DIPLOMARBEIT

„Comparison of the fish assemblage of three Danube segments on the basis of different sampling methods“

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Vorwort und Danksagung

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Introduction

Fish assemblages of large rivers are highly diverse communities (Schiemer 2000). Their community composition generally consists of a few common (core and secondary) and a majority of rare species (Magurran et al. 2011). In general, historical (i.e. geologic history) and contemporary processes are responsible for the species number in any region (Wotton, 1998). At the contemporary regional scale, habitat quality (availability, condition; Schlosser 1991; Wootton 1999), flow regime (discharge and temperature) (King et al. 2003, Poff et al. 1997) and water quality (pollution) control the diversity of river fish communities (Gorman et al. 1978).

Fish assemblages diversify alongside the course of large rivers (Illies et al. 1963), due to gradually changing environmental factors and appearing and disappearing of ecological niches (Vanotte et al. 1980). On a smaller scale, single fish species are adapted to specific environmental conditions, based on their morphology, ontogeny and behavioural aspects, as for example different species or life stages require different food sources and spawning site preferences differ between species (Schlosser 1991).

Gaining information of fish assemblages, especially for large rivers is a very difficult task, as no single uniform method exist, which addresses the fish assemblages as a whole. Multiple fish sampling methods need to be applied to get data of the total fish assemblage at hand, as the suitability of different methods varies between different habitat types and species, as all fishing methods are selective, particularly with respect to species and fish size (Growns et al. 1996). Therefore the combination of different sampling methods is necessary to estimate the overall species richness, abundance and population dynamics (structure, size) of large river fish assemblages, as each method favours different kinds of fish, regarding size, development and life stages and habitat preferences of different communities (litoral, pelagic, benthic).

A simple combination of data, by using the untreated combined data sets is not accomplishable as the basis and methodology for each data set differs substantially between the methods. However, for looking at the “true” (or a “less false”) picture of the fish assemblage at hand a combination of the results of different sampling methods is required. For this purpose a standardization of data is required to compare and to combine the catch data of the three methods, providing the knowledge to answer questions regarding species composition, abundance patterns and biodiversity in a more general way.

The binding of fish species, and also of different life stages (larvae, juveniles and adult fish) to specific habitats and their long span of life (several years to decades), make them excellent indicators for status and type of water bodies (Karr 1981, Schiemer et al. 1994). This information is essential as nowadays river degradation is a general issue of large rivers (Aarts et al. 2004, Allan et al. 1993, Gore et al. 1995, Humphries et al. 2000, Nilsson et al.2005, etc.). Like many large Rivers the Danube is affected by anthropogenic alterations and enhanced land and water use (Boon et al. (2000), Chovanec et al. 2005, Reckendorfer et al. 2005, Schiemer et al. 1989). Especially habitat loss (Aarts et al. 2004) reduced shore heterogeneity (Schiemer et al. 2001) and altered water dynamics, due to shore embankment, disconnection of side arms and hydroelectric power dams cause decline of diversity and alterations within the population structure (Schiemer 2000). Main causes for the decline of fish assemblages in large rivers are the poor condition, the low abundance or even the total absence of suiting spawning, nursery and foraging habitats (Schiemer et al 1991; Schiemer et al. 1994).

On its 350 km long course through Austria, the Danube still holds a diverse fish fauna of 57 native fish species. Several of these fish belong to endemic, endangered and rare species (Jungwirth 2003; Spindler 1997). Especially the endangered and rare fauna elements are concern of wildlife conservation, such as the Flora Fauna Habitat Directive (Annex II and V) and the Water Framework Directive.

To improve the situation within disturbed systems, it is important to understand the role and function of different habitat types for single fish species and the whole fish assemblages. Knowledge about the habitat use of different fish species (Galat et al. 2001, Erõs et al. 2008, Schlosser 1991) is crucial for restoration projects, as it allows the setting of concrete measures to improve the situation of anthropogenic altered rivers (Jungwirth et al. 2002), as a key element of conservation programs are self-sustaining populations. For this purpose the presence and availability of intact and ecologically “working” habitats (Chovanez et al. 2005; Schiemer et al. 1989; Schimer et al. 1994; Spindler 1997) and the continuum between these (Schiemer et al. 1991) are basic prerequisites.

The present study refers to species occurrence, species composition and fish abundance collected simultaneously during a three months period in three reaches of the main stem of the free flowing stretch of the River Danube east of Vienna. Three sampling methods (boat electro fishing, wading electro fishing and long line fishing) were carried out to quantify the fish assemblages of three Danube reaches which suffered anthropogenic alterations during the river regulation of the late 19th century.

With regard to community composition, diversity, abundance and fish size the following questions are to be answered for each applied method and for an integrative approach of all methods combined:

1. Are there differences between the Danube reaches?
2. Are there differences between pre-defined mesohabitats, irrespective of the reach?
3. Does the fish assemblage change during the sampling period?

The knowledge obained through answering these questions should highlight the importance of the main stem for the diversity of the fish community and might help with pressing issues concerning wildlife conservation and monitoring programs. For species protection it is important to know when and where endangered and species at risk might be found and also where and under which conditions invasive and exotic species are dominant (Schiemer et al. 1989). As most of the large rivers in Europe are altered by embankment and reduced lateral connectivity (Dynesius et al. 1994, Schiemer et al. 2007), alterations within the monotonous course might dramatically affect the fish community (Schiemer et al. 1989). Therefore it is important to gain information about the informative value of single reaches (several kilometres) in contrast to bigger segments of large rivers (like the Danube east of Vienna to the Slovakian border) as it might be important for ongoing monitoring programs, like the Water Framework Directive, if sampled areas are representative for whole river stretches or not.

In order to get more detailed information on the effect of sampling method, sampling area and mesohabitat on community composition of fish in the main channel of a large river, a detailed analysis of assemblage structure and biodiversity for three single methods, at the reach- and mesohabitat scale, as well as seasonal changes, were compared with results of combined data of all three methods. This approach enables to quantify the added informative value of data integration in contrast to information gained from single methods. Also, it will allow determination of quality and applicability of single methods for specific questions of river and fish ecology and present a contribution to enhance the quality of basic information, required for conservation issues, and to design experimental sampling schemes required for river restoration and management.

Study Site

The Danube is longest river in the European Union with a length of 2848 to 2888 km (based on the definition of its spring). The origin of this second longest stream of Europe (the longest is the Volga) lies within the Schwarzwald in Germany and disembogues in a five armed delta in the territory of Rumania and Bulgaria. The mean annual discharge is 6450 m^3s^{-1} draining a catchment area of 817.000 km^2 (www.donaukommission.org).

Due to the east-west flow direction of the Danube it is not only an important waterway for trade and tourism, it is also a bio corridor with a high biodiversity, linking the fauna of Central Europe with the Ponte Caspian and Inner Asian region. The Danube holds 60 fish species, 52 of them autochthonous.

The Austrian stretch of the Danube is 350 km long (stream kilometre 2223.15 to stream kilometre 1872.70) and is part of the spring region (rhithron), reaching from south western Germany to the Austrian/Slovakian border. The Austrian catchment area of the Danube consists of approx. 80.000 km^2, 96% of the Austrian territory. Four major tributaries (Inn, Traun, Enns, and March) affect the discharge, enhancing it from 1430 m^3s^{-1} (the annual mean discharge of the Danube entering Austria) to 2020 m^3s^{-1} (at the Slovakian border). The possibility for flood events is highest in March and April, when snow melts and rainfall induce high water levels.

Under natural condition, the Danube in Austria has been a braided river with a variety of side arms, back waters and ox bows. Due to the highly variable hydrodynamics of the stream big amounts of sediment were moved, building gravel banks, causing furcations and developing large flood plains. Starting in the middle of the 19th century, the Danube has been victim of several regulative measurements (straightening and fixation of the bank and the river bed, disconnection of side arms and back waters) to ensure safe passage for the increasing shipping travel. In the 1950s the building of hydro-electric power plants has started. Today, there are 10 hydropower stations situated in the Austrian Danube, leaving only two "free" flowing stretches: the Wachau and the Danube east of Vienna which became a National Park (Nationalpark Donauauen) in 1996.

Within the National Park the three study sites are situated (fig. 1): the Danube reach Witzelsdorf ("WITZ")" near Petronell-Carnuntum, the reach Bad Deutsch Altenburg ("BDA") and the reach near Hainburg ("HAIN").

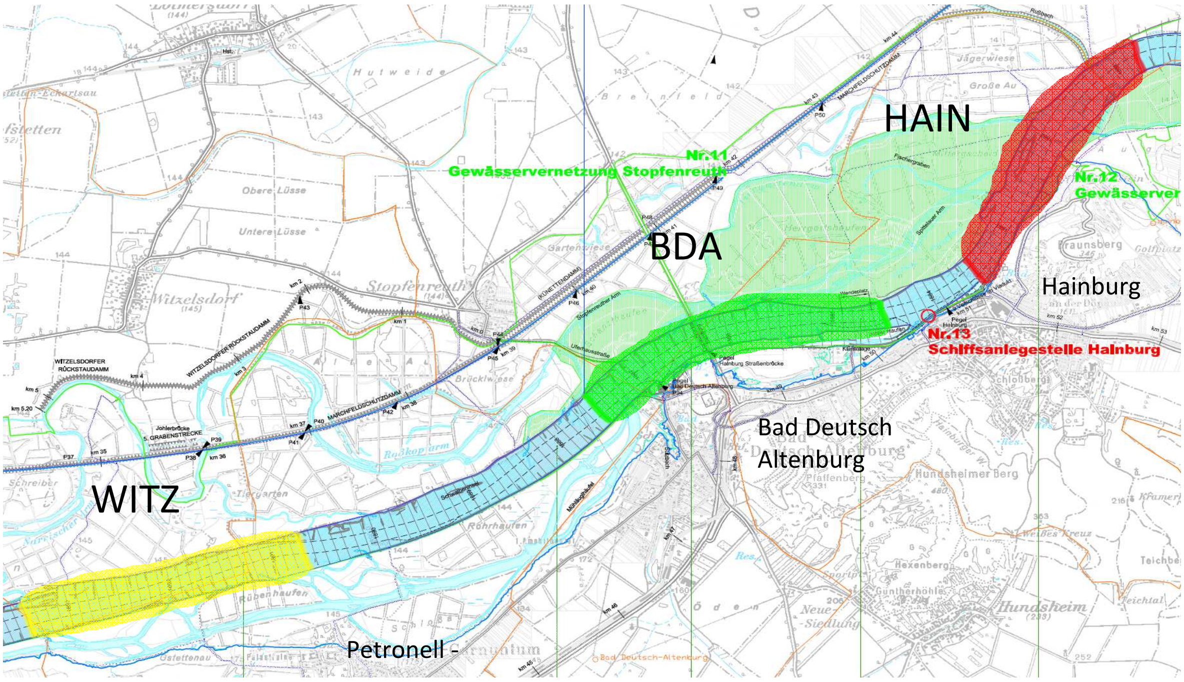

Figure 1: the three Danube reaches within the National Park “Donauauen”: yellow marked the Danube reach Witzelsdorf (WITZ), green marked the reach Bad Deutsch Altenburg (BDA) and red marked the Danube reach Hainburg (HAIN).

The Danube Reach Bad Deutsch Altenburg

The Danube reach Bad Deutsch Altenburg (BDA, fig. 2) is situated near the city of Bad Deutsch Altenburg, between the stream kilometre 1884,55 and 1887,5. This reach has a length of 2,95 km and covers an approximate area of 0,97 km² (measured with ImageJ), with a mean river width of 344 metre.

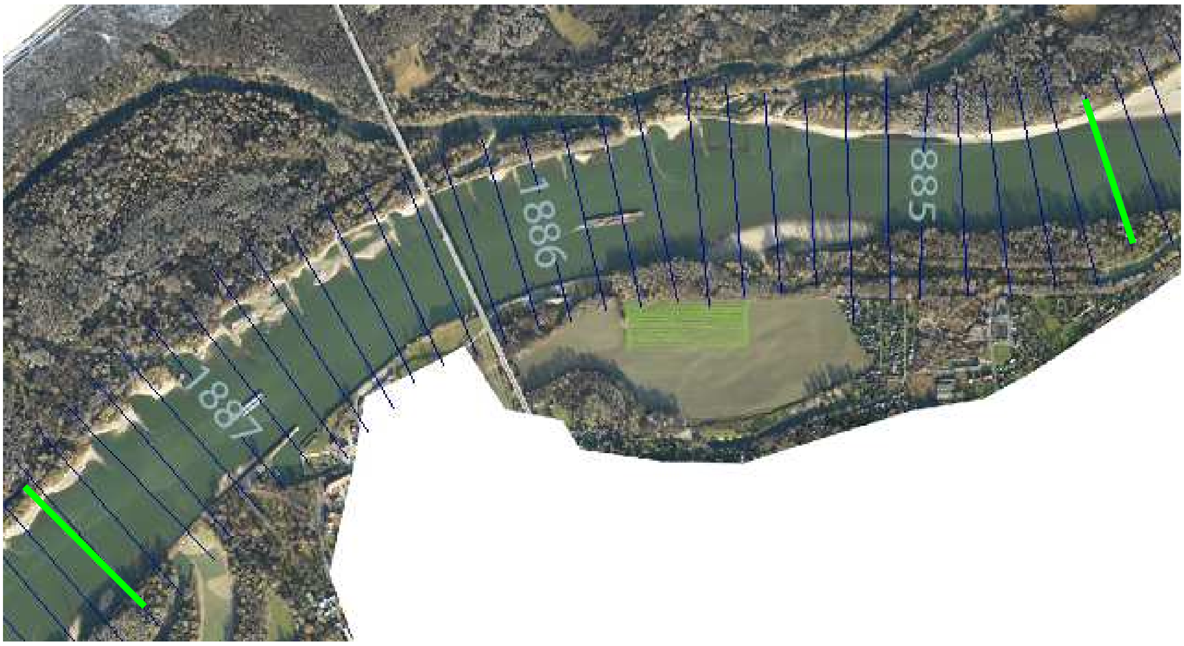

Figure 2: Danube reach Bad Deutsch Altenburg, the green lines mark the borders of the reach.

Approximately 45% of the cumulative length ob both shorelines (right and left) is covered with rip raps, 28% is formed by groin fields, 25% by gravel banks and 2% of the shoreline is formed by discharging side arms.

The Danube Reach Witzelsdorf

The Danube reach Witzelsdorf (WITZ, fig. 3) lies upstream of Hainburg, near the city of Petronell – Carnuntum and the village Witzelsdorf. The sampling site within WITZ expands from stream kilometre 1890,7 to 1893,5 with a length of 2,8 km, a mean width of approximately 360 metre and a mean area of 1,02 km² (measured with ImageJ).

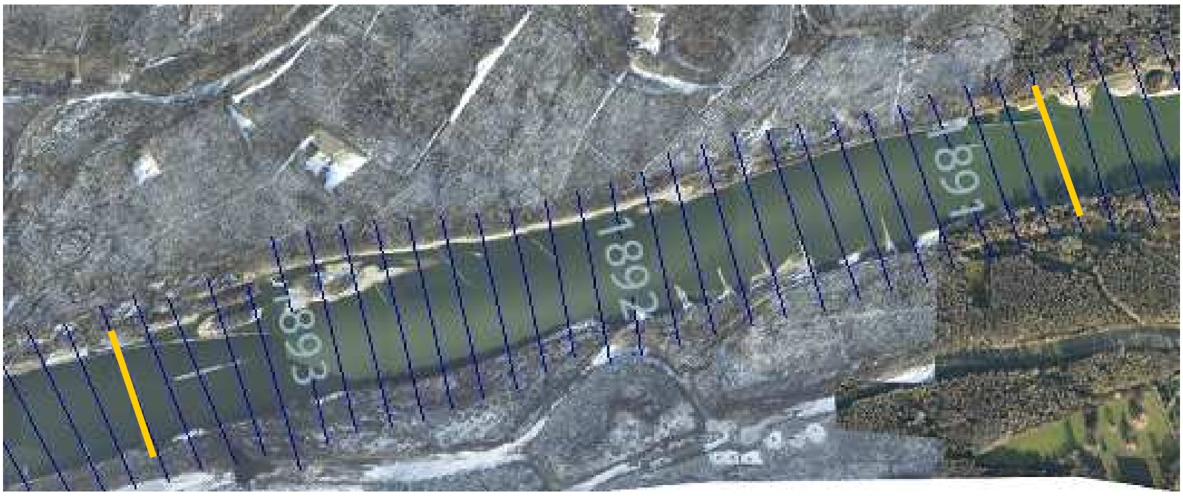

Figure 3: The Danube reach Witzelsdorf, the yellow lines mark the borders of the reach.

Approximately 44% of the cumulative length ob both shorelines (right and left) is covered with rip raps, 25% is formed by groin fields, 29% by gravel banks and 2% of the shoreline is formed by a discharging side arm.

The Danube Reach Hainburg

The third Danube reach (REF, fig. 4), near the city of Hainburg is situated between stream kilometre 1880,8 and 1883,5. This reach is 2,7 km long and covers an approximate area of 0,82 km² with a mean river width of 289 metre.

Approximately 43% of the cumulative length ob both shorelines (right and left) is covered with rip raps, only 5% is formed by groin fields, 48% by gravel banks and 4% of the shoreline is formed by a discharging side arm.

Figure 4: The Danube reach Hainburg, the red lines mark the borders of the reach.

Mesohabitats

The mesohabitats in this study have been classified visually due to structural changes of the natural shore line. The proportion of them within the three Danube reaches has been visually measured from ortho photos with the program ImageJ (http://rsbweb.nih.gov/ij/).

Five different mesohabitats have been classified and sampled: groin fields (GR), gravel banks (GB), rip raps (RR), pools (PO) and side arms (SA).

Groin Fields

Groin fields are structures made of stone blocks (armour stones), positioned in a right angle to the shoreline and directed toward the main channel. The aim of a groin field is to direct the counter-current into the navigation channel, ensuring that there is enough water left for shipping, especially under low flow conditions.

The current velocity within the groin field is reduced in comparison to the main channel leading to elevated sedimentation rates.

Rip Raps

Rip raps are artificial shore lines made of armour stone, preventing erosion of the shore line. Especially at undercut slope situations (outside bend) in the main channel, the high kinetic energy of the current would lead to enhanced erosion without this structural measure.

Rip raps tend to have steep bank angles, high flow velocities and rapidly rising water depth towards the navigation channel due to the exposure of the strong current at undercut slopes.

Gravel Banks

Gravel banks tend to have a lower depth gradient toward the navigation channel and are situated on slip-off slopes (inside bend). They have heterogeneous current situations and a more heterogeneous sediment configuration (from microlithal to psammal).

Pools

Pools are deep regions within the main channel, which occur due to the interaction of current velocity and turbulence. Such situations exist at groin heads and other river engineering structures (e.g. hydroelectric power dams) and cause digging (literally) into the sediment, leading to very deep regions (up to 12m).

Side Arms

For this study “side arm” is the mesohabitat name for inlets and outlets of side arms parallel to the main channel. Under low flow conditions some side arms are disconnected from the main channel, leading to low current velocities and the sedimentation of sand and silt of which the sediment is mainly composed.

Material and Method

Fish Sampling Methods

Three different fish sampling methods have been conducted to sample five types of different mesohabitats (gravel bank, rip-rap, groin field, pools and side arm) and all depth classes (from the litoral to the benthic zone). Figure 5 shows a schematic picture of the effective area for the different sampling methods applied. The shore line (littoral) of the main channel and side arms have been sampled by wading along the shore with a hand anode, boat electro fishing has been conducted near the bank (sublittoral) and long lines have been set in an angle of approx. 90° from the shore to the river bed.

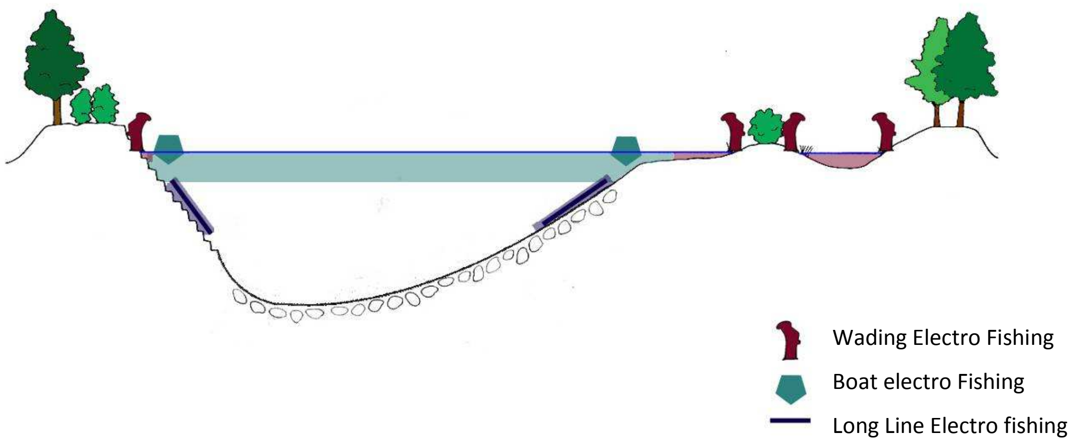

Fig. 5: Schematic description of the effective area (grey colours, black lines) for three different sampling methods shown in a cross section of the main channel and side arm. Long line fishing and boat electro fishing has also been conducted in the side arm, but is not separately indicated (adapted after Keckeis et al. 2010).

Electro Fishing

Electro fishing is an active fish sampling method, where an electric field is used to catch fish. This electric field is generated by sending direct current flow electricity in the water. The fish within the field are immobilised and are directed to the anode (galvanotaxis) where they can be collected. Electro fishing is a gentle fish sampling method and is therefore often used in ecological studies in Rivers.

The radius of the effective field is as a rule of thumb between 1,5 and 3 meter wide (Nelva et al., 1979; Persat et al. 1990), limiting the electro fishing through water depth. Other abiotic parameters, like water temperature (Zalewski & Cowx, 1990), conductivity and turbidity of the water, current velocity, habitat structure and the sediment also affect the catch efficiency (see also Peter & Erb, 1996).

Species specific parameters also affect the “catchability” of fish. On one hand, the body conductivity differs by a factor of 3 between different fish species (Sternin et al., 1972) but more important than physiological differences are the size and behaviour of fish. The “catchability” of benthic fish species, like bullhead, gudgeon, stone loach and lamprey is most affected by sediment composition. Pelagic and semipelagic species avoid the electric field and show escaping behaviour. Therefore species-rich fish communities are more difficult to quantify than communities with a low species number. In general, catching bigger fish is more likely due to a higher potential difference in the electric field between head and tail (Chiemelewski et al., 1972).

All electro fishing (boat and wading) was carried out by using one type of aggregate (Grassl®EL 64 II, 300/600 volt switch able, 7kW output) with 600 volt. For wading a 250 m cable drum was used to supply the current for the anode.

Boat Electro Fishing

Boat electro fishing has been conducted to sample the litoral and sublitoral fish assemblage. The boat used for fishing carried at the bug a rack formed anode arm (3 meters length). Six anode cables were hanging from that arm, ranging approx. 10 – 15 cm under the water surface. The cathode was a copper cable, carried in the last third alongside the boat.

Method

Two persons, standing on the bug, were catching the immobilised fish with dip nets, one person controlled the boat. Due to the low draft of the vehicle, sampling was possible till a water depth of 20 centimetres while the effective electric field lasted to 2-3 meters water depth. The actual depth was recorded with an echo sounder and the sampled stretch was geo-referenced every second during sampling.

Wading Electro Fishing

Wading electro fishing is used to sample the fish assemblage of the litoral zone. The anode used for this method consisted of a 2,3 meter long pole with a 30 centimetre wide and 6 mm mesh size dip net, while the dip net for catching the fish had 4 mm mesh size. Sampling was conducted by 3 persons: one person handling the anode, one person the additional dip net and one bucket bearer.

Method

Fishing always was carried out upstream approaching structures or the shore line. While sampling the groin base, the fishing was carried out in a right angle to the direction used before (up- or downstream of the groin base). The modified direction of motion was used to enhance the catch efficiency due to the fact that immobilised fish were drifting against the fishing team, escaping fish were blocked by the groin and minimizing the possibility of frightening fish through the presence of (or “by”) the electric field. Turbidity caused by the fishing team was avoided by wading upstream. Every sampling was conducted on the shoreline or on a parallel line to the bank.

Due to the fact that the size of the electric field is unknown and effects differ according to species and fish size, the sampled area was the area covered by the anode, meaning the length of the pole and the handling by the anode carrier (approx. 2 meters coverage). A sampling stretch was 20 meters long and in the mesohabitats groin field, rip rap and side arm an approximate area of 40 m^2 was covered. The mesohabitat gravel bar was sampled 2 meters away from the bank, fishing both sides (shore near and shore far), covering an area of 80 m^2. This modification of the sampling method was necessary because gravel bars have a very low angle of slope (low or medium water level) near the bank and in fact very low water depths near the edge of the water.

Long Line Fishing

The sampling with long lines is used to describe the benthic fish community because of its inaccessibility by other fish sampling methods like boat and wading electro fishing. Long line fishing is the adequate method to take samples from the riverbed, especially from deeper regions (Matschnig, 1995). It is a passive sampling method, meaning that the line remains stationary over a period of time. The fish actively take the baited hooks and get struck due to the resistance of the line. The used long lines have been designed and adapted according to the standard procedure (Zauner et. al. 1991 and 1996, Bjordal et. al. 1996).

An operational (ready for use) long line consists of following parts: mainline, side arm or paternoster line, swivels, hooks, bait, anchor, anchor line, surface marker buoy (Bammer, Diplomarbeit). The main line is a 52 meter long 4 mm strong braided polyester line. The side arms are made of 20 cm long 0,40 mm strong braided leader line with a breaking strain of approx. 30 kg. They are mounted in 1 meter gaps on the main line and play the role of pull linkage, breaking at very strong exposure. The swivels are used to attach the leaders (hook and line) fast and easily to the side arms; also they avoid twisting of the line by turbulences.

The hook size may affect the species and size selectivity (Johanessen, 1983; Bjordal & Lokkeborg, 1996; Høines & Korsbrekke, 2001). Therefore five different sizes were used to catch a broad spectrum ranging from small-sized benthic fish species like gudgeons (i.e. whitefin-gudgeon, *Gobio albipinnatus*) or endemic species like Danube streber (*Zingel streber*) to bigger–sized benthic species like barbel (*Barbus barbus*). Ready made leaders, labelled “Allround” from DAM, were applied from size Nr.14 (smallest) to size Nr.2 (biggest).

Anchor stones with 20 to 25 kg, connected with carabiners to the main line, were used to keep the line under all circumstances in place. In regions with very strong current, like groin heads and pools, an additional anchor (2,5 kg) was connected to the main line, 2 meters behind the anchor stone to fix the line to the ground.

Method

The boat was well anchored near structures (groin head, etc.) staying in the current. Two persons were needed to set the long line: one person baiting the hooks, the other attaching the leaders to the swivels. On the end of the line a marker buoy was placed and lowered on the rear end of the boat into the river. The current stretched the long line, leaving it on the surface and preventing entanglements. When all hooks were baited and connected to the main line the first anchor stone was attached. Now the boat was manoeuvred to the shore where this anchorage was lowered to the ground. After that, the marker buoy was replaced by the second anchor stone. The long line was now adjusted in a right angle to the shoreline and the second anchorage was lowered to the riverbed. In pools the long line was not adjusted in a right but in a current directed angle, due to strong current and turbulences making it impossible to anchor the line stable right angle to the shoreline.

To retrieve the long line the first anchor near the main channel was retrieved and exchanged to a marker buoy which was placed to adjust the line in flow direction. The long line was now surface near and stretched parallel to the shoreline. Next the second anchor was retrieved; the boat was fixed in the flow, the line was reeled in, the hooks were disconnected from the main line and the catch was journalised (fish species, fish length and weight, when possible sex, hook number, etc.).

Fish identification and measurement

All caught fish have been identified to species level (if possible) and measured to the nearest millimetre total length (from the tip of the snout to the tip of the longer lobe of the caudal fin). Number of individuals, species identification and the total length of every individual was recorded for every single catch at each sampling date.

Sampling Design

The data I am referring to has been collected between June and August 2007, within the project “Naturversuch Bad Deutsch Altenburg” and the restoration project “Witzelsdorf” (Keckeis et al. 2009 and 2010). Sampling design has been a stratified random sampling.

Data Processing / Statistical Analysis

Data Transformation

Prior to statistical analyses, fish abundance of all catches from all methods has been transformed into CPUE (catch per unit effort) data by weighting per sampling time (individuals per minute [Ind*min^{-1}]). This procedure allows a comparative observation within (mesohabitats) and between sampling sites within each method. Due to the high number of “0 catches” of individuals of single species, a logarithmic transformation to the CPUE values was applied, in order to meet he requirements of the statistical procedures. The log – transformation compresses high values and expands the difference between low values. The resulting distribution approximates a normal distribution and so a wider range of statistical analysis can be conducted. But biotic data show another characteristic, which has to be considered with transformations: zero values. In the majority of cases zero is the most abundant of variable values. Log(0) is mathematically not defined but this problem can be solved by adding a small value (e.g. 1) to all data points:

$$\mathbf{x' = log\ (x + 1)}$$

This form of transformation has been applied with the species number whose smallest value was one. The CPUE data have been transformed in a different way, after McCune & Grace (2002), due to the fact that the smallest occurring value has been less than one (<1):

$$\mathbf{x' = log\ (x + d) - c}$$

Assumed… **min(x)** equates the smallest “nonzero” value of the data set

Int(x) is a function to reduce a number to the cipher before the decimal point then… $\mathbf{c = Int (log(min(x))}$ "Dimension Constant"

$\mathbf{d = log^{-1} (c) = 10^c}$ "Decimal Constant"

Retransformation: $\mathbf{x = 10^y * 10^c - d}$

All transformations have been conducted with $\log_{10}$. The computed arithmetic mean from the log transformed data set corresponds retransformed with the geometric mean. The calculated standard deviation interval within the logarithmic data matrix equates the spread interval when retransformed.

Data Analysis

Several descriptive variables have been used to find differences or similarities between the fish communities, within (mesohabitats) and between sampling sites, during the sampling period (from June to August) and also between sampling methods. To characterize the fish assemblages species number, species abundance, diversity indices and the total fish length distribution have been calculated. The used diversity indices were the Shannon Weaver diversity index (H´), the Evenness (E) index and species accumulation curves (or "collectors curve").

Diversity Indices

The Shannon Index (H´),

$$\mathbf{H' = - \sum p_i \ln p_i}$$

where p_i is the ratio of the i-th species of the complete sample unit, is a measurement for biodiversity, depending on the species number and the species specific abundance. This index uses an open ended scale: more species produce higher values (Magurran 2004).

The Evenness Index (E),

$$\mathbf{E = H' / \ln S}$$

where H´ equates the Shannon Index and S equates the total species number of the observed sample unit, is a biodiversity measurement which indicates how equal a species community is distributed according to their species specific abundance.

The scale ranges from 0 (non-uniform distribution, one dominant species) to 1 (uniform distribution, all species equal abundant; Magurran 2004).

The Shannon and Evenness Index have been calculated with the standardised catch data (CPUE (Ind.min^{-1})).

The species accumulation curve or collectors curve is a powerful solution for observing the species richness (or alpha diversity). Under natural conditions it is impossible (most of the time) to enumerate the species richness in a direct way and therefore it is necessary to take a number of samples. In most cases species richness is dependent of the sample size, especially within the used fish sampling methods.

The species accumulation curve is a graph which displays the observed species as a function of the sampling effort (e.g. sample units per method or Danube reach) needed to observe them (Colwell et. al., 2004). The course of the curve (steadily rising, flattening, etc.) indicates the tendency of the found species number in contrast to the sampling effort. For example: If the slope of the curve is drawing near zero, enough samples have been taken to observe most of the species catchable within a mesohabitat, a Danube reach or with one method. Is the curve steadily rising, more samples have to be or should have been taken due to the fact that the potential of the method or the sampling site is not jet achieved.

This analysis is based on presence absence data (0 or 1), which is calculated for each sample unit.

PCA Analysis

For getting a general vision of the three Danube reaches and the accomplished methods principal component analysis (PCA) have been carried out using the biotic data set (fish data (Ind*min^{-1})) of each sampling method.

> "*The central idea of principal component analysis (PCA) is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This is achieved by transforming to a new set of variables, the principal components (PCs), which are uncorrelated, and which are ordered so that the first few retain most of the variation present in all of the original variables* (Jolliffe 2002, p. 1)."

The underlying dissimilarity matrix consists of an Euclidean distance matrix, meaning that nearby points share a high similarity and points far apart a high dissimilarity. The PC1 is the "best fitting" line / axis to the sample points and PC 1 and PC2 axes define a plane which is the “best fitting” plane (Clarke et al. 2001). Every succeeding principal component (PC3, PC4; …) accounts or adds a piece of information to the total picture. The Eigenvalues, received through analysis, are valuations for the variance explained by the principal components (as percentage). The sum of the Eigenvalues of all calculated principal components results in 100 percent, meaning all information is explained by the principal components.

In general the PCA displays the variability within each method and reach and therefore the influence of fish species on each catch by being absent, present or abundant.

SIMPER

To analyse which species accounts for similarities within and dissimilarities between groups SIMPER analysis (“similarity percentage”) have been conducted. The results display the percentage similarity within a given group, based on the replicas of this group, and the species responsible for the similarities. Between groups, the dissimilarity is calculated and the determining species are given. The quotient of the similarity co-efficient and the including standard deviation is a measure to which degree the determining species are responsible for differences between groups (Clarke et. al, 2001).

Non Metric Multidimensional Scaling Analysis (NMDS)

For further analysis of differences between methods, Danube reaches mesohabitats and months a non-metric multidimensional scaling analysis has been conducted. The NMDS is a multivariate analysis, displaying sample points in their relative distance to each other. This relative distance is, in this case, based on Bray Curtis rank similarity matrix which is used to quantify similarities or dissimilarities between different samples.

The NMDS constructs a “map”, displaying the sample points in a satisfying arrangement, imposed by the underlying rank similarity matrix (Clarke et. al. 2001). Due to the fact that this analysis works on a rank similarity (or dissimilarity) matrix and not on the original data set “…*there is complete freedom of choice to define similarity of community composition in whatever terms are biologically most meaningful*” (Clarke et. al. 2001, Chapter 5 p. 9).

Statistical Tests

Statistical methods have been applied to assess if a data set is normally distributed (Kolmogorov-Smirnov test), if there is a homogeneity of variance (Levene test), if there are differences between variables (ANOVA and Kruskal-Wallis tests; variables: reach, mesohabitats and month/period) on the basis of abundance (Ind*min^{-1}), diversity (Shannon –Evenness, species number) and total fish length data and which variables differ significantly within this data sets (TukeyHSD and Tamhane T2 Post Hoc tests).

The statistical analysis of the NMDS has been made by PERMANOVA tests, a permutation test similar to a multivariate ANOVA, comparing factors with a one or more variables (in this case species), on the basis of any resemblance measure (e.g.: Bray Curtis similarity matrix; see also Anderson et al. 2008).

Utilized Software

The data set used by me has been extracted from MS Access databanks to MS Excel worksheets, where most of the basic analysis and the data transformations have been done. Statistical analyses have been conducted with SPSS 16.0, Canoco 4.5, EstimateS Win 8.20, and PRIMER 6 (PERMANOVA package), the graphic elaboration has been done with SigmaPlot 12.0.

Results

Discharge and Temperature

The flow regime during the sampling period was most of the time characterized by a discharge below the mean annual discharge (MQ) of 1930 m^3*s^{-1}. During the three months of sampling the average discharge was 1680±365 m^3*s^{-1}, the maximum was 3236 m^3*s^{-1} on the 11th of July and the minimum discharge was 1176 m^3*s^{-1} on the 6th of August (fig. 6).

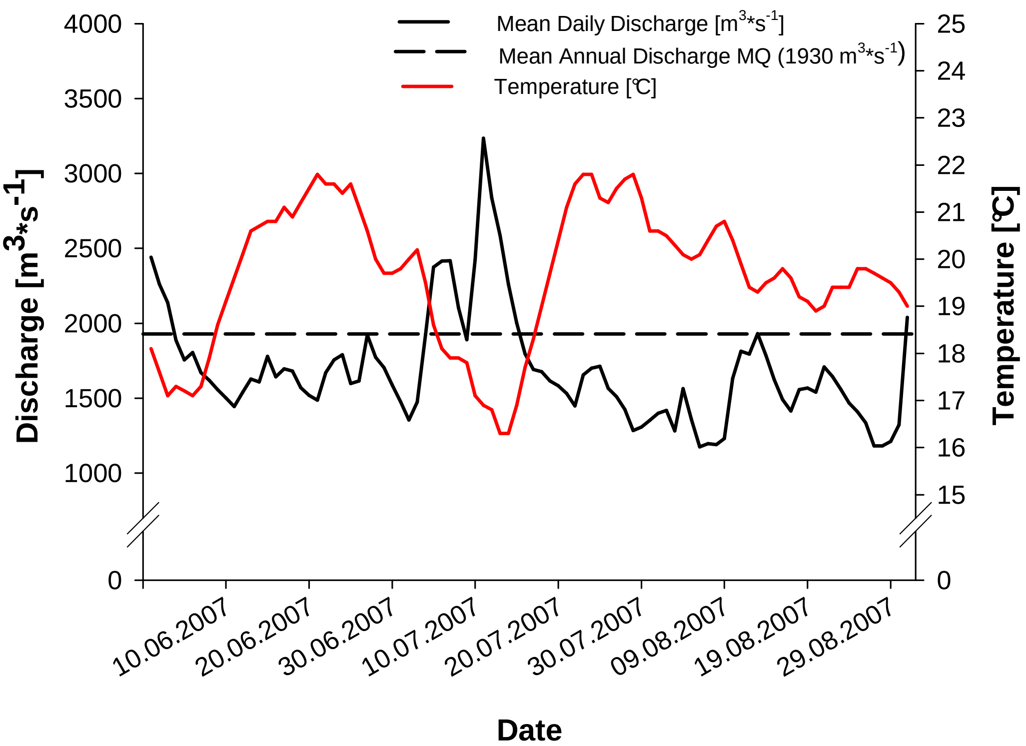

Figure 6: Discharge and water temperature (observation station Hainburg) during the sampling period, from June to August 2007. The black line is the discharge (dashed black line = mean annual discharge) and the red line is the temperature (right y-axis).

