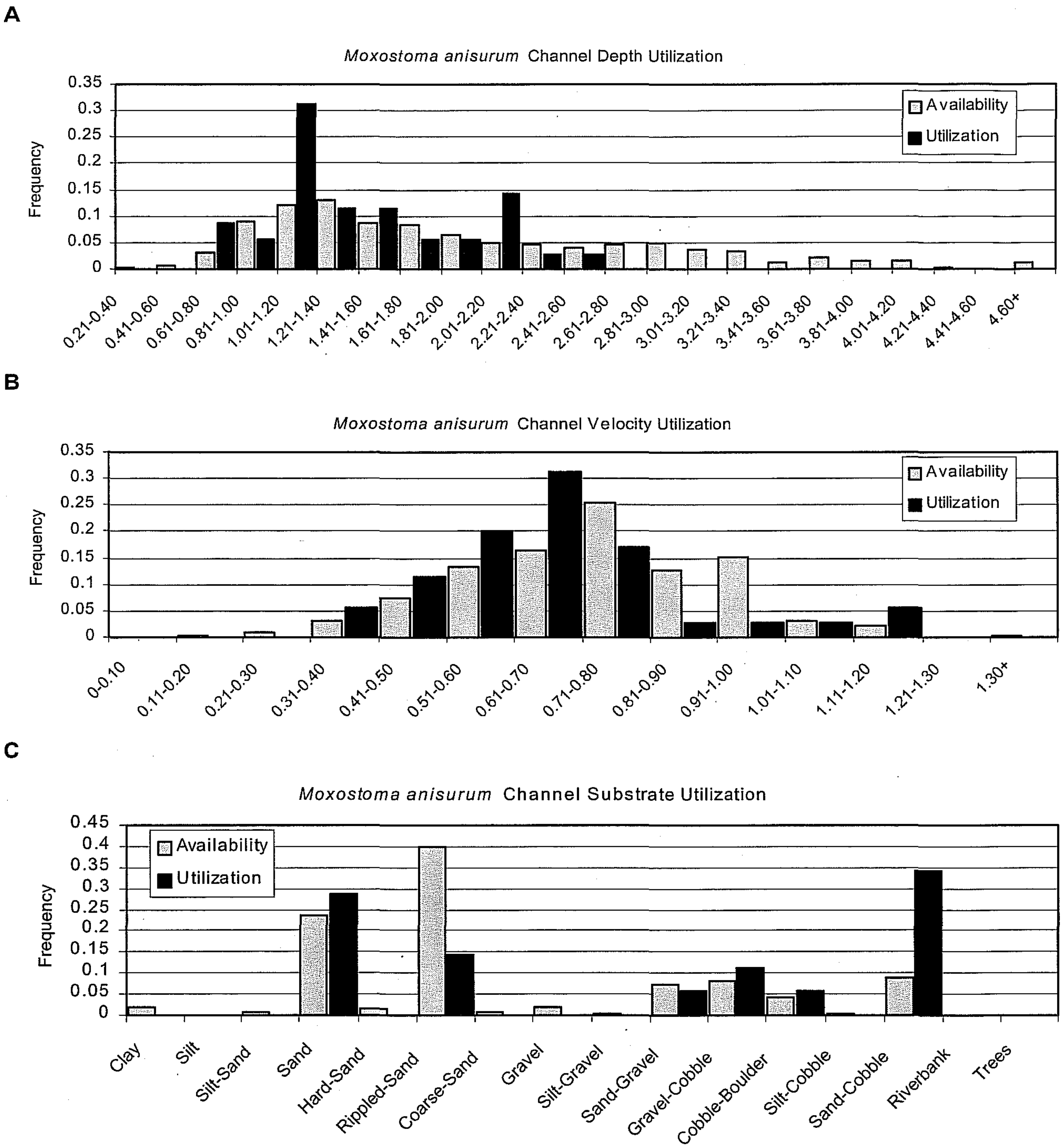


Figure 16: (A) Depth, (B) velocity and (C) substrate utilization for the silver redhorse (*Moxostoma anisurum*) in channel habitats (n=35).

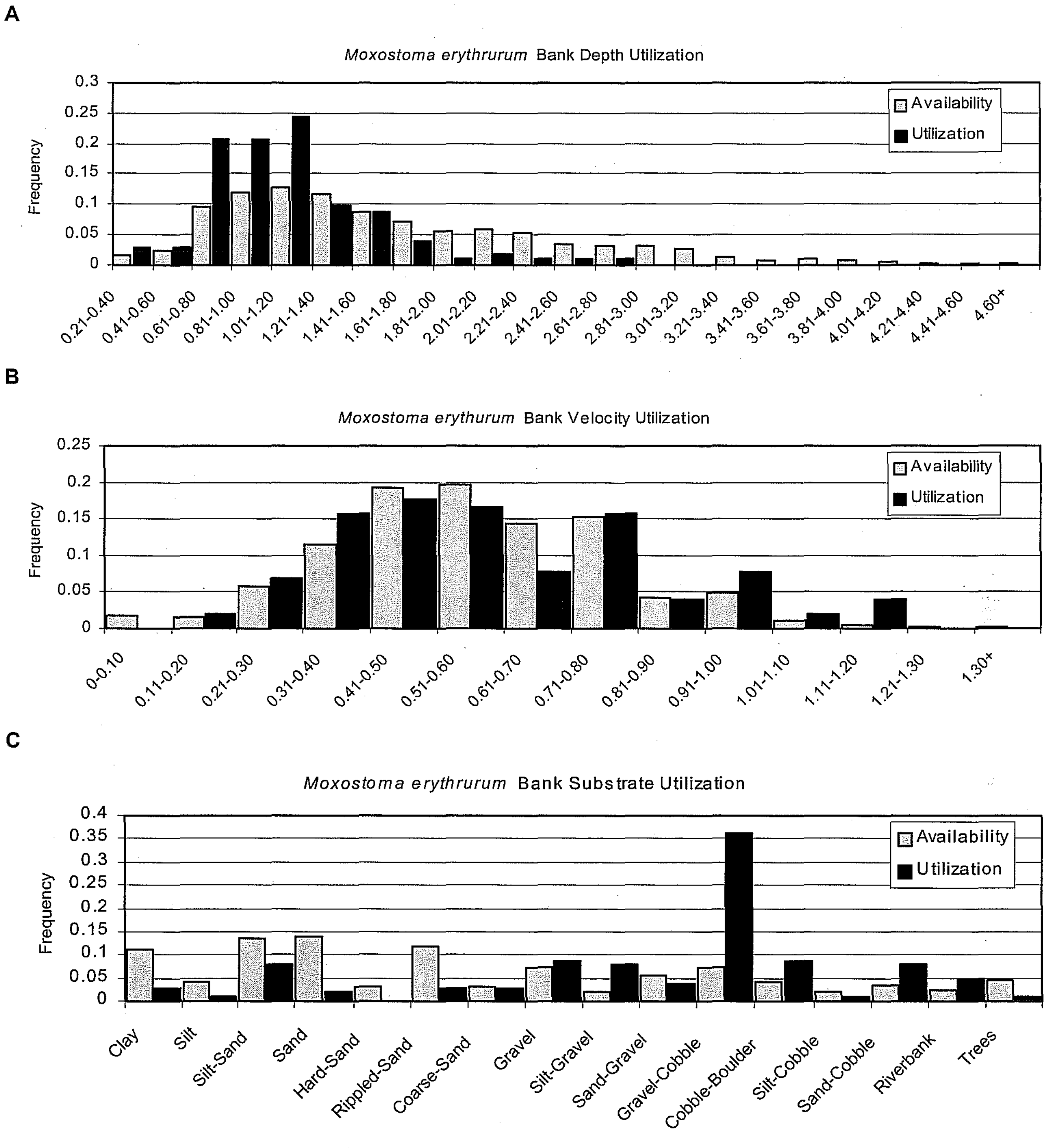


Figure 17: (A) Depth, (B) velocity and (C) substrate utilization for the golden redhorse (*Moxostoma erythrurum*) in bank habitats (n=102).

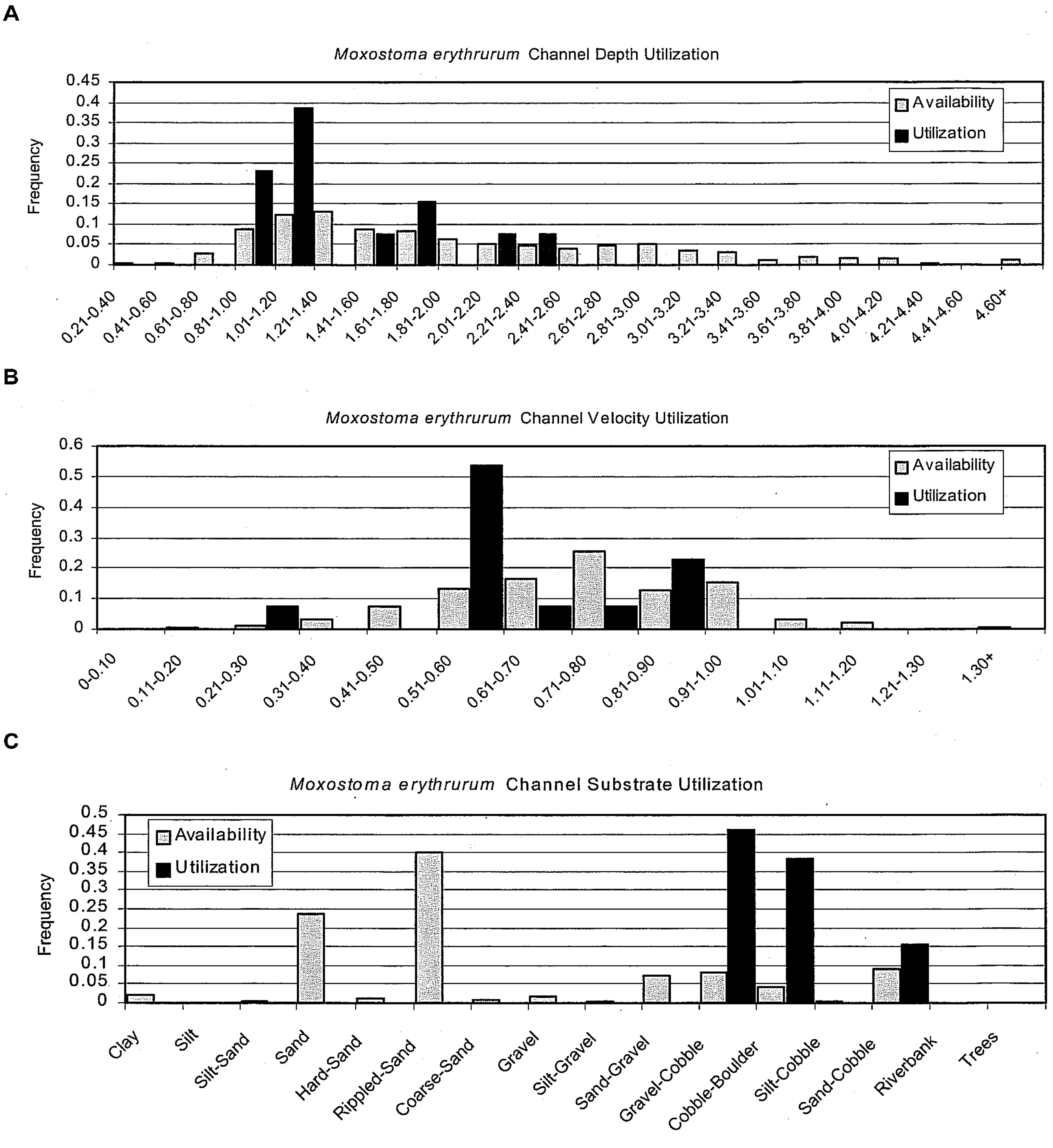


Figure 18: (A) Depth, (B) velocity and (C) substrate utilization for the golden redhorse (*Moxostoma erythrurum*) in channel habitats (n=13).