During the sampling period the mean water temperature was 19,7 ± 1,5 °C, rising from June to the end of July and decreasing toward the end of August. The highest water temperature of 21,8 °C was measured several times during June (21st of June) and July (23rd, 24th and 29th of July) while the lowest temperature (16,3 °C) was measured slightly after the flood on the 13th and 14th of July.

Total Catch

During the three month period of sampling, from June to August 2007, a total number of 431 samples have been taken with a total number of 5635 fish. Within the reach Bad

Deutsch Altenburg 2046 fish (36% of the total catch) has been caught; 2254 (40% of the total catch) fish within the reach Witzelsdorf and 1335 (24% of the total catch) within the reach near Hainburg. Altogether 36 species (and one undefined species) from 8 fish families (*Cyprinidae, Cottidae, Esocidae, Gasterosteidae, Gobiidae, Lotidae, Percidea* and *Siluridae*) were observed (tab. 1).

Table 1: Species list and occurrence of single fish species in different reaches and in the catches of different sampling methods. List of fish species Latin name, descriptor, shortcut, ecological guild and status of endangerment (FFH)) caught during three months of sampling with the three sampling methods in three Danube reaches. Schortcuts: R =rheophil; EU =eurytop; NZ =neozoa; ST =stagnophil; FFH =Flora Fauna Habitat Directive; Undef.= undefined (ecological guilds after Schiemer & Waidbacher, 1992; modified); BDA= Danube reach Bad deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg; B.E.F.= boat electro fishing; L.L.F.= long line fishing; W.E.F.= wading electro fishing.

Species /	Descriptor	Shortcut	Guild	FFH-Species	Reaches			Sampling Methods		
					BDA	WITZ	HAIN	B. E. F.	L. L. F.	W. E. F.
Abramis ballerus	Linne, 1758	A. ballerus	R		x		x		x	x
Abramis bjoerkna	Linne, 1758	A. bjoerkna	R		x	x	x	x	x	x
Abramis brama	Linne, 1758	A. brama	EU		x	x	x	x	x	
Abramis sapa	Pallas, 1814	A. sapa	R		x		x		x	x
Alburnus alburnus	Linne, 1758	A. alburnus	EU		x	x	x	x	x	x
Aspius aspius	Linne, 1758	A. aspius	R	II	x	x	x	x		x
Barbus barbus	Linne, 1758	B. barbus	R	V	x	x	x	x	x	x
Carassius gibelio	Bloch, 1782	C. gibelio	EU		x					x
Chondrostoma nasus	Linne, 1758	C. nasus	R		x	x	x	x		x
Cottus gobio	Linne, 1758	C. gobio	R	II	x	x			x	x
*Cyprinidae sp_*		Cyprinidae sp_	Undef.		x	x	x	x		x
Esox lucius	Linne, 1758	E. lucius	EU		x	x		x		x
Gasterosteus aculeatus	Linne, 1758	G. aculeatus	ST		x					x
Gobio albipinnatus	Lukash, 1933	G. albipinnatus	R	II	x		x		x	
Gobio gobio	Linne, 1758	G. gobio	R				x		x	
Gymnocephalus baloni	Holcik&Hensel, 1974	G. baloni	R	II			x		x	
Gymnocephalus schraetser	Linne, 1758	G. schraetser	R	II, V	x	x	x	x	x	
Leuciscus cephalus	Linne, 1758	L. cephalus	EU		x	x	x	x	x	x
Leuciscus idus	Linne, 1758	L. idus	R		x	x	x	x	x	x
Leuciscus leuciscus	Linne, 1758	L. leuciscus	R		x	x	x	x		x
Lota lota	Linne, 1758	L. lota	RT		x	x	x	x		x
Neogobius gymnotrachelus	Kessler, 1857	N. gymnotrachelus	NZ		x	x	x	x	x	x
Neogobius kessleri	Günther, 1861	N. kessleri	NZ		x	x	x	x	x	x
Neogobius melanostomus	Pallas, 1814	N. melanostomus	NZ		x	x	x	x	x	x
Perca fluviatilis	Linne, 1758	P. fluviatilis	EU		x	x	x	x	x	x
Proterorhinus marmoratus	Pallas, 1814	P. marmoratus	EU		x	x	x			x
Pseudoraspora parva	Temminck&Schlegel, 1842	P. parva	NZ		x					x
Rhodeus amarus	Bloch, 1782	R. amarus	ST	II	x	x	x	x		x
Rutilus pigus	La Cepéde, 1803	R. pigus	R	II	x	x	x	x		
Rutilus rutilus	Linne, 1758	R. rutilus	EU		x	x	x	x	x	x
Sander lucioperca	Linne, 1758	S. lucioperca	EU		x	x	x	x	x	x
Sander volgensis	Gmelin, 1788	S. volgensis	ST				x		x	
Scardinius erythrophthalmus	Linne, 1758	S. erythrophthalmus	ST				x	x		x
Silurus glanis	Linne, 1758	S. glanis	EU		x	x	x	x	x	
Vimba vimba	Linne, 1758	V. vimba	R		x	x	x	x	x	x
Zingel streber	Siebold, 1863	Z. streber	R	II	x	x	x		x	
Zingel zingel	Linne, 1766	Z. zingel	R	II, V		x	x		x	x

Ecological guilds refer to Schiemer and Waidbacher (1992) but they were slightly modified to meet the requirements of this study. The rheophilic fish guild (R) contain species which complete most their lifecycle in the fast flowing main stem of the River and connected side-arms within the river, limnophilous or stagnophilous (ST) fish are found in disconnected zones or areas with low connectivity of surface water in habitats with high densities of submerged vegetation and macrophytes, whereas eurytopic fish (E) can be found in all types of habitats of the River and the floodplain (generalistic species).

According to the Habitat Directive (1992) of the European Union 10 of the 36 found species belonged to endangered species, listed in the ANNEX II and V of the directive:

Aspius aspius (II), *Barbus barbus* (V), *Cottus gobio* (II), *Gobio albipinnatus* (II), *Gymnocephalus baloni* (II), *Gymnocephalus schraetser* (II, V), *Rhodeus amarus* (II), *Rutilus pigus* (II), *Zingel streber* (II) and *Zingel zingel* (II, V).

Six species have been exclusive to only one sampling site (*Carassius gibelio, Gasterosteus aculeatus* and *Gobio gobio, Gymnocephalus baloni, Pseudoraspora parva, Sander volgensis and Scardinius erythrophthalmus).* Within the Danube reach Bad Deutsch Altenburg 32 species have been found, 27 within the reach Witztelsdorf and32 fish species within the reach near Hainburg.

Due to the fact that 3 different methods have been used, 10 fish species have been detected only with one fish sampling method (e.g.: *Carassius gibelio, Gasterosteus aculeatus, Gobio albipinnatus, Gobio gobio, Gymnocephalus baloni, Proterorhinus marmoratus, Pseudoraspora parva, Rutilus pigus, Sander volgensis and Zingel streber*). With each of the two methods, boat electro fishing and long line fishing, 24 species were caught, the highest species number (28 fish species) was observed by wading electro fishing.

Boat Electro Fishing

Sampling Locations, Sampling Size and Season

Overall 157 samples have been taken and a total number of 2182 individuals (out of 24 species, tab. X) has been caught during the three months period of sampling within the three Danube reaches (tab. 2). The sampling effort has been similar within the reaches and the three months while the mesohabitats have been sampled on the basis of availability (discharge, flow) within the three segments of the main channel.

Table 2: Number of sample units within the three reaches, the mesohabitats and the three months. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg; GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm

Reach	Sample Units	Mesohabitat	Sample Units	Month	Sample Units
BDA	60	GB	40	June	53
WITZ	59	GR	59	July	52
HAIN	38	RR	52	August	52
		SA	6		
Overall	**157**		**157**		**157**

Species Assemblage

The most dominant fish species for boat electro fishing was *Alburnus alburnus*, as it showed the highest abundance within all reaches, mesohabitats and months (tab. 3). Further commonly observed species were *Barbus barbus, Aspius aspius* and *Leuciscus* *cephalus*. These four fish species dominated the three Danube reaches during the whole sampling period (tab. Simper).

The dissimilarity between the three Danube reaches ranged between 66 and 72% and was caused by changing average abundances of several species, including the three most abundant (*A. alburnus, B. barbus, A. aspius*), which contributed the most to the dissimilarities (table attachment). BDA differed by 66,4% from WITZ and by 71,9% from HAIN, while WITZ and HAIN differed to 70,3%.

Concerning the mesohabitats, also other fish species, beside the almost always dominating species (see above), accounted for the typification of the fish assemblages, like *Condrostoma nasus* for the gravel bars and *Vimba vimba*, *Perca fluviatilis* and *Abramis brama* for the side arms (tab. Simper). Between the mesohabitats the differences varied between 67 and 79 %. The crucial species were again the high abundant species, the typical species of each mesohabitat and also low abundant species. The side arms differed in a high degree from the gravel bars (79%) and the rip raps (78,7%) while a lower dissimilarity was found for the groin field (68,6%). The rip raps differed also in a high degree from the gravel bars (73,8%) while a lower difference was found for the groin fields (67,6%). The difference between gravel bars and groin fields was the lowest of all mesohabitats (67%, table A (attachment)).

Table 3: Results of SIMPER analysis, based on boat electro fishing abundance data, displaying diagnostic species (≥ 90% similarity) for the reaches, mesohabitats and months. Av.Abund = average abundance; Av.Sim = average similarity; BDA = Danube reach Bad Deutsch Altenburg; WITZ = Danube reach Witzelsdorf; HAIN = Danube reach Hainburg; GB = gravel bank; GR = groin field; RR = rip rap; SA = side arm

Reaches											
BDA	Av.Abund	Av.Sim	**WITZ**	Av.Abund	Av.Sim	**HAIN**	Av.Abund	Av.Sim			
A. alburnus	1,39	18,61	A. alburnus	1,72	35,84	A. alburnus	1,26	12,29			
B. barbus	0,67	5,19	B. barbus	0,41	1,81	B. barbus	0,88	10,51			
A. aspius	0,49	4,5				L. cephalus	0,43	1,87			
						A. aspius	0,26	1,36			
Mesohabitats											
GR	Av.Abund	Av.Sim	**GB**	Av.Abund	Av.Sim	**RR**	Av.Abund	Av.Sim	**SA**	Av.Abund	Av.Sim
A. alburnus	1,9	39,15	A. alburnus	1,27	14,71	A. alburnus	1,1	14,1	A. alburnus	2,14	17,56
A. aspius	0,37	2,63	B. barbus	0,88	8,78	B. barbus	0,73	6,37	V. vimba	0,97	2,98
			C. nasus	0,51	2,08	A. aspius	0,5	5,1	L. cephalus	0,92	2,83
									P. fluviatilis	1	2,46
									A. brama	0,67	1,4
Months											
June	Av.Abund	Av.Sim	**July**	Av.Abund	Av.Sim	**August**	Av.Abund	Av.Sim			
A. alburnus	1,23	22,89	A. alburnus	1,79	33,9	A. alburnus	1,43	13,79			
B. barbus	0,53	4,42	A. aspius	0,45	3,73	B. barbus	0,82	7,12			
			B. barbus	0,52	2,99	A. aspius	0,42	2,75			
						L. cephalus	0,41	1,49			

Regarding the sampling period not only the most abundant species, *A. alburnus*; *B. barbus* and *A. aspius*, but also several other species including *C. nasus*, *L. cephalus* and *A. brama* accounted for the observed dissimilarities between the three months. The dissimilarities ranged from 65 to 72%, where June differed with 65,3% from July, with 72,7% from August and July differed with 67,7% dissimilarity from August.

Species Composition and Abundance

The composition of the species assemblages was analysed by applying a PCA (Canoco 4.5) to the samples-species abundance matrix, the results are illustrated in figure 7 and table 4, the ordination plot for species scores displays the influence by single species on each axis. The first two axes (PC1 and PC2) of the principal component analysis (PCA) for boat electro fishing explained 48% of the total variance 30% were explained by PC1 and 18% by PC2. The highest influence showed *Alburnus alburnus, Vimba vimba* and *Perca fluviatilis* on the first (PC1) and *Barbus barbus, Chondrostoma nasus* and *Leuciscus idus* on the second axes (PC2, fig. 7).

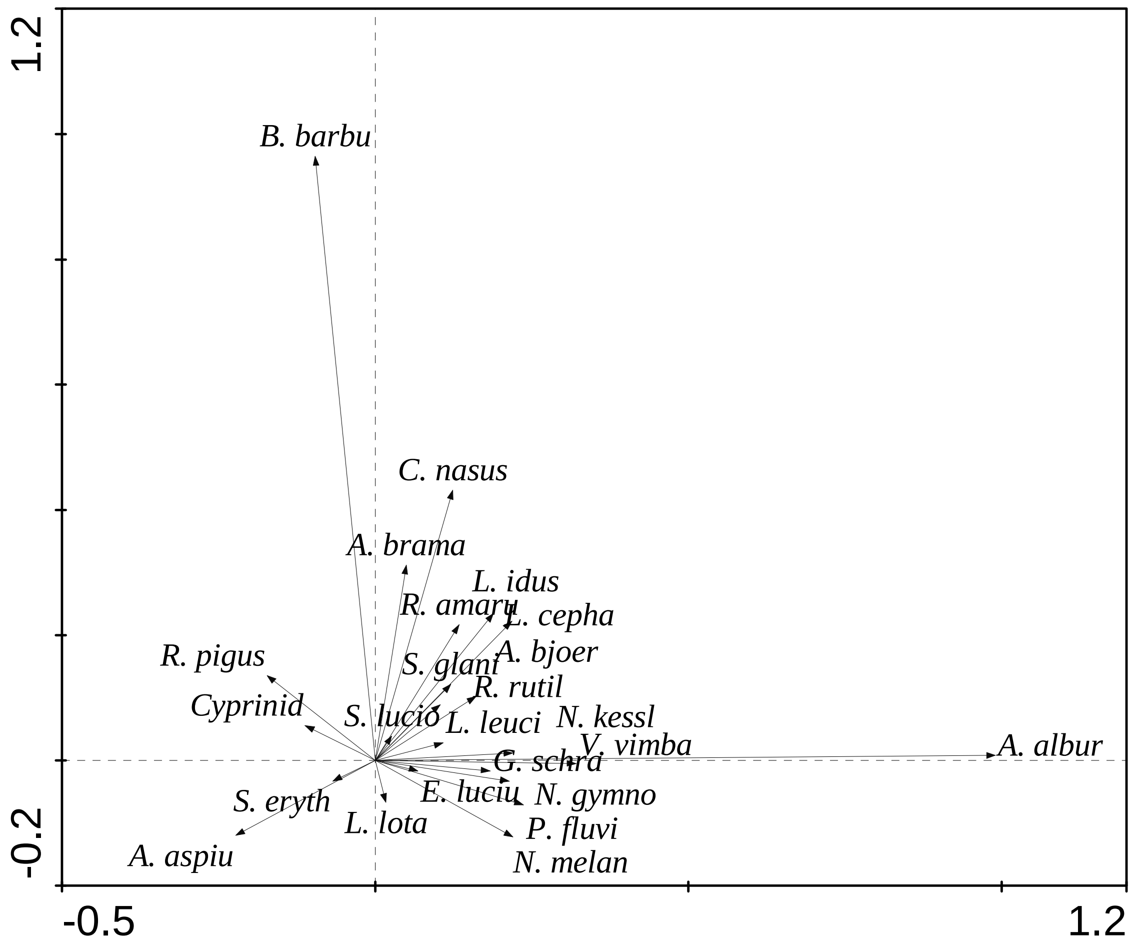

Figure 7: Two dimensional PCA ordination plot of species scores for boat electro fishing. PC 1 accounts for 30% and PC 2 accounts for 18% of the total species variability. The dotted line within the graph marks the origin (x= 0; y= 0).

The figures of the sample scores (colour coded for Danube reach, mesohabitats and month) showed that there are three separated aggregations of sample points (fig. 8), largely influenced by the presence or absence of *Alburnus alburnus* and *Barbus barbus.* Within samples of the left bulk, no abundance for *A. alburnus* has been found during the whole sampling period; while the bulk on the lower end of the y-axis (below 0) consisted of samples where *B. barbus* was absent. No clear pattern regarding Danube reach, mesohabitat or months was visible.

No significant differences between the scores of the Danube reaches, regarding values on the first axis (PC1) were observed (Kruskal Wallis test: Chi-Square= 3,66; p= 0,16; d.f.= 2; n= 157) whereas at the PC 2 significant differences between the reaches were found (Kruskal Wallis test: Chi-Square= 6,24; p= 0,044; d.f.= 2; n= 157, Tamhane Post Hoc test). A post-hoc test revealed a significant difference (p= 0,021) between the WITZ and HAIN site although no big distance was visible between the centroids of these two reaches.

Table 4: Eigenvalues and corresponding species loadings for the PCA ordination plot of species scores for boat electro fishing. PC 1 accounts for 30%, PC 2 accounts for 18%, PC 3 accounts for 11% and PC4 accounts for 9% of the total species variability.

Species	PC1	PC2	PC3	PC4	Species	PC1	PC2	PC3	PC4
Eigenvalues	0,30	0,18	0,11	0,09					
A. bjoerkna	0,16	0,10	0,76	-0,10	L. lota	0,02	-0,07	-0,03	-0,06
A. brama	0,05	0,31	0,02	-0,07	N. gymnotrachelus	0,21	-0,03	0,62	-0,09
A. alburnus	0,99	0,01	-0,10	0,07	N. kessleri	0,22	0,01	0,62	-0,09
A. aspius	-0,22	-0,12	0,08	0,95	N. melanostomus	0,22	-0,12	0,49	0,01
B. barbus	-0,10	0,96	-0,06	0,04	P. fluviatilis	0,24	-0,07	0,59	-0,20
C. nasus	0,12	0,43	-0,10	0,09	R. amarus	0,13	0,22	0,25	0,01
Cyprinidae sp.	-0,11	0,06	-0,01	-0,07	R. pigus	-0,17	0,14	-0,05	0,05
E. lucius	0,07	-0,02	-0,10	-0,01	R. rutilus	0,10	0,09	0,77	-0,17
G. schraetser	0,18	-0,02	0,06	-0,06	S. lucioperca	0,03	0,04	0,03	0,09
L. cephalus	0,22	0,22	0,76	0,12	S. erythrophthalmus	-0,07	-0,03	0,45	-0,14
L. idus	0,19	0,23	0,02	0,10	S. glanis	0,12	0,12	0,18	0,05
L. leuciscus	0,11	0,03	-0,05	0,15	V. vimba	0,32	-0,01	0,49	-0,02

Comparing the mesohabitats by their mean values, there was a highly significant difference at the x-axis (Kruskal Wallis test: Chi-Square= 19,16; p= 0,000; d.f.= 3; n= 157; TamhanePost Hoc test). The mesohabitat rip rap (RR) and groin field (GR) differed highest significantly (p= 0,000) and the mesohabitat gravel bank (GB) differed significantly (p= 0,047) from GR. The side arm differed not significantly from the other mesohabitats.

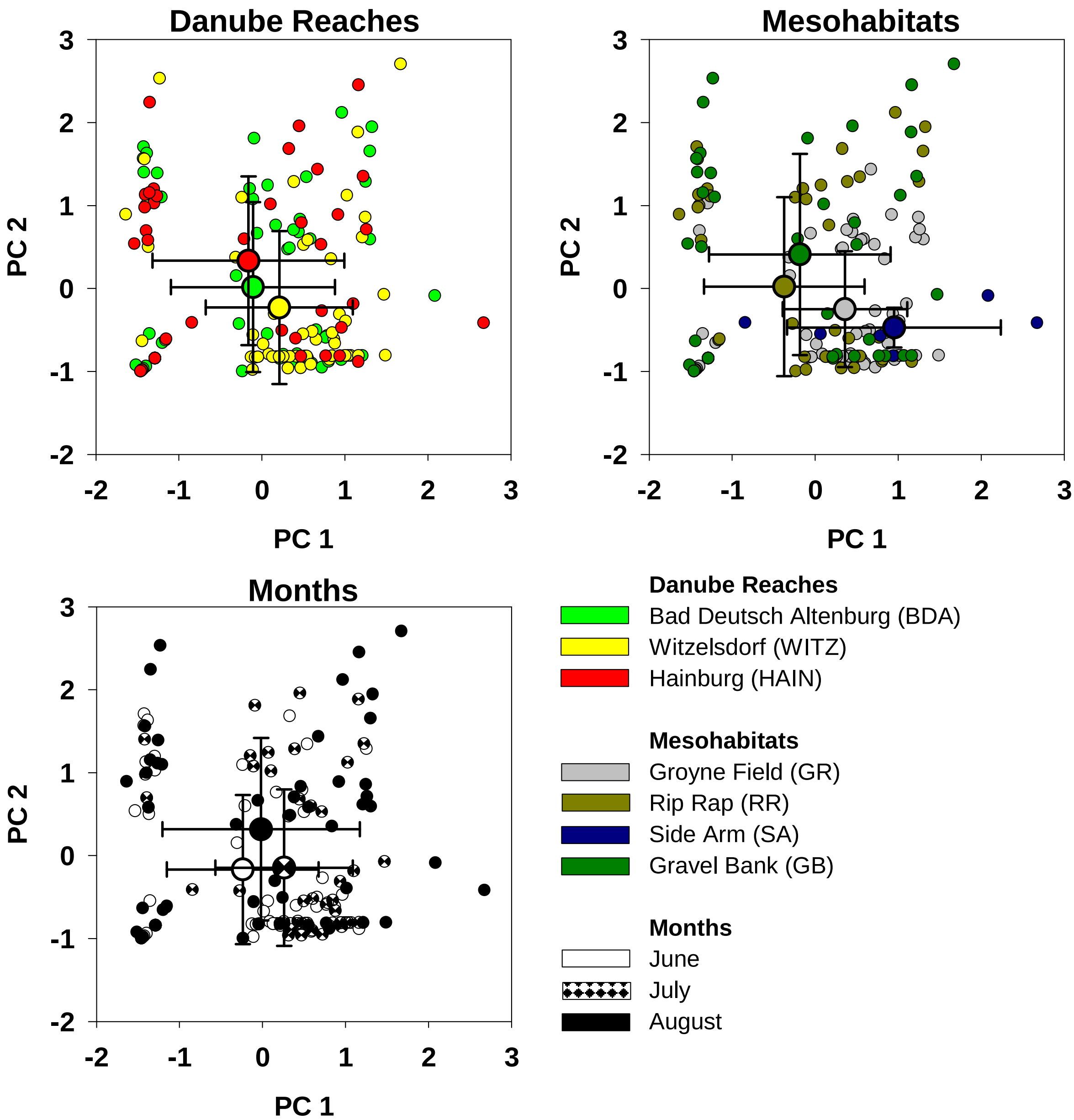

Figure 8: Two dimensional PCA ordination plot of sample scores from boat electro fishing results (species abundance). PC 1 accounts for 30 % and PC 2 accounts for 18% of the total sample variability. Danube reaches, mesohabitats and months are indicated by different colours/fills (see legend).

On the second axis, no significant differences between the mesohabitats were found (Kruskal Wallis test: Chi-Square= 6,29; p= 0,098; d.f.= 3; n= 157) although a clear separation of these mesohabitats is indicated in figure 8.

Regarding the sampling period, there was a significant difference between the centroids of PC 1 (Kruskal Wallis tets: Chi-Square= 7,03, p= 0,03; d.f.= 2; n= 157; Tamhane Post Hoc test) as the months June and July differ significantly (p= 0,02). On PC2 no significant difference was found (Kruskal Wallis test: Chi-Square= 5,75; p= 0,058; d.f.= 2; n= 157). Although statistical differences observed, no big spatial separation was given for the mean sample scores of the three months, and a clear overlap between all groups is indicated by their standard deviations.

Danube Reach

Species-abundance plots of the total catch for each reach are shown in fig.10. No significant difference of total abundance between the three Danube segments (ANOVA; p= 0,381; n= 157) was found. No significant differences of the mean abundance of fish per sample between the three Danube segments (ANOVA: F= 0,97; p= 0,381; d.f.= 2; n= 157) was observed. *Lota lota, Leuciscus leuciscus, Sander lucioperca, Rhodeus amarus, Scardinius erythrophthalmus, Neogobius gymnotrachelus* and *N. kessleri* occurred only in one single reach. *L. lota* and *S. lucioperca* were found in the BDA, *L. leuciscus, R. amarus* and *N. kessleri* in the WITZ and *S. erythrophthalmus* and *N. gymnotrachelus* in HAIN.

The species with the highest abundance in all reaches was *Alburnus alburnus* (fig. 10). Further high abundant species were *Barbus barbus, Aspius aspius, Chondrostoma nasus, Leuciscus idus, Abramis brama* and *Leuciscus cephalus*.

Mesohabitats

Species-abundance plots of the total catch for each mesohabitat are shown in fig. 11 .Between the mesohabitats, there was a significant difference (Kruskal Wallis test: Chi-Square= 10,91; p= 0,012; d.f.= 3; n= 157) concerning the total catch, however the post hoc test (Tamhane t-test) indicated no specific different mesohabitats. The highest mean abundance was found in the side arm (9, 69 ind*min^{-1}); lower but similar numbers of mean fish abundance were observed at the mesohabitats gravel bank (3,96 ind*min^{-1}), groin field (3,74 ind*min^{-1}) and rip rap (3,10 ind*min^{-1}) .

Lota lota, Leuciscus leuciscus, Esox lucius, Sander lucioperca, Rhodeus amarus, Scardinius erythrophthalmus and *Neogobius gymnotrachelus* were found in only one of the four sampled mesohabitats. *L. leuciscus, E. lucius and S. lucioperca* were only found at GR, *S. eryhtrophthalmus* and *N. gymnothrachelus* in the SA and at the GB *Lota lota* and *Rhodeus amarus*. The species with the highest abundance in all mesohabitats was again *Alburnus alburnus* (fig. 11). Further high abundant species were*, Aspius aspius* and *Barbus barbus* for groin fields and rip raps*, B. barbus Chondrostoma nasus* and *Abramis brama* for Gravel bars and *Vimba vimba, Abramis bjoerkna, Leuciscus cephalus, Perca fluviatilis and Rutilus rutilus* for side arms.

Sampling Period

Species-abundance plots of the total catch for each month are shown in Fig. 12 During the course of the sampling period, an increase of the mean abundance from June (2,67 ind*min^{-1}) to August (4,89 ind*min^{-1}) was observed (fig. X and fig. X). Fish abundance between the three months differed significantly (Kruskal Wallis test: Chi-Square= 15,35; p= 0,000; d.f.= 2; n= 157; Tamhane Post Hoc test), the values in June differed high significantly from those of July and August (June vs. July: p= 0,003; June vs. August: p= 0,001), while there was no significant difference between the mean abundances of July and August.

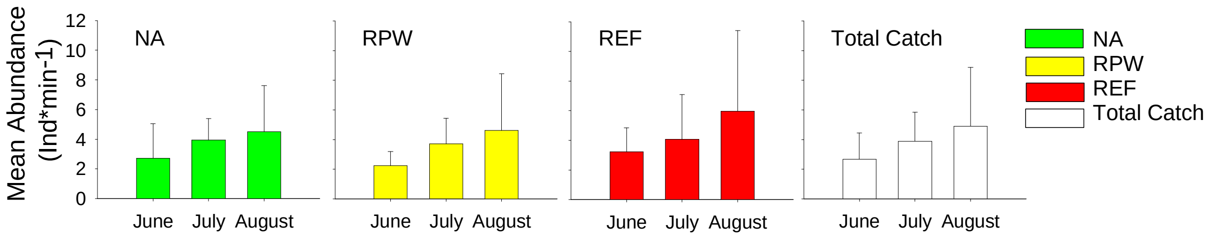

Figure 9: Total catch and within reach comparison of mean abundances (Ind*min^{-1}) during the sampling period. The X-axis shows the months, the Y-axis shows the abundance (average ± standard deviation). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

Especially the non-native fish species appeared in July (*Neogobius melanostomus*) and August (*Neogobius kessleri* and *Neogobius gymnotrachelus*). *Lota lota, Sander lucioperca, Rhodeus amarus, Scardinius erythrophthalmus, Neogobius gymnothrachelus* and *Neogobius kessleri* occured only during one month: *L. lota* and *S. erythrophthalmus* in July and *S. lucioperca*, *R. amarus*, *N. gymnothrachelus* and *N. kessleri* in August. The species with the highest abundance during the whole sampling period was *Alburnus alburnus* (fig. 12).

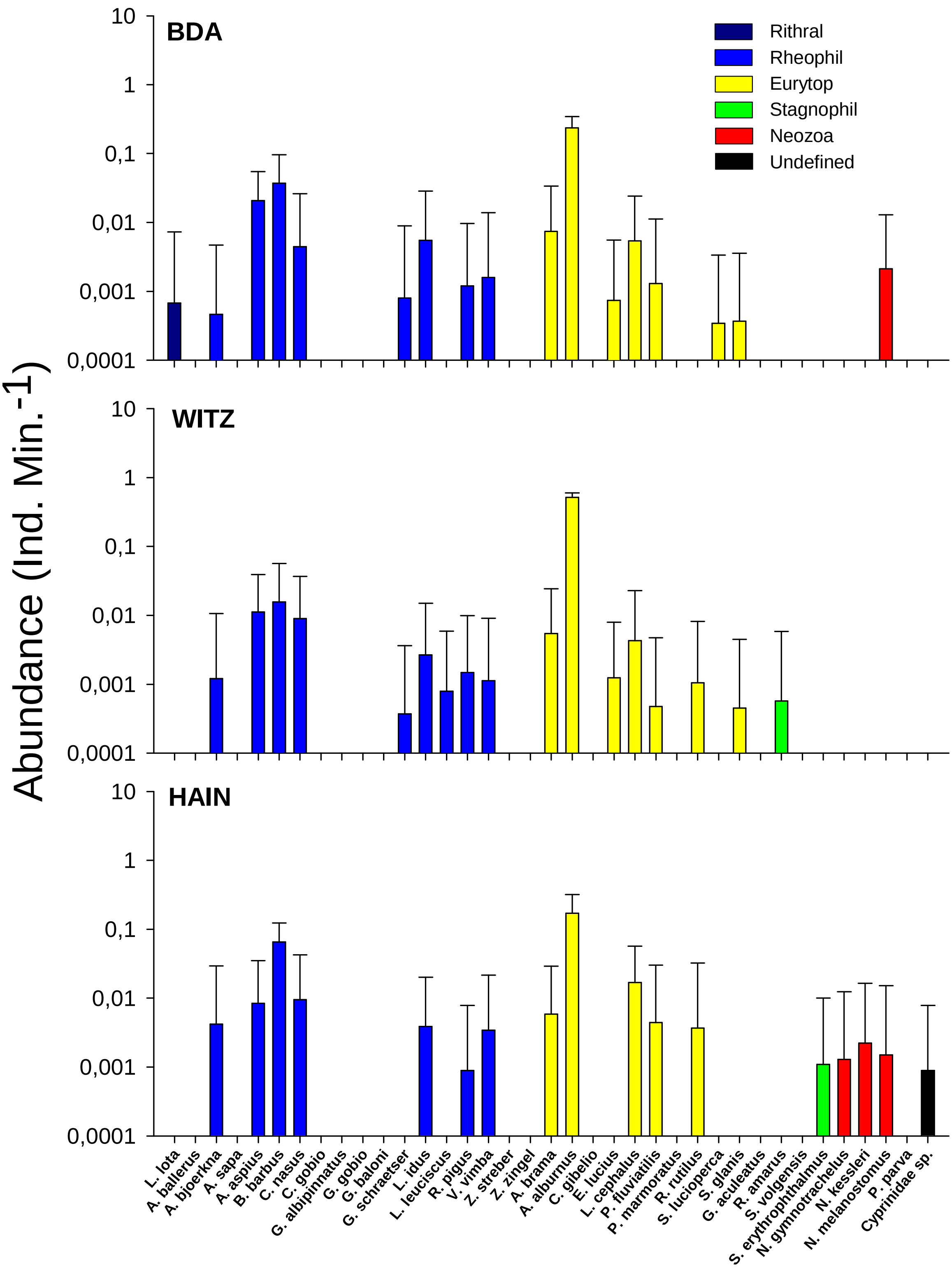

Figure 10: Species composition, species number and abundance of single fish species sampled by boat electro fishing in the three Danube reaches. The Y-axis shows the abundance ($\log_{10}$ logarithmic scaling). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg. Ecological guilds are indicated by different colouring.

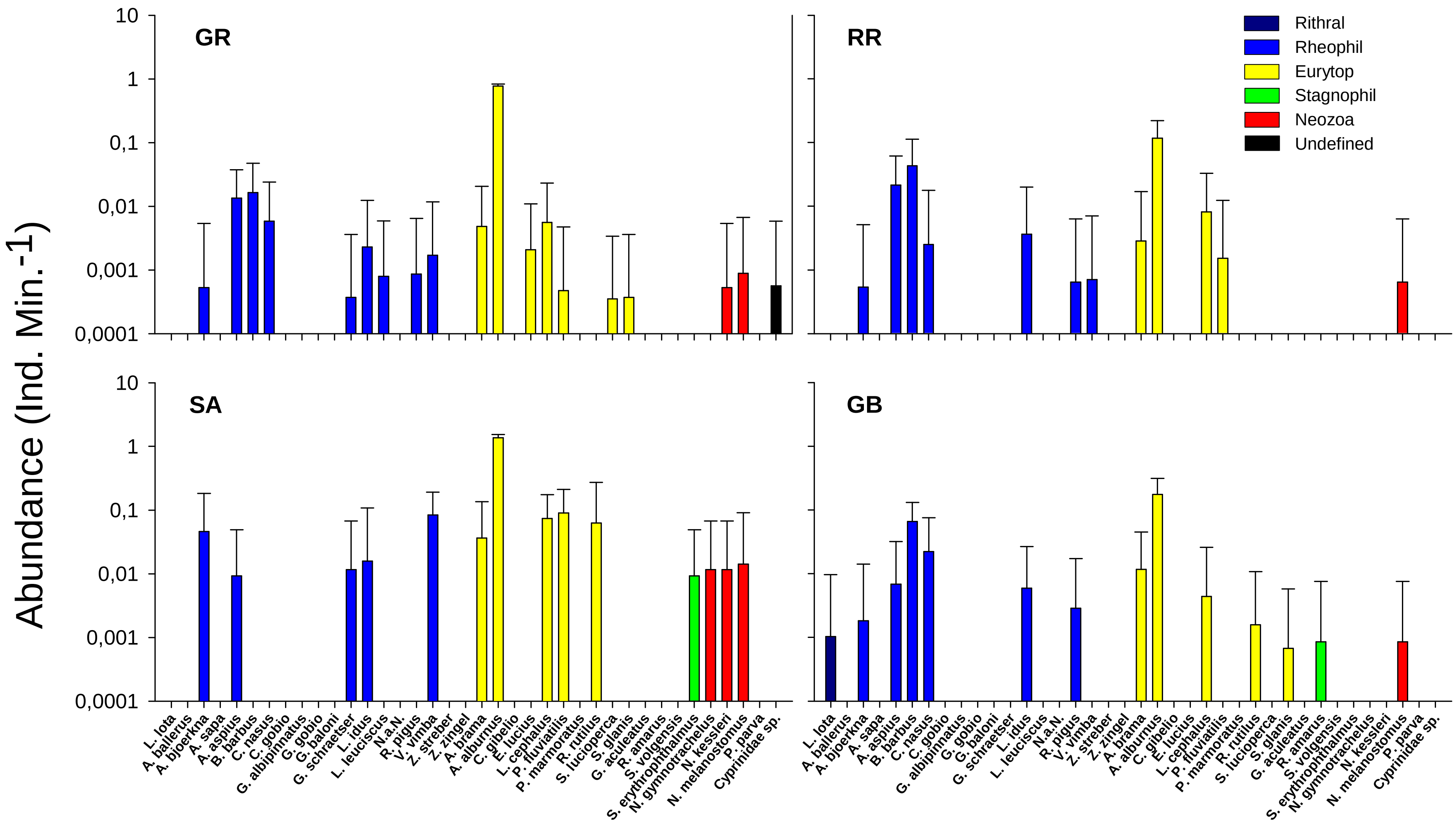

Figure 11: Species composition, species number and abundance of single fish species sampled by boat electro fishing in the four mesohabitats The Y-axis shows the abundance ($\log_{10}$ logarithmic scaling). GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm Ecological guilds are indicated by different colouring.