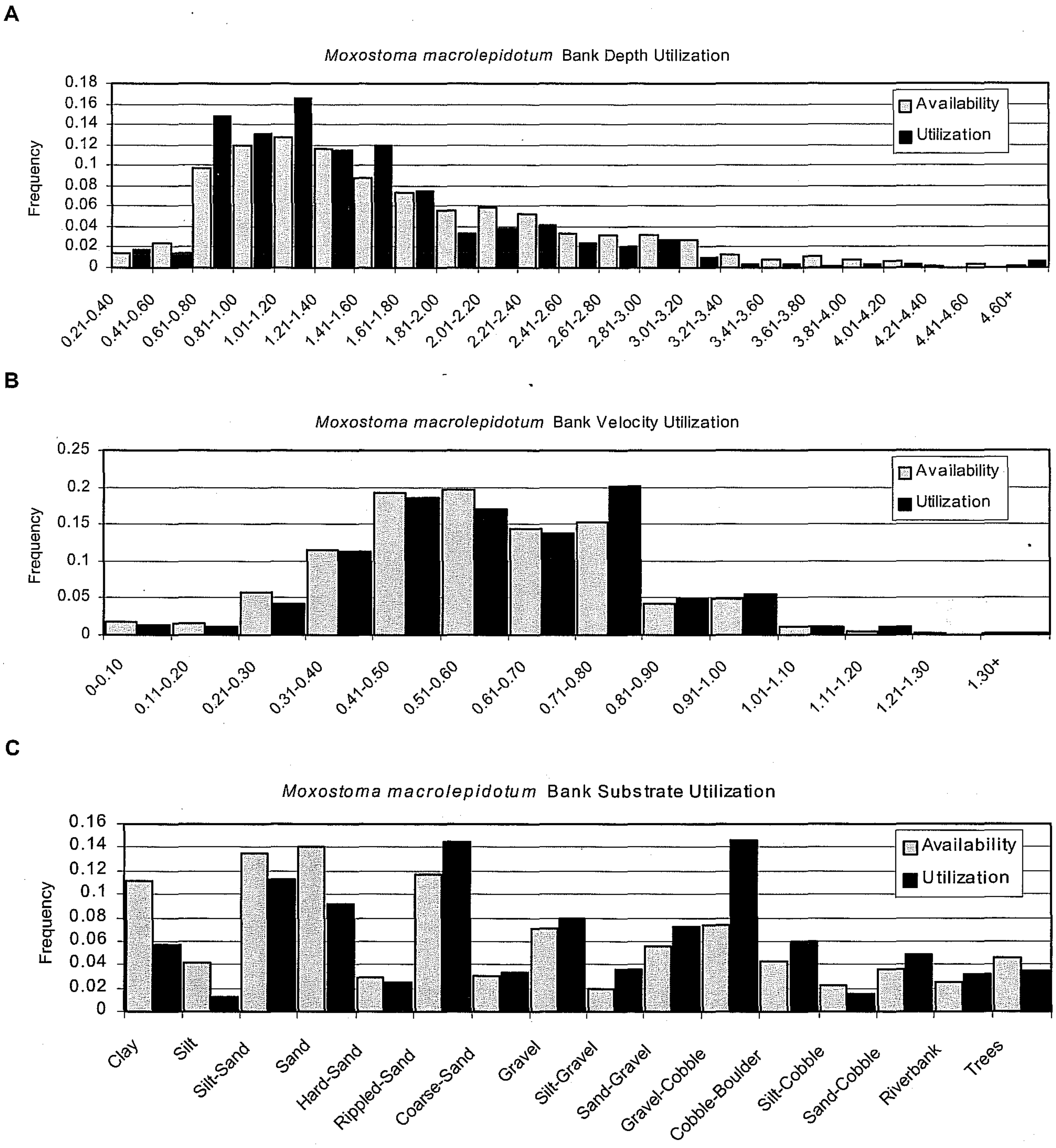


Figure 19: (A) Depth, (B) velocity and (C) substrate utilization for the shorthead redhorse (*Moxostoma macrolepidotum*) in bank habitats (n=1937).

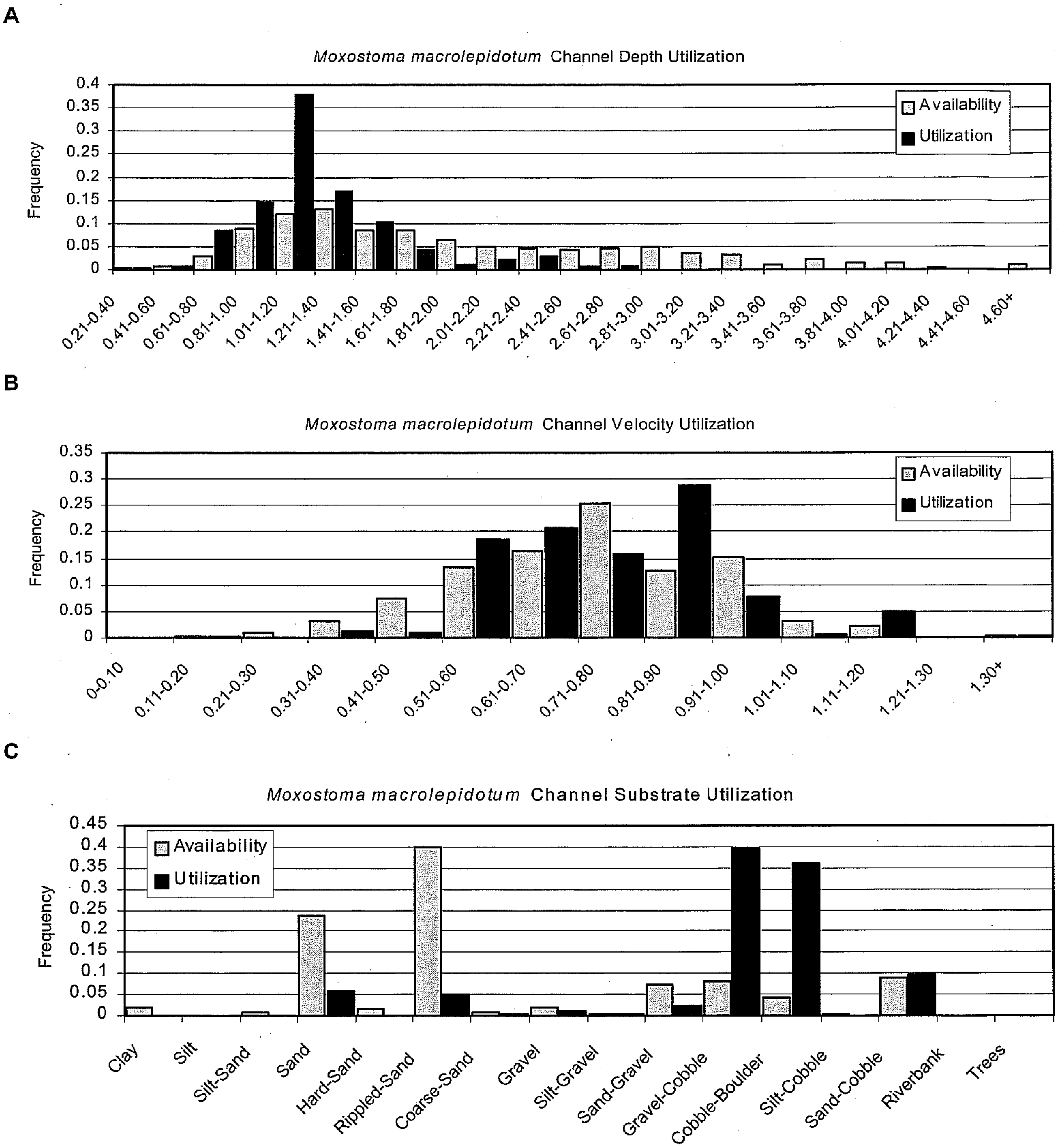


Figure 20: (A) Depth, (B) velocity and (C) substrate utilization for the shorthead redhorse (*Moxostoma macrolepidotum*) in channel habitats (n=355).

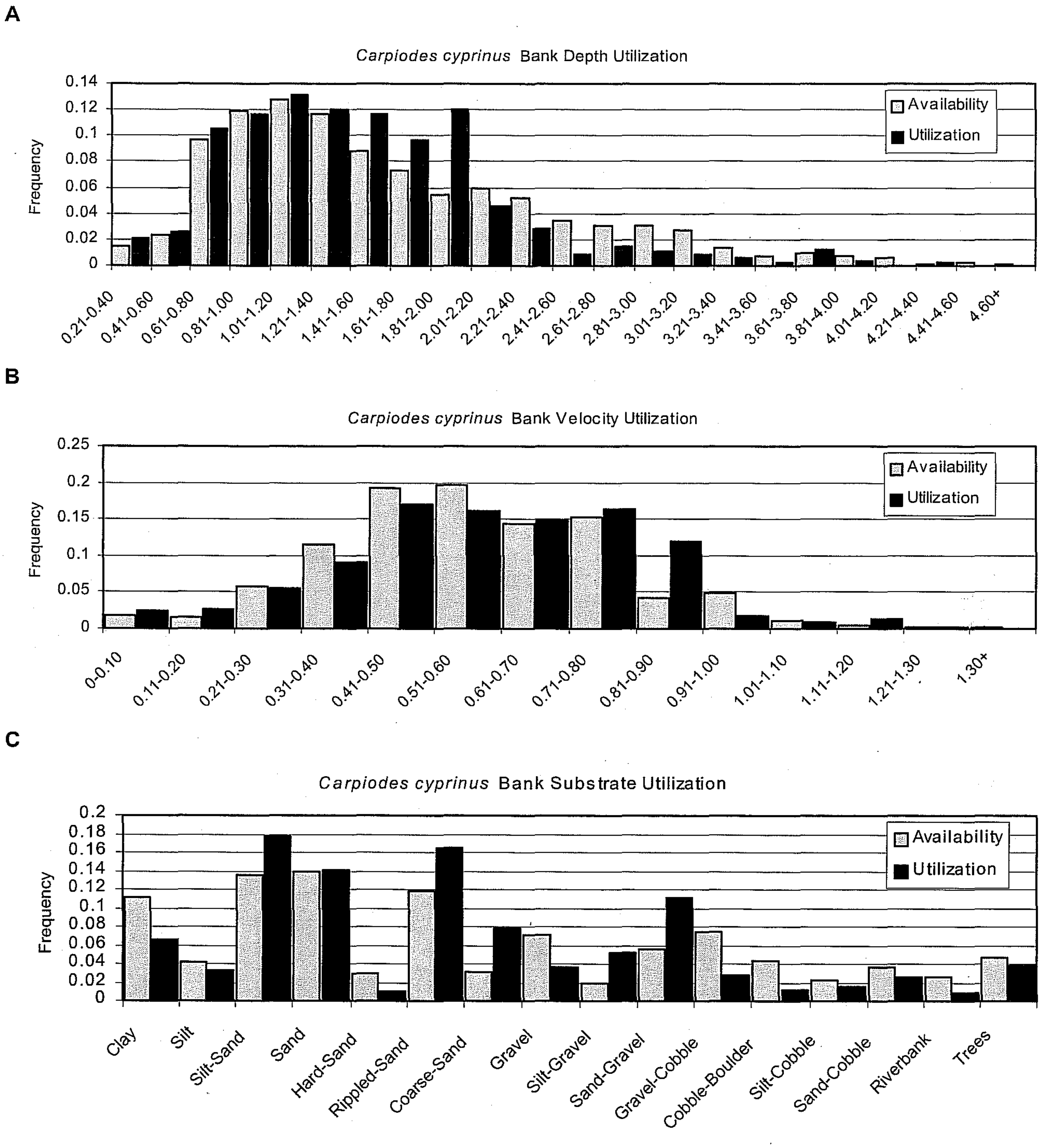


Figure 21: (A) Depth, (B) velocity and (C) substrate utilization for the quillback (*Carpiodes cyprinus*) in bank habitats (n=464).

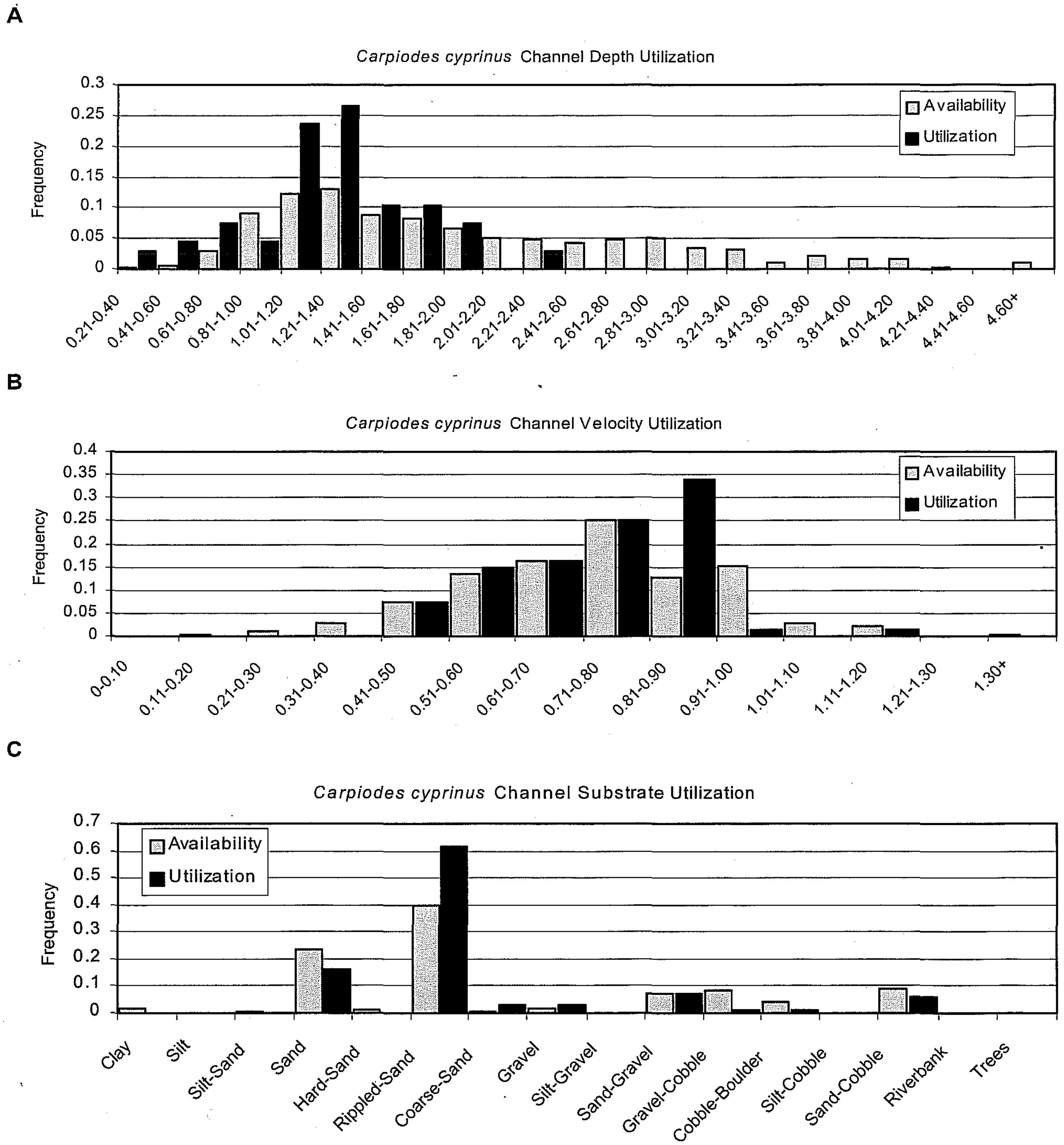


Figure 22: (A) Depth, (B) velocity and (C) substrate utilization for the quillback (*Carpiodes cyprinus*) in channel habitats (n=68).

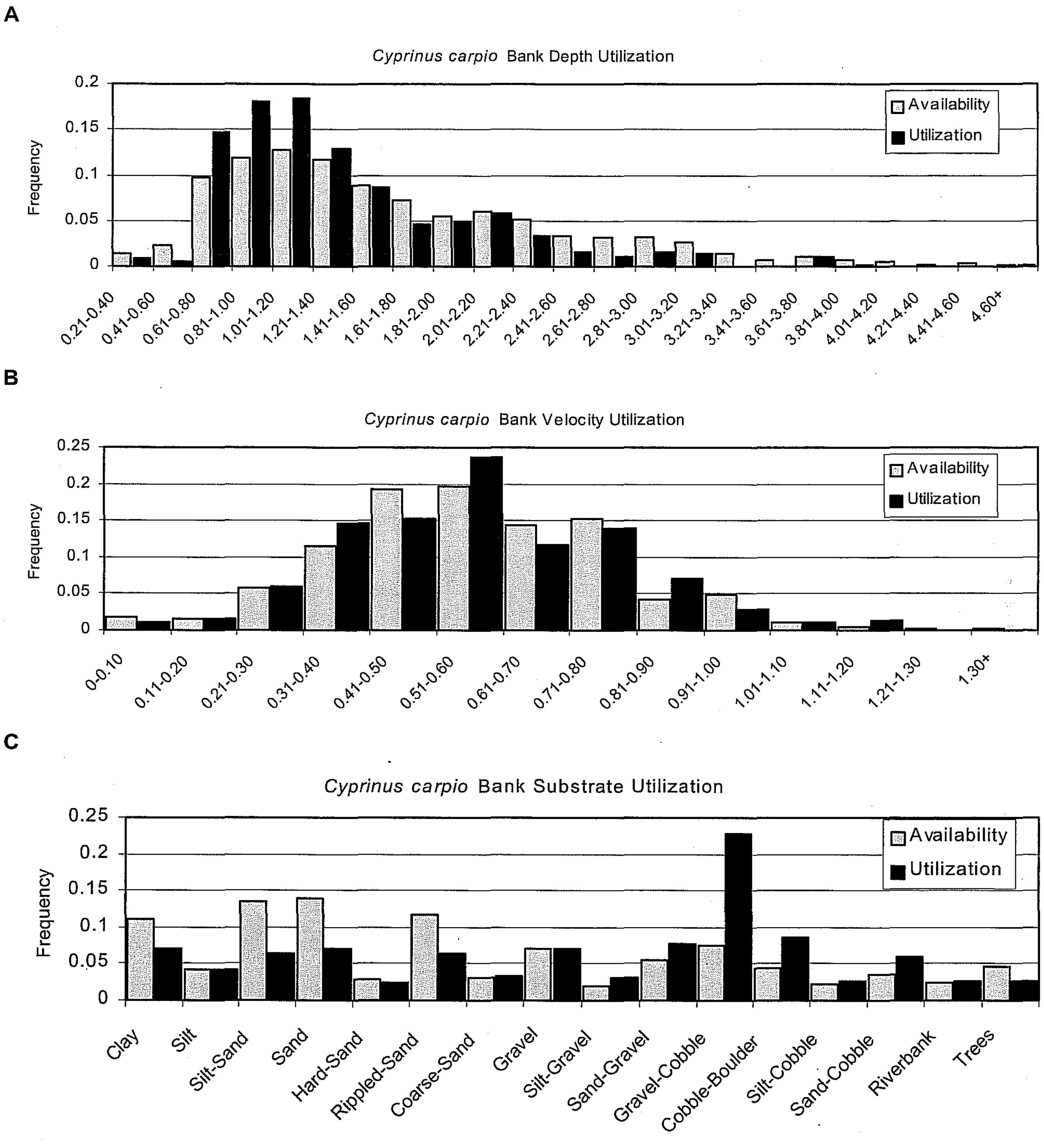
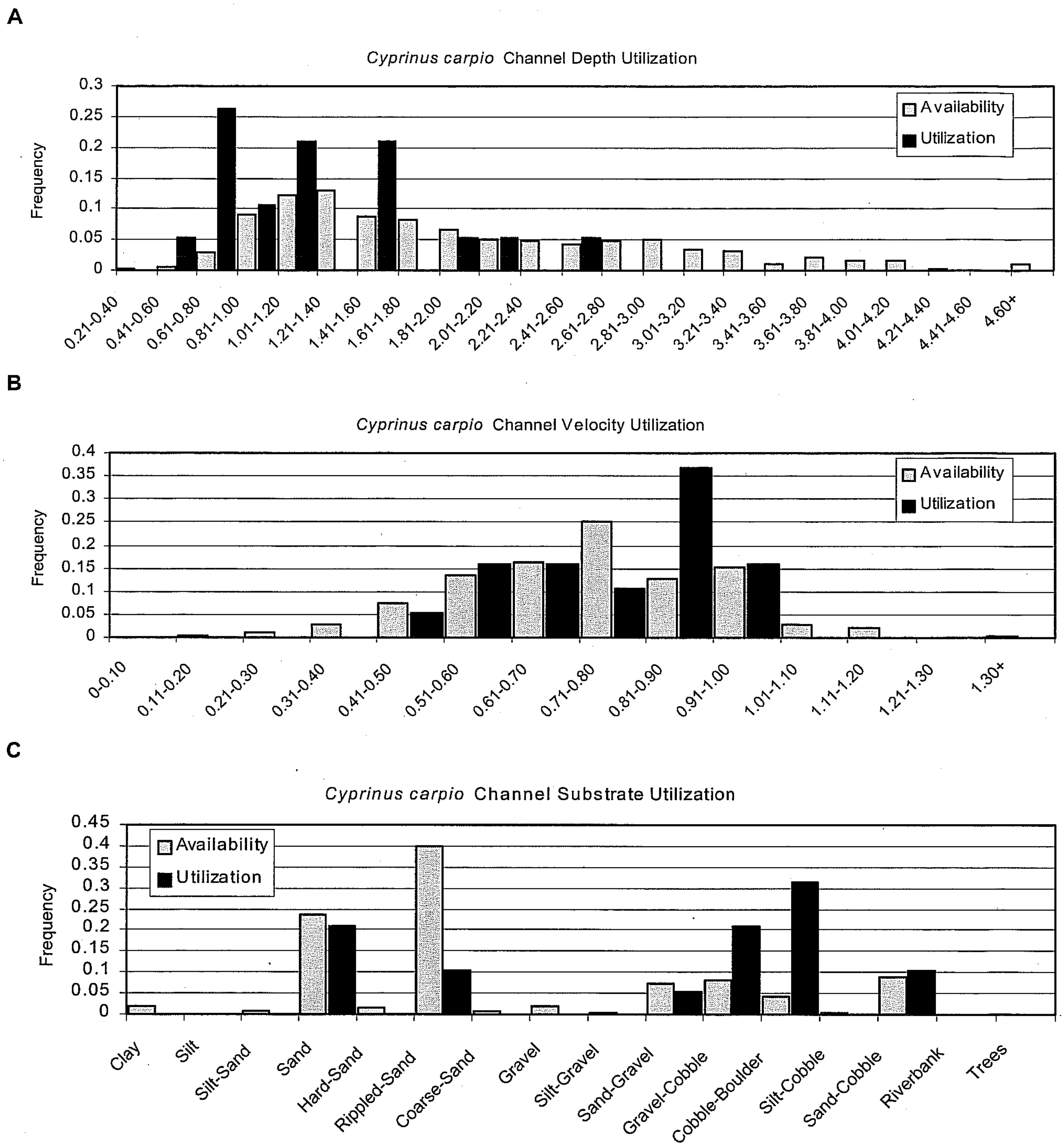


Figure 23: (A) Depth, (B) velocity and (C) substrate utilization for the carp (*Cyprinus carpio*) in bank habitats (n=585).



A *Cyprinus carpio* Channel Depth Utilization

B *Cyprinus carpio* Channel Velocity Utilization

C *Cyprinus carpio* Channel Substrate Utilization

Figure 24: (A) Depth, (B) velocity and (C) substrate utilization for the carp (*Cyprinus carpio*) in channel habitats (n=19).

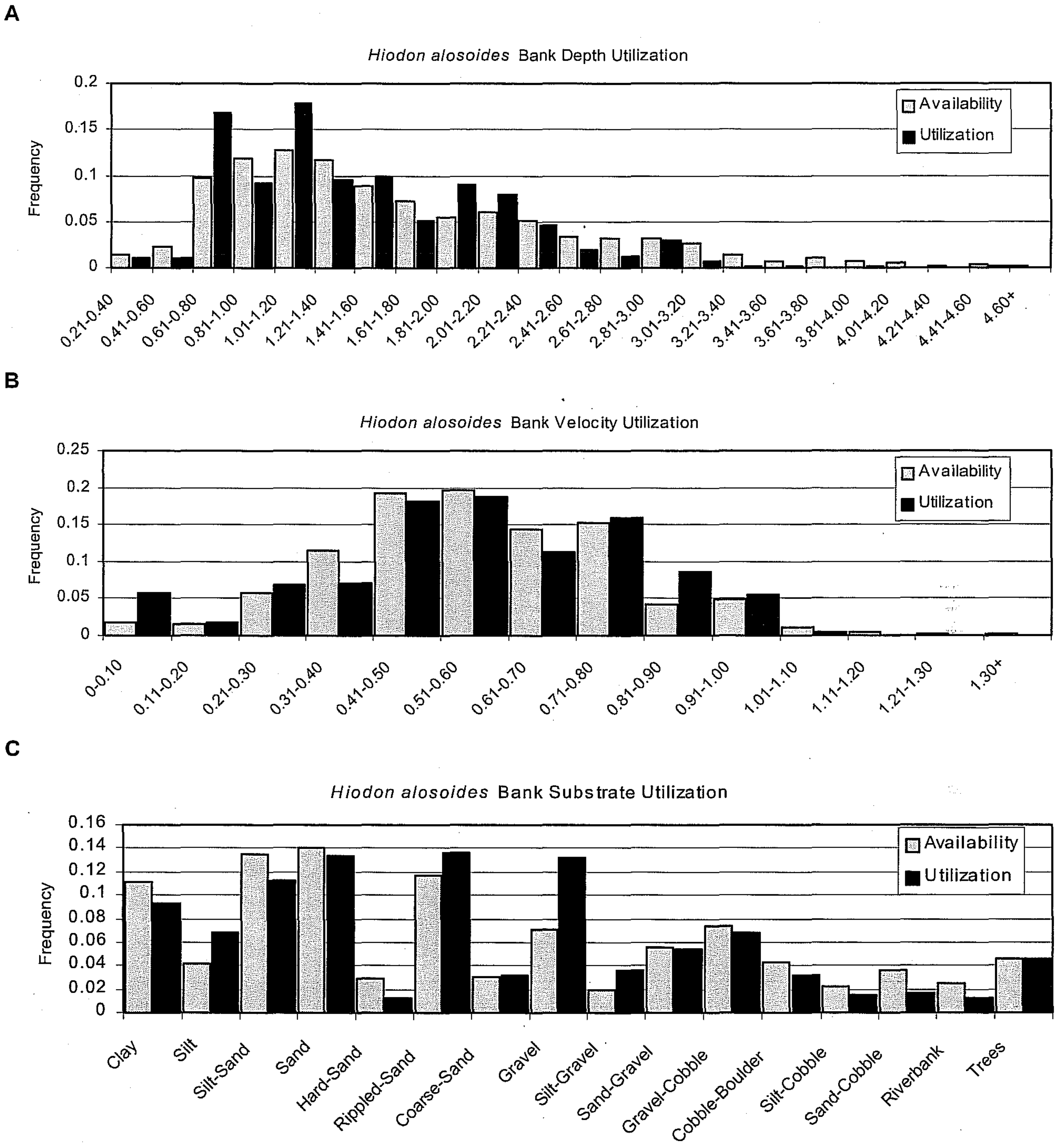


Figure 25: (A) Depth, (B) velocity and (C) substrate utilization for the goldeye (*Hiodon alosoides*) in bank habitats (n=410).