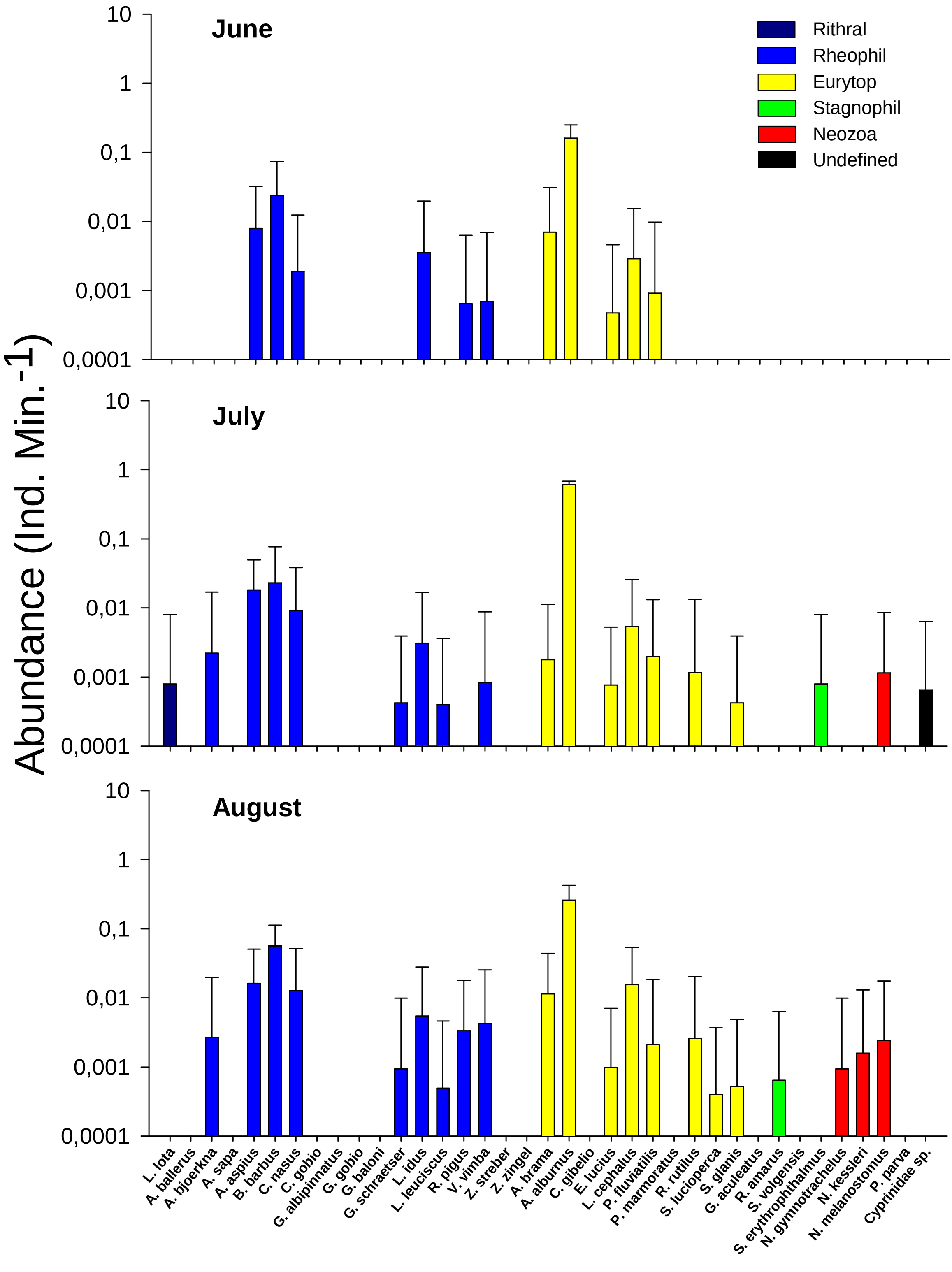

Figure 12: Species composition, species number and abundance of single fish species sampled by boat electro fishing of the three months of sampling June, July and August. The Y-axis shows the abundance (log_{10} logarithmic scaling). Ecological guilds are indicated by different colouring.

Biodiversity: Species Number, Shannon Weaver Index and Evenness

Danube Reach

Regarding the total catch, the highest species number has been found within the BDA and HAIN site, with 17 species each, followed by the WITZ with 16 species.

The mean species number per sample showed no significant difference between the Danube reaches (ANOVA: F= 4,18; p= 0,659; d.f.= 2; n= 157.)

Concerning the mean Shannon Index of the total catch, there was a significant difference (ANOVA: F= 4,12; p= 0,018; d.f.= 2; n= 145) between the three Danube reaches. A Tukey post-hoc test revealed that the WITZ reach had the lowest Shannon Index and differed significantly from the HAIN site (p=0,038). The diversity index between BDA and HAIN was not significantly different.

The highest mean Evenness was found within the HAIN site, followed by BDA. The Evenness of WITZ was significantly lower (ANOVA: F= 4,62; p= 0,011; d.f.= 2; n= 145; Tukey Post Hoc test) than the other two Danube reaches. WITZ differed significantly from BDA (p= 0,038) and HAIN (p= 0,023; fig 13).

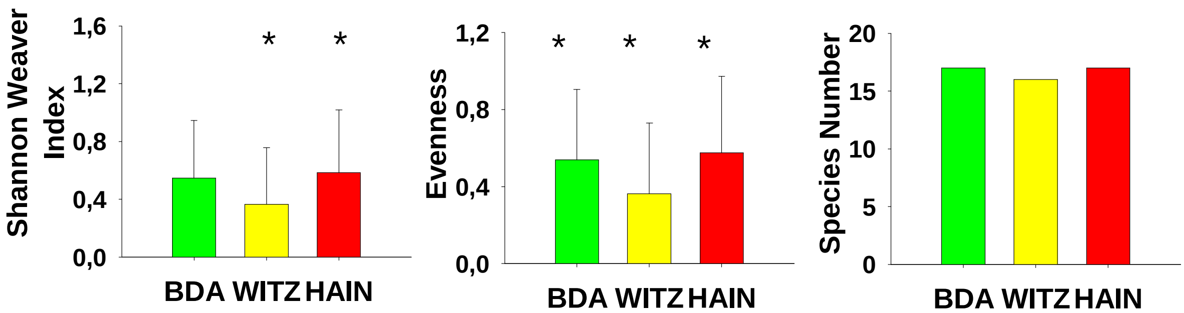

Figure 13: Shannon Weaver index, Evenness and total species number of the total catch in the three Danube reaches. Bars represent mean values, error bars represent standard deviation. Significant differences are indicated by star symbols. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

Within all three Danube segments, the species number rose during the sampling period from June to August. The least increase, from 8 to 14 species, was observed within BDA. Evenness decreased during the sampling period within the BDA and HAIN site; whereas in the WITZ reach an increase was observed (fig. 14).

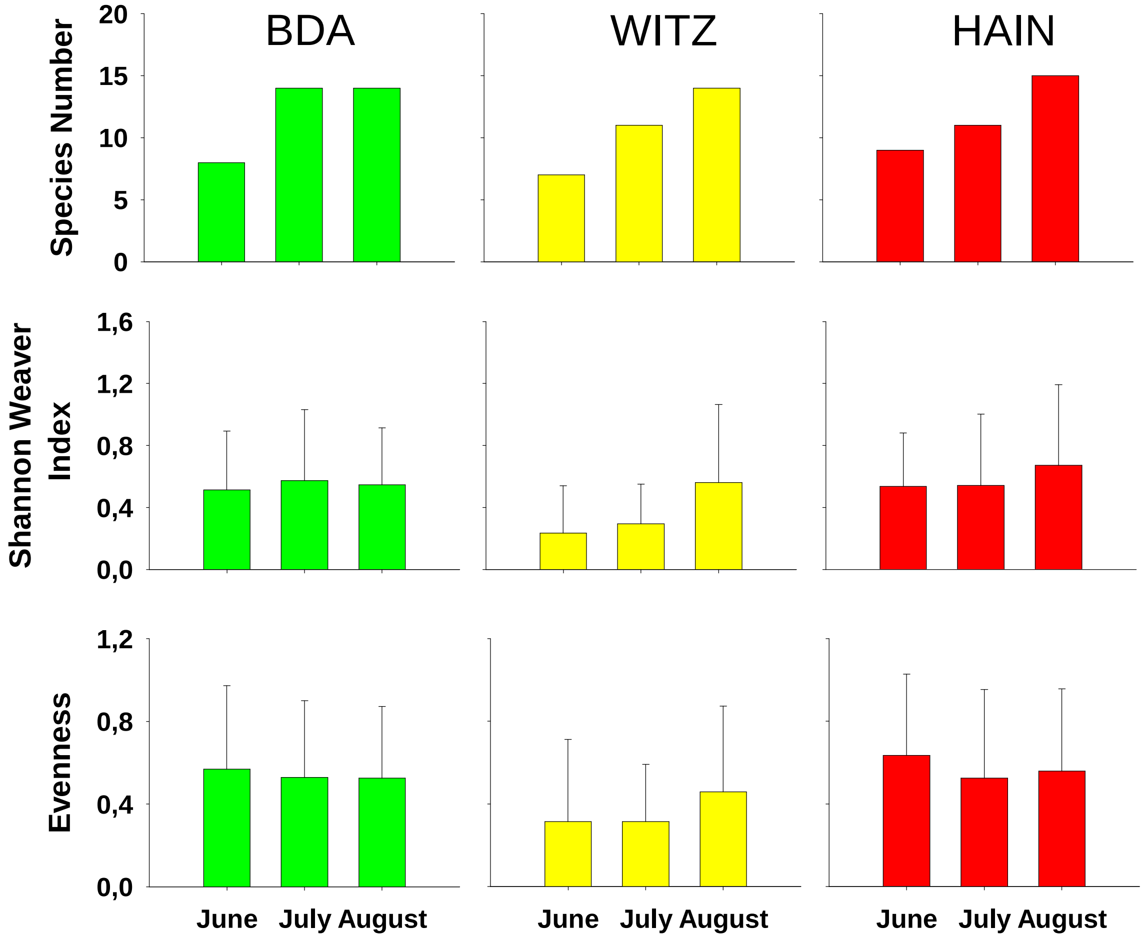

Figure 14: Species number, mean Shannon Weaver index and mean Evenness index and per month in the three Danube reaches. Bars represent mean values, error bars represent standard deviation. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

Mesohabitat

Out of all mesohabitats, the groin field (GR) had the highest species number (18). The mesohabitats SA and GB had equal species numbers (14) while the lowest number of different species was found in the RR mesohabitat (12). A significant difference between RR and SA concerning the mean species numbers were found (ANOVA: F= 4,40; p= 0,005; d.f.= 3; n= 157; Tukey Post Hoc test). The SA mesohabitats had significantly higher (p=0,010) mean species numbers than the RR site.

While the highest species number was observed within GR mesohabitats, the SA mesohabitats had the highest values for the mean Shannon Index (ANOVA: F= 4,17; p= 0,007; d.f.= 3; n= 145; Tukey Post Hoc test: SA vs. RR p= 0,021; SA vs. GR p= 0,009) and the Evenness (not significant) over the whole sampling period, while the mesohabitats with the lowest mean diversity indices were GR. (fig. 15).

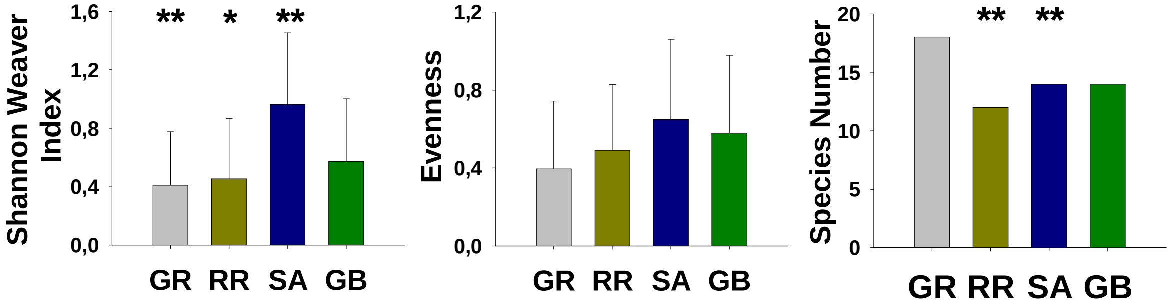

Figure 15: Shannon Weaver index, Evenness and total species number of the total catch in the four mesohabitats. Bars represent mean values, error bars represent standard deviation. Significant differences are indicated by star symbols. GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

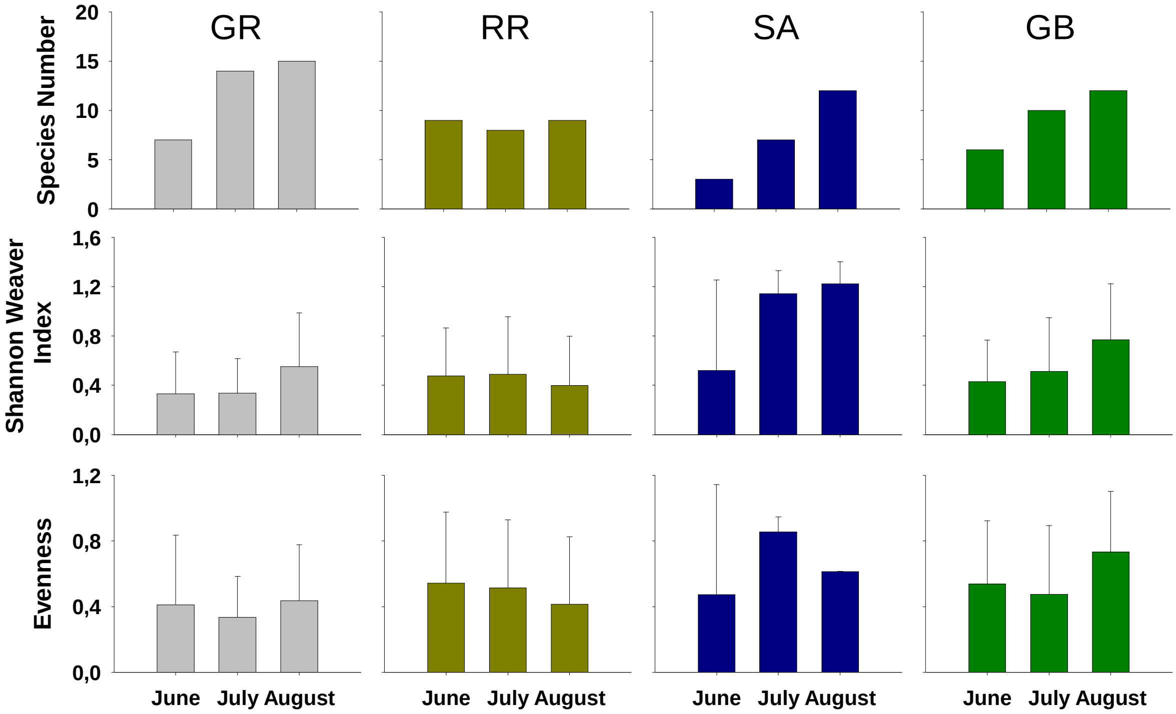

Figure 16: Species number, Shannon Weaver index and Evenness of the total catch in the four mesohabitats. Bars represent mean values, error bars represent standard deviation. GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

The Evenness Index revealed a different pattern among mesohabitats compared to species number and the Shannon Index. No significant difference between the mesohabitats (ANOVA: F= 2,225; p= 0,088; d.f.= 3; n= 145) was observed. The mesohabitats with the highest values for the mean Evenness were the SA and GB (fig. 15).

During the sampling period the species number rose within all mesohabitats, apart from RR, where the number of species remained similar.

Apart from RR, the Shannon Index showed an increasing trend during the sampling season, all other mesohabitats except RR show the highest values in August. No clear trend with time was observed for the Evenness (fig. 16).

Species Accumulation Curve ("Collectors Curve")

The species accumulation curve for boat electro fishing appeared to be a steadily rising curve with a flattening ascending slope (157 sample units, fig. X). The biggest increase was found from 0 to 10-15 samples.

A total number of 24 species has been observed during boat electro fishing, the calculated confidence intervals (95%) reveal a range from 20 to 28 species (rounded to the next integer; fig. 17)

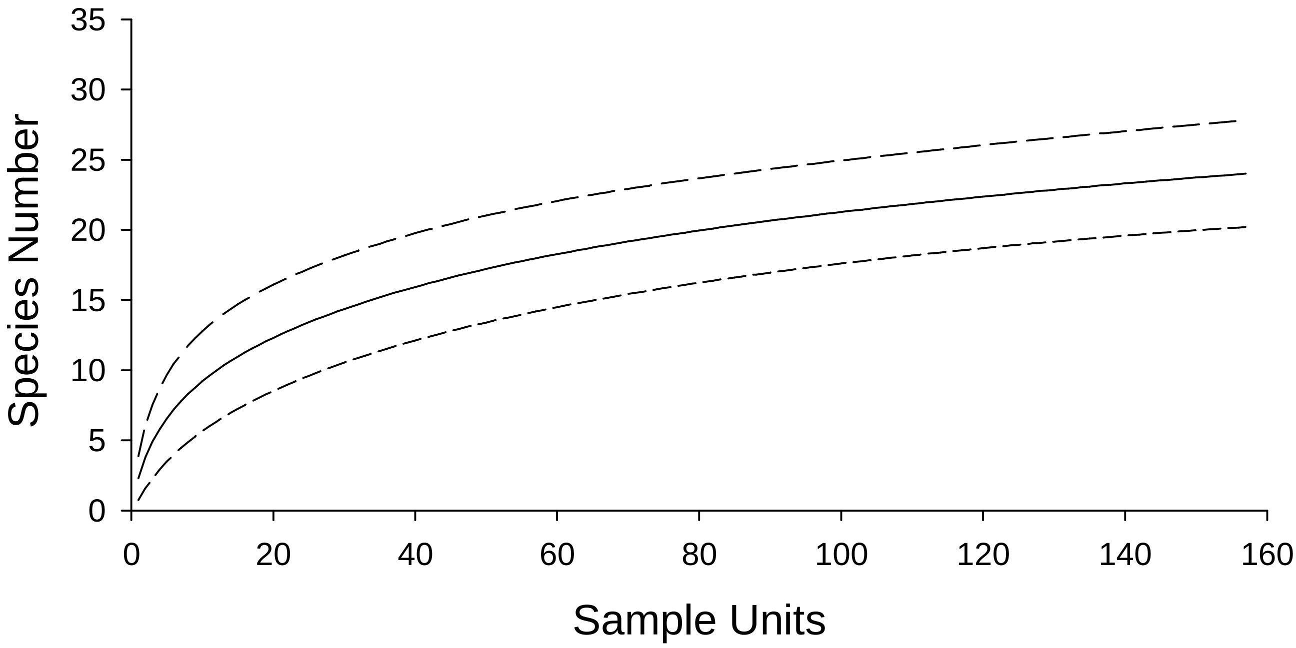

Figure 17: Species Accumulation Curve for the samples from boat electro fishing. The X-axis shows the sample units (number of samples), on the Y-axis the calculated species number is plotted**.** The solid line is the calculated value for the observed species number the dashed lines indicate the 95% confidence intervals.

Fish Size Distribution

Danube Reach

Figure 18 shows the frequency distribution of measured total length of single individuals in the different reaches. A dominance of small sized fish, between 10 and 20 cm total length, in all reaches was obvious. The median fish length of BDA and HAIN was 13,7 cm, and for WITZ 13,5 cm. The biggest fish caught in BDA had 76 cm total length, while the biggest fish in WITZ (66,5 cm) and HAIN (69 cm) were slightly smaller. Very few fish

were caught between 20 and 35 cm total length within all three Danube reaches, while bigger size classes were caught more frequently.
No significant difference (Kruskal Wallis test: Chi-Square= 2,08; p= 0,353; d.f.= 2; n= 2182) between the three Danube reaches concerning the average fish length was observed.

Mesohabitat
Overall the size distributions of the single mesohabitats displayed a similar picture with a high number of small-sized fish and a low number of bigger fish. In all mesohabitats small sized fish, between 10 and 20 cm total length were dominating (fig. 19). Significant differences between all meshoabitats were observed (Kruskal Wallis test: Chi-Square= 256,43; p= 0,000; d.f.=3; n= 2182; Tamhane Post Hoc test). The Post Hoc test revealed that all mesohabitats differed highest significantly (p= 0,000) from each other. The major visual differences between the mesohabitats were the occurrence of larger individuals, whichever occurred in all mesohabitats despite the side arms. Within the SA mesohabitats (median of total fish length = 9 cm) fish larger than 31,3 cm were not present in the samples, while large fish were observed in all other mesohabitats, especially in the RR mesohabitats (median of total fish length = 14,7 cm, max. total fish length = 76 cm) and in GB (median of total fish length = 14,2 cm; max. total fish length = 69 cm). Also within the GR big fish have been caught up to 73 cm length, but the median of the total fish length was at least one cm lower than within the other two mesohabitats (median of total fish length = 13,2 cm).

Sampling Period
According to the fish length distribution, there was no significant difference between the three months of sampling (Kruskal Wallis test: Chi-Square= 2,06; p= 0,361; d.f.= 2; n= 2182). The total length distribution was composed mainly of small fish of a size range of 10 to 20 cm and few large fish, with size ranging between 40 and 60 cm length (fig. 20). All three months showed visually similar distributions with similar median values (median June = 13,5 cm; median July = 13,5 cm; median August = 13,65 cm). But the maximum length of the caught fish rose from June (65 cm) to August (76 cm).

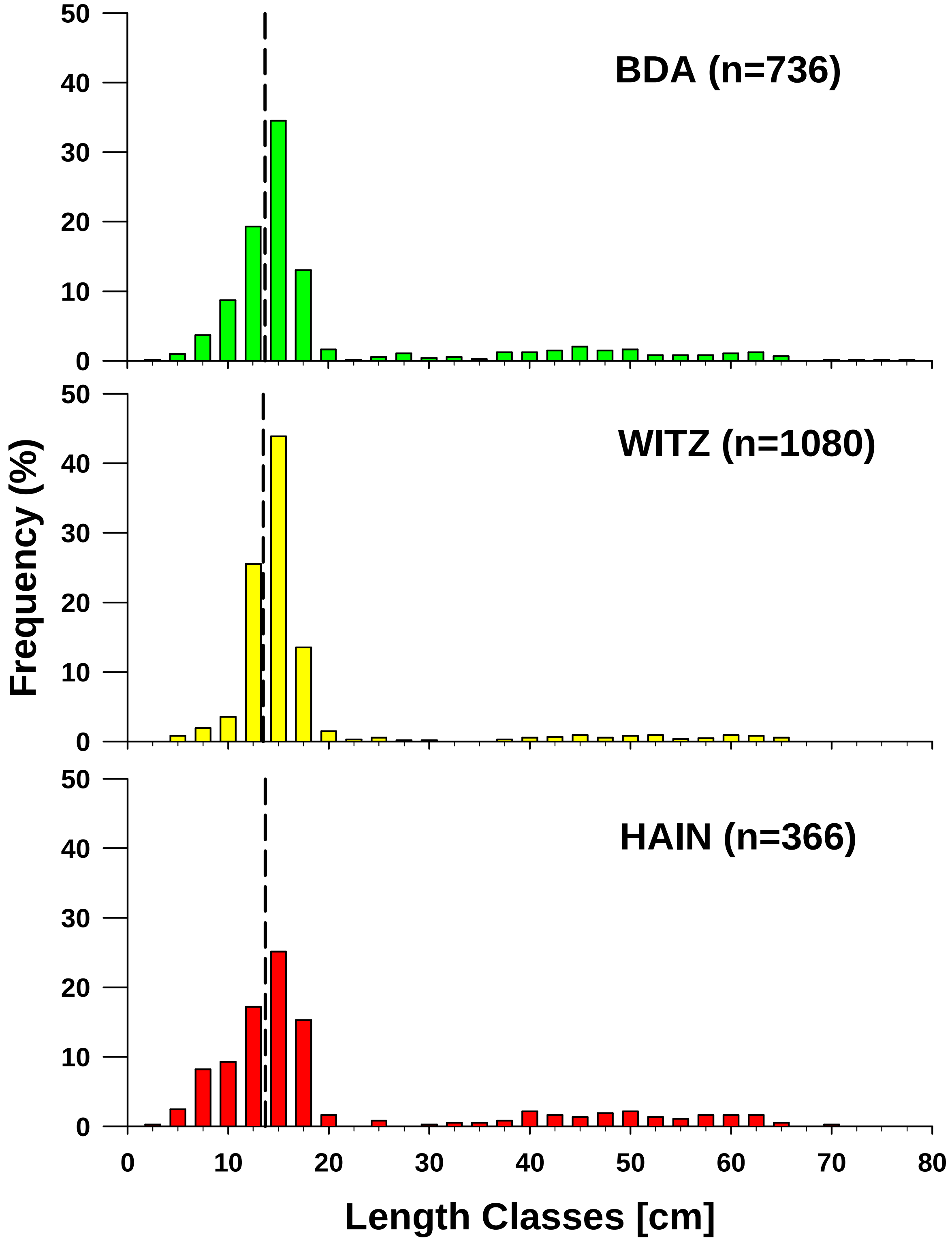

Figure 18: Frequency distribution of fish length classes at the three Danube reaches. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median BDA = 13,7 cm; median WITZ = 13,5 cm; median HAIN = 13,7 cm). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

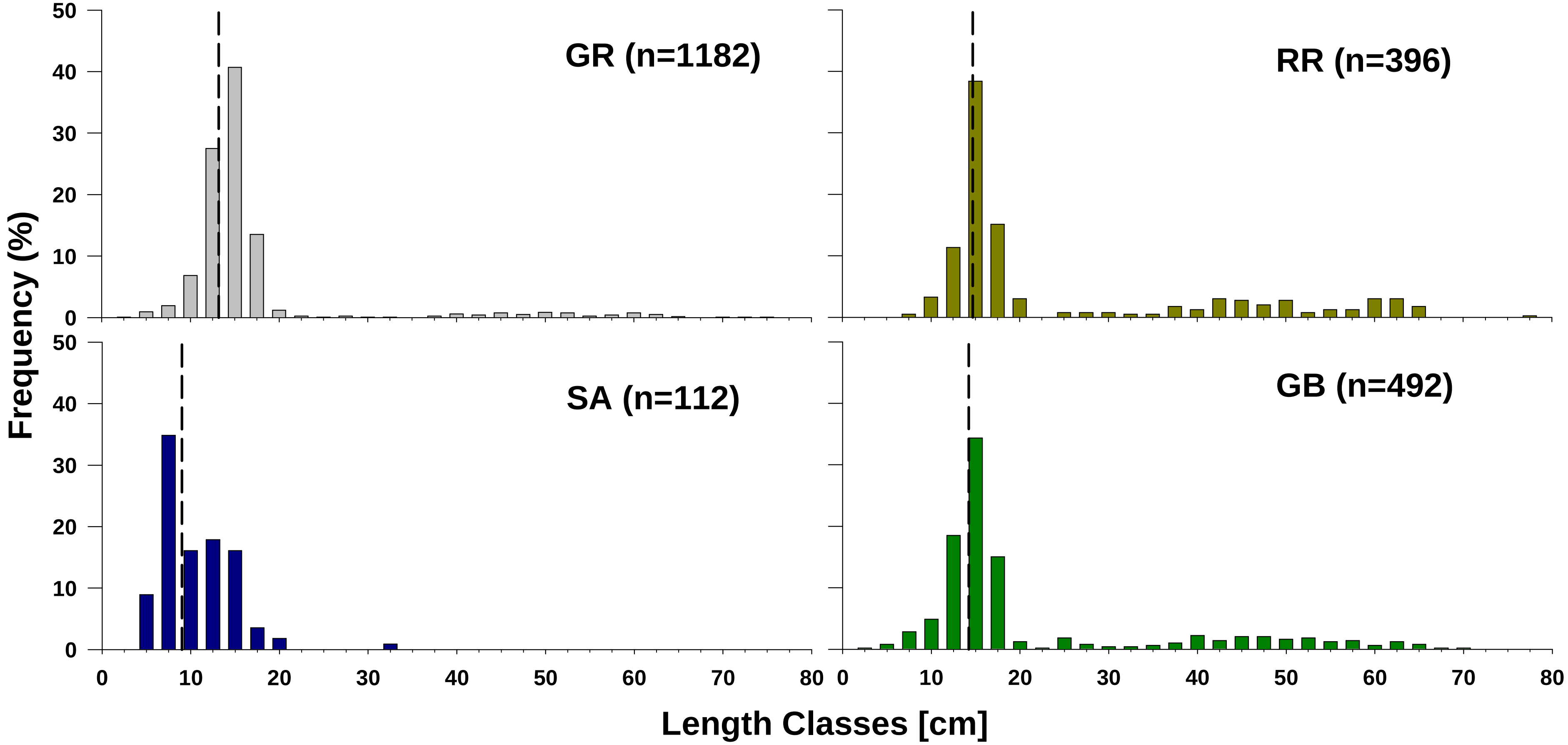

Figure 19: Figure X: Frequency distribution of fish length classes at the four mesohabitats. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median GR = 13,2 cm; median RR = 14,7 cm; median SA = 9 cm; median GB = 14,2 cm). GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

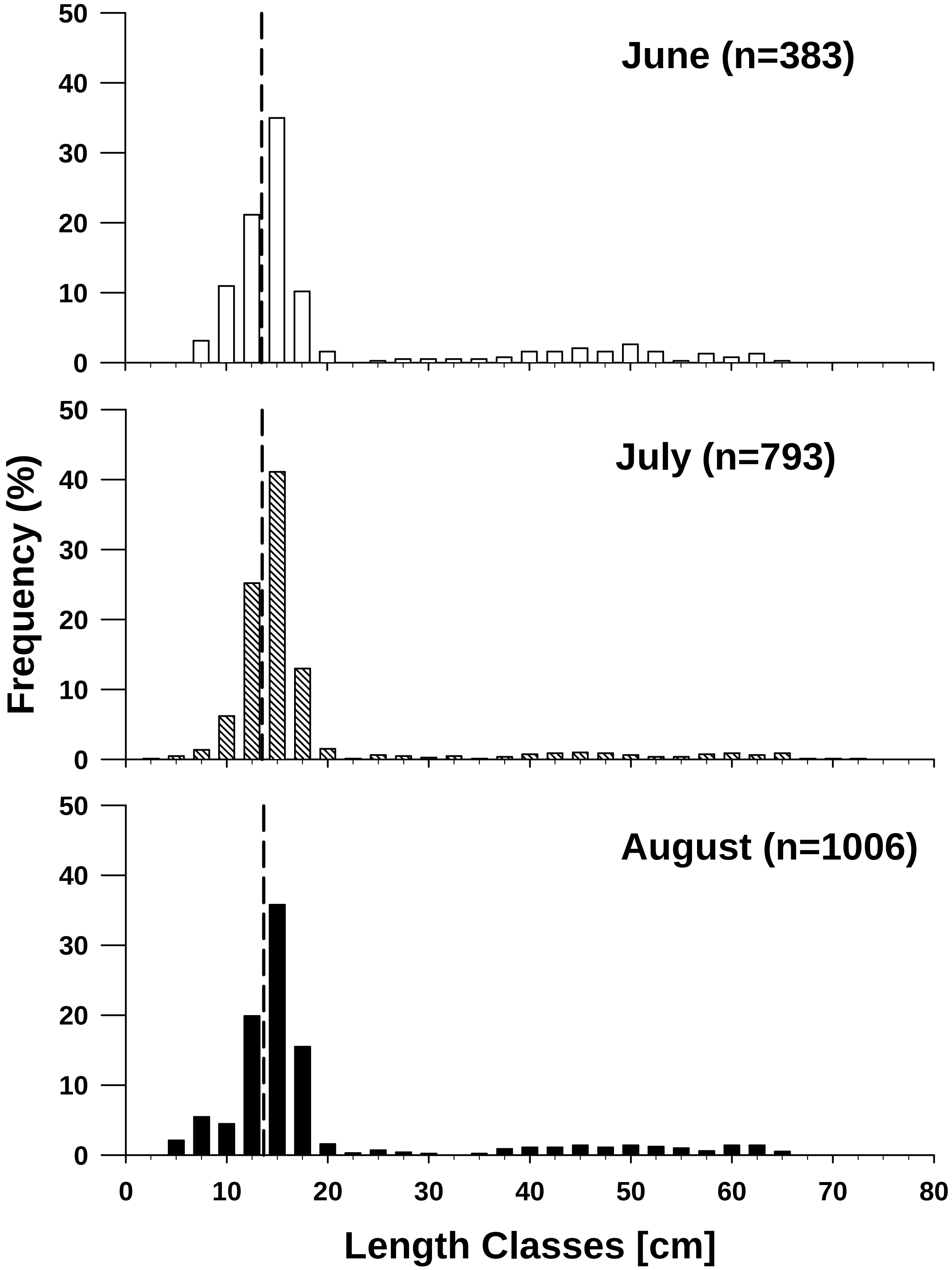

Figure 20: Figure X: Monthly frequency distribution of fish length classes at the three months of sampling: June, July and August. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median June = 13,5 cm; median July = 13,5 cm; median August = 13,65 cm).

Wading Electro Fishing

Sampling Locations, Sampling Size and Season

Overall 224 samples have been taken and a total number of 3144 fish (out of 28 species, tab. 1) has been caught during the three months period of sampling within the three Danube segments (tab. 5). The sampling effort has been similar within the reaches and the three months while the mesohabitats have been sampled on the basis of availability (discharge, flow) within the three segments of the main channel.

Table 5: Number of sample units within the three reaches, the mesohabitats and the three months. BDA= Danube reach Bad deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg; GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm

Reach	Sample Units	Mesohabitat	Sample Units	Month	Sample Units
BDA	75	GB	45	June	74
WITZ	75	GR	89	July	75
HAIN	74	RR	45	August	75
		SA	45		
Overall	**224**		**224**		**224**

Species Assemblage

In all three Danube reaches the most dominant species for wading electro fishing were the invasive fish *Neogobius kessleri* and *N. melanostomus*. Additional common fishes were *Aspius aspius, Leuciscus cephalus* and undefined Cyprinids (young of the year) for BDA, *Alburnus alburnus* for WITZ and *A. alburnus* and *A. aspius* for HAIN (tab. 6).

The dissimilarity between the three Danube reaches ranged from 71 to 76%. Between BDA and WITZ a dissimilarity of 71,4% has been found, between BDA and HAIN 76,1% and between WITZ and HAIN 72,1%. Varying abundance levels of the common and additional species were responsible for the dissimilarities between the three reaches, with the before mentioned most diagnostic species on top of the list (table attachment).

The species assemblage in single mesohabitats was dominated also by other species than the previously mentioned invasive fish species. Whereas the man-made groin fields and rip raps were dominated by the two highly abundant *Neogobius* species, the gravel bars were characterised by the occurrence of *Alburnus alburnus* and *N. kessleri* and side arms by *Leuciscus cephalus*, *Aspius aspius*, *Neogobius gymnotrachelus Proterorhinus marmoratus*, *Rutilus pigus* and *Perca fluviatilis* with again *N. kessleri* on top of the list of dominant fish species. *N. melanostomus* was less common within these “natural” or unaltered mesohabitats (tab. 6).

The dissimilarity between the mesohabitats ranged from 58 to 89%. The crucial species were the invasive fish species but also other fish species with varying abundances. Nearly all mesohabitats differed in a high degree from each other, apart from rip raps and groin fields, where only 57,9% dissimilarity has been found. The highest dissimilarity, of 88,9%, has been found between the side arms and gravel bars. All other mesohabitats differed in more or less the same degree, between 77 and 83% (table attachment MESOHABITATS).

Regarding the sampling period not only the most abundant species, *N. kessleri* and *N. melanostomus*, but also several other species, including undefined Cyprinids, *A. alburnus* and *A. aspius*, were dominating species for the three months (tab. 6).

A way longer list accounted for the found dissimilarities between the three months (table attachment). The dissimilarities ranged from 73 to 76%, where June differed with 74,7% from July and with 72,3% from August while July differed with 75,3% dissimilarity from August.

Table 6: Results of SIMPER analysis, based on wading electro fishing abundance data, displaying diagnostic species (90% similarity) for the reaches, mesohabitats and months. Av.Abund = average abundance; Av.Sim = average similarity; BDA = Danube reach Bad Deutsch Altenburg; WITZ = Danube reach Witzelsdorf; HAIN = Danube reach Hainburg; GB = gravel bank; GR = groin field; RR = rip rap; SA = side arm

Reaches

BDA	Av.Abund	Av.Sim	WITZ	Av.Abund	Av.Sim	HAIN	Av.Abund	Av.Sim
N. kessleri	0,81	13,31	N. kessleri	0,79	16,38	N. kessleri	0,68	12,17
N. melanostomus	0,5	6,02	N. melanostomus	0,82	14,25	N. melanostomus	0,46	5,26
Cyprinidae sp.	0,3	1,46	A. alburnus	0,27	1,64	A. alburnus	0,35	3,78
A. aspius	0,26	1,28				A. aspius	0,22	1,25
L. cephalus	0,26	1,23						

Mesohabitats

GR	Av.Abund	Av.Sim	GB	Av.Abund	Av.Sim	RR	Av.Abund	Av.Sim	SA	Av.Abund	Av.Sim
N. kessleri	0,89	19,45	A. alburnus	0,39	6,97	N. kessleri	0,93	23,06	N. kessleri	0,69	6,93
N. melanostomus	0,81	16,07	N. kessleri	0,42	6,12	N. melanostomus	0,81	16,22	L. cephalus	0,44	3,92
			N. melanostomus	0,17	0,75	A. alburnus	0,47	4,98	A. aspius	0,4	2,9
									N. gymnotrachelus	0,33	2,01
									N. melanostomus	0,37	1,75
									P. marmoratus	0,29	1,64
									R. pigus	0,26	1,21
									P. fluviatilis	0,23	1,12

Months

June	Av.Abund	Av.Sim	July	Av.Abund	Av.Sim	August	Av.Abund	Av.Sim
N. kessleri	0,84	16,18	N. kessleri	0,69	10,47	N. melanostomus	0,83	15,86
N. melanostomus	0,52	5,92	A. alburnus	0,59	7,11	N. kessleri	0,76	15,53
Cyprinidae sp.	0,41	2,42	N. melanostomus	0,43	4,8			
			A. aspius	0,36	2,81			
			Cyprinidae sp.	0,25	1,17			

Species Composition and Abundance

The contribution of single species to the total fish assemblages in the inshore areas are illustrated in Fig. 21. The first two axes of the principal component analysis (PCA) for wading electro fishing explained 42% of the total variance, where 25% are explained by PC1 and 17% by PC2.

The species with the highest influence on the x-axis were *Neogobius melanostomus, Neogobius kessleri, Alburnus alburnus, Aspius aspius and Proterorhorinus marmoratus*. *N. kessleri* also influenced the y-axis in a certain degree along with undetermined, small cyprinids, *A. alburnus, A. aspius Leuciscus cephalus* and *Chondrostoma nasus* (tab. 7).

Samples with negative x values tended to have higher abundances of *N. melanostomus* and *N. kessleri* while samples with positive x and y values tended to have higher abundances of *A.alburnus*, *A. aspius* and undefined cyprinids.

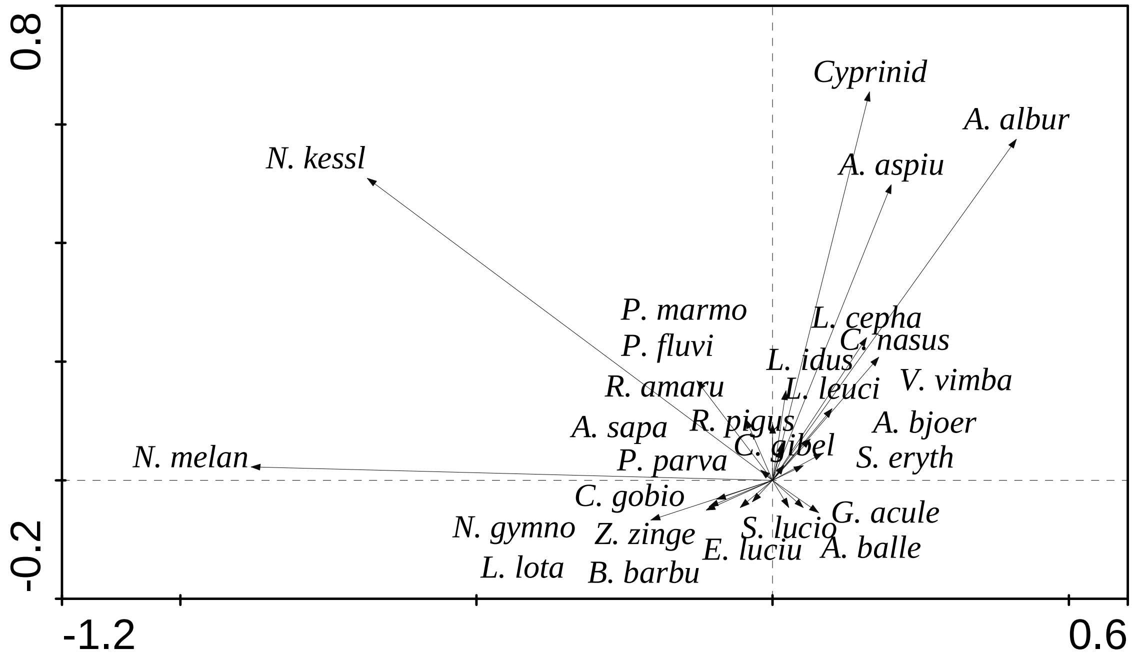

Figure 21: Two dimensional PCA ordination plot of species scores for wading electro fishing. PC 1 accounts for 25% and PC 2 accounts for 17% of the total species variability. The dotted line marks the origin (x= 0; y= 0).

Table 7: Eigenvalues and corresponding species loadings for the PCA ordination plot of species scores for wading electro fishing. PC 1 accounts for 25%, PC 2 accounts for 17%, PC 3 accounts for 12% and PC4 accounts for 10% of the total species variability.

Species	PC1	PC2	PC3	PC4	Species	PC1	PC2	PC3	PC4
Eigenvalues	0,25	0,17	0,12	0,10					
A. ballerus	0,08	-0,05	-0,04	0,00	L. leuciscus	0,10	0,12	-0,27	0,28
A. bjoerkna	0,06	0,07	-0,07	-0,02	L. lota	-0,21	-0,07	0,04	-0,09
A. sapa	0,01	0,05	-0,15	0,07	N. gymnotrachelus	-0,05	-0,05	-0,31	0,18
A. alburnus	0,41	0,57	0,68	0,08	N. kessleri	-0,68	0,51	-0,11	0,47
A. aspius	0,20	0,50	-0,16	-0,20	N. melanostomus	-0,88	0,02	0,24	-0,36
B. barbus	-0,09	-0,03	-0,01	0,04	P. fluviatilis	-0,05	0,10	-0,10	-0,05
C. gibelio	0,02	0,03	-0,11	0,14	P. marmoratus	-0,13	0,17	-0,38	0,15
C. nasus	0,18	0,21	-0,20	-0,19	P. parva	-0,02	0,02	-0,09	0,15
C. gobio	-0,11	-0,05	0,02	-0,07	R. amarus	0,00	0,09	-0,32	0,20
Cyprinidae sp.	0,16	0,65	-0,39	-0,48	R. pigus	0,02	0,06	-0,33	0,02
E. lucius	-0,03	-0,04	-0,06	0,02	S. lucioperca	0,03	-0,05	-0,03	0,06
G. aculeatus	0,05	-0,05	-0,07	0,03	S. erythrophthalmus	0,05	0,02	-0,17	0,10
L. cephalus	0,16	0,24	-0,34	0,28	V. vimba	0,08	0,05	-0,22	0,06
L. idus	0,02	0,15	-0,18	-0,04	Z. zingel	-0,11	-0,04	0,03	-0,03

The figures of the sample scores did not show a clear separation into distinct different groups by indicating factors for reaches and mesohabitats of sample points, only a more fluffily arrangement of sample points in the positive region of PC 2 (y-axis) where higher abundances of *Alburnus alburnus*, *Aspius aspius* and *Cyprinidae sp.* were found. Here the sample points, composed of all types of Danube reaches and mesohabitats, tended to have larger distances between each other. Also, above the value of 1,4 on the y-axis, no sample points, taken in August, were found (fig. 22).

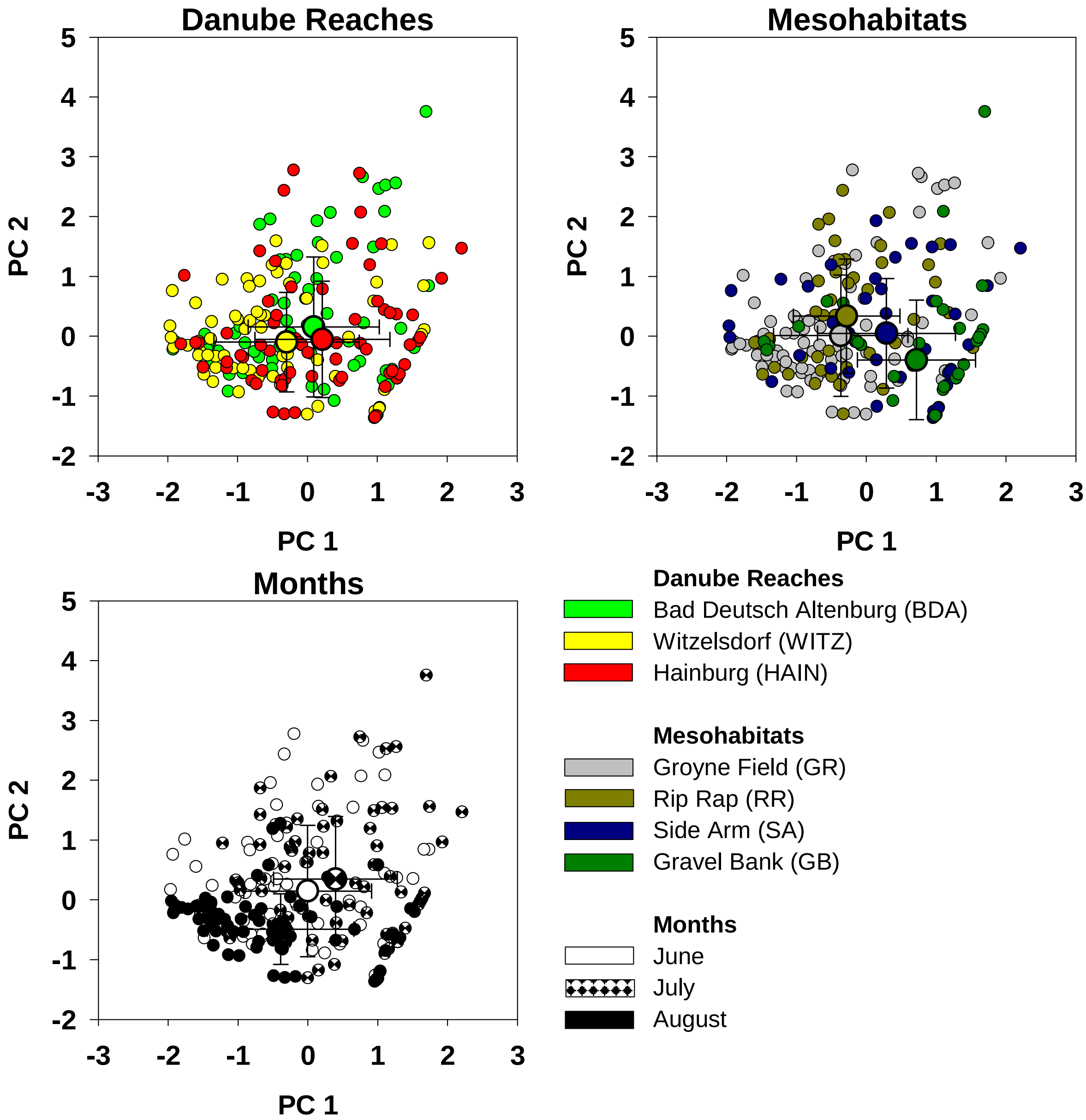

Figure 22: Two dimensional PCA ordination plot of sample scores from wading electro fishing. PC 1 accounts for 25 % and PC 2 accounts for 17% of the total sample variability. Different colour coding for Danube reaches, mesohabitats and months (see legend).

The comparison of the sample scores of the single samples of the Danube reaches showed a significant difference for PC 1 (Kruskal Wallis test: Chi-Square= 10,66; p= 0,005; d.f.= 2; n= 224; Tamhane Post Hoc test) where WITZ and the HAIN site differed high significantly (p= 0,007). No significant difference has been found for sample scores of PC 2 (Kruskal Wallis test: Chi-Square= 1,18; p= 0,553; d.f.= 2; n= 224).

The centroids of the mesohabitats were significantly different regarding the first two principal components; Kruskal Wallis test: PC 1 Chi-Square= 43,85; p= 0,000; d.f.= 3; n= 224; PC 2 Chi-Square= 15,08; p= 0,002; d.f.= 3; n= 224. At the first axis, the centroid of RR differed significantly (p=0,017) from SA and highly significantly (p=0,000) from SB. The SA differed high significant (p= 0,003) from GB, and GB highly significant (p=0,000) from GR. At the second Axis, a high significant difference between RR and SB (p= 0,004) was observed.
Concerning the three months of sampling, highly significant differences were found between the mean values for the sample scores; Kruskal Wallis test: PC 1 Chi-Square= 23,59; p= 0,000; PC 2 Chi-Square= 27,46; p= 0,000; for both tests: d.f.= 2; n= 224. On PC 1 June and July differed significantly from each other (p= 0,022) and July and August highly significant (p= 0,000) On PC2, June and August and July and August differed highly significant from each other (p= 0,000).

Danube Reach

The species composition and abundance of the total catch in the three reaches is shown in Fig. 23. No significant differences of the mean abundance between the three Danube segments was found (ANOVA: F= 2,49; p= 0,085, d.f.= 2; n= 224). *A. ballerus*, *C. gibelio*, *E. lucius*, *G. aculeatus*, and *P. parva* were found only in BDA, *S. lucioperca* only in WITZ and *A. sapa* and *S. erythrophthalmus* only in HAIN. The species with very high abundances in all reaches were *Alburnus alburnus*, *Neogobius kessleri* and *Neogobius melanostomus*.

Mesohabitat

The species composition and abundance of the total catch in the four mesohabitats is shown in Fig. 24. Significant differences between the mesohabitats were observed (Kruskal Wallis Test: Chi – Square= 45,88; p= 0,000; d.f.= 3; n= 224; Tamhane Post Hoc test). All mesohabitats, except GR and RR, differed significantly from each other (highly significant: GB vs. GR, SA and RR p=0,000; GR vs. SA: p= 0,004; RR vs. SA p= 0,038).
The highest mean abundance was found within the SA mesohabitat (4,195 ind*min^{-1}) followed by RR (3,095 ind*min^{-1}) and GR mesohabitats (2,806 ind*min^{-1}). Lowest values of average abundance were found at the gravel bank (GB, 1,462 ind*min^{-1}).
G. aculeatus was found only within the GR, *A. ballerus, A. sapa, C. gibelio, E. lucius, R. rutilus, S. erythrophthalmus and P. parva* were found only in the SA, *Z. streber* occured only at RR and *Sander lucioperca* was found only at GB. The species with high

abundances in all mesohabitats were *Alburnus alburnus, Neogobius kessleri and Neogobius melanostomus,* although *Leuciscus cephalus, Perca fluviatilis, Proterorhinus marmoratus* and *Rutilus rutilus* outnumber *A. alburnus* at the SA (fig. 24).

Sampling Period

The species composition and abundance of the total catch of each month is shown in Fig. 25. Significant differences (Kruskal Wallis test: Chi-Square= 8,69; p= 0,013; d.f.= 2; n= 224; Tamhane Post Hoc test) between the three months were found; most pronounced were the differences between July and August (p= 0,005). The highest mean abundance was found in July (3,274 ind*min^{-1}), followed by June (2,944 ind*min^{-1}) while the lowest mean abundance was observed in August (2,379 ind*min^{-1}).

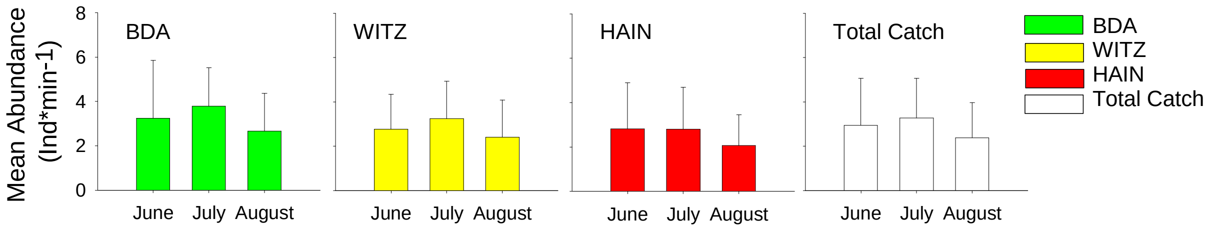

Figure 26: Total catch and and within reach comparison of mean abundance during the sampling period. The X-axis shows the months, the Y-axis shows the abundance (average ± standard deviation). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg

In all three reaches the mean abundance rises slightly from June to July and decreases in August (fig. 26).

Abramis ballerus, Abramis sapa, Zingel zingel, Carassius gibelio, Esox lucius, Sander lucioperca, Gasterosteus aculeatus, Scardinius erythrophthalmus and *Pseudoraspora parva* were exclusively found in only one single month. *S. lucioperca, G. aculeatus* were found only in June, *A. ballerus, A. sapa* and *S. erythrophthalmus* in July and *Z. zingel, C. gibelio* and *E. lucius* in August (fig. 25).

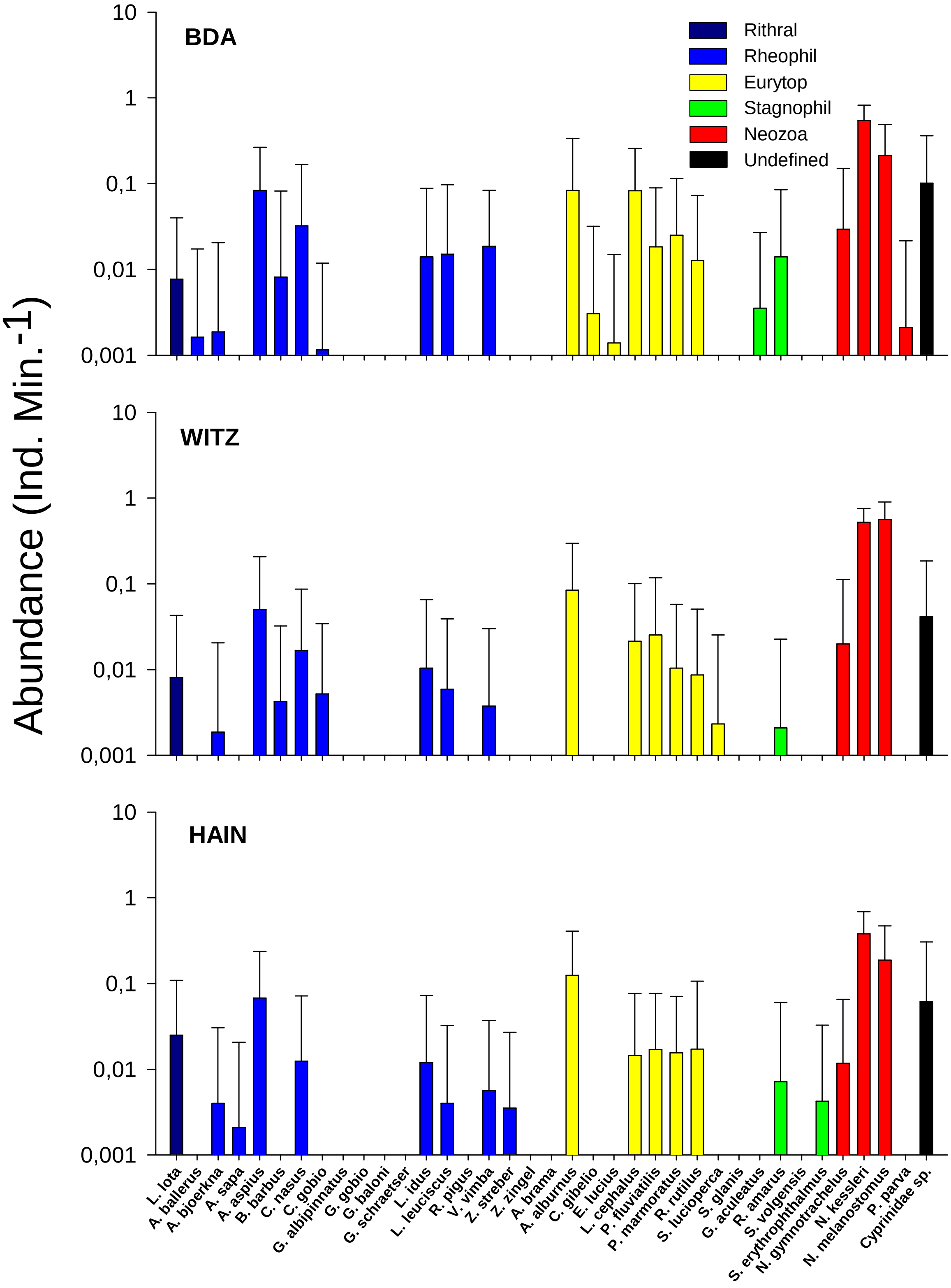

Figure 23: Species composition, species number and abundance of single fish species sampled by wading electro fishing in the three Danube reaches. The Y-axis shows the abundance ($\log_{10}$ logarithmic scaling). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg. Ecological guilds are indicated by different bar colours.

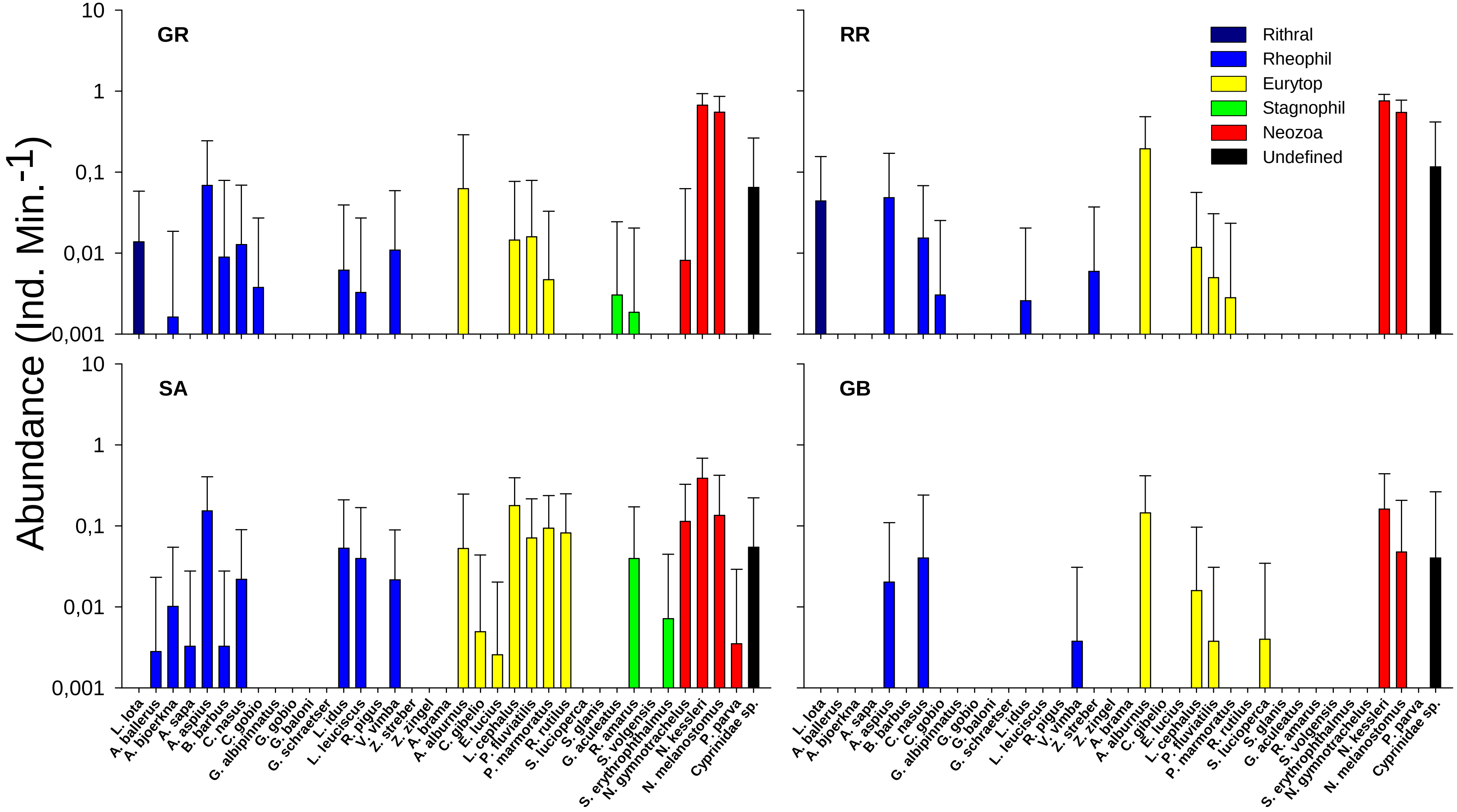

Figure 24: Species composition, species number and abundance of single fish species sampled by wading electro fishing in the four mesohabitats The Y-axis shows the abundance (log_{10} logarithmic scaling). GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm. Ecological guilds are indicated by different bar colours.

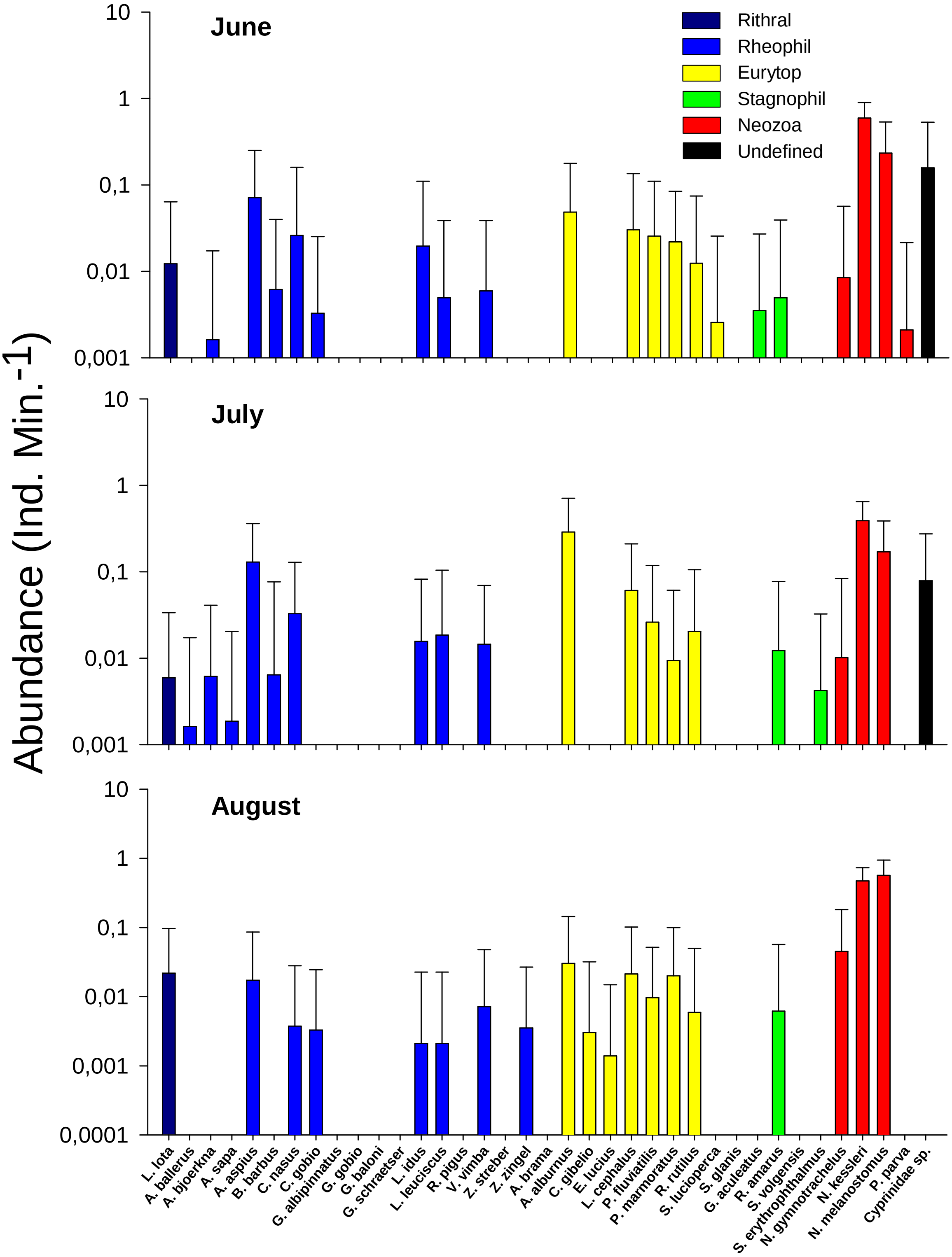

Figure 25: Species composition, species number and abundance of single fish species sampled by wading electro fishing of the three months of sampling June, July and August. The Y-axis shows the abundance (log_{10} logarithmic scaling).

Biodiversity: Species Number, Shannon Weaver Index and Evenness

Danube Reach

In general, the highest number of fish species was found in BDA (24) while the WITZ and the HAIN Danube reaches had equal numbers of species (20). No significant difference was found between the sampling sites regarding the mean number of species per sample (ANOVA: F= 1,16; p= 0,305; d.f.= 2; n= 224).

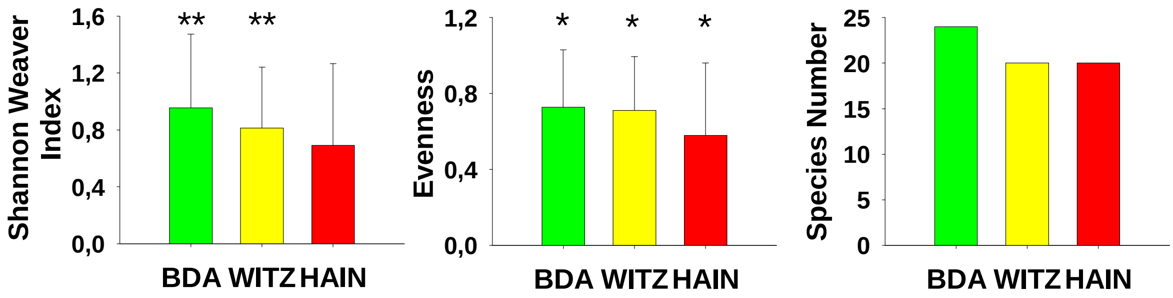

Figure 27: Shannon Weaver index, Evenness and total species number of the total catch in the three Danube reaches. Bars represent mean values, error bars represent standard deviation. Significant differences are indicated by star symbols. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

The Shannon Index differed significantly (ANOVA: F= 4,52; p= 0,012; d.f.= 2; n= 202; Tukey Post Hoc test) between the three Danube reaches. The highest Shannon Index was found at BDA, followed by WITZ and HAIN. BDA and HAIN sites differ high significantly from each other (p= 0,008).

Comparing the three Danube reaches, Evenness showed a similar pattern like the Shannon Index: the highest values were found at BDA, the lowest at HAIN Danube reach (ANOVA: F= 4,23; p= 0,016; d.f.= 2; n= 202; Tukey Post Hoc test). There was a significant difference between the BDA and HAIN site (p= 0,024) and between HAIN and WITZ (p= 0,049, fig. 27).

Species numbers in all three Danube segments showed a decreasing tendency over the sampling period from June to August. Also the Shannon Index decreases from June to August, after a slight increase in July.

The Evenness Index did not reveal a clear tendency during the sampling period within the three sampling sites (fig. 28).

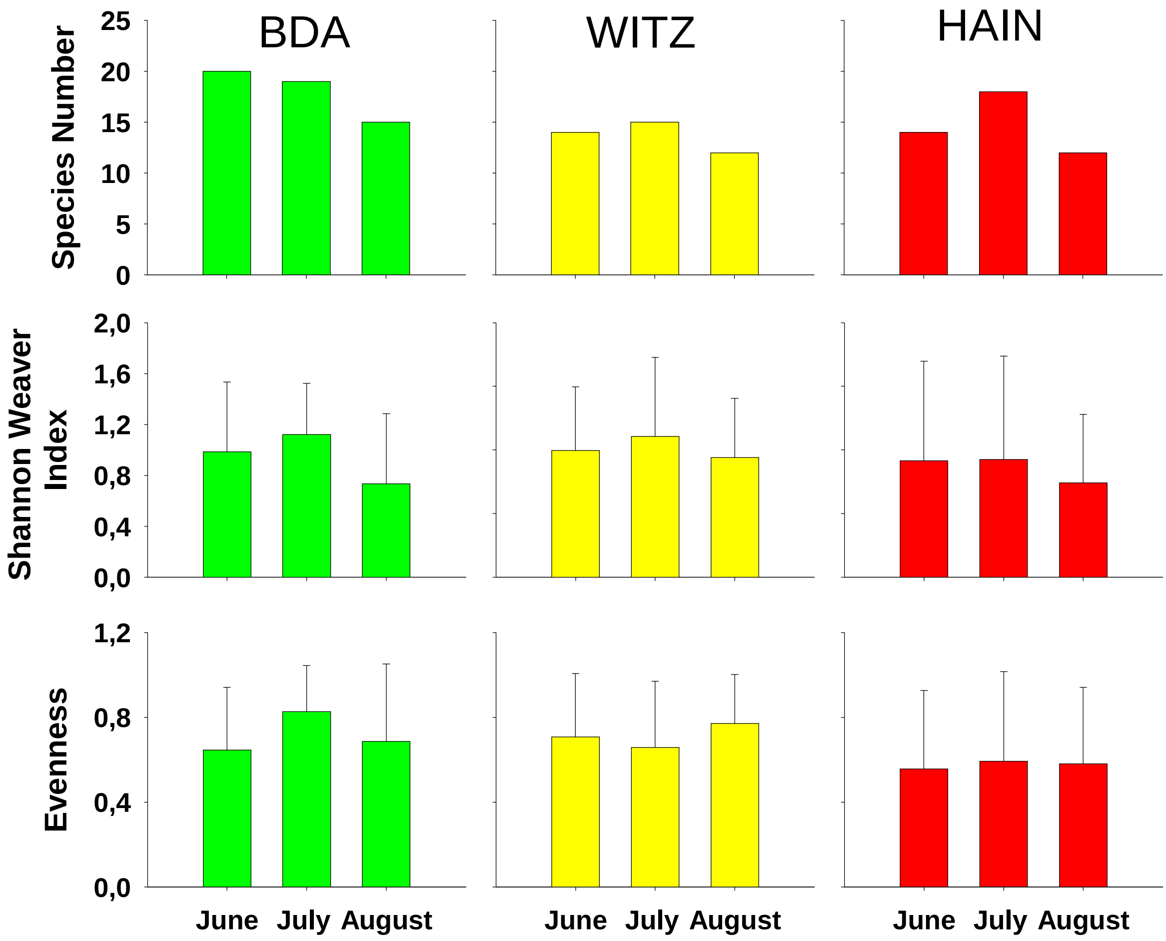

Figure 28: Species number, mean Shannon Weaver index and mean Evenness index and per month in the three Danube reaches. Bars represent mean values, error bars represent standard deviation. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

Mesohabitat

In general, the highest number of different fish species was found at the SA (23) and the GR (19) whereas the RR (13) and GB (10) mesohabitats had lower species numbers.

Concerning the mean species numbers a significant difference between the mesohabitats was found (Kruskal-Wallis Test: Chi – Square= 58,34; p= 0,000; d.f.= 3, n= 224; Tamhane Post Hoc test): GB differed from all other mesohabitats highly significant (p= 0,000). The side arms differed significantly from the groin fields (p= 0,012).

Concerning the mean Shannon Index, there was a significant difference (ANOVA: F= 13,58; p= 0,000; d.f.= 3; n= 202; Tukey Post Hoc test) between the mesohabitats. RR differed highly significant from GB (p= 0,000), SA highly significant from GB (p= 0,000) and high significantly from GR (p= 0,001) and GB differs high significantly from GR (0,002). The highest mean Shannon Index was found within the SA, the lowest within the GB, the mean values for GR and RR lay in between these two.

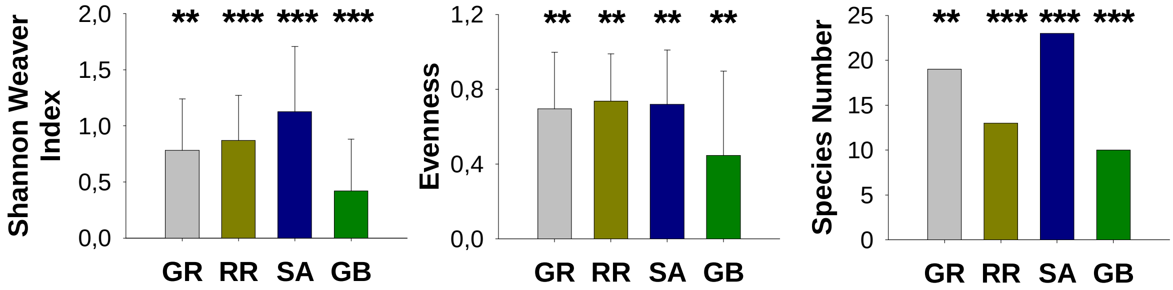

Figure 29: Shannon Weaver index, Evenness and total species number of the total catch in the four mesohabitats. Bars represent mean values, error bars represent standard deviation. Significant differences are indicated by star symbols. GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

The mean Evenness Index showed a significant difference between the four mesohabitats (ANOVA: F= 6,27; p= 0,000; d.f.= 3; n=202; Tukey Post Hoc test) with the highest values found at the RR and the lowest at the GB. RR differed high significantly from GB (p= 0,001), SA high significantly from GB (p= 0,002) and GB differed high significantly from GR (p=0,001; fig. 29).

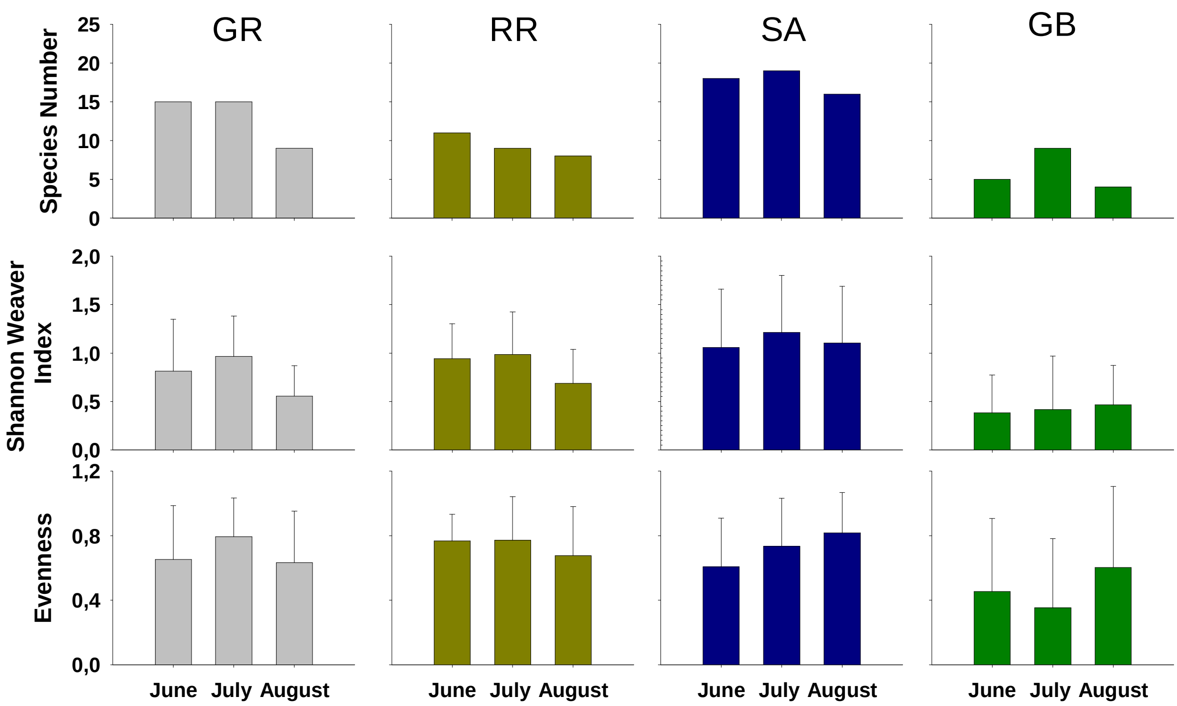

Figure 30: Species number, Shannon Weaver index and Evenness of the total catch in the four mesohabitats. Bars represent mean values, error bars represent standard deviation. GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

The species number of all mesohabitats decreased over the sampling period. The SA and GB had the highest species numbers in July.