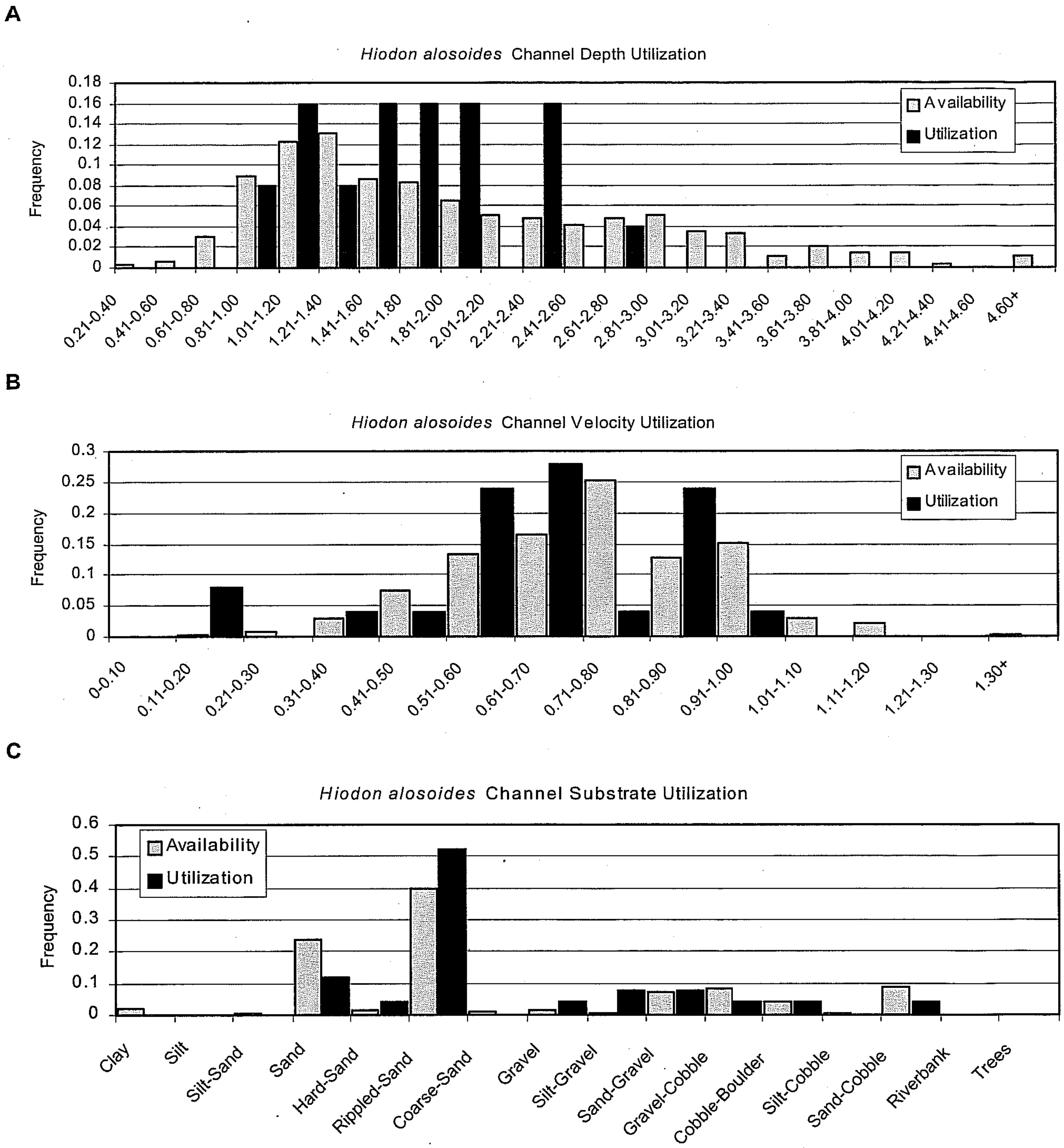


Figure 26: (A) Depth, (B) velocity and (C) substrate utilization for the goldeye (*Hiodon alosoides*) in channel habitats (n=25).

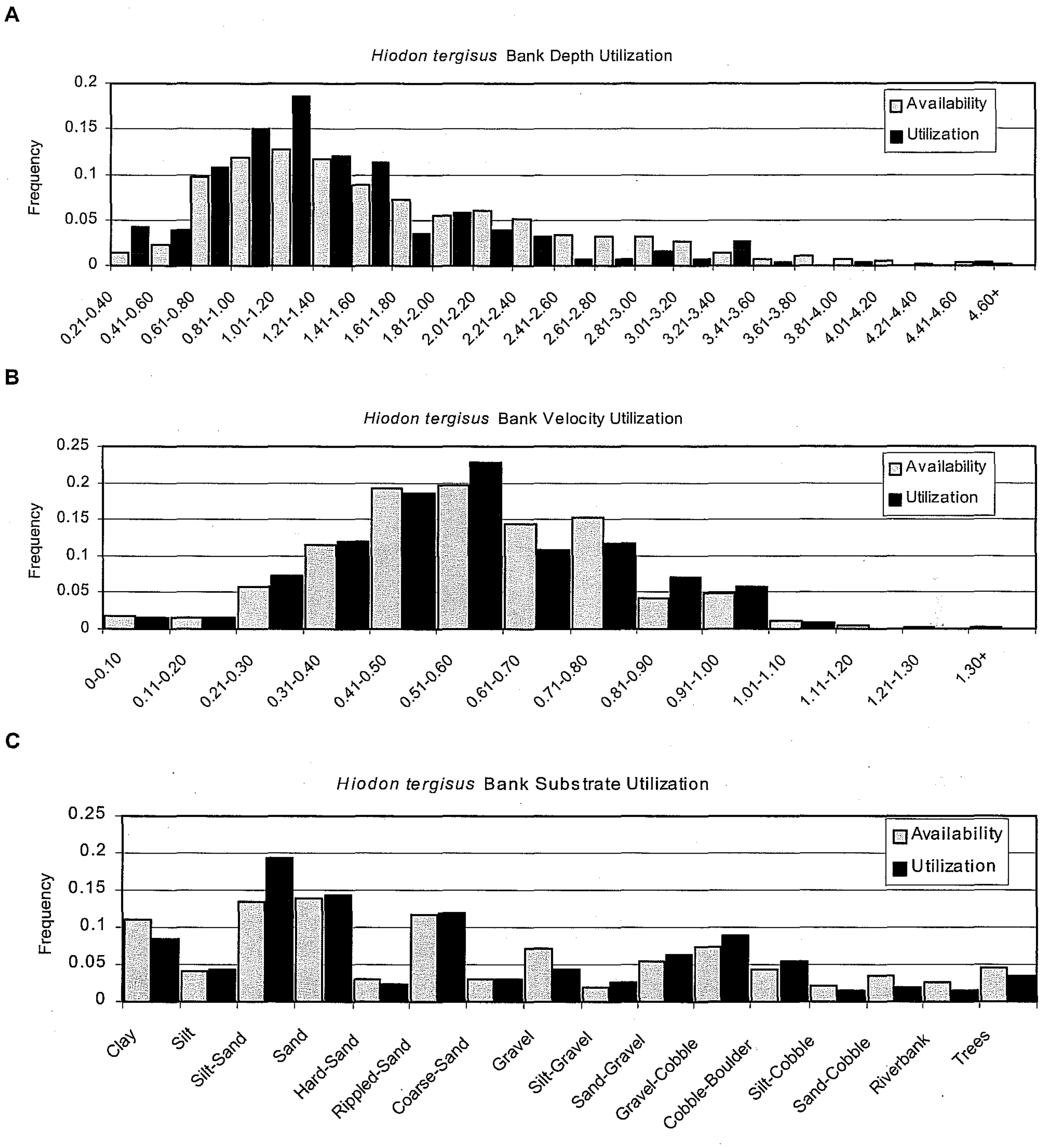


Figure 27: (A) Depth, (B) velocity and (C) substrate utilization for the mooneye (*Hiodon tergisus*) in bank habitats (n=258).

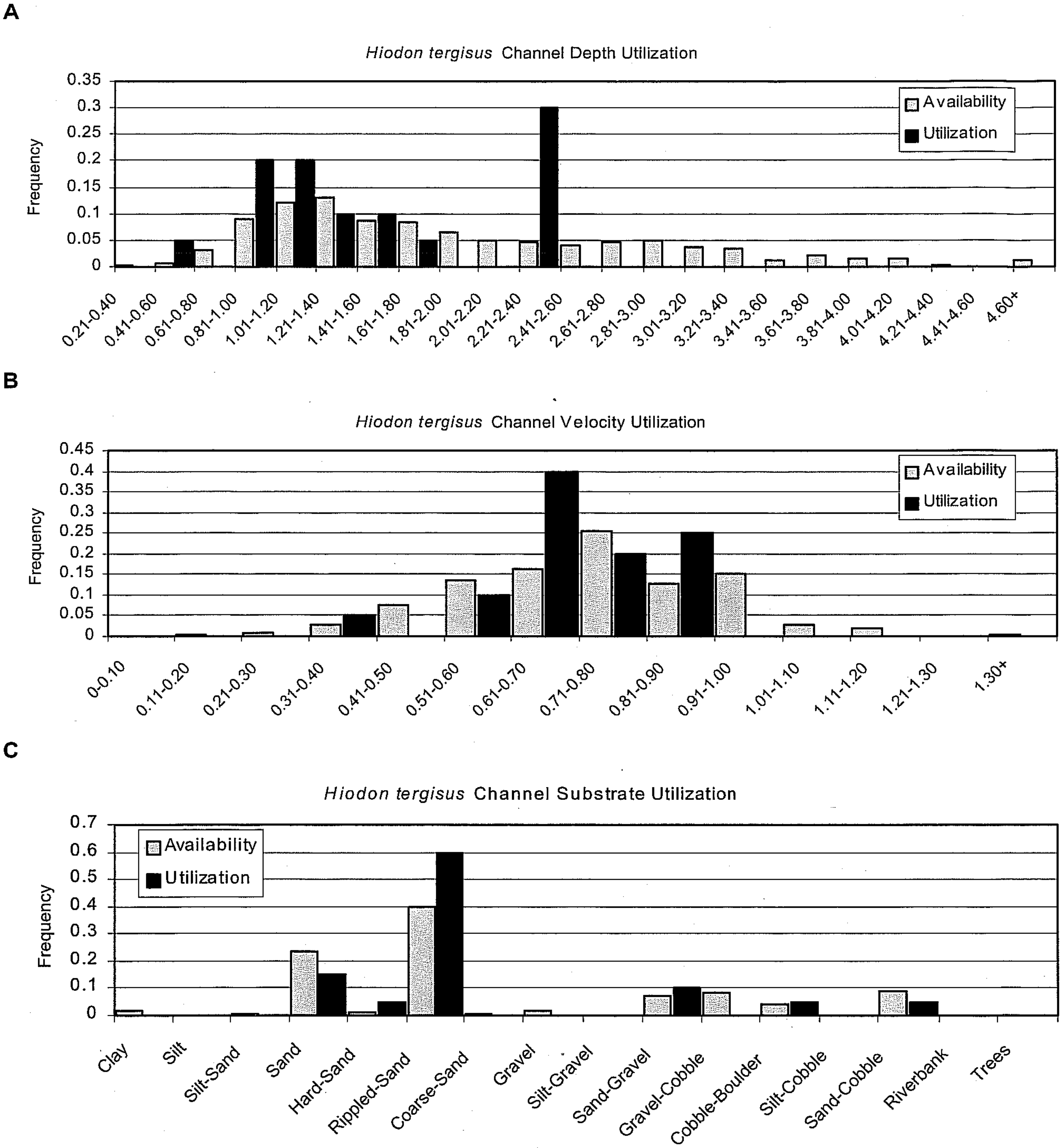


Figure 28: (A) Depth, (B) velocity and (C) substrate utilization for the mooneye (*Hiodon tergisus*) in channel habitats (n=20).

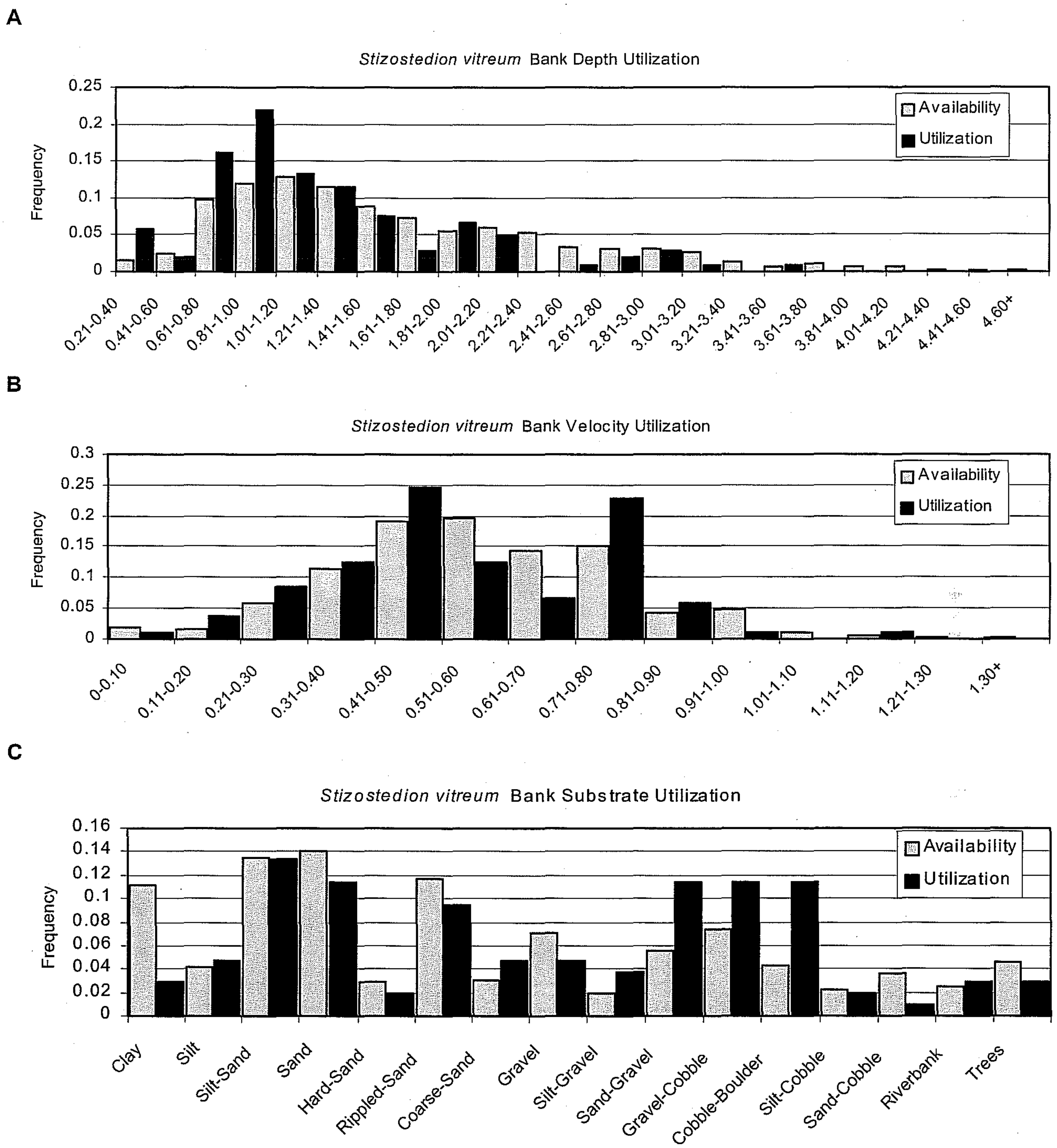


Figure 29: (A) Depth, (B) velocity and (C) substrate utilization for the walleye (*Stizostedion vitreum*) in bank habitats (n=105).

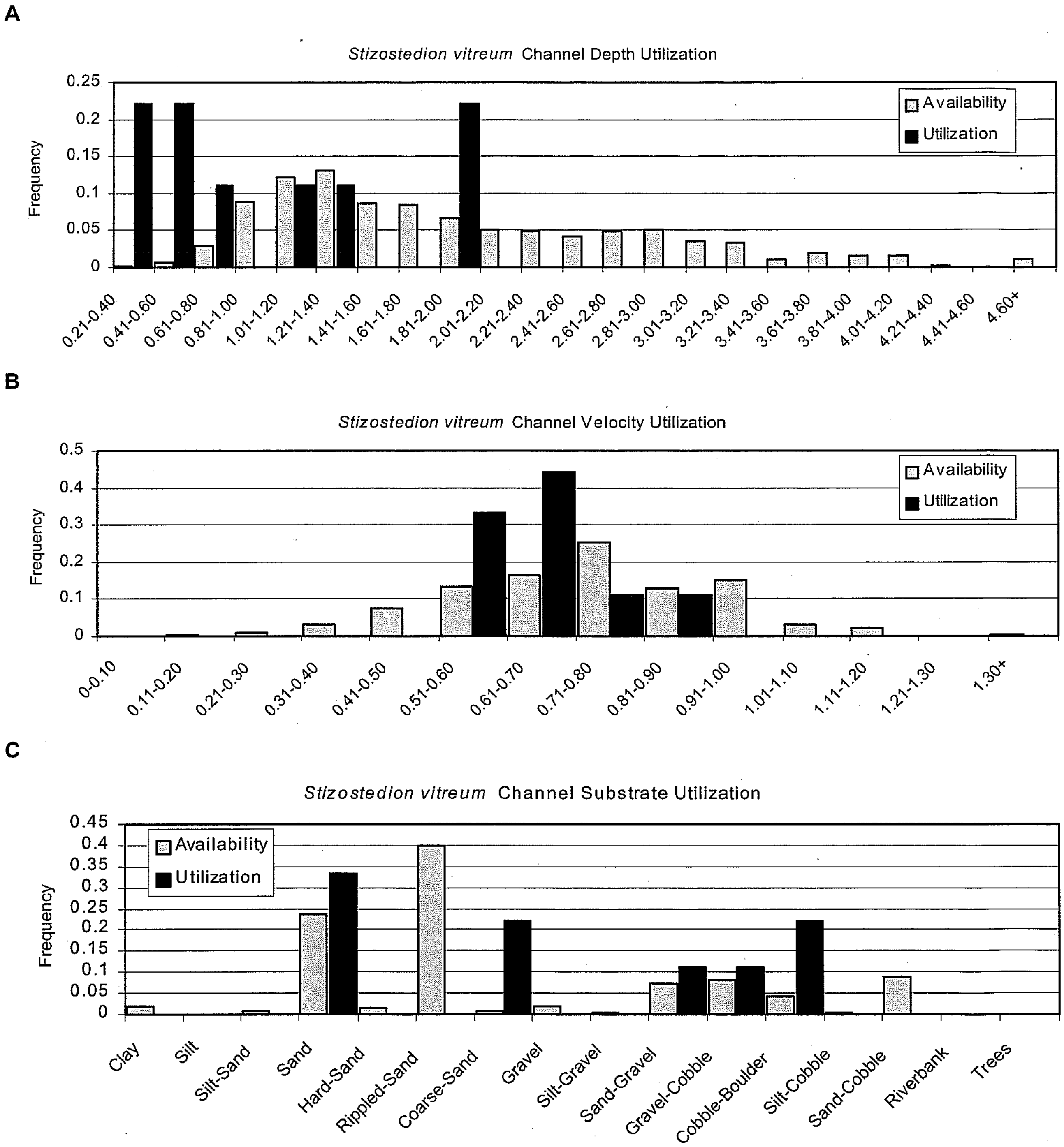
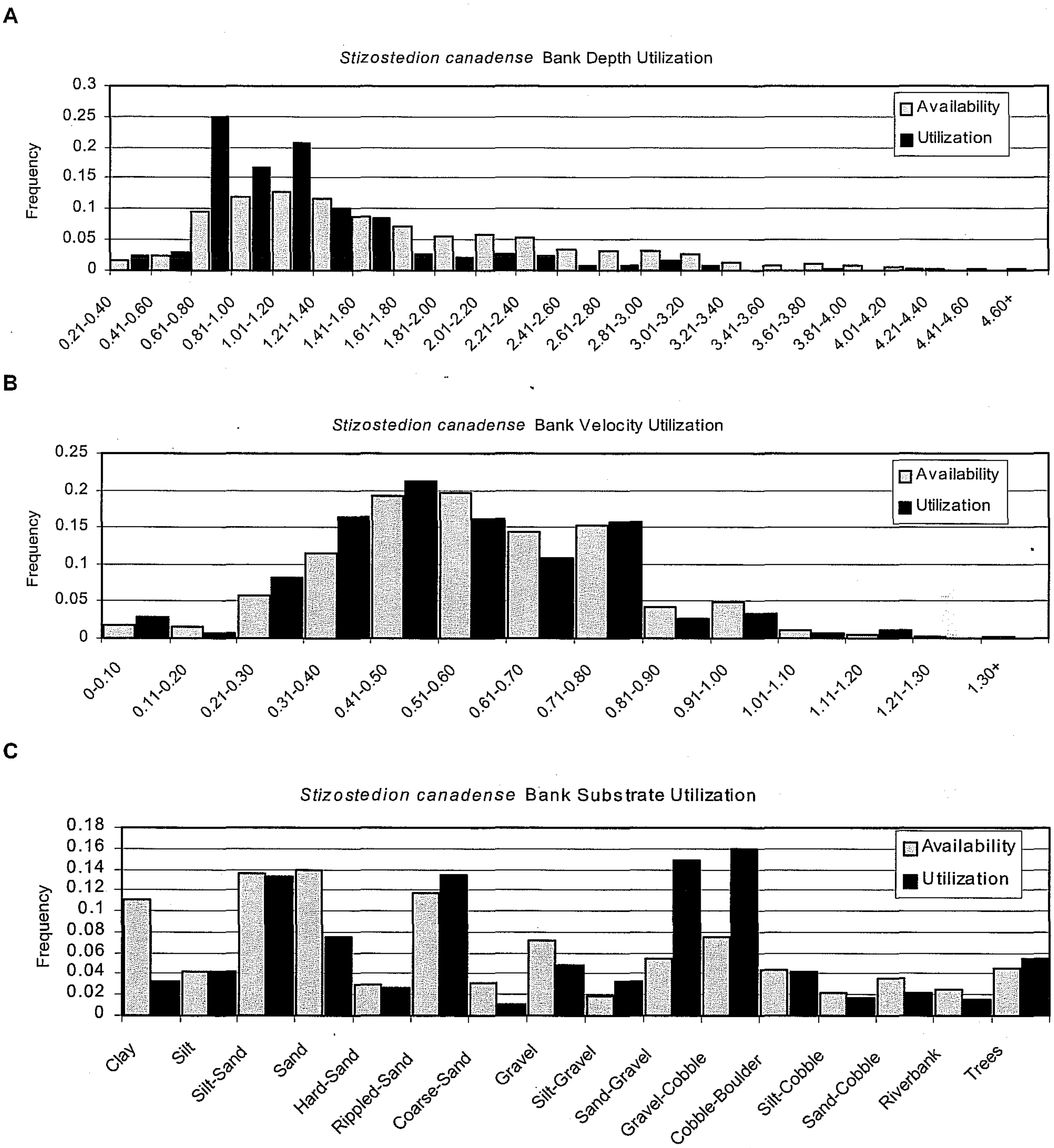


Figure 30: (A) Depth, (B) velocity and (C) substrate utilization for the walleye (*Stizostedion vitreum*) in channel habitats (n=9).



Stizostedion canadense Bank Depth Utilization

Stizostedion canadense Bank Velocity Utilization

Stizostedion canadense Bank Substrate Utilization

Figure 31: (A) Depth, (B) velocity and (C) substrate utilization for the sauger (*Stizostedion canadense*) in bank habitats (n=451).