During the sampling period the mean Shannon Index rose within SA and GB and dropped within the mesohabitats RR and GR after an increase in July.

Over the sampling period Evenness increased within the mesohabitats SA and GB. In GR and RR the Evenness stayed on more or less the same level over the whole period (fig. 30).

Species Accumulation Curve ("Collectors Curve")

The species accumulation curve for wading electro fishing appeared to be a steadily rising curve with a decreasing slope (fig. 31, 224 sample units). The highest increase can be seen between 0 and 20-30 samples.

A total number of 28 species has been observed with this method with calculated confidence intervals (95%) of 24 and 32 species.

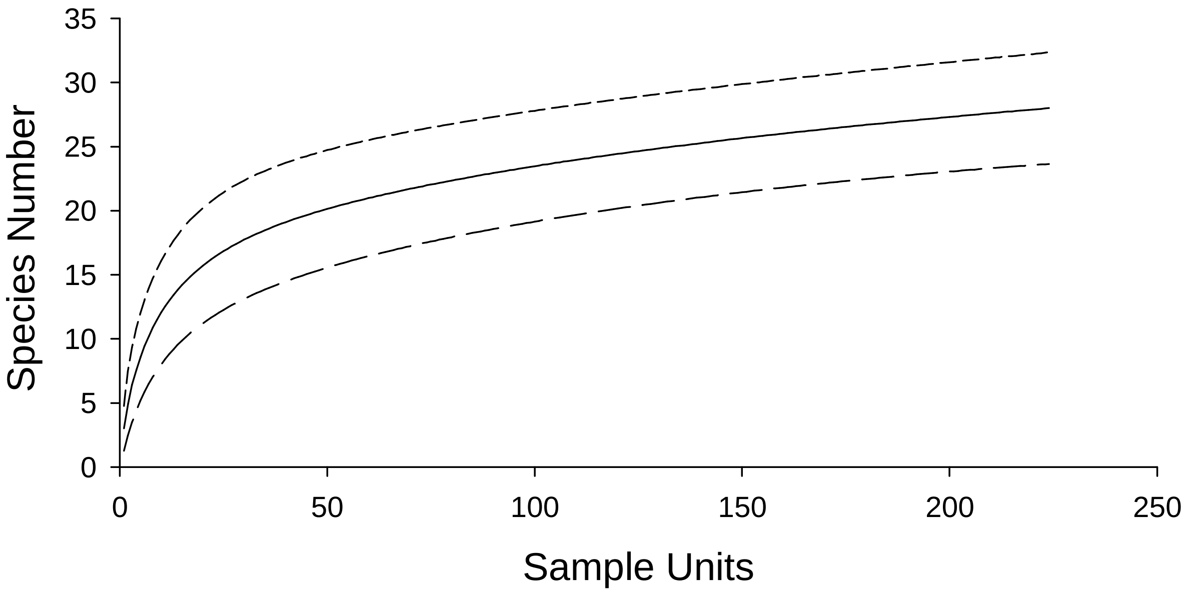

Figure 31: Species Accumulation Curve for the samples from wading electro fishing. The X-axis shows the sample units (number of samples), on the Y-axis the calculated species number is plotted**.** The solid line is the calculated value for the observed species number the dashed lines indicate the 95% confidence intervals.

Fish size distribution

Danube Reach

During sampling with wading electro fishing a total number of 3144 fish has been caught. There was a significant difference between the three Danube segments concerning their fish length distribution (Kruskal Wallis test. Chi-Square= 15,06; p= 0,001; Tamhane Post Hoc) however, which could not be separated by a Post Hoc test.

Overall the three Danube reaches displayed a similar pattern with a high number of small fish and very low number of bigger fish. The median fish size of the three reaches ranged between 4 and 5,5 cm. BDA showed a median fish size of 5 cm (n = 1202), WITZ had a median fish size of 5,2 cm (n = 1093) and within the HAIN site the median fish size was 4,4 cm (n = 849). The existing statistical differences between the length distributions of the Danube reaches were rather of mathematical (high n) than biological nature (fig. 32).

Most of the observed individuals had a total length less than 10 cm long like *Alburnus alburnus, Neogobius melanostomus* or *Neogobius kessleri.* Only a small number of larger sized individuals of other species (>20 cm total length) has been caught with wading electro fishing (fig. X; also see: abundance wading electro fishing, fig. 32).

Mesohabitat

There was a significant difference between the fish length distribution of the four mesohabitats (Kruskal Wallis test: Chi-Square= 91,19; p= 0,000; d.f.= 3; Tamhane Post Hoc test). All mesohabitats, except SA vs. GB differ highly significant (p= 0,000) from each other for the latter had a high significant difference (p= 0,003). No significant differences between GR vs. GB have been found.

Most of the caught individuals (2436 individuals ≙ 77% of the total catch) were smaller than 10 cm. Within GR the highest number of fish has been found (1315 individuals, median fish size = 5 cm), with only a few individuals exceeding 20 or 30 cm. A similar pattern has been seen within RR (676 individuals, median fish length = 6 cm), where the maximum frequency lay between 10 to 20 cm fish length. Within this mesohabitat the biggest fish was caught (*Lota lota* 43,5 cm). The SA (907 individuals, median fish length = 4,5 cm) had again the maximum density of fish under 10 cm total length and no fish within this habitat type exceeded 30 cm. Within the GB the lowest number of fish was found (246 individuals, median fish length = 4,5 cm). The majority of this fish was less than 5 or 10 cm long and no fish longer than 20 cm has been caught (biggest fish: *Leuciscus cephalus* 18,7 cm, fig. 33).

Sampling Period

There was a significant difference of the fish length distribution, between the three months (Kruskal Wallis test: Chi-Square= 213,61; p=0,000; d.f.= 2; Tamhane Post Hoc test). June vs. July and June vs. August differed highly significant (p= 0,000) while July vs. August only differed significantly (p= 0,025). The highest number of fish were caught in June (1144 individuals, median fish length = 4,0 cm) and July (1125 individuals, median fish length = 5,3 cm) while in August a lower number has been caught (875 individuals, median fish length = 5,6 cm). In June the maximum fish density was found within the 5 cm size class while this peak broadens in July and August to bigger size classes (7,5 to 10,0 cm). At all three months a few number (35 individuals ≙ 1,1%) of fish bigger than 20 cm was caught (fig. 34).

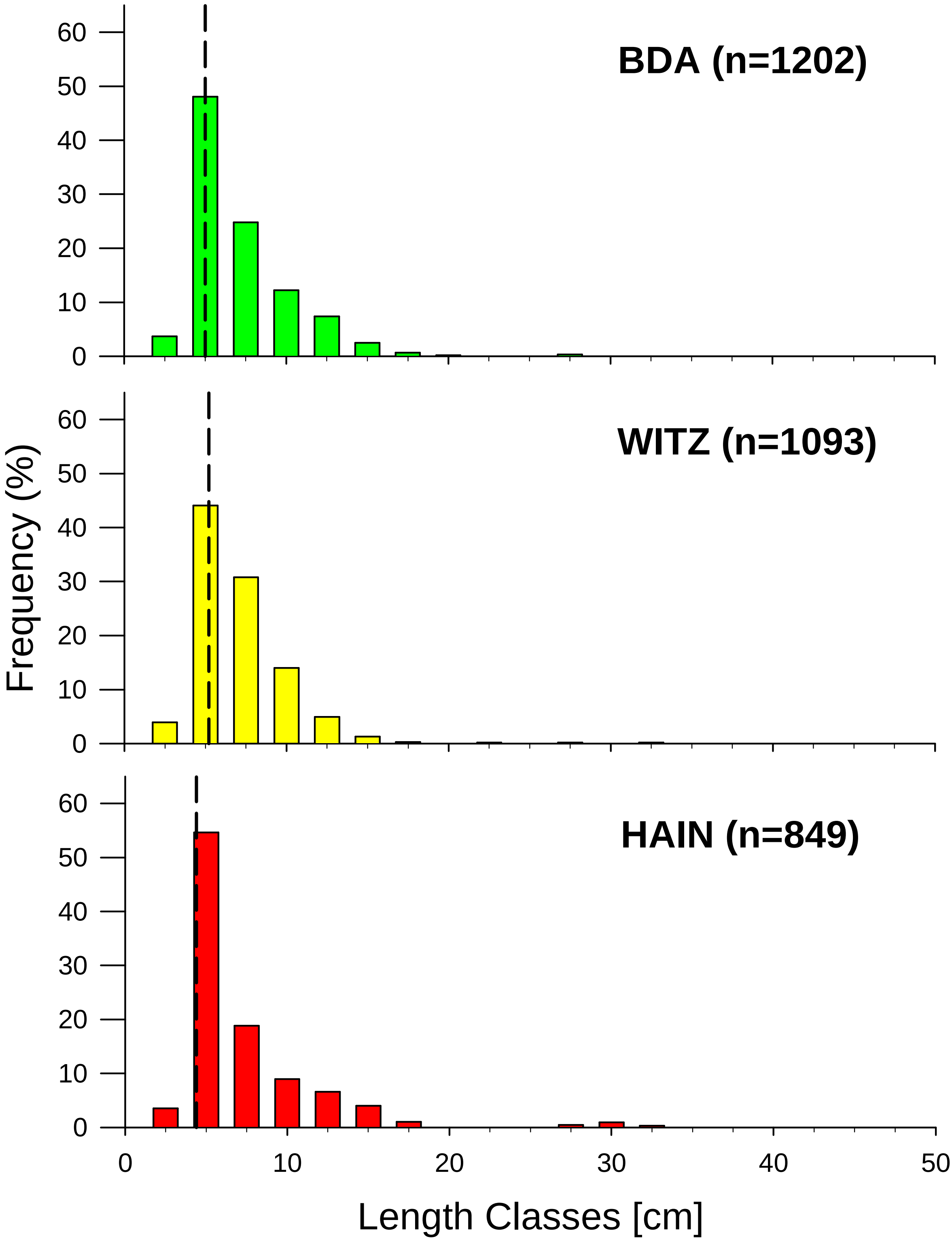

Figure 32: Frequency distribution of fish length classes at the three Danube reaches. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median BDA = 5 cm; median WITZ = 5,2 cm; median Hain = 4,4 cm). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

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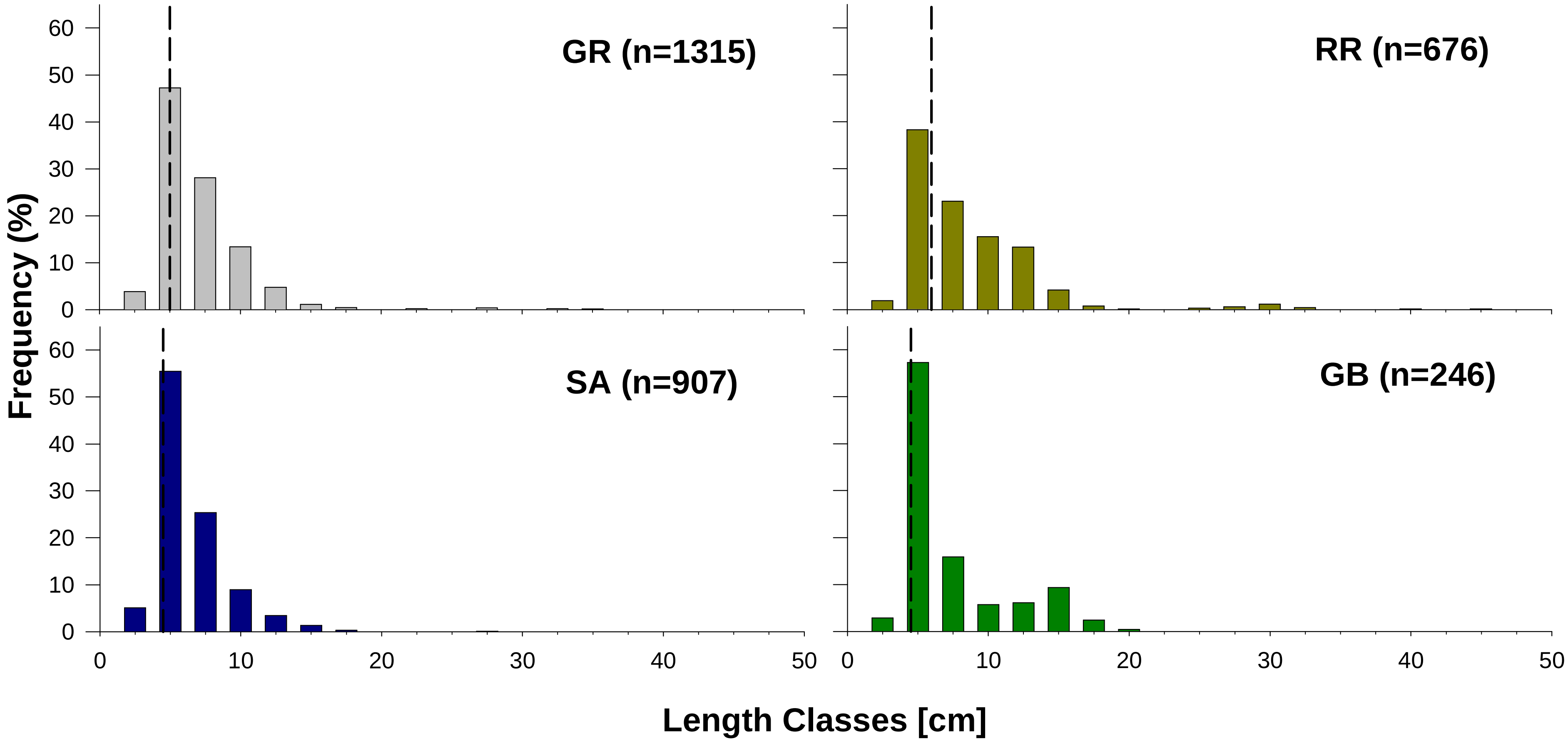

Figure 33: Frequency distribution of fish length classes at the four mesohabitats. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median GR = 5 cm; median RR = 6 cm; median SA = 4,5 cm; median GB = 4,5 cm). GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

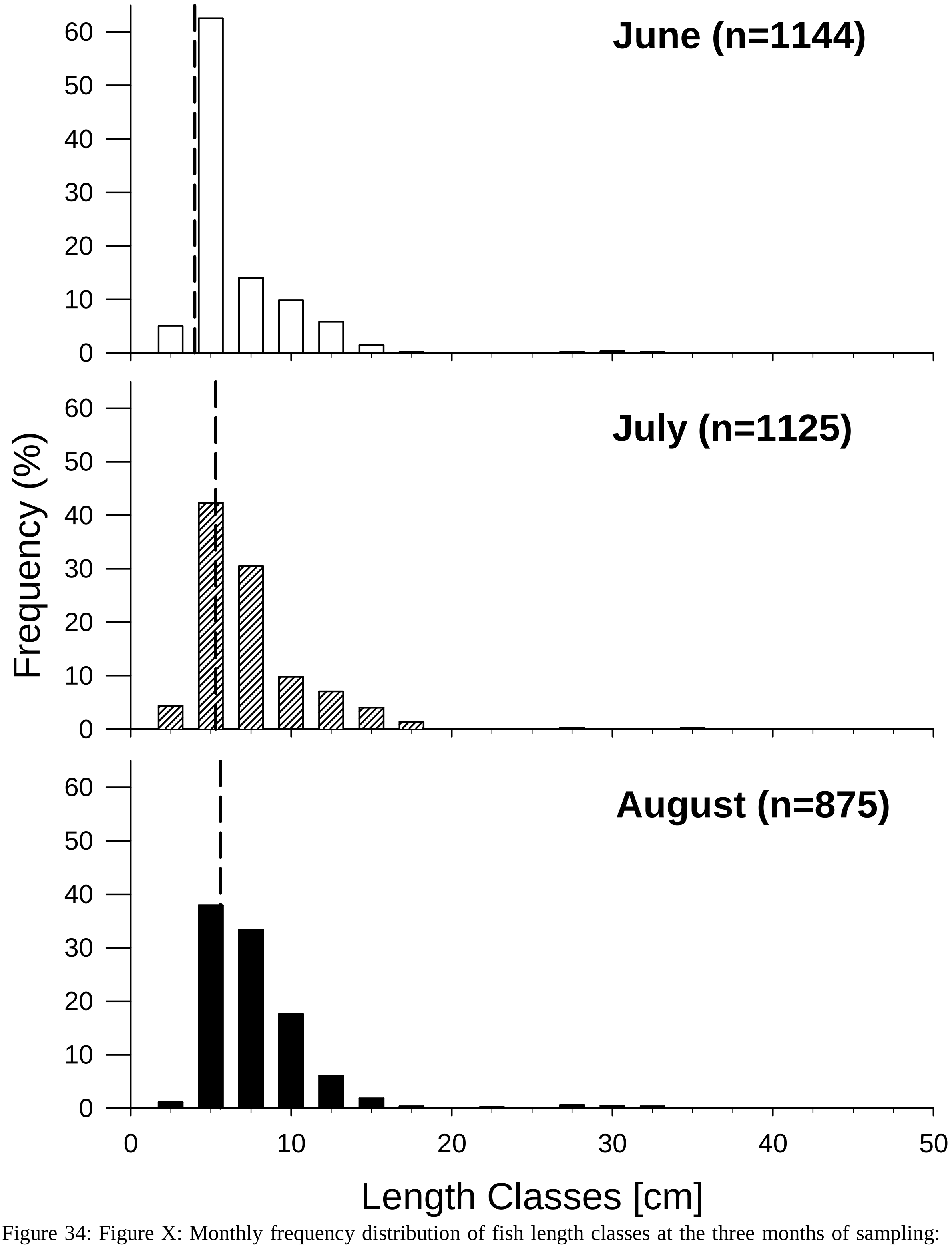

Figure 34: Figure X: Monthly frequency distribution of fish length classes at the three months of sampling: June, July and August. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median June = 4 cm; median July = 5,3 cm; median August = 5,6 cm).

Long Line Fishing

Sampling Locations, Sampling Size and Season

Overall 50 samples were taken with long line fishing during the three month of sampling, and altogether a total number of 309 fish out of 24 species were caught. Within the three Danube segments and during the three months of sampling the sampling effort was nearly the same (tab. 8). The mesohabitats were sampled based on availability and accessibility.

Table 8: Number of sample units within the three reaches, the mesohabitats and the three months. BDA= Danube reach Bad deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg; GR= groin field; PO = pool; SA = side arm; GB = gravel bank

Reach	Sample Units	Mesohabitat	Sample Units	Month	Sample Units
BDA	18	GR	18	June	17
WITZ	17	PO	15	July	17
HAIN	15	SA	8	August	16
		GB	9		
Overall	**50**		**50**		**50**

Species Assemblage

Overall, differences between reaches, mesohabitats and months were characterized by their fish species composition and abundances. The most dominant fish species of the assemblage, found with long line fishing, was the , invasive species *Neogobius melanostomus*, which dominated all three Danube reaches, all mesohabitats (except GB), and throughout the whole sampling period.

,Also several other species were characteristic for the three reaches. Apart from *N. melanostomus, N. kessleri*, *Barbus barbus*, *Abramis bjoerkna*, *A. brama*, *Gobio albipinnatus*, *N. gymnotrachelus*, *Silurus glanis*, *Zingel zingel* and *Z. streber* were characteristic for the species assemblage of the Danube reaches BDA, WITZ and HAIN (tab 9).

The dissimilarity between the three Danube reaches ranged between 75 and 78% and was caused by different average abundances of the characteristic (see above) and other occurring species. The dominating fish species *N. melanostomus* contributed the most to the dissimilarities (table attachment REACHES). BDA differed to 75,9% from WITZ and to 78,2% from HAIN, while WITZ differed to 77,9% from HAIN.

Concerning the mesohabitats only one additional species (*Vimba vimba*), to the before mentioned species of the Danube reaches, accounted for the classification of the mesohabitats. Within three of four mesohabitats the invasive fish species *N. melanostomus* dominated the fish assemblage, except for gravel bars, where B. barbus, *G. albipinnatus, V. vimba* and *Z. streber* accounted for the similarities between the replicas (tab. 9).

Between the mesohabitats the differences varied between 69 and nearly 97%. The lowest dissimilarity, of 69,5% has been found between groin fields and side arms, while the highest has been found between side arms and gravel bars. Especially the gravel bars differed in a high degree (>90%) from all other mesohabitats, as *N. melanostomus* was not found within the side arms (tab. (attachment) C). The above mentioned dominant species, plus one additional species (*Perca fluviatilis*) affected the classification of assemblages of different months (tab. 9).

A way longer list of species, including the most dominant species, accounted for the observed dissimilarities between months, ranging from 75 to 82%. June differed from July by 77,6% and from August by 81,8%, while July and August differed by 75,3%.

Table 9: Results of SIMPER analysis, based on long line fishing abundance data, displaying diagnostic species (90% similarity) for the reaches, mesohabitats and months. Av.Abund = average abundance; Av.Sim = average similarity; BDA = Danube reach Bad Deutsch Altenburg; WITZ = Danube reach Witzelsdorf; HAIN = Danube reach Hainburg; GB = gravel bank; GR = groin field; PO = pool; SA = side arm

Reaches											
BDA	Av.Abund	Av.Sim	**WITZ**	Av.Abund	Av.Sim	**HAIN**	Av.Abund	Av.Sim			
N. melanostomus	0,86	10,97	N. melanostomus	0,96	17,48	N. melanostomus	0,87	9,19			
N. kessleri	0,44	2,55	B. barbus	0,24	1,64	N. kessleri	0,49	3,36			
B. barbus	0,26	1,79	N. kessleri	0,32	1,62	A. bjoerkna	0,38	1,73			
A. bjoerkna	0,35	1,67	Z. zingel	0,2	0,95	G. albipinnatus	0,29	1,64			
A. brama	0,28	1,35	A. brama	0,23	0,94	S. glanis	0,25	1,23			
						N. gymnotrachelus	0,33	1,02			
						Z. streber	0,23	0,7			
Mesohabitats											
GR	Av.Abund	Av.Sim	**GB**	Av.Abund	Av.Sim	**KO**	Av.Abund	Av.Sim	**SA**	Av.Abund	Av.Sim
N. melanostomus	1,31	25,69	B. barbus	0,61	9,67	N. melanostomus	0,94	19,84	N. melanostomus	0,9	9,37
N. kessleri	0,51	3,79	G. albipinnatus	0,48	4,8	B. barbus	0,19	2,22	N. gymnotrachelus	0,9	9,07
A. bjoerkna	0,46	2,98	V. vimba	0,46	4,61				A. ballerus	0,69	7,22
A. brama	0,32	1,82	Z. streber	0,37	2,22				A. bjoerkna	0,68	7,14
									N. kessleri	0,66	4,77
Months											
June	Av.Abund	Av.Sim	**July**	Av.Abund	Av.Sim	**August**	Av.Abund	Av.Sim			
N. melanostomus	0,81	14,44	N. melanostomus	0,97	12,99	N. melanostomus	0,89	9,26			
A. brama	0,29	2,06	N. kessleri	0,57	5,17	N. kessleri	0,63	5,87			
B. barbus	0,24	1,27	A. bjoerkna	0,43	2,5	P. fluviatilis	0,37	1,81			
A. bjoerkna	0,19	0,74	Z. zingel	0,22	1,08	V. vimba	0,24	1,31			
			B. barbus	0,17	0,94	B. barbus	0,24	1,03			
			N. gymnotrachelus	0,25	0,91	N. gymnotrachelus	0,3	0,69			

Species Composition and Abundance

The first two axes of the principal component analysis (PCA) for long line fishing explained 42% of the total variance, 28% by PC1 and 14% by PC2. The crucial species for the x-axis were *Neogobius melanostomus*, *Neogobius kessleri, Barbus barbus* and *Perca fluviatilis*. *N. kessleri* correlated also with the y-axis in an equal degree as with the x-axis. Further species correlating with PC 2 were *Neogobius gymnotrachelus* and *Abramis ballerus* (tab. 10, fig. 35).

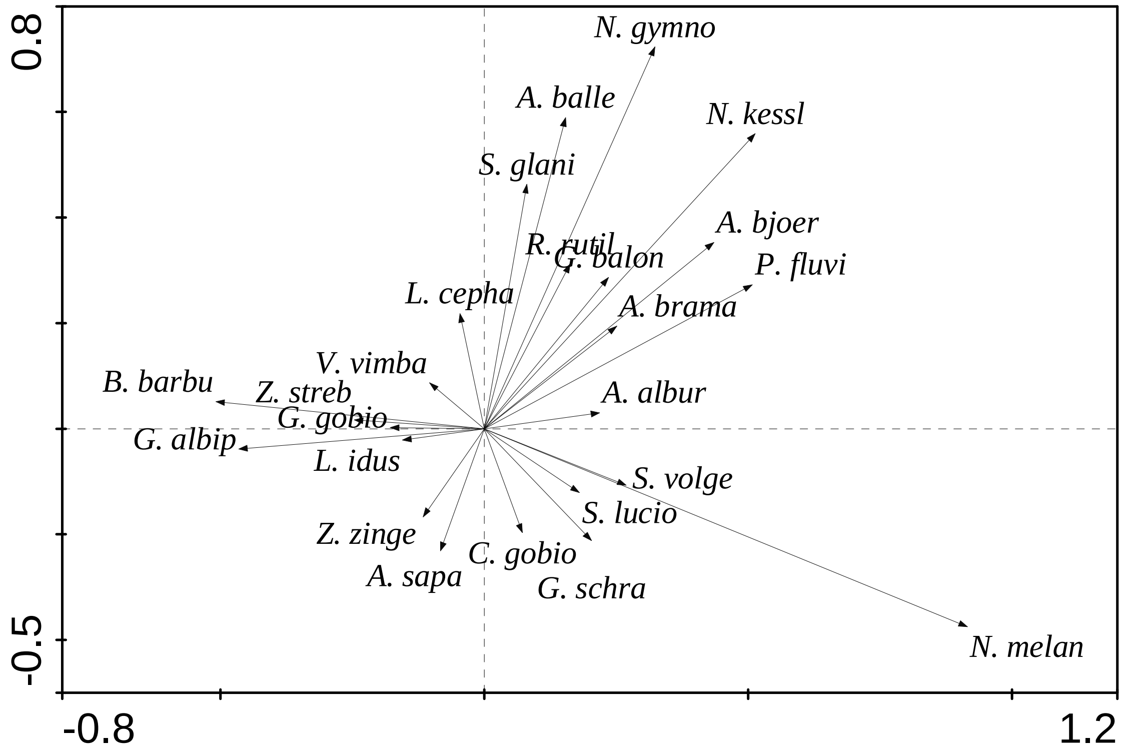

Figure 35: Two dimensional PCA ordination plot of species scores for long line fishing. PC 1 accounts for 28% and PC 2 accounts for 14% of the total species variability. The dotted line marks the origin (x= 0; y= 0).

Table 10: Eigenvalues and corresponding species loadings for the PCA ordination plot of species scores for long line fishing. PC 1 accounts for 28%, PC 2 accounts for 14%, PC 3 accounts for 9% and PC4 accounts for 8% of the total species variability.

Species	PC1	PC2	PC3	PC4	Species	PC1	PC2	PC3	PC4
Eigenvalues	0,28	0,14	0,09	0,08					
A. ballerus	0,15	0,59	0,02	-0,38	L. idus	-0,16	-0,02	-0,01	-0,02
A. bjoerkna	0,44	0,35	-0,57	0,03	N. gymnotrachelus	0,32	0,72	-0,03	-0,39
A. brama	0,25	0,19	0,77	-0,13	N. kessleri	0,51	0,56	0,05	0,57
A. sapa	-0,08	-0,23	-0,05	0,03	N. melanostomus	0,92	-0,37	0,01	0,00
A. alburnus	0,22	0,03	-0,17	0,33	P. fluviatilis	0,51	0,27	0,22	0,09
B. barbus	-0,51	0,05	-0,13	0,29	R. rutilus	0,16	0,31	0,13	-0,13
C. gobio	0,07	-0,20	-0,01	-0,09	S. lucioperca	0,18	-0,12	-0,21	-0,03
G. albipinnatus	-0,47	-0,04	0,12	0,20	S. volgensis	0,27	-0,11	-0,13	0,14
G. gobio	-0,18	0,00	0,33	0,17	S. glanis	0,08	0,46	-0,03	-0,23
G. baloni	0,24	0,29	0,33	-0,24	V. vimba	-0,10	0,09	0,31	0,55
G. schraetser	0,20	-0,21	-0,26	0,19	Z. streber	-0,25	0,02	0,10	0,32
L. cephalus	-0,05	0,22	-0,14	0,09	Z. zingel	-0,12	-0,17	0,17	0,18

Samples with negative x-values tended to lack *N. melanostomus* but instead contained *B. barbus.* Also Perca fluviatilis was missing in the samples with an x-value below 1. Samples with negative y-values tended lack individuals of *N. kesslei* and *N. gymnotrachelus* (fig. 36).

The figures of the sample scores did show a clear separation into two different bulks of sample points, one bulk in the negative region of the x-axis and one in the positive. This two big aggregations of samples were distinguished by the abundance of *N. melanostomus* and *B. barbus* due to the fact that the left bulk (negative region of x) lacked *N. melanostomus* and the right one *B. barbus* (fig. 36).

Comparison of the mean sample scores for the three Danube reaches revealed no significant difference between the river segments.

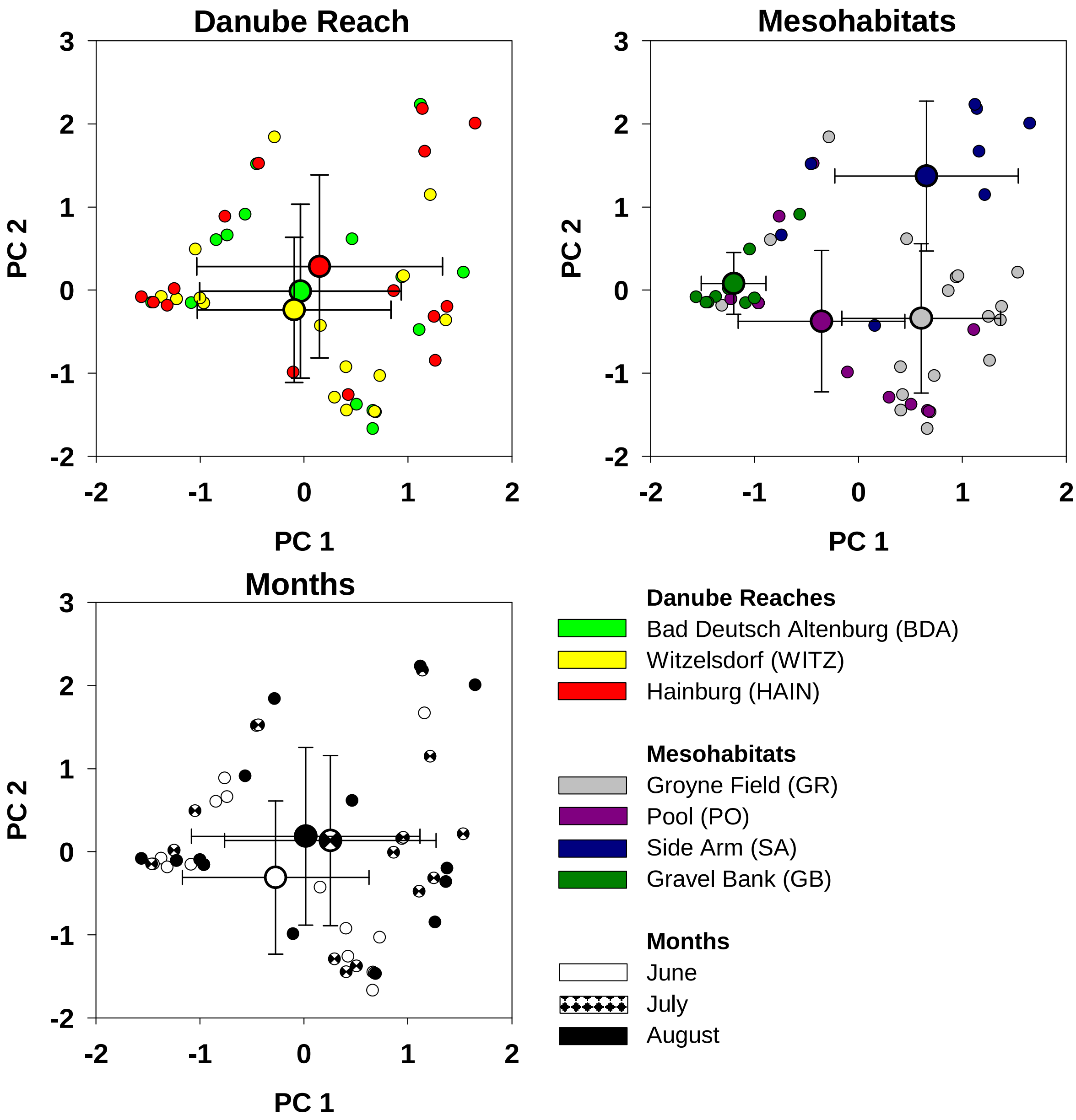

Figure 36: Two dimensional PCA ordination plot of sample scores from long line fishing. PC 1 accounts for 28 % and PC 2 accounts for 14% of the total sample variability. Different colour coding for Danube reaches, mesohabitats and months are indicated by different colours/fills (see legend).

Significant differences between the mesohabitats at both axes were observed (PC 1 Kruskal Wallis test: Chi-Square= 25,42; p= 0,000; PC 2 Kruskal Wallis test: Chi-Square=15,72; p= 0,001; for both tests d.f.= 3; n=50; Tamhane Post Hoc tests). On PC 1 the SA differed high significantly (p= 0,002) from the GB, the GB differs highly significant (p= 0,000) from the GR and high significantly (p= 0,009) from the PO and the GR differed high significantly (p= 0,009) from the PO. On PC 2, SA differed at least significantly from all other mesohabitats (SA vs. GB: p= 0,025; SA vs. GR: p= 0,003; SA vs. KO: 0,003) while they did not differ from each other.

The sample scores of the mesohabitats showed a similar pattern as mentioned above. The sample points of the gravel banks (GB) were grouped at the left side of the x-axis, these catches contained no *N. melanostomus* but were characterised by the occurrence of *B. barbus* and other species (fig. 36).

No significant differecnes between the three months were observed. Sample points from each month were found within each region (positive or negative) of PC 1 and PC 2.

Danube Reach

There was a significant difference between the mean fish abundance of the three Danube segments (ANOVA: F= 5,23; p= 0,009; d.f.= 2; n= 50; Tukey Post Hoc test): The WITZ and HAIN sites differed high significantly from each other (p= 0,007) as the highest mean abundance was found within the HAIN site (4,513 ind*min^{-1}) and the lowest within the WITZ site (2,239 ind*min^{-1}). The mean abundance of BDA (3,034 ind*min^{-1}) lay in between.

The species with the highest abundance in all Danube reaches was *Neogobius melanostomus*. *C. gobio, Leuciscus idus* and *A. alburnus were found only* within BDA and G. gobio, G. baloni, *R. rutilus*, *S. lucioperca, S. glanis* and *S. volgensis* only within the HAIN site (fig. 38).

Mesohabitat

Between the four mesohabitats a significant difference concerning their fish abundance was found (Kruskal Wallis test: Chi-Square= 19,53; p= 0,000; d.f.= 3; n= 50; Tamhane Post Hoc test). The SA and PO habitats differed significantly (p= 0,028) from each other, GR and PO even highly significant (p= 0,000). The highest mean abundance was found within the SA (5,311 ind*min^{-1}), followed by GR (3,915 ind*min^{-1}) and GB (2,914 ind*min^{-1}) while the lowest mean abundance was found in the PO(1,413 ind*min^{-1}).

A. alburnus, S. lucioperca and *S. vogensis* were found only within GR, *G. baloni, G. schraetser* and *R. rutilus* within SA, *C. gobio only* within PO and *G. gobio* and *L. idus* only within the mesohabitat GB (fig. 39).