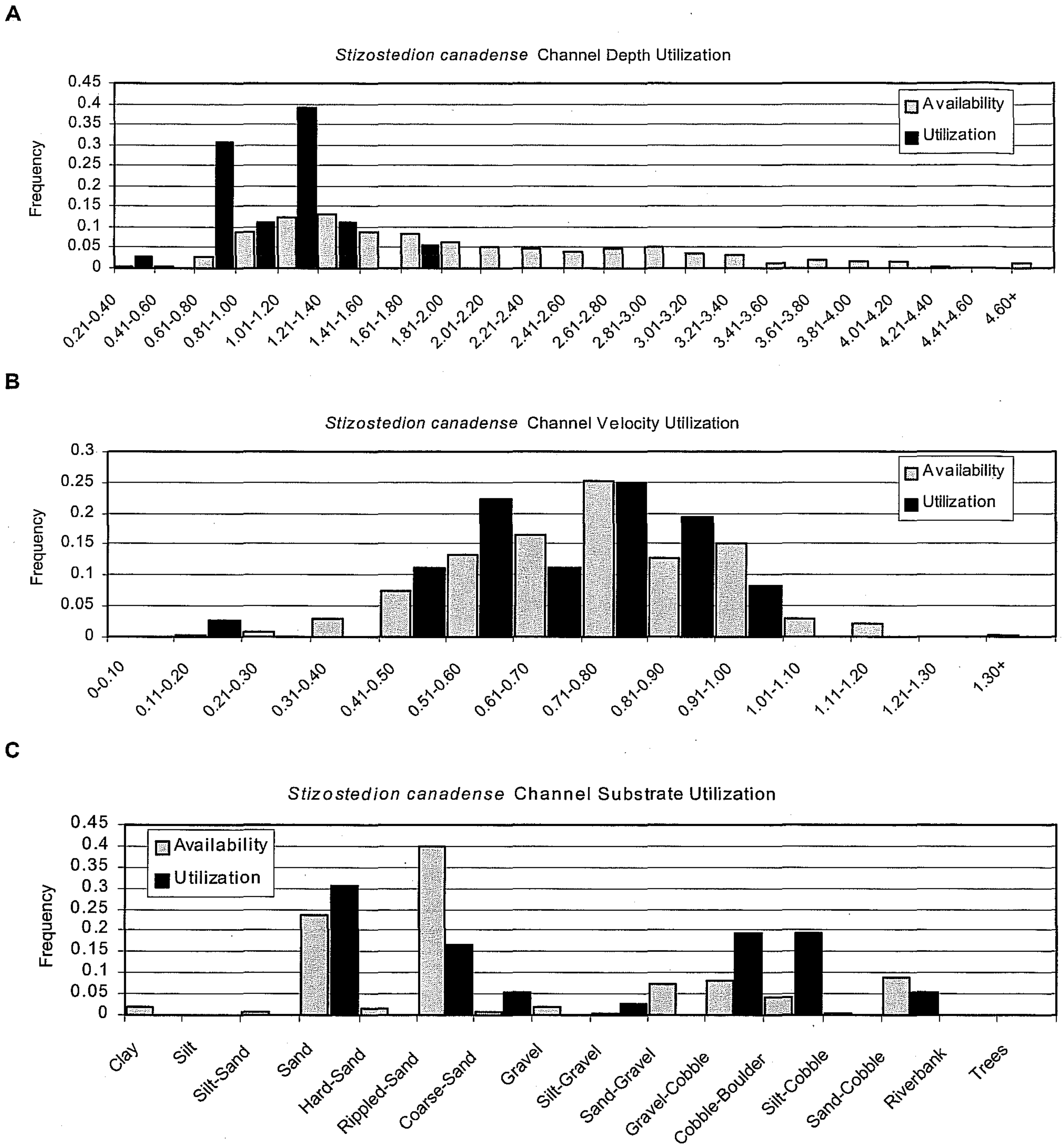


Figure 32: (A) Depth, (B) velocity and (C) substrate utilization for the sauger (*Stizostedion canadense*) in channel habitats (n=36).

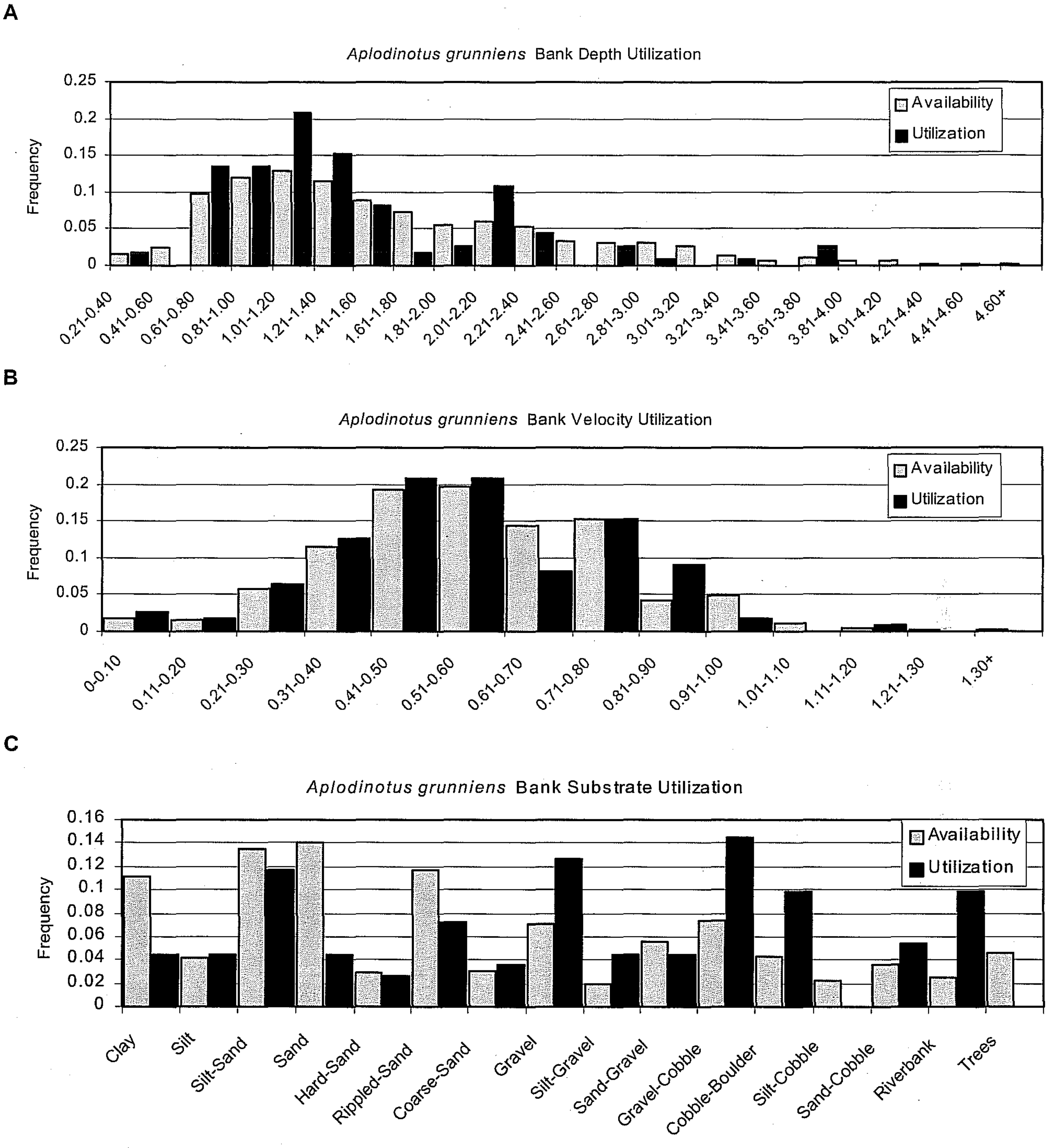


Figure 33: (A) Depth, (B) velocity and (C) substrate utilization for the freshwater drum (*Aplodinotus grunniens*) in bank habitats (n=111).

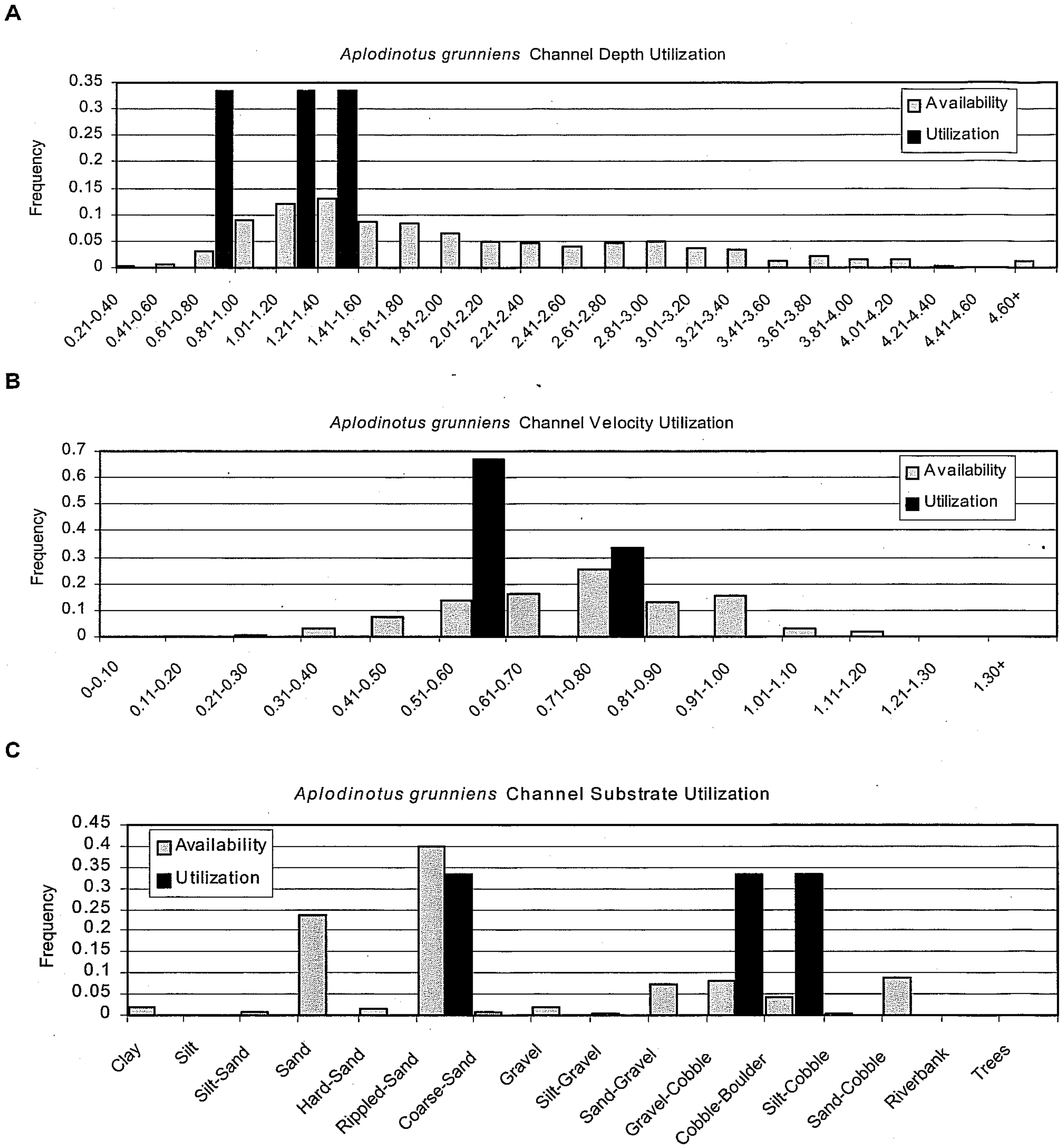


Figure 34: (A) Depth, (B) velocity and (C) substrate utilization for the freshwater drum (*Aplodinotus grunniens*) in channel habitats (n=3).

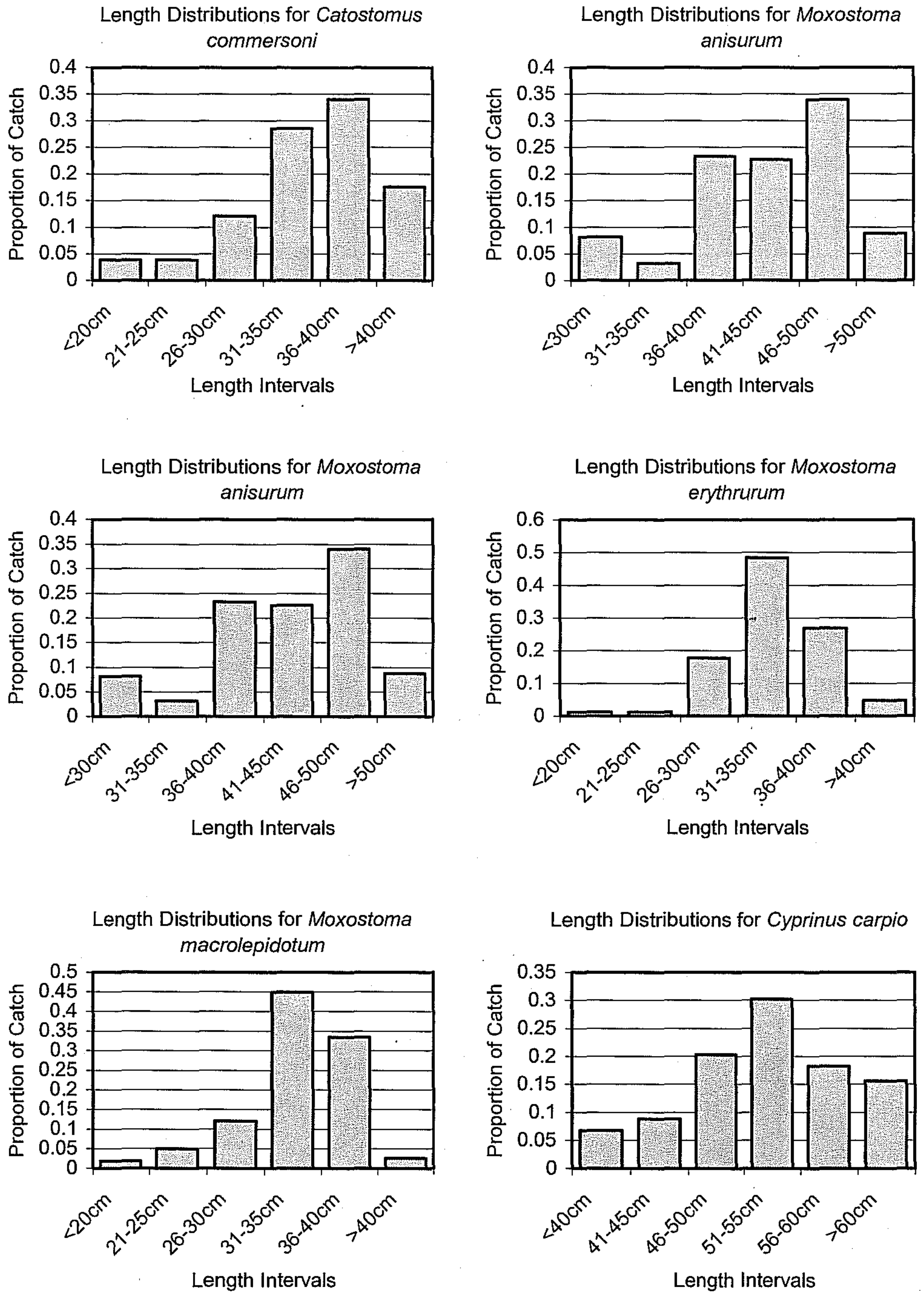
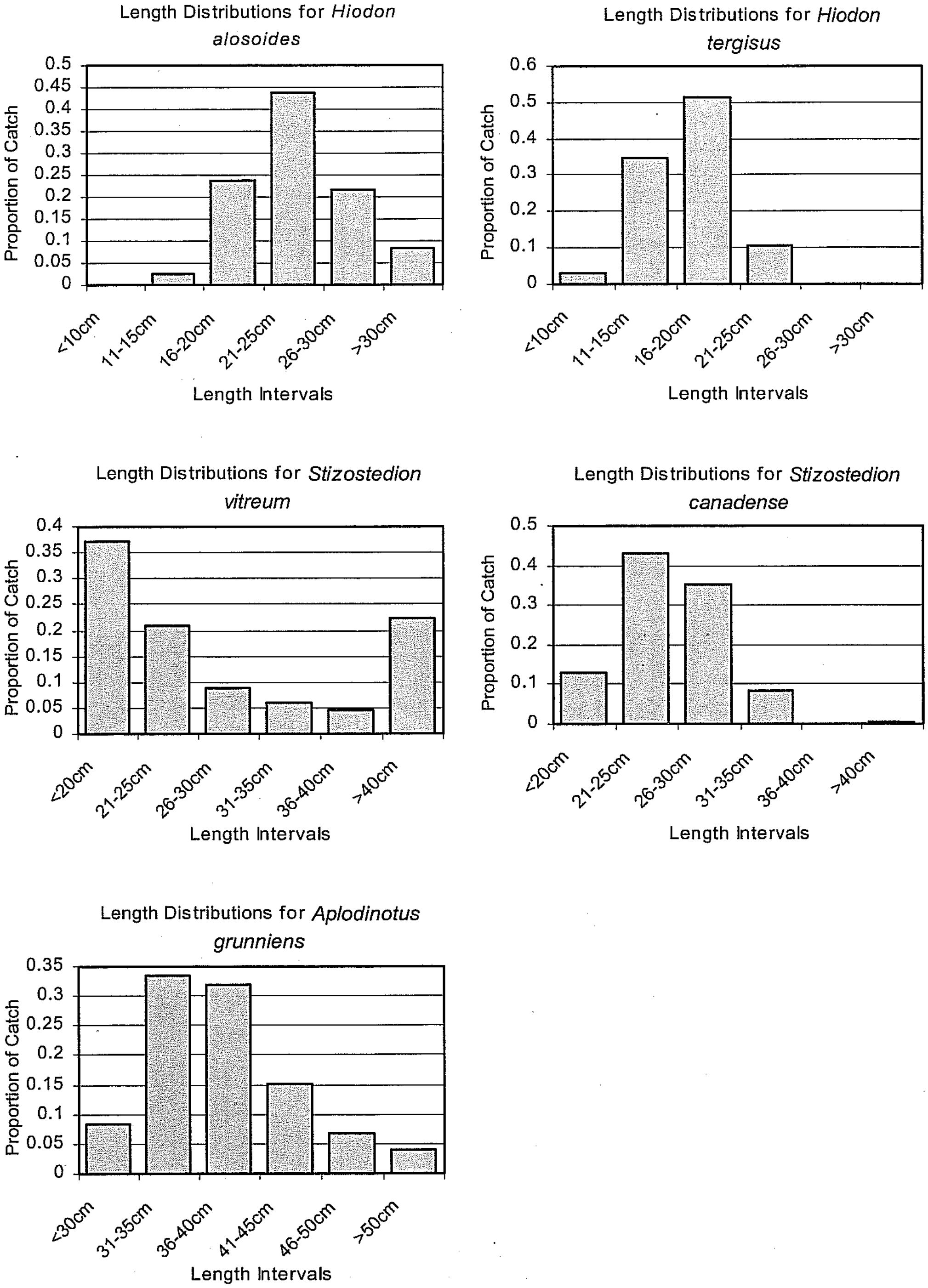


Figure 35: Length distribution for the five sucker species and carp sampled during the 1995 and 1996 seasons. (n-values are as follows; *Catostomus commersoni* = 182; *Moxostoma anisurum* = 159; *M. erythrurum* = 86; *M. macrolepidotum* = 801; *Carpiodes cyprinus* = 279; *Cyprinus carpio* = 191)



Length Distributions for *Hiodon alosoides*

Length Distributions for *Hiodon tergisus*

Length Distributions for *Stizostedion vitreum*

Length Distributions for *Stizostedion canadense*

Length Distributions for *Aplodinotus grunniens*

Figure 36: Length distribution for the goldeye, mooneye, walleye, sauger and freshwater drum sampled during the 1995 and 1996 seasons. (n values are as follows; *Hiodon alosoides* = 203; *H. tergisus* = 124; *Stizostedion vitreum* = 67; *S. canadense* = 320; *Aplodinotus grunniens* = 72).

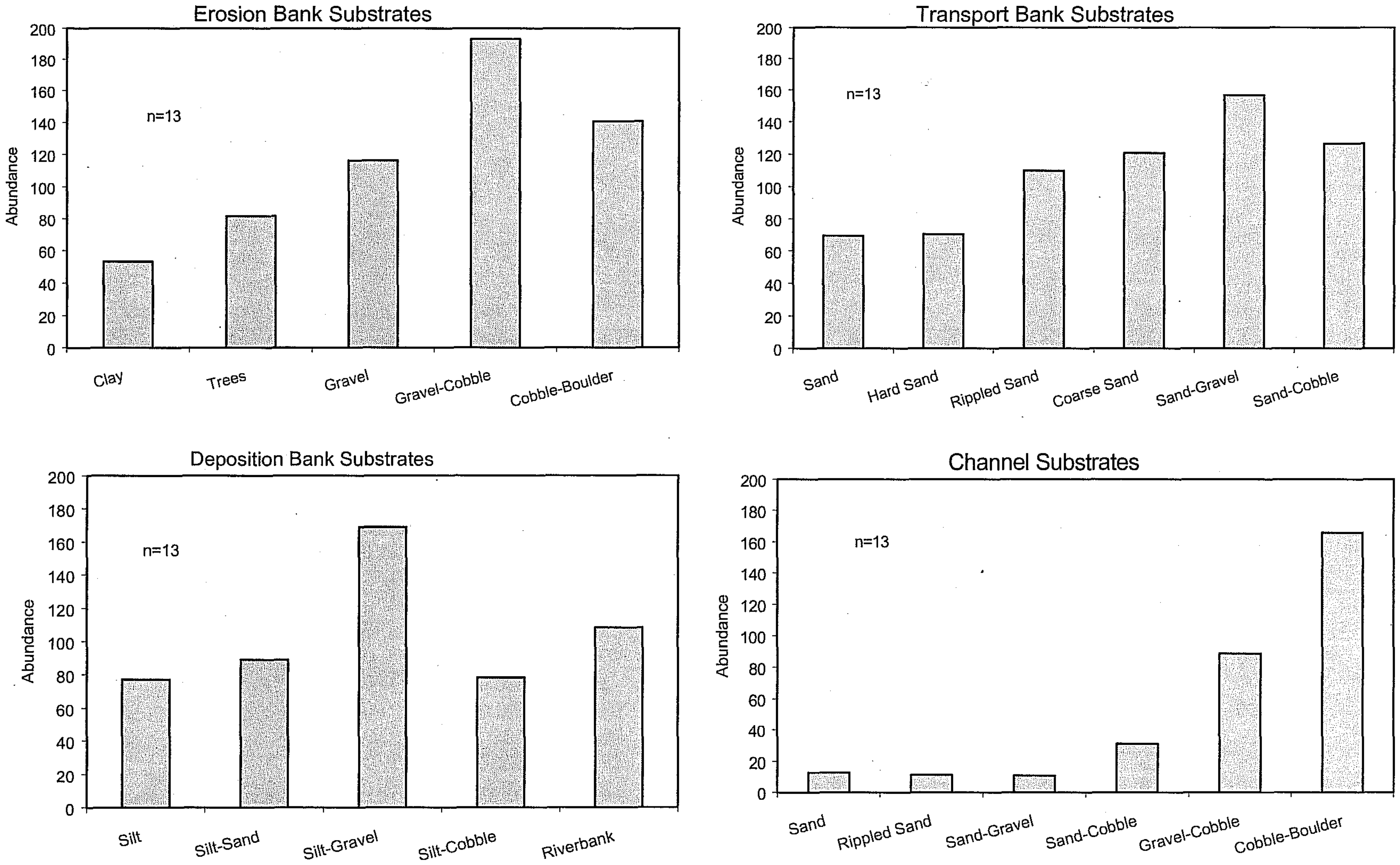


Figure 37: Estimates of mean fish abundance over different (binary) substrate classes determined by re-sampling our data matrices.

Appendix 1: Bank habitat depth availability and utilization by 11 species of fish from the Assiniboine River.

Depth Intervals	Bank Availablity	WS Utilization	SR Utilization	GR Utilization	SH Utilization	QB Utilization	Carp Utilization	GE Utilization	ME Utilization	SV Utilization	SC Utilization	FD Utilization
0.21-0.40	0.0149	0.0103	0.0033	0.0294	0.0176	0.0216	0.0085	0.0098	0.0426	0.0571	0.0244	0.0180
0.41-0.60	0.0238	0.0241	0.0265	0.0294	0.0139	0.0259	0.0051	0.0098	0.0388	0.0190	0.0288	0.0000
0.61-0.80	0.0967	0.1586	0.0960	0.2059	0.1487	0.1056	0.1470	0.1683	0.1085	0.1619	0.2483	0.1351
0.81-1.00	0.1190	0.1862	0.0993	0.2059	0.1301	0.1164	0.1812	0.0927	0.1512	0.2190	0.1663	0.1351
1.01-1.20	0.1280	0.2138	0.1623	0.2451	0.1652	0.1315	0.1846	0.1780	0.1860	0.1333	0.2062	0.2072
1.21-1.40	0.1161	0.0621	0.1424	0.0980	0.1151	0.1207	0.1299	0.0951	0.1202	0.1143	0.0998	0.1532
1.41-1.60	0.0878	0.0862	0.1026	0.0882	0.1193	0.1164	0.0872	0.1000	0.1124	0.0762	0.0843	0.0811
1.61-1.80	0.0729	0.0483	0.0762	0.0392	0.0754	0.0970	0.0462	0.0512	0.0349	0.0286	0.0266	0.0180
1.81-2.00	0.0551	0.0241	0.0497	0.0098	0.0336	0.1207	0.0496	0.0902	0.0581	0.0667	0.0222	0.0270
2.01-2.20	0.0595	0.0586	0.0364	0.0196	0.0377	0.0453	0.0581	0.0805	0.0388	0.0476	0.0266	0.1081
2.21-2.40	0.0521	0.0276	0.0331	0.0098	0.0408	0.0280	0.0342	0.0463	0.0310	0.0000	0.0244	0.0450
2.41-2.60	0.0342	0.0103	0.0430	0.0098	0.0243	0.0086	0.0154	0.0195	0.0078	0.0095	0.0067	0.0000
2.61-2.80	0.0313	0.0241	0.0331	0.0098	0.0207	0.0151	0.0103	0.0122	0.0078	0.0190	0.0067	0.0270
2.81-3.00	0.0313	0.0483	0.0232	0.0000	0.0274	0.0108	0.0154	0.0293	0.0155	0.0286	0.0155	0.0090
3.01-3.20	0.0268	0.0103	0.0132	0.0000	0.0103	0.0086	0.0137	0.0073	0.0078	0.0095	0.0089	0.0000
3.21-3.40	0.0134	0.0000	0.0000	0.0000	0.0036	0.0065	0.0000	0.0024	0.0271	0.0000	0.0000	0.0090
3.41-3.60	0.0074	0.0000	0.0000	0.0000	0.0026	0.0022	0.0000	0.0024	0.0039	0.0095	0.0000	0.0000
3.61-3.80	0.0104	0.0000	0.0066	0.0000	0.0021	0.0129	0.0103	0.0000	0.0000	0.0000	0.0022	0.0270
3.81-4.00	0.0074	0.0000	0.0497	0.0000	0.0036	0.0043	0.0017	0.0024	0.0039	0.0000	0.0000	0.0000
4.01-4.20	0.0060	0.0000	0.0033	0.0000	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000
4.21-4.40	0.0015	0.0069	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.41-4.60	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0039	0.0000	0.0000	0.0000
4.60+	0.0015	0.0000	0.0000	0.0000	0.0057	0.0000	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000

* Abbreviations for species are the same as Table 2.