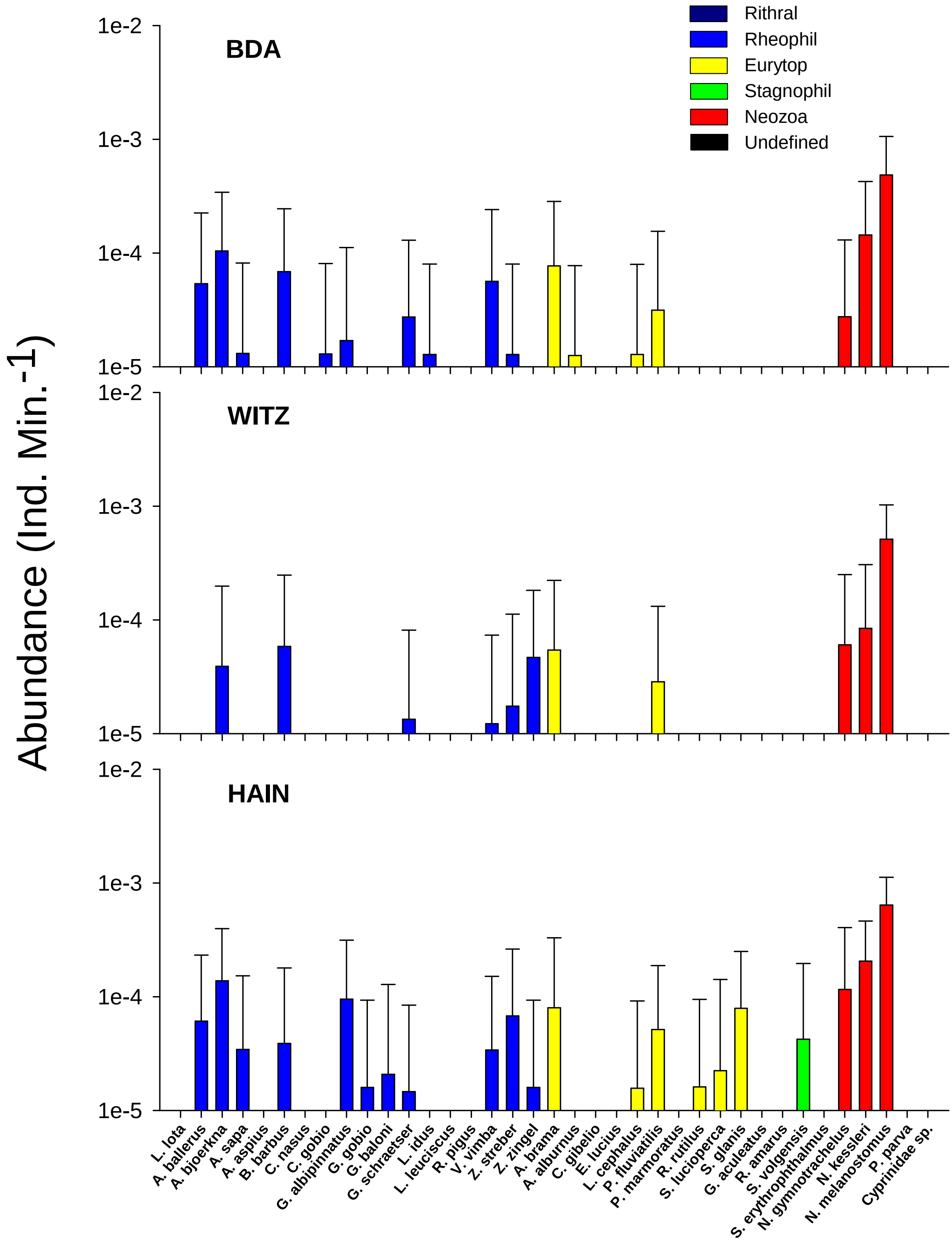

Figure 38: Species composition, species number and abundance of single fish species sampled by long line fishing in the three Danube reaches. The Y-axis shows the abundance (log_{10} logarithmic scaling). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

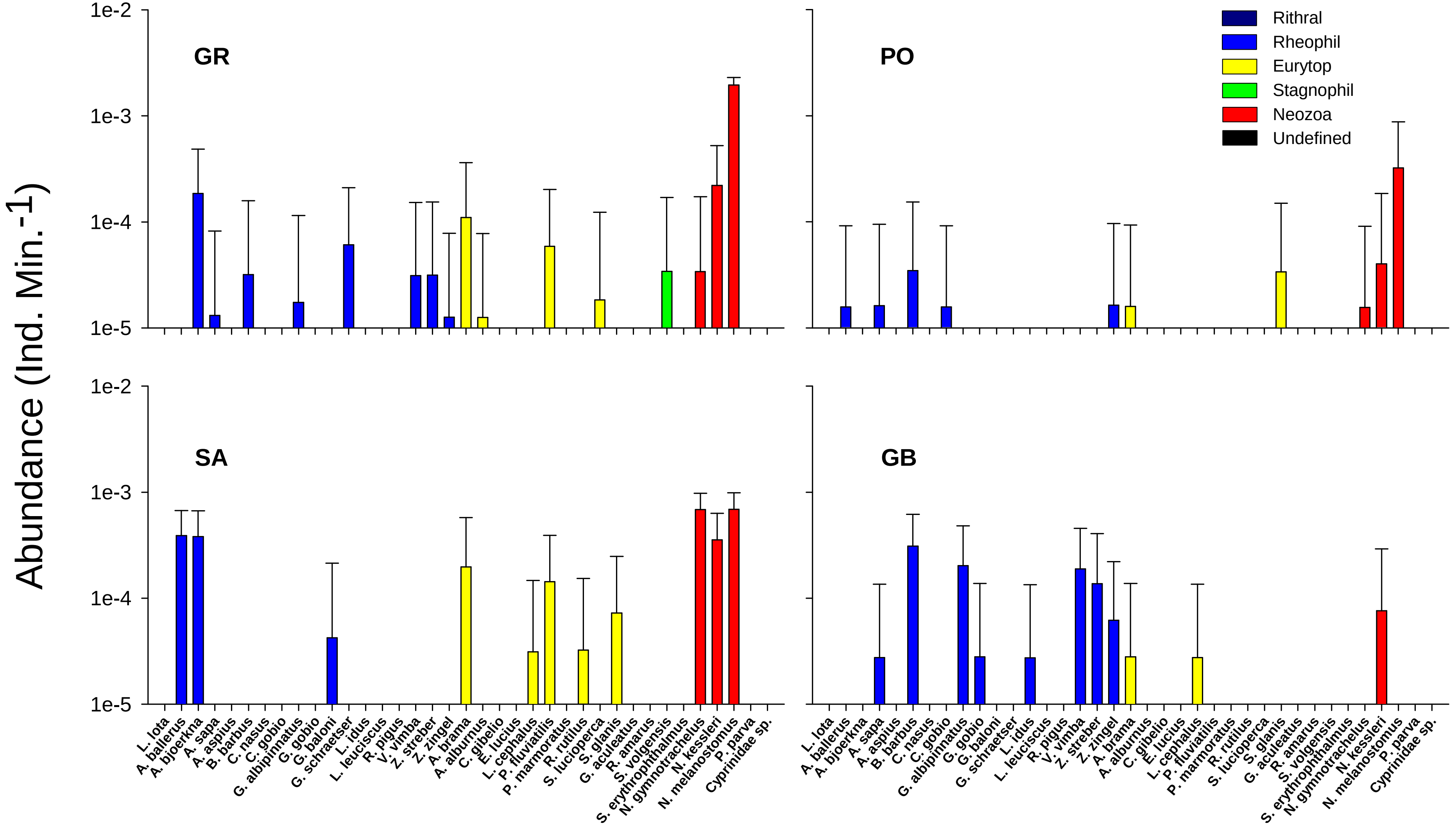

Figure 39: Species composition, species number and abundance of single fish species sampled by long line fishing in the four mesohabitats The Y-axis shows the abundance ($\log_{10}$ logarithmic scaling). GB = gravel bank; GR= groin field; PO = pool; SA = side arm

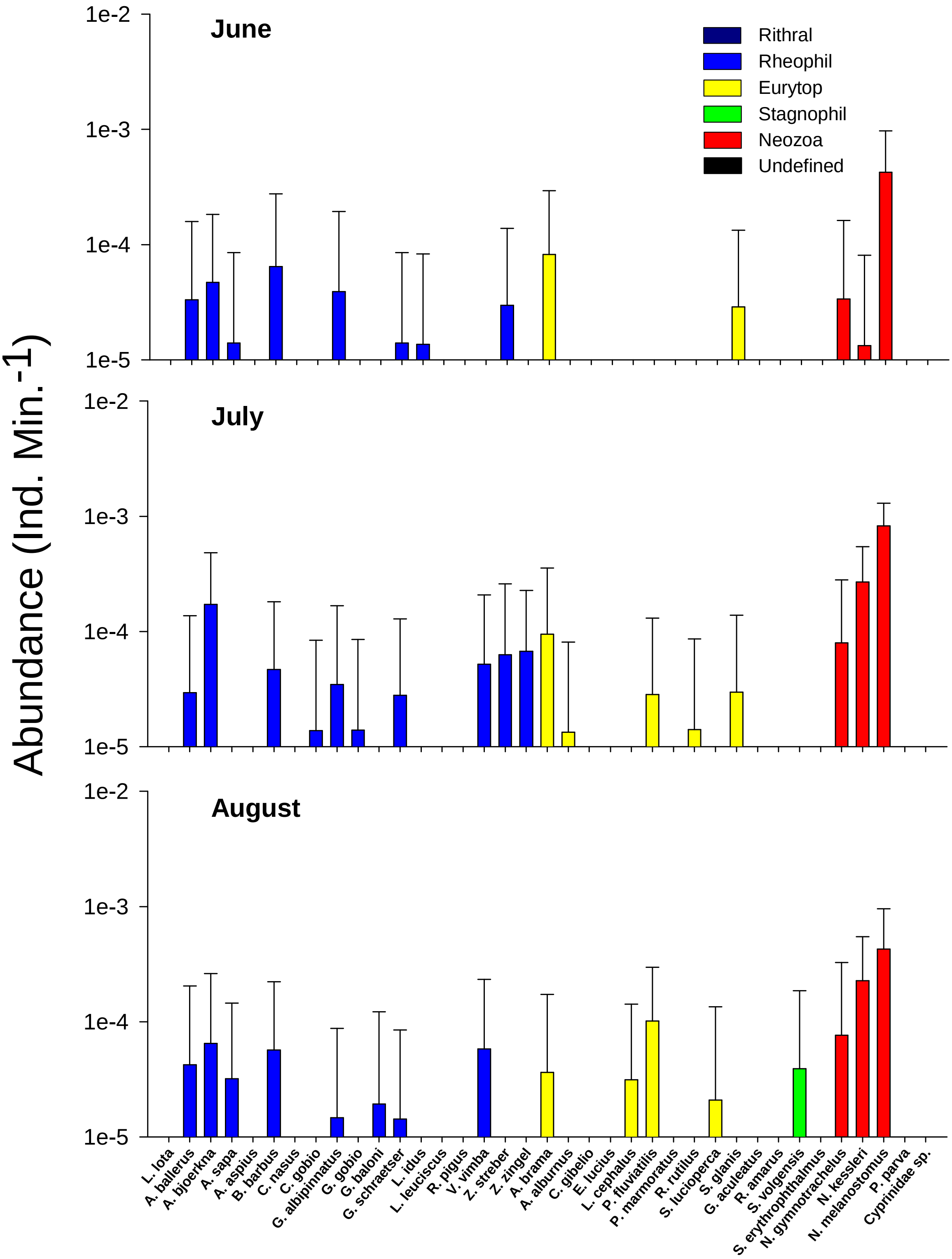

Figure 40: Species composition, species number and abundance of single fish species sampled long line fishing of the three months of sampling June, July and August. The Y-axis shows the abundance ($\log_{10}$ logarithmic scaling).

Sampling Period

Overall the highest mean abundance has been found in July. There was a significant difference between the mean abundances of the three months (Kruskal Wallis test: Chi-Square= 8,66; p= 0,013; d.f.= 2; n= 50; Tamhane Post Hoc Test) where June differed high significantly (p= 0,005) from July.

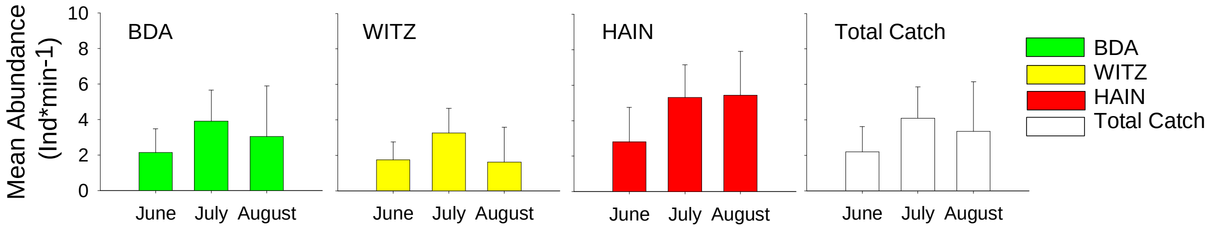

Figure 37: Within reach and total catch comparison of mean abundance (Ind*min^{-1}) during the sampling period. The X-axis shows the months, the Y-axis shows the average abundance. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

The species -specific abundance changed during the sampling period. The species number rose from 13 in June to 18 in July and decreased to 16 in August. *Cottus gobio*, *Gobio gobio, Gymnocephalus baloni, Leuciscus idus, Zingel zingel, Alburnus alburnus, Leuciscus cephalus, Rutilus rutilus, Sander lucioperca* and *Sander volgensis* appeared in only one month: *L. idus* in June, *C. gobio, G. gobio, A. alburnus, Z. zingel* and *R. rutilus* in July and *G. baloni, L. cephalus, S. lucioperca* and *S. volgensis* in August (fig. 40).

The highest mean abundance during the sampling period was found within the Danube reaches BDA and WITZ in July while the HAIN site has nearly equal values for July and August (fig. 37).

Biodiversity: Species Number, Shannon Weaver Index and Evenness

Danube Reach

Between the three sampling sites was a high significant difference, concerning their mean species number (ANOVA: F= 5,24; p= 0,009; d.f.=2; n= 50; Tukey Post Hoc test). The lowest number of species was found within WITZ (11), the highest within the HAIN site (21). These two sampling sites differed high significantly (p= 0,007) from each other while BDA (17 species) showed no significant difference.

There was also a significant difference regarding the mean Shannon Weaver Index (ANOVA: F= 4,03; p= 0,025; d.f.=2; n= 45; Tukey Post Hoc test): the WITZ site differed significantly from the HAIN Danube reach (p= 0,021).

The mean Evenness did not differ significantly between the sampling sites (ANOVA: F= 1,664; p= 0,202; d.f.= 2; n=45; fig. 41).

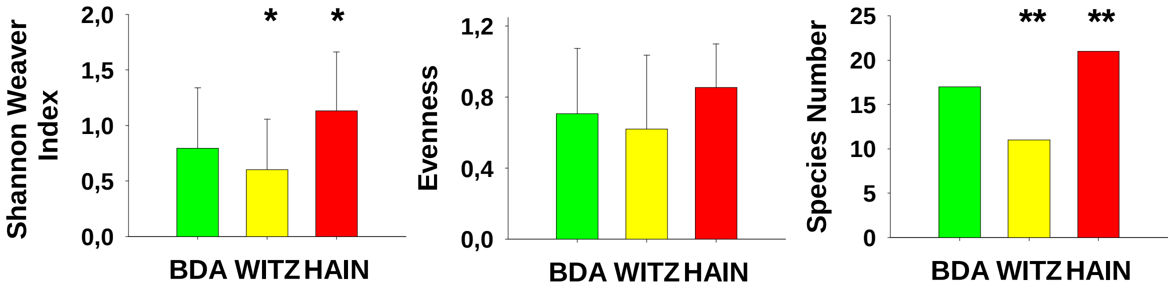

Figure 41: Shannon Weaver index, Evenness and total species number of the total catch in the three Danube reaches. Bars represent mean values, error bars represent standard deviation. Significant differences are indicated by star symbols. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

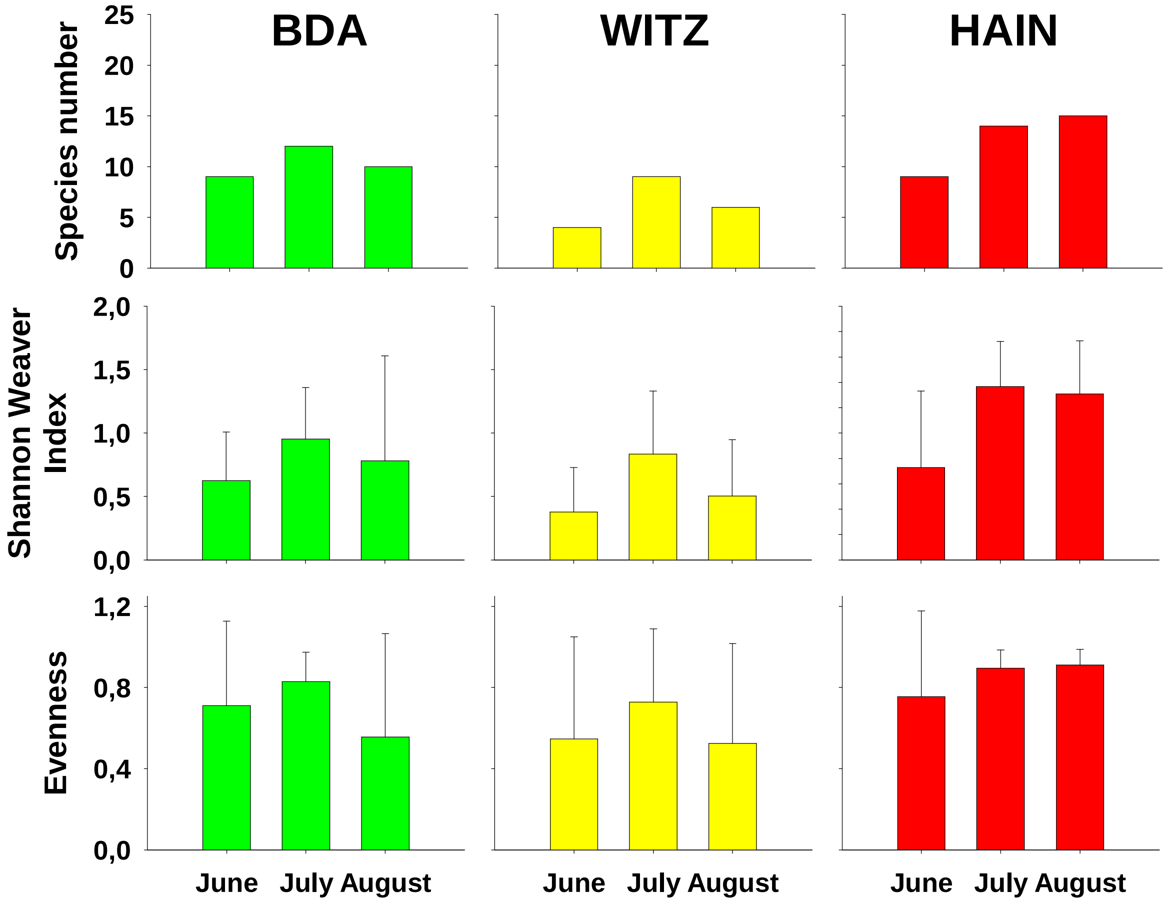

Figure 42: Species number, mean Shannon Weaver index and mean Evenness index and per month in the three Danube reaches. Bars represent mean values, error bars represent standard deviation. BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

During the sampling period, the species number rose within the HAIN site from 9 species in June to 15 in August, while BDA and WITZ had the highest species number in July (12 and 9 species).

BDA and WITZ had the highest values for the mean Shannon Weaver Index in July (also compare "species number"). The HAIN site, having the highest mean Shannon values of all three Danube reaches, showed equally high values in July and August. Also the Evenness shared a similar tendency over the sampling period like the Shannon Index within the three Danube reaches (fig. 42).

Mesohabitat

In general the highest number of different fish species has been found within the GR (16) mesohabitat, the lowest within the PO (10). Comparing the mean species number of the four mesohabitats a highly significant difference has been found (Kruskal Wallis test: Chi-Square= 19,21; p= 0,000; d.f.= 3; n=50; Tamhane Post Hoc test). SA vs. PO and GR vs. PO differed highly significantly (p= 0,000) from each other. The mesohabitat with the highest mean Shannon Weaver Index was the SA, the PO had the lowest value, while GR and GB shared a similar mean Shannon Index. SA and PO differed high significantly (ANOVA: F= 5,66; p= 0,002; d.f.= 3; n= 45; Tukey Post Hoc test: SA vs. PO p= 0,001).
The comparison of the mean Evenness Index between the mesohabitats showed a similar trend like the Shannon Index but no significant differences were found (ANOVA: F= 2,49; p= 0,073; d.f.= 3; n= 45; fig. 43).

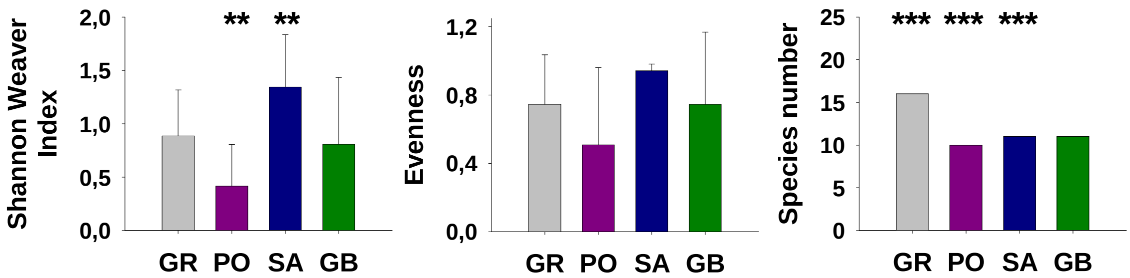

Figure 43: Shannon Weaver index, Evenness and total species number of the total catch in the four mesohabitats. Bars represent mean values, error bars represent standard deviation. Significant differences are indicated by star symbols. GB = gravel bank; GR= groin field; PO = pool; SA = side arm.

During the sampling period, the highest species numbers occurred in July within GR, PO and GB. The mesohabitat SA had equal species numbers in July and August.
Concerning the Shannon Weaver Index all mesohabitats had the highest values in July, except for the SA. Here the index rose steadily over the three months of sampling. Also the Evenness displayed a similar tendency compared to the Shannon Index, except for the SA, where the values stayed on the same level (fig. 44).

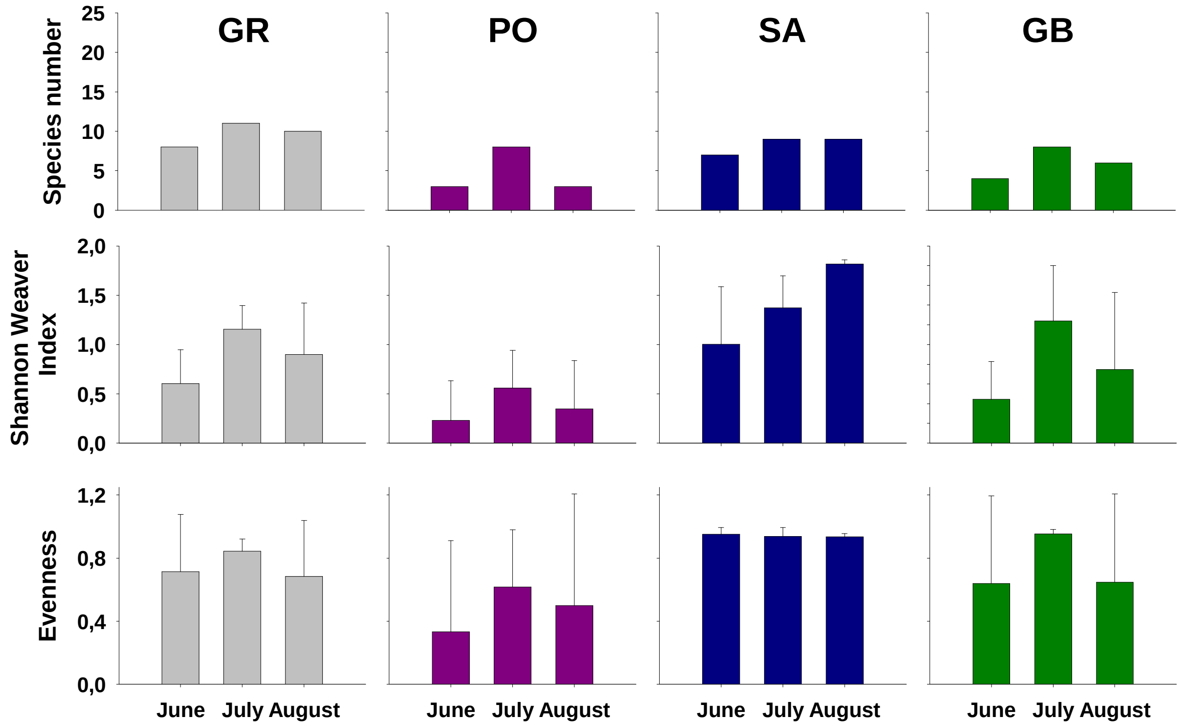

Figure 44: Species number, Shannon Weaver index and Evenness of the total catch in the four mesohabitats. Bars represent mean values, error bars represent standard deviation. GB = gravel bank; GR= groin field; PO = pool; SA = side arm.

Species Accumulation Curve ("Collectors Curve")

The species accumulation curve for long line fishing appears to be a steadily rising curve with a decreasing slope (fig. 45, 50 sample units). The highest increase can be seen between 0 and 10 samples.

A total number of 24 species has been observed with this method with calculated confidence intervals (95%) of 18 and 30 species (rounded to the next integer).

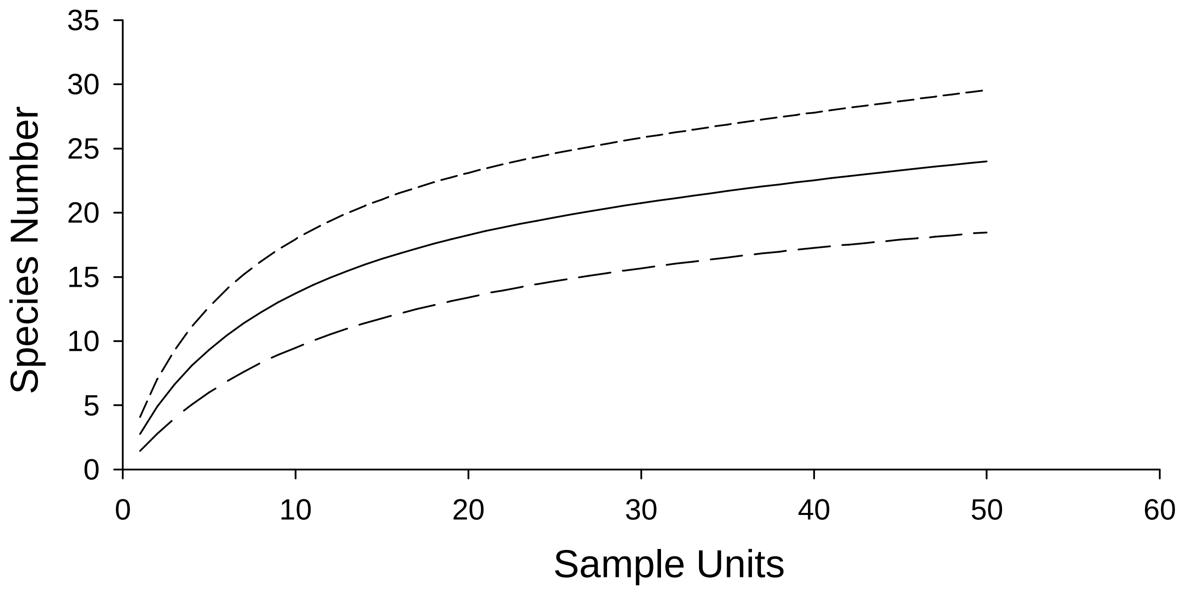

Figure 45: Species Accumulation Curve for the samples from long line fishing. The X-axis shows the sample units (number of samples), on the Y-axis the calculated species number is plotted**.** The solid line is the calculated value for the observed species number the dashed lines indicate the 95% confidence intervals.

Fish Size Distribution

Danube Reach

With long line fishing a total number of 309 fish has been caught, 108 within the BDA, 81 within the WITZ and 120 within the HAIN site. The median fish length of the three Danube reaches ranged between 10,4 cm in WITZ, 11 cm in BDA and 11,6 cm in HAIN. No significant difference between the three sampling sites was observed (Kruskal Wallis test: Chi-Square= 4,75; p= 0,093; d.f.= 3; n= 309). Most of the fish caught within the three Danube segments had a total-length between 5 and 20 cm, but also fish up to 60 cm were caught frequently within all sampling sites. The largest fish (*Silurus glanis*, 97cm) was caught within the HAIN site (fig. 46).

Mesohabitat

Concerning the fish length distribution a highly significant difference between the four mesohabitats was oberved (Kruskal Wallis test: Chi-Square= 3,04; p= 0,000; d.f.= 3; n= 309; Tamhane Post Hoc test). While GR (162 individuals, median fish length = 10,3 cm), PO (44 individuals, median fish length = 11,5 cm) and SA (67 individuals, median fish length = 11,5 cm) had similar length distributions (maximum frequency between 5 and 20 cm, several individuals longer than 20 cm), the GB (36 individuals, median fish length = 16,4 cm) differed significantly from the GR mesohabitat (p= 0,021) due to the lowest number of fish and a different length distribution in the mesohabitat GB (fig. 47).

Sampling Period

The number of caught fish by long line fishing rose from 74 in June (median fish length = 11,8 cm) to 111 in August (median fish length = 11,3 cm), while the maximum number of fish was caught in July (124 individuals, median fish length = 10,6 cm). But there was no significant difference between the fish length distributions of the three months (Kruskal Wallis test: Chi-Square= 3,04; p= 0,219; d.f.= 2; n= 309). All three months display nearly the same picture: a high frequency of measured fish lengths between 5 and 20 cm and low numbers of individuals between 20 and 50 cm (fig. 48). The biggest fish (Silurus glanis, 97 cm) was caught in July.

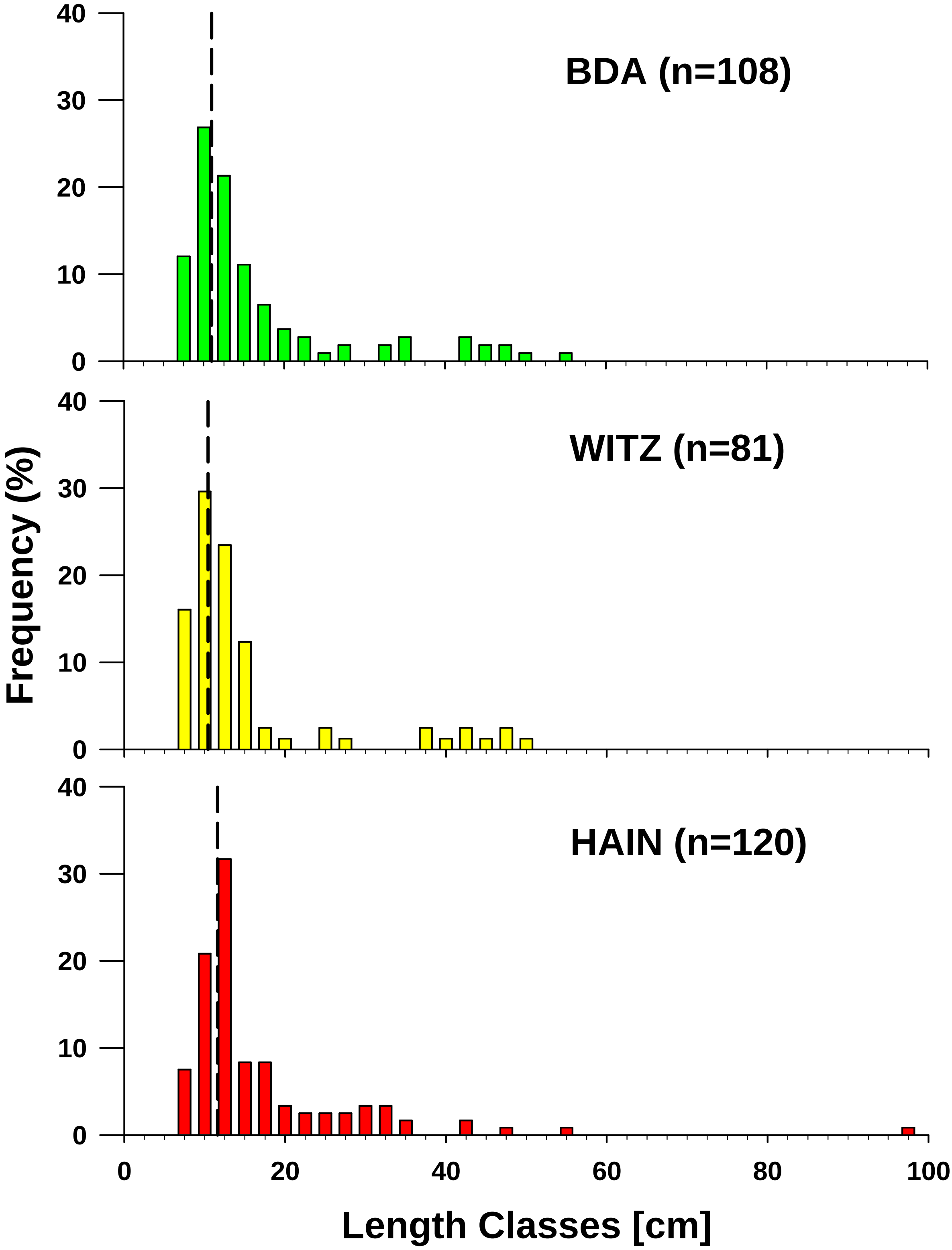

Figure 46: Frequency distribution of fish length classes at the three Danube reaches. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median BDA = 11 cm; median WITZ = 10,4 cm; median HAIN = 13,7 cm). BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg.

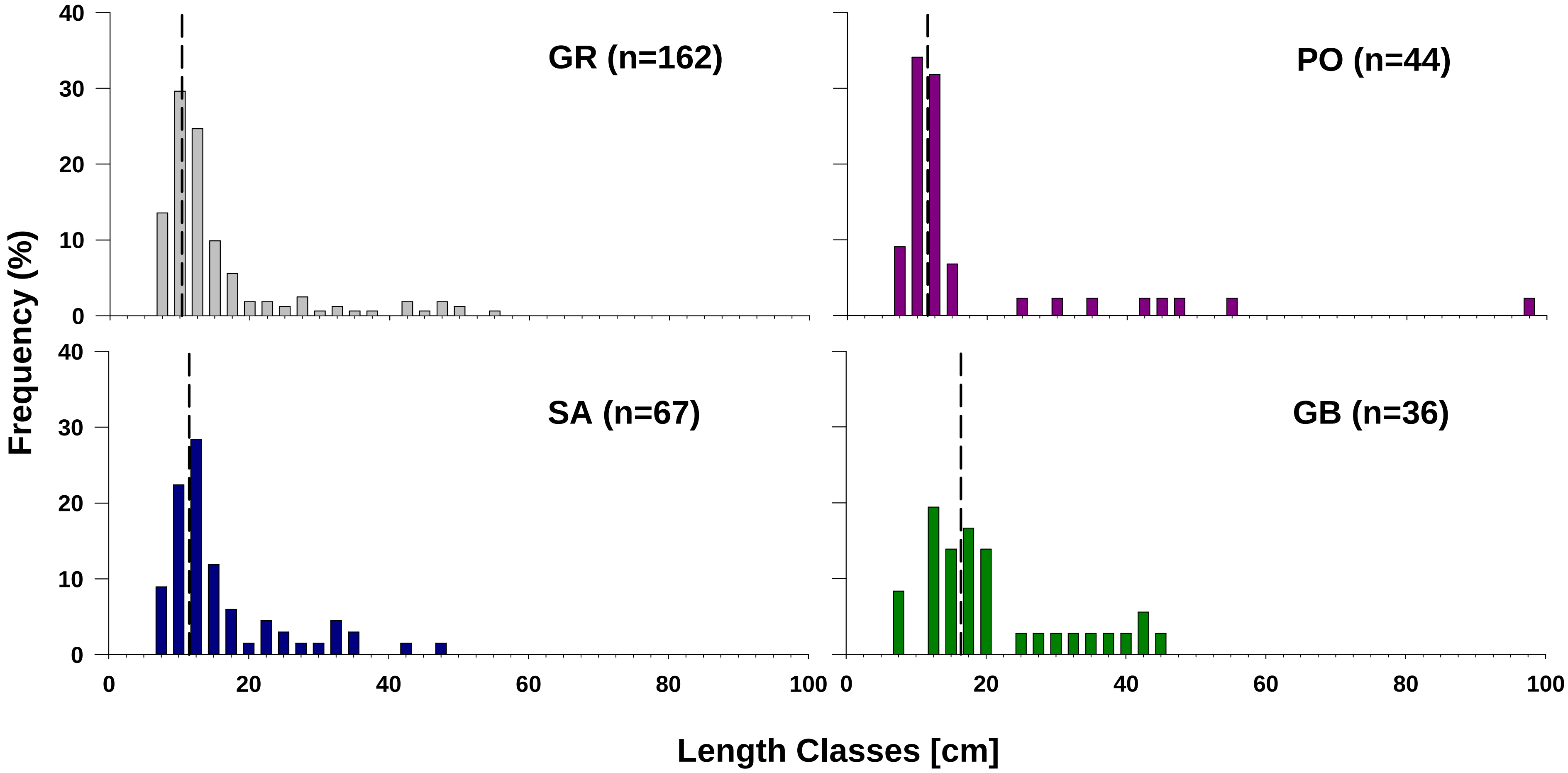

Figure 47: Frequency distribution of fish length classes at the four mesohabitats. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median GR = 10,3 cm; median PO = 11,5 cm; median SA = 11,5 cm; median GB = 16,4 cm). GB = gravel bank; GR= groin field; PO = pool; SA = side arm.

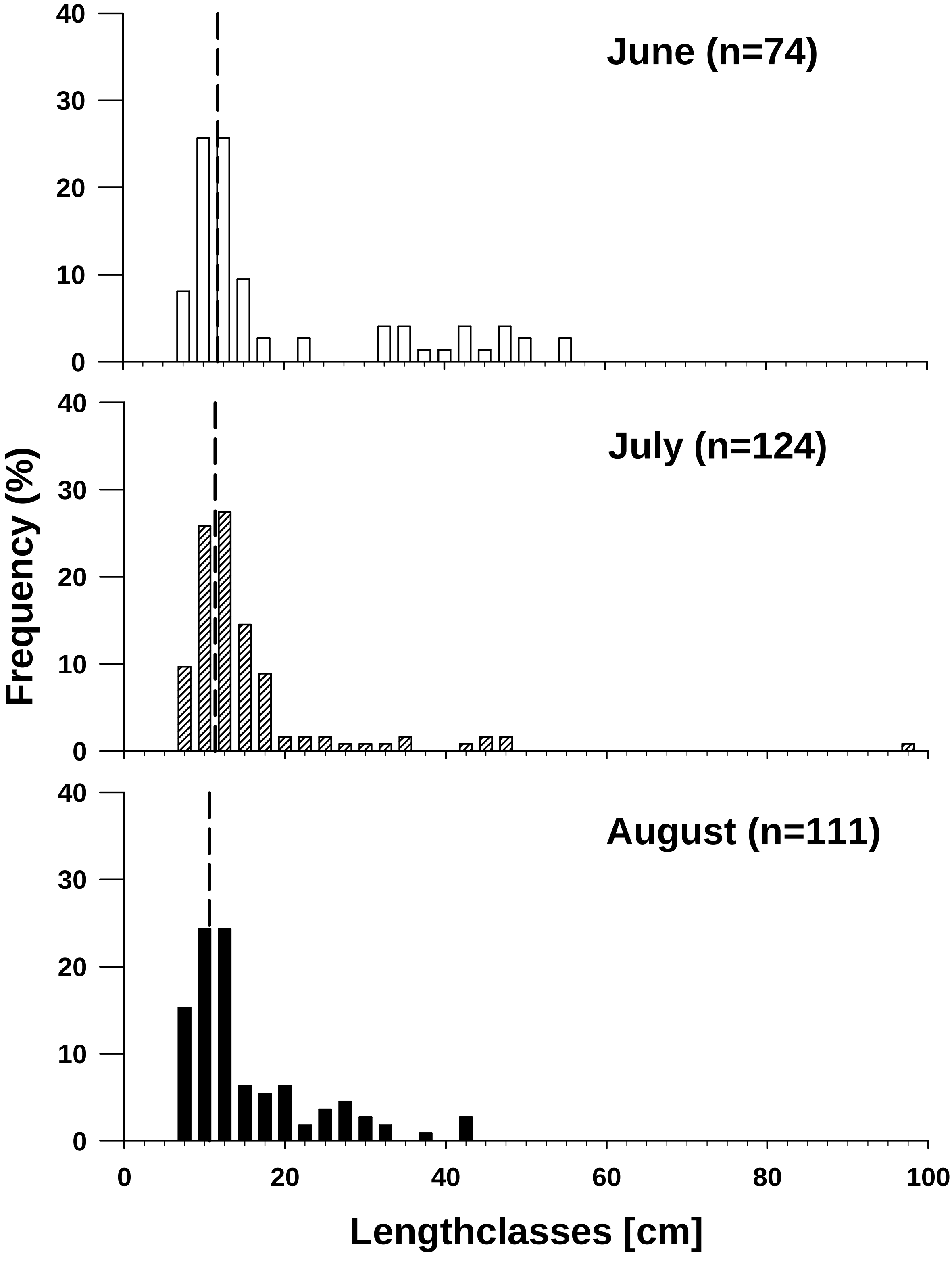

Figure 48: Figure X: Monthly frequency distribution of fish length classes at the three months of sampling: June, July and August. The minor ticks represent the length classes (2,5cm), the dashed line the median of the length distribution (median June = 11,8 cm; median July = 11,3 cm; median August = 10,6 cm).

Comparison and Combination of Methods / Multivariate Analysis

Cumulative Species Accumulation Curve ("Collectors Curve")

The highest species number was observed for wading electro fishing (28 species), while boat and long line fishing had equal species numbers (each 24 species). By combining the three methods (the catch data was based on presence and absence) all species were displayed in one curve indicating the success proportional to the effort of the three methods combined.

The curve (fig. 49, black segmented line, 431 sample units) had a high gradient in the beginning which nearly perfectly overlapped the long line species accumulation curve (red dashed line). The highest increase was seen between 0 and 100 samples followed a low increase of new species with increasing sample number. This low increase of the curve indicated that there was a low probability of observing even more species by taking additional samples.

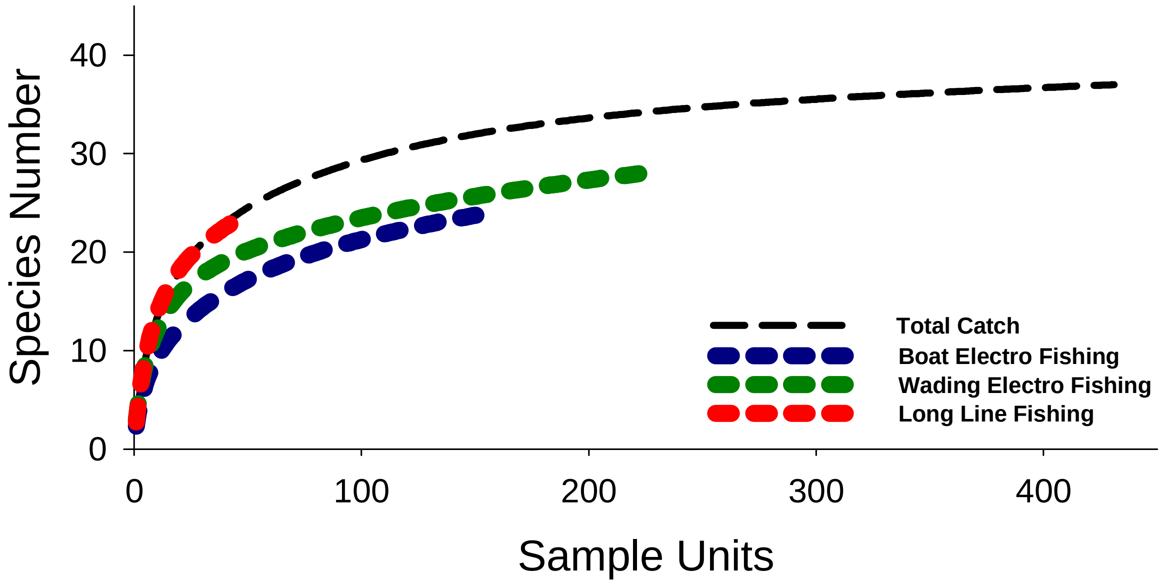

Figure 49: Species Accumulation Curve for all methods combined and for each method separately (see legend). The X-axis shows the sample units (number of samples), on the Y-axis the calculated species number is plotted.

Multivariate Analysis of the Total Species Assemblage (all methods)

For further analysis of differences between methods, Danube reaches, mesohabitats and months a non-metric multidimensional scaling analysis (NMDS) was conducted. Therefore all untransformed CPUE data were combined and normalized. Normalization was carried out by calculating the proportion of the abundance of each single species of each sample ($\sum = 1$). This procedure eliminates the differences of the weighted fish abundances between methods (i.e. CPUE values of longline catches and CPUE values of electrofishing), as finally all CPUE data are now displayed as proportion catch per sample.

With this data matrix a Bray Curtis similarity matrix has been calculated. This similarity matrix was the basis for the NMDS plot and also for PERMANOVA tests (see also Material & Methods; Anderson et al. 2008).

Each symbol within the NMDS plots represents a sample, coded with colour and shape for method, reach, mesohabitat and month (fig. 50, see legend).

Method

Between the methods there was a global difference (PERMANOVA: Pseudo-F= 32,96; p= 0,0001; d.f.= 2; n= 381). Visually the NMDS plot and the mean values showed a clear separation between boat electro fishing and the other two methods (fig. 50) but statistically all methods differed highest significantly from each other (p= 0,0001).

Danube Reach

Overall, there was no significant difference between the Danube reaches detectable with this analysis (PERMANOVA: Pseudo-F= 1,72; p= 0,0687; d.f.= 2; n= 381). Also the distribution of the sample points in the NMDS plot and the plot for the mean values showed no visually recognisable separation of the three Danube reaches (fig. 50).

Mesohabitat

Between the four plotted and tested mesohabitats, a global difference was found (PERMANOVA: Pseudo-F= 7,15; p= 0,0001; d.f.= 3; n= 381). Despite a large overlap of mesohabitat sample points (fig. 50), all mesohabitats differed at least highly significant from each other (tab. 11), apart from rip rap vs. groin field, where no significant difference was found.

Table 11: Statistical significance values (P(perm) for PERMANOVA between the mesohabitats (groups). GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

Groups	P (perm)
GB vs. GR	p = 0,0001
GB vs. RR	p = 0,0040
GB vs. SA	p = 0,0001
GR vs. RR	p = 0,0676
GR vs. SA	p = 0,0005
RR vs. SA	p = 0,0025

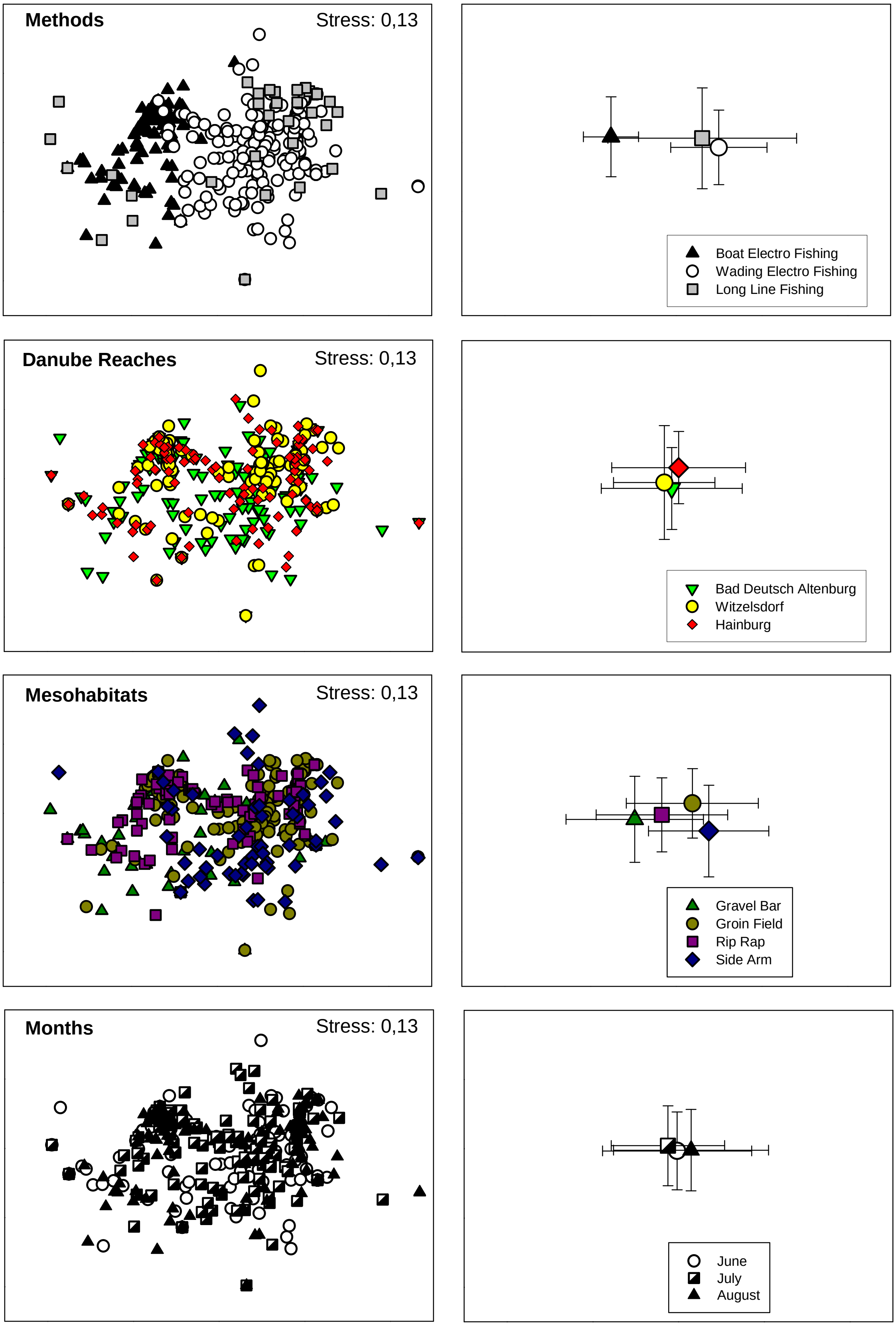

Figure 50: MDS plot (left side, based on Bray Curtis Similarity Matrix) of abundance data of all samples combined and mean sample scores (right side, error bars represent standard deviation). Different greyscale (methods), colour (reaches and mesohabitats) and shape coding for methods, Danube reaches, mesohabitats and Months (see legends).

A clear separation of the mesohabitats is visible regarding the mean scores for the interaction plot of reaches and mesohabitats (fig. 51). On the first axis, the centroids are grouped together and a clear progression from left to the right is evident, with gravel bars on the left side, followed by rip raps, groin fields and side arms on the right side (Fig. 51).

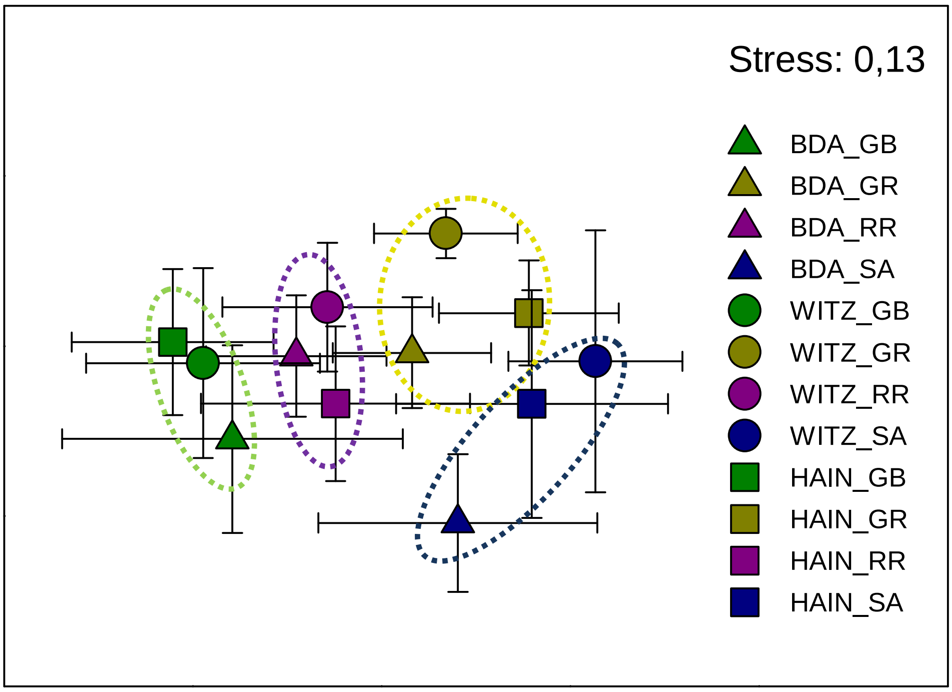

Figure 51: MDS plot of mean sample scores of mesohabitats per Danube reach (right side, error bars represent 95% confidence interval). Different colour (mesohabitats) and shape coding for Danube reaches and mesohabitats (see legends).

Sampling Period

Between the three months of sampling, a highly significant difference was found (PERMANOVA: Pseudo-F= 3,19; p= 0,0008; d.f.= 2; n= 381). Although graphically no obvious difference is visible (fig. 50), regarding the NMDS and the mean score plot, all months differ at least significantly from each other. June differed significantly from July (p= 0,0143) and high significantly from August (p = 0,0095). July and August differed also high significantly from each other (p= 0,0086).

Summary and Discussion

Fish Assemblage

A broad variety of different fish species, from 8 families and 4 ecological guilds, has been found in the main channel of the free-flowing section of the Danube. All in all a number of 36 species was observed during the sampling period in 2007. Zauner et al. (2007) on the other hand recorded a higher number of fish species in the Danube segment in the eastern Machland (Upper Austria). Altogether Zauner observed 43 different fish species within the main channel of the Danube and the connected side arms.

Reyjol et al. (2007) reported a total number of 233 fish species in European river systems and mentions that the whole Ponto-Caspian region (including the Danube) is one of the most diverse bio-geographical areas in Europe, regarding fish species diversity.

Compared to other big European rivers, the Danube holds a very species-rich fish assemblage. According to Jungwirth et al. (2003) there are 57 fish species native to the Danube in Austria. The Loire (32 fish species; Lasne et a. 2007), Seine and Rhône (together, they hold at least 47 different fish species; Daufresne et al. 2007), or the Rhine (43 fish species; Siepel et al. 1993) harbour a less divers fish community.

In this study, the use of three different fish sampling methods enabled the detection of a broad spectrum of species in the main channel of the Danube during a relatively short period of sampling. All three methods proved to be able to capture most of the common fish species. On the other hand, one sampling method on its own would not have been able to describe more than 50 % of all the possibly occurring fish species. Each of the sampling methods respectively detected fish species, the others did not: Boat electro fishing exclusively accounted for one species, while long line fishing added 5 and wading electro fishing added 4 species to the total amount of 36 fish species. Thus the combined methods accounted for 63% of the known fish fauna of the Danube in Austria. Furthermore it seems that each method focused on a different part of the fish assemblage, as certain groups of species were dominant for each method (pelagic and near-ground fish species for boat electro fishing, litoral fish species for wading electro fishing and benthic fish species for long line fishing). Generally, the suitability of various fish sampling methods differs for certain habitat types and species (Growns et al. 1996). Therefore, the application of multiple fish sampling methods is the best way to collect data of the total fish assemblage at hand (Growns et al. 1996, Casselman et al. 1990, Weaver et al. 1993).

However, the differences between the methods, observed from the combined and normalised data set of all methods, indicated, that not only methodological selectivity and/or suitability is responsible for the occurrence of different assemblages in different regions (inshore, sublittoral, river-bed) of the river. On the contrary, it is to be concluded, that indeed the fish assemblages vary in different regions.

Regarding the three different Danube reaches examined in this study it is to be noted, that they showed similarities regarding the common fish species but differed regarding the presence or absence of rare and specialised species. The lowest number of species was observed within the Danube reach Witzelsdorf (27 species), while in the reaches Bad Deutsch Altenburg and Hainburg equal numbers (32 species respectively) were caught. The dominant fish species (*A. alburnus, A. aspius, B. barbus, C. nasus, Neogobius sp.*, etc.) were found within all three reaches in similar quantities. This pattern is not surprising, as these fish are rated as core species for large epipotamal rivers in Austria, like the Danube east of Vienna (Haunschmid et al. 2010). Also Zauner et al. (2007) and Tarkus et al. (2010) came to the same results regarding a Danube segment in the lower Machland (Upper and Lower Austria) and a Danube reach upstream of the hydropower plant Freudenau (Vienna), where core species dominated the assemblage and secondary species where less abundant.

However, some exclusive and rare species were found within each of the three examined reaches. These species consisted of fluvial specialists (*Gobio gobio* and *Gymnocephalus baloni* in the Hainburg reach) as well as generalists (*Carassius gibelio* in Bad Deutsch Altenburg) and stagnophile fish species (*Gasterosteus aculeatus* in Bad Deutsch Altenburg, *Sander volgensis* and *Scardinius erythrophthalmus* in Hainburg).

Having thus outlined the consistency of the fish assemblages on a larger scale, we will now turn to the discussion of the different fish assemblages found within the five mesohabitats. Only four species (*A. brama, B. barbus, N. kessleri and N. melanostomus*) occurred within each of these mesohabitats.

The highest number of different fish species was found in groin fields. Confirming the study at hand, Fladung et. al (2003) detected a very similar number of fish species in groin fields in the river Elbe. The high alpha diversity in this type of mesohabitat might be explained by the wide expanse of groin fields and the availability of different microhabitats within them (woody debris, spare room between armour stones, etc.; Angermeier et al., 1988), which provide food and shelter. Especially the neozoen (invasive) fish species *Neogobius gymnotrachelus, N. kessleri* and *N. melanostomus* showed high abundances within this mesohabitat. These gobies are benthic, speleophil (cavity or cave lover), fish species, which use the room between rocks and armour stones e.g. for egg deposition (Ahnelt et al. 1998; Polacik et al. 2008). Furthermore, these gobies showed the highest abundance in the anthropogenic mesohabitats rip raps and groin fields. These man-made

habitats, made of armour stones, seem to be unfilled ecological niches, which suite *Neogobius sp.* best (Bammer, 2010). However, gobies were found within all reaches, in all mesohabitats and throughout the whole period of sampling. The lowest abundance of *Neogobius sp*. was found at the gravel bars, where expanded stone or other sheltering structures are normally missing. The fish assemblage of this mesohabitat mainly consisted of the common pelagic / eurotopic (*A. alburnus*) and rheophilic species (*B. barbus, C. nasus*), accompanied by a group of less abundant species (see also chapter Results). The same pattern was found in rip rap mesohabitats, with the exception that gobies (*Neogobius sp.*) dominated the fish assemblage, due to the availability of armour stone structures.
Gobies were also present and abundant within the side arms. They did not, however, dominate these habitats, since various eurotopic *(A. alburnus, L. cephalus, R. rutilus, P. fluviatilis*) and rheophilic species (*A. aspius*) were also found there. Generally, inshore areas tend to hold a more diverse fish assemblage than main channel habitats. Especially side arms and bays provide enhanced shore heterogeneity and elevated productivity of river plankton, which positively affects the fish community (Schiemer et al. 2001). This pattern is also reflected in the results of the study at hand. The least number of different fish species was observed in pool habitats of the main channel. This fish assemblage was dominated by *Neogobius sp*. but also included rithral (*L. lota*), rheophilic (*A. ballerus, A. sapa, B. barbus, C. gobio, Z. zingel*) and eurytopic fish species (*A. brama and S. glanis*). During a hydro-acoustic investigation, Rakowitz (in press) discovered, that pools tend to be refugial habitats for large numbers of fish, especially during low flow conditions in winter. However, no applied and available standard fishing technique is capable of collecting fish (semi-) quantitatively in large deep pools in the fast flowing main channel of a large river.
All in all, almost a third (28%) of the fish species found during the sampling period, belonged to endangered species (Habitat Directive from 1992; ANNEX II and V). This high percentage of vulnerable species and the general high abundance of fish indicated the high ecological value of the three sampled Danube reaches and the importance of the National Park "Donauauen" in the remaining free-flowing Danube stretch east of Vienna.

Danube Reaches

Boat electro fishing

The comparison of PCA scores for boat electro fishing showed a small, albeit significant difference between the sample points of the Danube reaches WITZ and HAIN. However, this difference could not be detected by the comparison of the total abundance data.

Regarding the calculated biodiversity indices, significant differences were found, indicating the existence of different fish assemblages in WITZ and HAIN. The lowest diversity values were found in the Danube reach Witzelsdorf and the highest in Hainburg. These two Danube reaches differed concerning the availability of groin fields and gravel bars (see also Study Site). The pelagic and sub-litoral (near-ground) fish assemblage was definitely affected by the availability of habitats. It seems, that the study site Hainburg was better suited (or in a better ecological condition) to meet the needs of the fish community sampled by boat electro fishing (pelagic, sub litoral and near-ground fish species).

Wading electro fishing

The comparison of the PCA scores for wading electro fishing (inshore or near shore fish assemblages) also showed significant differences between Witzelsdorf and Hainburg. However, these differences were not based on variations of the total abundance in the three reaches.

Regarding the biodiversity indices, a different picture, compared to boat electro fishing, has been revealed: the lowest diversity values were found in HAIN and the highest in BDA. Here the sampling sites differed significantly concerning Shannon index and Evenness. Again, the differing availability of mesohabitats might have been responsible for the occurring differences. Generally, wading electro fishing works best in groin fields, side arms and rip raps, where escaping fish can be blocked by existing obstacles (groins, armour stone structures etc.), or be drawn from their hiding places (e.g.: *Neogobius sp.*). But on gravel bars fish can escape nearly in all directions, making it impossible to catch all fish at hand (Peter et al. 1996).

Furthermore, a general significant difference between the fish length distribution of the three reaches has been found, but no further distinction between the single study sites was possible, due to non-significant Post Hoc tests. As the length distribution patterns and the average / medians of the three reaches were very similar, the observed statistical differences were rather of statistical / mathematical (high sample number) than of biological nature.

Long line fishing

In contrast to both electro fishing methods, the comparison of PCA scores for long line fishing did not reveal any significant differences between the three Danube segments. However, regarding the total abundance a highly significant difference was found between the Danube reaches Witzelsdorf and Hainburg. This difference was based on the high number of species and the high fish abundance in HAIN, in contrast to the lower number of species and a rather low fish abundance in WITZ (fig 38). A very similar pattern was uncovered in the biodiversity indices, where the Danube reaches WITZ and HAIN differed significantly. Similar to boat electro fishing, the lowest diversity values were found in WITZ and the highest in HAIN. In summary, these results show that in terms of diversity and species richness, there are differences between the fish assemblages of WITZ and HAIN.

Recapitulatory, differences between the three Danube reaches regarding species richness and diversity have been detected with all three methods. However, no consistent pattern, concerning the results from the different methods, could be detected. Irrespective of the Danube reaches, pronounced differences between mesohabitats were found. Differences between the three Danube reaches might have been based on the availability (or non-availability) of mesohabitats. Furthermore, the varying proportions of habitat types within the reaches probably acted as a major factor for differences between the fish assemblages. For example, BDA and WITZ shared similar percentages of mesohabitats (GR, GB, RR, SA), while a higher proportion of gravel bars and very few groin fields were found in the HAIN site, which might be a reason for dissimilar inshore fish communities. The different shore configuration of HAIN (although of a near natural character) led to low diversity values for wading electro fishing. However, this picture was not validated by boat and long line fishing, as these methods found the most divers fish assemblage within the HAIN reach. This observation might indicate, that the Danube reach near Hainburg, with its near natural shore configuration, provides better ecological conditions for riverine fish, than the other two reaches. However, the proximity of the two consecutive Danube reaches, BDA and HAIN, might have affected the results, as both study sites shared a similar pelagic and sub litoral fish assemblage. Due to the wide homing ranges of species found within the two sites, normally expanding over multiple kilometres (e.g. *A. alburnus, B. barbus, C. nasus*; Rakowitz et al. 2009, Zitek et al. 2004), wading electro fishing observed the most divers and abundant fish assemblage within the Danube reach BDA. Here suitable shore configurations for sampling by wading electro fishing were at hand (groins acting as barriers, rip raps, less gravel bars).

Generally, the results of wading electro fishing show, that different angles of view (in this case: different fish sampling methods) are necessary to understand the composition and condition of the whole fish assemblage at hand, as different fishing techniques are limited

by environmental factors (water depth, current, shore configuration etc.), as mentioned before.
Overall, the length distributions did not show significant differences between the Danube reaches, but each method appeared to be selective regarding fish size (Growns et al. 1996; see also chapter “Introduction”). Wading electro fishing has been concentrated on the litoral zone (inshore areas) of the river, where small fish tend to be found in higher numbers (Schlosser 1991). The other two methods were applied farther away of the shoreline, in the main channel, which is – according to Wolter et al. (2001) – generally colonized by bigger fish.

Mesohabitats

Between the pre-defined mesohabitats significant differences, regarding total abundance, species diversity and fish size, were found. These results were detected with all three applied fishing methods.

Boat electro fishing

The comparison of PCA scores of boat electro fishing uncovered significant differences between the mesohabitats. Groin fields differed highest significantly from the rip raps and significantly from the gravel bars. Furthermore, the analysis of total abundance also indicated a significant difference between these mesohabitats.
Moreover, the diversity indices differed between the mesohabitats: the highest species numbers were found in the groin fields, the lowest in the rip raps. Distinct differences were also observed regarding the Shannon index of side arms and rip raps, as well as side arms and groin fields, as the highest Shannon values were found in the side arms and the lowest in the rip raps.
All in all, the majority of fish, caught in all mesohabitats, had a length ranging between 10 and 20 cm. The length of the biggest fish reached up to over 70 cm. In the side arms, no fish exceeded 35 cm total length.

Wading electro fishing

The results of wading electro fishing displayed significant differences between the mesohabitats. However, in contrast to boat electro fishing, the comparison of total abundance detected significant differences between all mesohabitats, except for rip raps and groin fields, where no significant difference was uncovered.

Regarding the biodiversity indices, the highest values were found in the side arms and the lowest in the gravel bars, which differed significantly from all other mesohabitats, while no significant difference was found between side arms and gravel bars.

Furthermore, the comparison of the total length distribution detected significant differences between the mesohabitats. However, no fish caught within the side arms exceeded 20 cm, while all the other mesohabitats harboured bigger fish. In contrast to boat electro fishing, side arms sampled by wading electro fishing, held the second highest number of individuals, while the highest number was again detected in the groin fields.

Long line fishing

The comparison of the abundance data revealed significant differences between the mesohabitats. The gravel bars differed from all other mesohabitats (side arms, groin fields and pools), while the side arms only differed from the gravel bars.

Furthermore, differences between these mesohabitats were discovered regarding the number of species and the Shannon index. The highest number of species was found within the groin fields, while the highest Shannon values were detected in the side arms. The lowest diversity values were found within the pool mesohabitats.

Concerning the fish length distribution, significant differences were detected between the mesohabitats, especially between gravel bars, where the lowest number of individuals was discovered, and groin fields, where the highest fish density was found. However, the length distributions of all mesohabitats seemed to be similar, as the majority of fish did not exceed a total length of 10 to 20 cm. An interesting side aspect pertained to the pool habitats, where the largest fish of the whole study was caught: a catfish (*Silurus glanis*), with a total length of 97 cm.

The discovered differences, regarding abundance data, biodiversity indices and length distribution, indicated, that the visual classification of the mesohabitats was effective enough to detect differences between the site-specific fish assemblages, although overlaps existed.

However, the results of boat, wading and long line fishing differed between each other, as each method has been applied in different areas and (depth)layers (litoral, sub-litoral, pelagial, benthal; Peter et al. 1996, Bjordal et al. 1996) of the mesohabitats. Therefore the methods sampled different parts of the fish assemblage, as already mentioned before.

Especially regarding the abundance data (mean CPUE, PCA), differences between the methods were noticed. Where boat electro fishing uncovered differences, wading electro fishing could not (GR vs. RR), although both methods are based on a similar methodology. A possible explanation may be the different habitat and depth layer use of different sized fish and, in general, of different species. The whole fish assemblage of one mesohabitat type cannot be sampled by one sampling method, as mentioned before.

However, several similarities between the three methods have been discovered. The highest number of species was always detected in the groin fields or the side arms. Not only do groin fields cover vast areas in the main channel of the Danube, they also hold a huge volume of water, providing enough space and different ecological niches for a great number of fish and fish species (Angermeier et al., 1988). However, the highest diversity values (Shannon Weaver index and Evenness) were always detected in the side arms, while all other mesohabitats had lower values (fig. 15, 29 and 43).

In general, side arms seem to contribute refugial and nursery habitats for small fish and are used as spawning (Hohausová et al. 2003) and foraging areas for many species (Schiemer et al. 1994). Especially the riparian vegetation and woody debris within side arms provide a variety of microhabitats, used by different fish species for food, hiding and spawning (Schiemer et al. 1989, Pander et al. 2010).

Be that as it may, the order of the other mesohabitats, in terms of biodiversity, varied between the methods. In the gravel bars low diversity values were detected for long line and especially for wading electro fishing, due to methodical problems, as already noted. Boat electro fishing, on the other hand, found the second most diverse fish assemblage within this mesohabitat. Generally, extensive heterogeneous gravel bars, with access to floodplains, side arms and backwaters, provide good habitats for riverine fish (Hirzinger et al. 2004). However, the depth layer use of different fish species and size classes in the gravel bars definitely affected the results of the three methods.

Regarding wading electro fishing, the second most divers fish assemblage was detected in the rip raps, where low numbers of species (second lowest, fig. 24) and similar abundance patterns of the most common species (*A. alburnus, Neogobius sp.*) resulted in elevated diversity levels. Generally, artificial habitats (rip raps and groin field) provide different sediment material (armour stone, boulders, large stones) in contrast to the general river bed material sand and gravel. Therefore, these mesohabitats act as ecological niches, where especially neozoen (invasive) fish species are frequent (Erõs et al. 2008), using the space between armour stone structures as refugial and spawning sites.

The lowest diversity values and number of species have been found in pool mesohabitats (fig. 43). This result may be explained by the small number of sites and the limited capacity of long line fishing. However, Rakowitz (in press) revealed during an echo sounder investigation ("Flussbauliches Gesamtprojekt"), that pools in the main channel of the Danube are more than deep holes in the river bed. They provide refugial habitats for large numbers of fish, especially during low flow conditions in winter, as already discussed.

All in all, the results at hand indicate, that small sized fish species, like gobies, and juveniles preferred the litoral zone, while adult fish were detected in deeper regions (Schlosser 1991; Wolter et al. 2001).

Sampling Period

In summary, every month of sampling brought different results – regardless of which method was applied – but no consistent pattern was recognizable.

Boat Electro Fishing

All measured parameters (abundance, species number and diversity) were increasing from June to August, in all reaches and mesohabitats. Furthermore, no visible difference was found for the total length distribution of the three months.

During the whole sampling period, *A. alburnus, B. Barbus and A. aspius* were the most dominant species.

Wading Electro Fishing

The results of wading electro fishing showed a directly antithetic result compared to boat electro fishing: abundance, species number and biodiversity declined from June to August (after a small peak in July). This trend was observed for all Danube reaches and for the mesohabitats groin field and rip raps. In gravel bars and side arms more or less stable values have been detected. A possible explanation for the decline of abundance during the sampling period might be found in habitat shifts of the litoral fish community from shallow to deeper regions. Furthermore, these results are also reflected in the rising abundance uncovered by boat electro fishing, which was applied in / over deeper regions.

Regarding the total length distribution, differences between the months were detected. A slight increase in total length has been noticed (from 4 to 5,6 cm median length), which might have been caused by the growth of fish.

In a nutshell, the most dominant species during the three months of sampling were *Neogobius sp.*, undefined cyprinids and *A. alburnus.*

Long Line Fishing

The highest abundance, species number and biodiversity was monitored in July, while in June and August lower values were observed. This trend was equally prevailing in all reaches and mesohabitats, except in the side arms, where a steady increase in fish diversity was detected.

Moreover, the dominant fish species during the three months of sampling were *Neogobius sp*. and various benthic fish species. The composition of these benthic fish species changed during the advancing sampling period (see also tab. 9 and fig. 40).

Regarding the total length (median), a decline from June to July (11,8 to 10,6 cm) has been detected.

All in all, the observed differences for each method did not follow a consistent pattern, as mentioned before. Be that as it may, the detected effects could be natural variations in the fish community, based on behavioural mechanisms (migration, predation, food competition, etc.), or on variations of environmental factors, like flow regime and water temperature. Each factor might have caused the detected habitat shifts within the fish assemblage.

The discharge and water temperature changed during the sampling period. A minor flood occurred during the mid of July (peak discharge on the 11th July 2007). This event might have affected the fish community (King et al. 2003), due to water level based changes in habitat availability (Gorman et al. 1978), but has not been tested in this study. However, the results indicated, that there was a general variation in the fish community during the three consecutive months. Sampling throughout a whole year would certainly display a more pronounced picture of fish assemblage changes during the seasons.

Integrative Approach

After discussing the results for each single method, a more holistic way of interpretation is needed to understand general fish assemblage characteristics of large rivers. Therefore the fish abundance data of all methods has been combined, creating an integrative approach to investigate (or at least draw nearer to) the “true” picture of the fish assemblage at hand.

First of all, this combined fish data set discovered that enough samples have been taken to describe the fish assemblage at hand, as indicated by the course of the collectors curve for the combined methods (fig. 49). The highest increase of species was detected for long line fishing. More samples taken by this method would probably have increased the total number of species. However, this method is laborious, expensive and time consuming and was at its maximum capacity, regarding this study.

Further analysis of the combined and normalized data set indicated that differing fish assemblages were found in different regions of the main channel. Furthermore, the results of PERMANOVA tests revealed differences between the methods, the mesohabitats and the months.

Method

Regarding the sampling methods, the results indicated, that each method focused on a specific part of the fish assemblage, given that all methods differed from each other, even after the normalisation of the combined data set. This procedure should damp the effect of method-specific selectivity. However, this aspect is not only based on presence and absence of species, as overlaps exist between the method (seen in the NMDS plot, fig. 50), but also on the species specific abundance, which differed between the methods. Cadwallader (1984) postulated that all fishing techniques are selective and each attempt to describe fish communities with a certain method is to some extend biased. Regarding the study at hand, long line fishing definitely underestimated the abundance of *Alburnus alburnus* and other small pelagic fish species, due to methodical issues (e.g.: the use of hooks and the general focus on the benthic community), behavioural, morphological and ecological characteristics of the fish species. Moreover, boat electro fishing detected unrepresentative abundance data for *Neogobius sp*., compared to the results of the two other methods. On the other hand, it seems reasonable that the occurrence and abundance of *Neogobius sp*. was lower in the open water and near bottom areas of the sublittoral zone of the river, compared to inshore areas covered with big stones and providing large interstitial volume. Though, morphological (no swim bladder) and behavioural aspects (habitat preferences) of *Neogobius sp*. made an unbiased approach nearly impossible, because these fish were mainly found in or near bank side structures, where a quantitative approach of boat and long line fishing was hardly not accomplishable.

Based on this knowledge, a combination of data becomes even more reasonable. Each method contributes a different angle of view for a more holistic picture of the fish assemblage at hand.

In summary, the results of each method represented a combination of selectivity–induced patterns, as well as preferences of species and individuals. To discriminate these factors, extensive studies are required and have to be undertaken.

Danube Reach

Regarding the analysis of the combined and normalized data set, no significant difference between the reaches has been detected. A general conclusion from this result is, that, despite the differences of mesohabitat availability (between Hainburg and the other two reaches, BDA and WITZ), the main channel of the Danube seems to be characterised by a distinct fish assemblage. However, significant differences between reaches exist, when specific elements of the total assemblage (sublittoral, near-bottom, inshore assemblage) are compared.

Mesohabitat

Nearly all mesohabitats differed from each other, except for groin fields and rip raps, where no significant difference has been detected. This result underlines the general fact that different types of mesohabitats are colonized by different fish assemblages (Erõs et al 2008, Schiemer et al 1994, Schlosser 1991, Wolter et al. 2001). Moreover, the results of each method discovered a similar pattern of fish assemblage structure in the discrete mesohabitats.

Furthermore, a similar trend has been found for the combined and normalized data set. Here, the progression of centroids, regarding the interaction plot of reaches and mesohabitats, revealed an interesting pattern (fig. 51): the arrangement of the data points, from the left to the right, indicated, that the mesohabitats not only were colonized by different fish assemblages, furthermore, these assemblages changed regarding the environmental conditions within the discrete mesohabitats. This sequence seems to follow a clear gradient of velocity, assuming that the highest flow velocities occurred in gravel bars and rip-raps, while lower velocity-patterns existed in groin fields and side arm mesohabitats. Lamouroux et al. 1999 discovered, that riverine fish communities are largely affected by hydraulic conditions, as fish assemblage structure and composition (species composition, abundance, size classes) depend on hydraulic factors. Concerning this study, this pattern is also reflected in the fish assemblages of groin fields and side arms, where number and abundance of eurotopic and stagnophile fish species were proportionally higher, than in main channel habitats. These mesohabitats (gravel bars and rip raps) were characterised by rheophilic and the most dominant eurytopic species (fig. 11, 24 and 39).

Sampling Period

Although the sample points of the sampling period largely overlapped, a significant difference between the three month has been discovered. The results of SIMPER analysis indicated, that varying abundances of A. alburnus, *Neogobius sp., B. barbus* and *A. aspius* were responsible for the detected differences. However, the underlying mechanism, which caused these differences was not discovered. Whether these variations of the fish assemblage were based on natural fluctuations or environmental induced changes (changes in water level etc) was not clarified by the study at hand.

Zusammenfassung

Fließgewässer sind im globalen Zusammenhang höchst bedeutsame „hot spots“ der Biodiversität und der Artenentstehung. Neben vielen anderen Organismen, bilden Fische in großen Flüssen sehr diverse Artengemeinschaften, deren rezente Zusammensetzung und Persistenz primär von Habitatverfügbarkeit, Abflussregime und hydraulischen Bedingungen und der Wasser- bzw. Gewässerqualität kontrolliert werden.

Aussagen über Struktur, Zustand und Diversität von Fischzönosen in großen Fließgewässern zu treffen stellt eine große Herausforderung dar, da sämtliche zur Verfügung stehenden Erhebungs-, bzw. Sammelmethoden größen- und artenselektiv für bestimmte Teilzönosen (Litoral, Pelagial, Benthal) sind. Eine Kombination mehrerer Methoden ist daher erforderlich um ein universelleres Bild der tatsächlichen Gegebenheiten entwerfen zu können.

Aufgrund ihrer langen Lebensdauer und ihrer schnellen Reaktionen auf sich verändernde Umweltbedingungen stellen Fische wichtige Indikatoren für die ökologische Integrität großer Fließgewässer dar. Unter dem Gesichtspunkt einer voranschreitenden Fragmentierung und Degenerierung dieser Systeme sind Informationen über den Zustand der Fischgesellschaft daher essentiell, da sie als Bioindikatoren des Gewässerökosystems eine elementare Basis für Schutz- und Restaurationsprojekte (Flora Fauna Habitat Richtlinie, Wasserrahmenrichtlinie) darstellen.

Renaturierungsmaßnahmen werden seit einigen Jahrzehnten auch an der österreichischen Donau angewandt, um einer zunehmenden Habitatfragmentierung und Bedrohung der artenreichen Fischgesellschaft (57 sp.) entgegenzuwirken.

Die vorliegende Untersuchung konzentriert sich auf eine möglichst umfassende Erhebung der Fischartengemeinschaft im Hauptstrom der Donau östlich von Wien. Dazu wurde eine Kombination aus drei verschiedenen Fangmethoden (Bootsbefischung, Uferbefischung und Langleinenbefischung), in drei Donauabschnitten (Witzelsdorf, Bad Deutsch Altenburg und Hainburg), während einer 3-monatigen Probennahme (Juni – August 2007) angewandt. Das Hauptaugenmerk lag auf der Beantwortung dreier Fragen:

1.) Inwieweit unterscheiden sich die drei Hauptarmabschnitte voneinander?
2.) Bestehen Unterschiede zwischen vorab definierten Mesohabitate unabhängig von den Donauabschnitten?
3.) Inwieweit sind Unterschied zwischen den 3 Monaten der Probennahme ersichtlich?

Differenzen zwischen den Abschnitten im Hauptarm der Donau, hinsichtlich Artenzusammensetzung, Abundanz und Biodiversität, waren bei allen einzelnen eingesetzten Methoden ersichtlich. Generell wiesen aber Abschnitten mit ähnlicher Habitatkonfiguration keinen signifikanten Unterschied, bezüglich deren Fischzönosen, auf.
Höchst signifikante Unterschiede ergaben sich im Vergleich der einzelnen Mesohabitate (Schotterbank, Blockwurfufer, Buhnenfeld, Kolk und Seitenarm). Das Artenspektrum der jeweiligen Habitattypen kann unter anderem durch die vorherrschenden Strömungsverhältnissen erklärt werden. Mesohabitate mit zu erwartenden hohen Fließgeschwindigkeiten (Schotterbank und Blockwurf) wiesen eher strömungsliebende Vertreter der rheophilen Gilde auf, während bei lentischen Bedingungen eurytope und stagnophile Fischarten dominierten. Generell kann daraus geschlossen werden, dass Mesohabitate mit unterschiedlichen Stömungsverhältnissen auch unterschiedliche Fischzönosen beherbergen, wobei anthropogen entstandene Strukturen (Buhnenfelder und Blockwurfstrukuren) besonders von Neozoen (Gattung *Neogobius*) genutzt werden.
Auch während des Probenzeitraums konnten Variationen in der Fischgemeinschaft festgestellt werden. Ob diese natürlichen Ursprungs waren und durch Verhalten oder durch veränderte Umweltbedingungen hervorgerufen wurden konnte im Rahmen dieser Studie nicht geklärt werden. Generell sind, Variationen in drei aufeinander folgenden Monaten innerhalb und zwischen Abschnitten in der Fischartengemeinschaft des Hauptstromes der Donau zu beobachten.

Die Datenerhebung für diese Studie erfolgte im Rahmen des § 27 Projektes FA5720061 [TP: Voruntersuchungen 2006 für den Naturversuch Bad Deutsch Altenburg (Pre-Monitoring) im Rahmen des Flussbaulichen Gesamtprojektes Donau östlich von Wien] im Auftrag der viadonau – Österreichische Wasserstraßengesellschaft. Der Standort Ost (Bad Deutsch-Altenburg) der viadonau stellte seine Infrastruktur (Bootsliegeplatz, Hafenbenutzung) großzügig zur Verfügung. Die Elektrobefischungen erfolgten durch die Bewilligungen seitens des Nationalparks Donauauen sowie des Bescheids NÖ LFV-E11/07.

Abstract

Fish communities as well as single fish species are important indicators for the assessment of type and status of large water bodies. Regarding the growing number of endangered, invasive and exotic species it is important to gain information concerning the community composition, species diversity as well as the spatial and temporal distribution of single species. The free flowing main channels of Large Rivers are important habitats for many riverine species; many of them are classified endangered. In large Rivers it is a difficult task to get data reflecting the ”true picture” of communities. By combining different sampling methods it is possible to approach the natural picture of the fish assemblage.

This kind of information is very important for conservation and restoration projects, like the “River Engineering Project” within the National Park “Donauauen” to investigate the effects of restructuring measures on the fish communities. Increasing quality, availability and structural diversity of habitats is an essential aspect for nature conservation and restoration not only for fishes, but for the whole aquatic environment.

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Attachement

Tabel A: Results of SIMPER analysis, based on boat electro fishing abundance data. Displayed are fish species, contributing 90% of dissimilarity between 2 groups. Av.Abund = average abundance; Av.Diss = average dissimilarity; Diss/SD = ratio of average dissimilarity and corresponding standard deviation; Contrib% = percental contribution; Cum.% = cumulative contribution; BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg; GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

Reaches

Groups BDA & WITZ
Average dissimilarity = 66,38%

Species	BDA Av.Abund	WITZ Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,39	1,72	21,31	0,92	32,11	32,11
B. barbus	0,67	0,41	11,26	0,81	16,97	49,08
A. aspius	0,49	0,33	9,72	0,71	14,64	63,72
C. nasus	0,16	0,28	4,79	0,53	7,22	70,94
A. brama	0,24	0,19	4,42	0,55	6,66	77,61
L. cephalus	0,19	0,15	3,74	0,45	5,63	83,23
L. idus	0,19	0,1	3,17	0,41	4,78	88,02
R. pigus	0,05	0,06	1,43	0,27	2,15	90,17

Groups BDA & HAIN
Average dissimilarity = 71,86%

Species	BDA Av.Abund	HAIN Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,39	1,26	18,91	0,98	26,32	26,32
B. barbus	0,67	0,88	13,72	0,9	19,09	45,41
A. aspius	0,49	0,26	9,43	0,62	13,13	58,54
L. cephalus	0,19	0,43	6,14	0,6	8,55	67,09
C. nasus	0,16	0,29	4,86	0,53	6,76	73,85
A. brama	0,24	0,2	4,82	0,53	6,71	80,56
L. idus	0,19	0,14	3,55	0,44	4,94	85,5
P. fluviatilis	0,05	0,16	1,54	0,32	2,14	87,64
V. vimba	0,06	0,13	1,44	0,32	2,01	89,65
N. melanostomus	0,08	0,06	1,29	0,29	1,8	91,44

Groups WITZ & HAIN
Average dissimilarity = 70,33%

Species	WITZ Av.Abund	HAIN Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,72	1,26	21,14	1	30,05	30,05
B. barbus	0,41	0,88	13,33	0,92	18,96	49,01
A. aspius	0,33	0,26	7,58	0,57	10,77	59,78
L. cephalus	0,15	0,43	6,21	0,59	8,83	68,61
C. nasus	0,28	0,29	5,43	0,63	7,73	76,34
A. brama	0,19	0,2	4,42	0,51	6,29	82,63
L. idus	0,1	0,14	2,71	0,41	3,85	86,48
P. fluviatilis	0,02	0,16	1,45	0,3	2,06	88,54
A. bjoerkna	0,05	0,15	1,3	0,33	1,84	90,38

Groups SA & GB
Average dissimilarity = 78,97%

	SA	GB				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	2,14	1,27	14,1	0,87	17,85	17,85
B. barbus	0	0,88	7,3	0,84	9,24	27,09
V. vimba	0,97	0	6,84	0,82	8,66	35,75
A. brama	0,67	0,34	6,82	0,74	8,63	44,38
L. cephalus	0,92	0,16	6,8	0,92	8,61	52,99
P. fluviatilis	1	0	5,59	0,96	7,08	60,07
R. rutilus	0,86	0,06	5,05	0,69	6,4	66,47
A. bjoerkna	0,75	0,07	4,59	0,65	5,81	72,28
A. aspius	0,28	0,23	4,54	0,54	5,76	78,03
C. nasus	0	0,51	3,69	0,57	4,67	82,7
L. idus	0,41	0,2	3,56	0,58	4,51	87,21
S. erythrophthalmus	0,28	0	2,1	0,44	2,66	89,87
G. schraetser	0,33	0	1,94	0,44	2,46	92,33

Groups SA & RR
Average dissimilarity = 78,73%

	SA	RR				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	2,14	1,1	15,78	0,88	20,05	20,05
L. cephalus	0,92	0,26	7,5	0,92	9,53	29,58
V. vimba	0,97	0,03	7,3	0,83	9,27	38,84
A. brama	0,67	0,11	6,5	0,66	8,25	47,1
A. aspius	0,28	0,5	6,49	0,69	8,24	55,34
B. barbus	0	0,73	6,27	0,7	7,97	63,3
P. fluviatilis	1	0,06	6,03	0,97	7,66	70,96
R. rutilus	0,86	0	5,09	0,66	6,47	77,43
A. bjoerkna	0,75	0,02	4,71	0,64	5,98	83,41
L. idus	0,41	0,14	3,27	0,54	4,15	87,56
S. erythrophthalmus	0,28	0	2,22	0,44	2,81	90,38

Groups GB & RR
Average dissimilarity = 73,77%

	GB	RR				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,27	1,1	21,26	0,95	28,82	28,82
B. barbus	0,88	0,73	15,5	0,89	21,01	49,82
A. aspius	0,23	0,5	10,31	0,61	13,98	63,8
C. nasus	0,51	0,1	6,64	0,63	9	72,8
A. brama	0,34	0,11	5,31	0,53	7,2	80
L. cephalus	0,16	0,26	4,96	0,47	6,72	86,72
L. idus	0,2	0,14	3,65	0,48	4,95	91,67

Mesohabitats (continuation)

Groups SA & GR
Average dissimilarity = 68,55%

Species	SA Av.Abund	GR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	2,14	1,9	9,7	0,9	14,16	14,16
V. vimba	0,97	0,07	6,86	0,86	10,01	24,16
L. cephalus	0,92	0,19	6,83	0,97	9,96	34,12
A. brama	0,67	0,17	6,29	0,73	9,18	43,3
P. fluviatilis	1	0,02	5,65	0,98	8,24	51,54
A. aspius	0,28	0,37	5,19	0,7	7,57	59,11
R. rutilus	0,86	0	4,87	0,67	7,11	66,22
A. bjoerkna	0,75	0,02	4,47	0,64	6,52	72,74
B. barbus	0	0,42	3,49	0,61	5,09	77,83
L. idus	0,41	0,09	3,05	0,52	4,45	82,28
S. erythrophthalmus	0,28	0	2,1	0,44	3,06	85,34
G. schraetser	0,33	0,02	2,04	0,46	2,98	88,32
N. melanostomus	0,38	0,04	1,83	0,48	2,66	90,98

Groups GB & GR
Average dissimilarity = 67,01%

Species	GB Av.Abund	GR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,27	1,9	20,8	0,98	31,04	31,04
B. barbus	0,88	0,42	12	0,97	17,91	48,95
A. aspius	0,23	0,37	7,22	0,64	10,78	59,72
C. nasus	0,51	0,2	6,9	0,71	10,3	70,03
A. brama	0,34	0,17	5,44	0,61	8,11	78,14
L. idus	0,2	0,09	3,35	0,42	5	83,14
L. cephalus	0,16	0,19	3,22	0,53	4,8	87,94
R. pigus	0,11	0,04	1,77	0,32	2,64	90,58

Groups RR & GR
Average dissimilarity = 67,61%

Species	RR Av.Abund	GR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,1	1,9	23,29	1,02	34,45	34,45
B. barbus	0,73	0,42	11,92	0,91	17,63	52,08
A. aspius	0,5	0,37	10,32	0,75	15,27	67,35
L. cephalus	0,26	0,19	5,37	0,57	7,94	75,29
C. nasus	0,1	0,2	3,7	0,46	5,48	80,77
A. brama	0,11	0,17	3,33	0,47	4,93	85,7
L. idus	0,14	0,09	2,84	0,35	4,2	89,9
E. lucius	0	0,08	1,21	0,27	1,78	91,68

Months

Groups June & July
Average dissimilarity = 65,28%

Species	June Av.Abund	July Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,23	1,79	21,97	0,95	33,66	33,66
B. barbus	0,53	0,52	11,88	0,8	18,2	51,86
A. aspius	0,25	0,45	9,63	0,66	14,75	66,61
C. nasus	0,08	0,28	4,34	0,52	6,65	73,26
A. brama	0,23	0,07	3,68	0,49	5,64	78,89
L. cephalus	0,11	0,19	3,58	0,48	5,49	84,38
L. idus	0,13	0,12	2,9	0,43	4,45	88,83
P. fluviatilis	0,04	0,08	1,33	0,27	2,04	90,87

Groups June & August
Average dissimilarity = 72,65%

Species	June Av.Abund	August Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,23	1,43	20,85	1	28,7	28,7
B. barbus	0,53	0,82	13,26	0,89	18,25	46,95
A. aspius	0,25	0,42	9,18	0,6	12,64	59,59
L. cephalus	0,11	0,41	5,96	0,52	8,2	67,79
A. brama	0,23	0,33	5,95	0,61	8,19	75,98
C. nasus	0,08	0,36	5,15	0,52	7,1	83,08
L. idus	0,13	0,19	3,63	0,4	5	88,07
R. pigus	0,03	0,12	2,06	0,32	2,83	90,9

Groups July & August
Average dissimilarity = 67,7%

Species	July Av.Abund	August Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
A. alburnus	1,79	1,43	18,44	0,98	27,24	27,24
B. barbus	0,52	0,82	11,16	0,91	16,49	43,73
A. aspius	0,45	0,42	8,71	0,71	12,86	56,59
C. nasus	0,28	0,36	5,73	0,65	8,47	65,06
L. cephalus	0,19	0,41	5,43	0,6	8,02	73,08
A. brama	0,07	0,33	3,93	0,53	5,81	78,9
L. idus	0,12	0,19	2,93	0,43	4,33	83,22
R. pigus	0	0,12	1,52	0,3	2,24	85,46
V. vimba	0,04	0,15	1,34	0,33	1,98	87,44
N. melanostomus	0,05	0,09	1,32	0,3	1,95	89,39
A. bjoerkna	0,09	0,1	1,27	0,33	1,87	91,26

Tabel B: Results of SIMPER analysis, based on wading electro fishing abundance data. Displayed are fish species, contributing 90% of dissimilarity between 2 groups. Av.Abund = average abundance; Av.Diss = average dissimilarity; Diss/SD = ratio of average dissimilarity and corresponding standard deviation; Contrib% = percental contribution; Cum.% = cumulative contribution; BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg; GB = gravel bank; GR= groin field; RR = rip rap; SA = side arm.

Reaches

Groups BDA & WITZ
Average dissimilarity = 71,37%

	BDA	WITZ				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,5	0,82	14,39	1,01	20,17	20,17
N. kessleri	0,81	0,79	13,66	0,89	19,14	39,3
A. alburnus	0,26	0,27	7,56	0,61	10,59	49,9
Cyprinidae sp.	0,3	0,15	6,14	0,64	8,61	58,5
A. aspius	0,26	0,18	5,6	0,65	7,85	66,35
L. cephalus	0,26	0,08	4,54	0,63	6,36	72,71
N. gymnotrachelus	0,11	0,08	2,87	0,36	4,02	76,73
C. nasus	0,12	0,07	2,69	0,41	3,77	80,5
P. fluviatilis	0,07	0,1	2,54	0,38	3,55	84,05
P. marmoratus	0,1	0,04	1,67	0,42	2,34	86,39
V. vimba	0,07	0,02	1,57	0,27	2,2	88,59
L. lota	0,03	0,03	1,25	0,34	1,75	90,33

Groups BDA & HAIN
Average dissimilarity = 76,08%

	BDA	HAIN				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. kessleri	0,81	0,68	15,14	0,91	19,9	19,9
N. melanostomus	0,5	0,46	12,63	0,86	16,61	36,51
A. alburnus	0,26	0,35	10,1	0,64	13,28	49,79
Cyprinidae sp.	0,3	0,21	6,89	0,63	9,06	58,85
A. aspius	0,26	0,22	6,58	0,65	8,64	67,49
L. cephalus	0,26	0,06	4,46	0,61	5,86	73,35
C. nasus	0,12	0,05	2,6	0,39	3,42	76,77
N. gymnotrachelus	0,11	0,05	2,51	0,32	3,3	80,07
L. lota	0,03	0,1	2,27	0,41	2,99	83,05
P. marmoratus	0,1	0,06	1,99	0,46	2,61	85,66
P. fluviatilis	0,07	0,07	1,87	0,45	2,46	88,13
V. vimba	0,07	0,02	1,73	0,29	2,27	90,4

Groups WITZ & HAIN
Average dissimilarity = 72,12%

	WITZ	HAIN				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,82	0,46	15,89	1,04	22,04	22,04
N. kessleri	0,79	0,68	15,29	0,95	21,2	43,24
A. alburnus	0,27	0,35	10,63	0,66	14,74	57,98
A. aspius	0,18	0,22	6,05	0,57	8,38	66,36
Cyprinidae sp.	0,15	0,21	5,16	0,52	7,16	73,52
P. fluviatilis	0,1	0,07	2,49	0,38	3,46	76,98
L. cephalus	0,08	0,06	2,49	0,39	3,45	80,43
L. lota	0,03	0,1	2,35	0,41	3,25	83,68
N. gymnotrachelus	0,08	0,05	2,29	0,31	3,18	86,86
C. nasus	0,07	0,05	1,92	0,37	2,66	89,53
R. pigus	0,04	0,07	1,37	0,34	1,9	91,43

Mesohabitats

Groups SA & RR
Average dissimilarity = 77,2%

	SA	Group	RR			
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,37	0,81	11,86	1,1	15,36	15,36
N. kessleri	0,69	0,93	11,02	0,97	14,28	29,63
A. alburnus	0,18	0,47	8,21	0,74	10,64	40,27
A. aspius	0,4	0,17	6,47	0,77	8,39	48,66
L. cephalus	0,44	0,05	6,17	0,88	7,99	56,65
Cyprinidae sp.	0,19	0,33	5,72	0,66	7,41	64,06
N. gymnotrachelus	0,33	0	4,62	0,6	5,99	70,05
P. marmoratus	0,29	0,01	3,52	0,74	4,55	74,6
P. fluviatilis	0,23	0,02	3,4	0,52	4,4	79
R. pigus	0,26	0	3,27	0,62	4,23	83,24
L. lota	0	0,16	2,43	0,44	3,15	86,39
L. idus	0,19	0,01	2,14	0,47	2,77	89,17
C. nasus	0,09	0,06	1,71	0,5	2,22	91,38

Groups SA & GB
Average dissimilarity = 88,88%

	SA	Group	GB			
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. kessleri	0,69	0,42	14,06	0,87	15,82	15,82
A. alburnus	0,18	0,39	10,23	0,62	11,51	27,33
A. aspius	0,4	0,08	8,97	0,62	10,1	37,42
L. cephalus	0,44	0,06	8,75	0,81	9,85	47,27
N. melanostomus	0,37	0,17	7,78	0,71	8,76	56,03
N. gymnotrachelus	0,33	0	6,89	0,52	7,76	63,79
P. fluviatilis	0,23	0,02	4,87	0,43	5,48	69,26
P. marmoratus	0,29	0	4,49	0,71	5,06	74,32
Cyprinidae sp.	0,19	0,15	4,44	0,47	5	79,32
R. pigus	0,26	0	4,32	0,61	4,86	84,18
C. nasus	0,09	0,15	3,19	0,44	3,59	87,77
L. idus	0,19	0	2,6	0,45	2,93	90,7

Groups RR & GB
Average dissimilarity = 78,12%

	RR	Group	GB			
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. kessleri	0,93	0,42	20,69	1,16	26,49	26,49
N. melanostomus	0,81	0,17	19,43	1,19	24,87	51,36
A. alburnus	0,47	0,39	14,7	0,85	18,81	70,17
Cyprinidae sp.	0,33	0,15	7,64	0,66	9,78	79,96
A. aspius	0,17	0,08	4,27	0,53	5,46	85,42
L. lota	0,16	0	3,84	0,46	4,92	90,34

Groups SA & GR
Average dissimilarity = 78,14%

Species	SA Av.Abund	Group Av.Abund	GR Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,37	0,81	12,86	1,02	16,46	16,46
N. kessleri	0,69	0,89	12,02	0,96	15,39	31,85
A. aspius	0,4	0,23	7,25	0,77	9,28	41,13
L. cephalus	0,44	0,06	6,62	0,85	8,47	49,6
N. gymnotrachelus	0,33	0,03	5,24	0,59	6,7	56,31
A. alburnus	0,18	0,21	4,94	0,52	6,32	62,63
Cyprinidae sp.	0,19	0,22	4,82	0,55	6,17	68,8
P. fluviatilis	0,23	0,06	3,91	0,54	5	73,8
P. marmoratus	0,29	0,02	3,71	0,74	4,75	78,54
R. pigus	0,26	0	3,41	0,62	4,36	82,91
L. idus	0,19	0,03	2,4	0,49	3,07	85,98
L. leuciscus	0,14	0,01	1,75	0,42	2,24	88,22
C. nasus	0,09	0,05	1,75	0,45	2,24	90,46

Groups RR & GR
Average dissimilarity = 57,87%

Species	RR Av.Abund	Group Av.Abund	GR Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,81	0,81	12,81	1,05	22,14	22,14
N. kessleri	0,93	0,89	11,18	0,92	19,31	41,46
A. alburnus	0,47	0,21	9,5	0,82	16,41	57,87
Cyprinidae sp.	0,33	0,22	7,03	0,72	12,16	70,02
A. aspius	0,17	0,23	4,82	0,71	8,33	78,36
L. lota	0,16	0,06	3,43	0,55	5,92	84,28
C. nasus	0,06	0,05	1,68	0,42	2,9	87,18
L. cephalus	0,05	0,06	1,52	0,39	2,62	89,8
P. fluviatilis	0,02	0,06	1,18	0,37	2,03	91,84

Groups GB & GR
Average dissimilarity = 82,56%

Species	GB Av.Abund	Group Av.Abund	GR Av.Diss	Diss/SD	Contrib%	Cum.%
N. kessleri	0,42	0,89	21,72	1,1	26,31	26,31
N. melanostomus	0,17	0,81	21,42	1,08	25,94	52,25
A. alburnus	0,39	0,21	11,85	0,72	14,36	66,61
Cyprinidae sp.	0,15	0,22	6,54	0,51	7,92	74,52
A. aspius	0,08	0,23	5,72	0,56	6,93	81,45
C. nasus	0,15	0,05	3,4	0,41	4,12	85,57
L. cephalus	0,06	0,06	2,26	0,36	2,74	88,31
V. vimba	0,02	0,05	1,76	0,22	2,13	90,44

Months

Groups June & July
Average dissimilarity = 74,68%

Species	June Av.Abund	July Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. kessleri	0,84	0,69	13,25	0,95	17,75	17,75
A. alburnus	0,17	0,59	12,05	0,72	16,13	33,88
N. melanostomus	0,52	0,43	10,87	0,93	14,56	48,43
Cyprinidae sp.	0,41	0,25	7,98	0,76	10,68	59,11
A. aspius	0,23	0,36	7,42	0,71	9,94	69,05
L. cephalus	0,12	0,21	4,14	0,59	5,54	74,59
C. nasus	0,1	0,12	3,22	0,45	4,32	78,91
P. fluviatilis	0,1	0,1	2,67	0,45	3,57	82,48
L. idus	0,08	0,06	1,68	0,39	2,24	84,73
R. pigus	0,05	0,08	1,67	0,38	2,24	86,97
V. vimba	0,03	0,06	1,61	0,25	2,16	89,13
P. marmoratus	0,09	0,04	1,5	0,42	2,01	91,14

Groups June & August
Average dissimilarity = 72,32%

Species	June Av.Abund	August Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,52	0,83	17,15	1	23,71	23,71
N. kessleri	0,84	0,76	16,89	0,89	23,36	47,07
Cyprinidae sp.	0,41	0	6,89	0,58	9,53	56,61
A. alburnus	0,17	0,12	5,37	0,47	7,43	64,04
A. aspius	0,23	0,07	4,54	0,52	6,28	70,32
N. gymnotrachelus	0,03	0,16	3,59	0,37	4,97	75,29
L. cephalus	0,12	0,08	2,97	0,45	4,1	79,39
L. lota	0,05	0,09	2,5	0,42	3,46	82,84
P. fluviatilis	0,1	0,04	2,29	0,34	3,17	86,01
P. marmoratus	0,09	0,08	2,08	0,49	2,88	88,89
C. nasus	0,1	0,02	1,78	0,31	2,47	91,36

Groups July & August
Average dissimilarity = 75,26%

Species	July Av.Abund	August Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,43	0,83	14,51	1,08	19,29	19,29
N. kessleri	0,69	0,76	13,44	1	17,86	37,14
A. alburnus	0,59	0,12	12,8	0,74	17	54,14
A. aspius	0,36	0,07	6,97	0,64	9,26	63,41
L. cephalus	0,21	0,08	4,3	0,58	5,71	69,12
Cyprinidae sp.	0,25	0	4,09	0,52	5,44	74,56
N. gymnotrachelus	0,04	0,16	3,11	0,42	4,13	78,69
C. nasus	0,12	0,02	2,39	0,39	3,18	81,87
L. lota	0,02	0,09	2,05	0,4	2,72	84,59
P. fluviatilis	0,1	0,04	1,97	0,4	2,62	87,21
V. vimba	0,06	0,03	1,8	0,27	2,39	89,6
R. pigus	0,08	0,03	1,43	0,33	1,89	91,49

Tabel C: Results of SIMPER analysis, based on long line fishing abundance data. Displayed are fish species, contributing 90% of dissimilarity between 2 groups. Av.Abund = average abundance; Av.Diss = average dissimilarity; Diss/SD = ratio of average dissimilarity and corresponding standard deviation; Contrib% = percental contribution; Cum.% = cumulative contribution; BDA= Danube reach Bad Deutsch Altenburg; WITZ= Danube reach Witzelsdorf; HAIN= Danube reach Hainburg; GB = gravel bank; GR= groin field; PO = pool; SA = side arm.

Reaches

Groups BDA & WITZ
Average dissimilarity = 75,89%

Species	BDA Av.Abund	WITZ Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,86	0,96	16	1,01	21,08	21,08
N. kessleri	0,44	0,32	8,18	0,86	10,78	31,86
B. barbus	0,26	0,24	8,01	0,67	10,55	42,42
A. brama	0,28	0,23	6,76	0,72	8,9	51,32
A. bjoerkna	0,35	0,17	6,44	0,73	8,49	59,8
N. gymnotrachelus	0,12	0,25	4,88	0,58	6,43	66,24
V. vimba	0,22	0,06	4,48	0,49	5,9	72,14
A. ballerus	0,21	0	3,52	0,44	4,64	76,79
Z. zingel	0	0,2	3,3	0,49	4,35	81,14
P. fluviatilis	0,13	0,13	2,84	0,55	3,74	84,88
G. schraetser	0,12	0,07	2,56	0,45	3,37	88,25
Z. streber	0,06	0,09	2,46	0,36	3,24	91,49

Groups BDA & HAIN
Average dissimilarity = 78,17%

Species	BDA Av.Abund	HAIN Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,86	0,87	12,39	0,98	15,85	15,85
N. kessleri	0,44	0,49	7,45	0,94	9,53	25,39
A. bjoerkna	0,35	0,38	6,16	0,88	7,88	33,26
G. albipinnatus	0,08	0,29	5,31	0,57	6,79	40,05
B. barbus	0,26	0,14	5,13	0,62	6,56	46,61
A. brama	0,28	0,26	5,12	0,71	6,55	53,17
N. gymnotrachelus	0,12	0,33	4,58	0,65	5,86	59,03
A. ballerus	0,21	0,21	4,38	0,62	5,6	64,62
Z. streber	0,06	0,23	3,81	0,53	4,87	69,5
V. vimba	0,22	0,13	3,66	0,55	4,68	74,18
S. glanis	0	0,25	3,59	0,54	4,6	78,77
P. fluviatilis	0,13	0,18	2,77	0,61	3,54	82,31
A. sapa	0,06	0,13	2,69	0,43	3,44	85,75
G. schraetser	0,12	0,06	2,03	0,44	2,6	88,34
S. volgensis	0	0,15	1,75	0,38	2,23	90,58

Groups WITZ & HAIN
Average dissimilarity = 77,92%

Species	WITZ Av.Abund	HAIN Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,96	0,87	12,95	1	16,62	16,62
N. kessleri	0,32	0,49	7,59	0,92	9,74	26,36
N. gymnotrachelus	0,25	0,33	6,1	0,72	7,83	34,19
A. bjoerkna	0,17	0,38	5,94	0,75	7,62	41,81
B. barbus	0,24	0,14	5,77	0,57	7,41	49,22
G. albipinnatus	0	0,29	5,15	0,53	6,61	55,83
A. brama	0,23	0,26	4,96	0,66	6,36	62,19
Z. streber	0,09	0,23	4,13	0,54	5,3	67,49
S. glanis	0	0,25	3,92	0,54	5,03	72,52
Z. zingel	0,2	0,06	3,34	0,54	4,28	76,81
P. fluviatilis	0,13	0,18	3,04	0,62	3,91	80,71
V. vimba	0,06	0,13	2,71	0,43	3,48	84,19
A. ballerus	0	0,21	2,55	0,47	3,28	87,47
A. sapa	0	0,13	2,34	0,36	3	90,47

Mesohabitats

Groups GR & PO
Average dissimilarity = 71,99%

	GR	PO				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	1,31	0,94	15,43	1,01	21,43	21,43
N. kessleri	0,51	0,22	8,47	0,91	11,77	33,2
A. bjoerkna	0,46	0	6,7	0,76	9,3	42,5
A. brama	0,32	0,1	6,32	0,65	8,77	51,27
B. barbus	0,12	0,19	5,54	0,56	7,7	58,97
N. gymnotrachelus	0,13	0,09	3,87	0,45	5,37	64,34
G. schraetser	0,21	0	3,36	0,52	4,67	69,01
S. glanis	0	0,19	3,16	0,48	4,38	73,39
P. fluviatilis	0,2	0	2,7	0,53	3,75	77,15
A. sapa	0,05	0,1	2,53	0,4	3,52	80,66
Z. zingel	0,05	0,1	2,43	0,4	3,38	84,04
Z. streber	0,12	0	2,26	0,34	3,13	87,18
G. albipinnatus	0,07	0	1,66	0,24	2,3	89,48
S. volgensis	0,13	0	1,66	0,35	2,3	91,78

Groups GR & SA
Average dissimilarity = 69,49%

	GR	SA				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	1,31	0,9	10,06	1,01	14,47	14,47
N. gymnotrachelus	0,13	0,9	8,87	1,39	12,77	27,24
A. ballerus	0	0,69	8,21	1,07	11,81	39,05
A. bjoerkna	0,46	0,68	7,74	1,09	11,13	50,18
N. kessleri	0,51	0,66	7,1	1,03	10,22	60,41
A. brama	0,32	0,47	6,51	0,88	9,36	69,77
P. fluviatilis	0,2	0,39	4,4	0,86	6,33	76,1
G. schraetser	0,21	0	2,37	0,5	3,41	79,51
S. glanis	0	0,24	2,19	0,57	3,16	82,67
Z. streber	0,12	0	1,52	0,33	2,19	84,86
B. barbus	0,12	0	1,39	0,32	2	86,86
S. volgensis	0,13	0	1,23	0,34	1,77	88,63
G. baloni	0	0,15	1,22	0,37	1,76	90,39

Groups PO & SA
Average dissimilarity = 79,36%

	PO	SA				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,94	0,9	12,76	1,08	16,07	16,07
N. gymnotrachelus	0,09	0,9	10,73	1,43	13,52	29,6
A. bjoerkna	0	0,68	10,27	1,11	12,94	42,54
A. ballerus	0,1	0,69	10,23	1,01	12,89	55,43
N. kessleri	0,22	0,66	7,97	1,05	10,05	65,48
A. brama	0,1	0,47	6,64	0,76	8,37	73,84
S. glanis	0,19	0,24	4,4	0,67	5,54	79,38
P. fluviatilis	0	0,39	4,32	0,75	5,45	84,83
B. barbus	0,19	0	3,81	0,44	4,8	89,63
A. sapa	0,1	0	1,56	0,31	1,97	91,6

Mesohabitats (continuation)

Groups GR & GB
Average dissimilarity = 91,63%

Species	GR Av.Abund	GB Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	1,31	0	20,85	1,57	22,75	22,75
B. barbus	0,12	0,61	9,94	0,93	10,85	33,6
N. kessleri	0,51	0,25	8,07	0,89	8,81	42,41
G. albipinnatus	0,07	0,48	7,53	0,78	8,21	50,62
V. vimba	0,12	0,46	7,32	0,81	7,99	58,62
A. bjoerkna	0,46	0	6,17	0,75	6,73	65,34
Z. streber	0,12	0,37	6,04	0,73	6,59	71,93
A. brama	0,32	0,11	5,7	0,64	6,22	78,15
G. schraetser	0,21	0	3,08	0,51	3,36	81,51
Z. zingel	0,05	0,21	3,04	0,55	3,32	84,82
P. fluviatilis	0,2	0	2,5	0,52	2,73	87,55
N. gymnotrachelus	0,13	0	2,29	0,32	2,5	90,06

Groups PO & GB
Average dissimilarity = 91,6%

Species	PO Av.Abund	GB Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,94	0	19,68	1,04	21,48	21,48
B. barbus	0,19	0,61	13,5	0,94	14,73	36,22
V. vimba	0	0,46	9,56	0,75	10,43	46,65
G. albipinnatus	0	0,48	9,36	0,76	10,22	56,87
N. kessleri	0,22	0,25	7,16	0,67	7,81	64,68
Z. streber	0	0,37	6,65	0,67	7,26	71,95
Z. zingel	0,1	0,21	4,47	0,58	4,88	76,83
S. glanis	0,19	0	3,86	0,47	4,22	81,