Appendix 2: Bank habitat velocity and substrate availability and utilization by 11 species of fish from the Assiniboine River.

Velocity Intervals	Velocity Availablity	WS Utilization	SR Utilization	GR Utilization	SH Utilization	QB Utilization	Carp Utilization	GE Utilization	ME Utilization	SV Utilization	SC Utilization	FD Utilization
0-0.10	0.0179	0.0138	0.0199	0.0000	0.0129	0.0237	0.0103	0.0585	0.0155	0.0095	0.0288	0.0270
0.11-0.20	0.0164	0.0000	0.0033	0.0196	0.0108	0.0259	0.0154	0.0171	0.0155	0.0381	0.0067	0.0180
0.21-0.30	0.0580	0.0655	0.0430	0.0686	0.0413	0.0560	0.0598	0.0683	0.0736	0.0857	0.0820	0.0631
0.31-0.40	0.1146	0.1241	0.1126	0.1569	0.1136	0.0905	0.1470	0.0707	0.1202	0.1238	0.1641	0.1261
0.41-0.50	0.1920	0.1690	0.1589	0.1765	0.1848	0.1703	0.1521	0.1805	0.1860	0.2476	0.2129	0.2072
0.51-0.60	0.1964	0.1345	0.2086	0.1667	0.1709	0.1616	0.2359	0.1878	0.2287	0.1238	0.1619	0.2072
0.61-0.70	0.1429	0.0828	0.0993	0.0784	0.1363	0.1487	0.1162	0.1122	0.1085	0.0667	0.1086	0.0811
0.71-0.80	0.1518	0.2655	0.1523	0.1569	0.2013	0.1638	0.1385	0.1585	0.1163	0.2286	0.1574	0.1532
0.81-0.90	0.0417	0.0379	0.0795	0.0392	0.0480	0.1185	0.0718	0.0854	0.0698	0.0571	0.0266	0.0901
0.91-1.00	0.0491	0.0621	0.0695	0.0784	0.0558	0.0172	0.0291	0.0561	0.0581	0.0095	0.0333	0.0180
1.01-1.10	0.0119	0.0103	0.0530	0.0196	0.0108	0.0086	0.0103	0.0049	0.0078	0.0000	0.0067	0.0000
1.11-1.20	0.0045	0.0345	0.0000	0.0392	0.0108	0.0129	0.0137	0.0000	0.0000	0.0095	0.0111	0.0090
1.21-1.30	0.0015	0.0000	0.0000	0.0000	0.0005	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.30+	0.0015	0.0000	0.0000	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Substrate Classes	Substrate Availablity	WS Utilization	SR Utilization	GR Utilization	SH Utilization	QB Utilization	Carp Utilization	GE Utilization	ME Utilization	SV Utilization	SC Utilization	FD Utilization
Clay	0.1116	0.0241	0.0695	0.0294	0.0573	0.0668	0.0701	0.0927	0.0853	0.0286	0.0333	0.0450
Silt	0.0417	0.0345	0.0099	0.0098	0.0124	0.0323	0.0427	0.0683	0.0426	0.0476	0.0421	0.0450
Silt-Sand	0.1354	0.0483	0.1093	0.0784	0.1120	0.1767	0.0650	0.1122	0.1938	0.1333	0.1330	0.1171
Sand	0.1399	0.0379	0.0894	0.0196	0.0914	0.1401	0.0701	0.1341	0.1434	0.1143	0.0754	0.0450
Hard-Sand	0.0298	0.0069	0.0265	0.0000	0.0248	0.0108	0.0239	0.0122	0.0233	0.0190	0.0266	0.0270
Rippled-Sand	0.1176	0.0552	0.1291	0.0294	0.1451	0.1659	0.0650	0.1366	0.1202	0.0952	0.1353	0.0721
Coarse-Sand	0.0313	0.0103	0.0331	0.0294	0.0336	0.0776	0.0325	0.0317	0.0310	0.0476	0.0111	0.0360
Gravel	0.0714	0.1207	0.1291	0.0882	0.0790	0.0366	0.0701	0.1317	0.0426	0.0476	0.0488	0.1261
Silt-Gravel	0.0193	0.0379	0.0166	0.0784	0.0361	0.0517	0.0308	0.0366	0.0271	0.0381	0.0333	0.0450
Sand-Gravel	0.0551	0.1172	0.1126	0.0392	0.0723	0.1121	0.0769	0.0537	0.0620	0.1143	0.1486	0.0450
Gravel-Cobble	0.0744	0.2138	0.1093	0.3627	0.1461	0.0280	0.2274	0.0683	0.0891	0.1143	0.1596	0.1441
Cobble-Boulde	0.0432	0.1483	0.0762	0.0882	0.0599	0.0129	0.0872	0.0317	0.0543	0.1143	0.0421	0.0991
Silt-Cobble	0.0223	0.0276	0.0099	0.0098	0.0155	0.0151	0.0256	0.0146	0.0155	0.0190	0.0177	0.0000
Sand-Cobble	0.0357	0.0621	0.0232	0.0784	0.0485	0.0259	0.0598	0.0171	0.0194	0.0095	0.0222	0.0541
Riverbank	0.0253	0.0379	0.0331	0.0490	0.0315	0.0086	0.0256	0.0122	0.0155	0.0286	0.0155	0.0991
Trees	0.0461	0.0172	0.0232	0.0098	0.0346	0.0388	0.0274	0.0463	0.0349	0.0286	0.0554	0.0000

Appendix 3: Channel habitat depth availability and utilization by 11 species of fish from the Assiniboine River.

Depth Intervals	Depth Availablity	WS Utilization	SR Utilization	GR Utilization	SH Utilization	QB Utilization	Carp Utilization	GE Utilization	ME Utilization	SV Utilization	SC Utilization	FD Utilization
0.21-0.40	0.0030	0.0000	0.0000	0.0000	0.0028	0.0294	0.0000	0.0000	0.0000	0.2222	0.0278	0.0000
0.41-0.60	0.0060	0.0000	0.0000	0.0000	0.0056	0.0441	0.0526	0.0000	0.0500	0.2222	0.0000	0.0000
0.61-0.80	0.0298	0.0923	0.0857	0.0000	0.0845	0.0735	0.2632	0.0000	0.0000	0.1111	0.3056	0.3333
0.81-1.00	0.0893	0.1077	0.0571	0.2308	0.1437	0.0441	0.1053	0.0800	0.2000	0.0000	0.1111	0.0000
1.01-1.20	0.1220	0.2923	0.3143	0.3846	0.3775	0.2353	0.2105	0.1600	0.2000	0.1111	0.3889	0.3333
1.21-1.40	0.1310	0.1385	0.1143	0.0000	0.1690	0.2647	0.0000	0.0800	0.1000	0.1111	0.1111	0.3333
1.41-1.60	0.0863	0.1231	0.1143	0.0769	0.1014	0.1029	0.2105	0.1600	0.1000	0.0000	0.0000	0.0000
1.61-1.80	0.0833	0.0462	0.0571	0.1538	0.0423	0.1029	0.0000	0.1600	0.0500	0.0000	0.0556	0.0000
1.81-2.00	0.0655	0.1231	0.0571	0.0000	0.0113	0.0735	0.0526	0.1600	0.0000	0.2222	0.0000	0.0000
2.01-2.20	0.0506	0.0462	0.1429	0.0769	0.0225	0.0000	0.0526	0.0000	0.0000	0.0000	0.0000	0.0000
2.21-2.40	0.0476	0.0154	0.0286	0.0769	0.0282	0.0294	0.0000	0.1600	0.3000	0.0000	0.0000	0.0000
2.41-2.60	0.0417	0.0000	0.0286	0.0000	0.0056	0.0000	0.0526	0.0000	0.0000	0.0000	0.0000	0.0000
2.61-2.80	0.0476	0.0154	0.0000	0.0000	0.0056	0.0000	0.0000	0.0400	0.0000	0.0000	0.0000	0.0000
2.81-3.00	0.0506	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3.01-3.20	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3.21-3.40	0.0327	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3.41-3.60	0.0119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3.61-3.80	0.0208	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3.81-4.00	0.0149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.01-4.20	0.0149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.21-4.40	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.41-4.60	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4.60+	0.0119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix 4: Channel habitat velocity and substrate availability and utilization by 11 species of fish from the Assiniboine River.

Velocity Intervals	Velocity Availablity	WS Utilization	SR Utilization	GR Utilization	SH Utilization	QB Utilization	Carp Utilization	GE Utilization	ME Utilization	SV Utilization	SC Utilization	FD Utilization
0-0.10	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.11-0.20	0.0030	0.0000	0.0000	0.0000	0.0028	0.0000	0.0000	0.0800	0.0000	0.0000	0.0278	0.0000
0.21-0.30	0.0089	0.0308	0.0000	0.0769	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.31-0.40	0.0298	0.0308	0.0571	0.0000	0.0113	0.0000	0.0000	0.0400	0.0500	0.0000	0.0000	0.0000
0.41-0.50	0.0744	0.0000	0.1143	0.0000	0.0085	0.0735	0.0526	0.0400	0.0000	0.0000	0.1111	0.0000
0.51-0.60	0.1339	0.2462	0.2000	0.5385	0.1859	0.1471	0.1579	0.2400	0.1000	0.3333	0.2222	0.6667
0.61-0.70	0.1637	0.2154	0.3143	0.0769	0.2085	0.1618	0.1579	0.2800	0.4000	0.4444	0.1111	0.0000
0.71-0.80	0.2530	0.0923	0.1714	0.0769	0.1577	0.2500	0.1053	0.0400	0.2000	0.1111	0.2500	0.3333
0.81-0.90	0.1280	0.2000	0.0286	0.2308	0.2873	0.3382	0.3684	0.2400	0.2500	0.1111	0.1944	0.0000
0.91-1.00	0.1518	0.1077	0.0286	0.0000	0.0789	0.0147	0.1579	0.0400	0.0000	0.0000	0.0833	0.0000
1.01-1.10	0.0298	0.0154	0.0286	0.0000	0.0056	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.11-1.20	0.0208	0.0462	0.0571	0.0000	0.0507	0.0147	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.21-1.30	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.30+	0.0030	0.0154	0.0000	0.0000	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Substrate Classes	Availability Availablity	WS Utilization	SR Utilization	GR Utilization	SH Utilization	QB Utilization	Carp Utilization	GE Utilization	ME Utilization	SV Utilization	SC Utilization	FD Utilization
Clay	0.0208	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Silt	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Silt-Sand	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sand	0.2381	0.0769	0.2857	0.0000	0.0592	0.1618	0.2105	0.1200	0.1500	0.3333	0.3056	0.0000
Hard-Sand	0.0149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0400	0.0500	0.0000	0.0000	0.0000
Rippled-Sand	0.3988	0.0615	0.1429	0.0000	0.0507	0.6176	0.1053	0.5200	0.6000	0.0000	0.1667	0.3333
Coarse-Sand	0.0089	0.0000	0.0000	0.0000	0.0028	0.0294	0.0000	0.0000	0.0000	0.2222	0.0556	0.0000
Gravel	0.0179	0.0000	0.0000	0.0000	0.0113	0.0294	0.0000	0.0400	0.0000	0.0000	0.0000	0.0000
Silt-Gravel	0.0030	0.0000	0.0000	0.0000	0.0028	0.0000	0.0000	0.0800	0.0000	0.0000	0.0278	0.0000
Sand-Gravel	0.0744	0.0000	0.0571	0.0000	0.0225	0.0735	0.0526	0.0800	0.1000	0.1111	0.0000	0.0000
Gravel-Cobble	0.0833	0.3538	0.1143	0.4615	0.3944	0.0147	0.2105	0.0400	0.0000	0.1111	0.1944	0.3333
Cobble-Boulder	0.0417	0.3385	0.0571	0.3846	0.3606	0.0147	0.3158	0.0400	0.0500	0.2222	0.1944	0.3333
Silt-Cobble	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sand-Cobble	0.0893	0.1692	0.3429	0.1538	0.0958	0.0588	0.1053	0.0400	0.0500	0.0000	0.0556	0.0000
Riverbank	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trees	0.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA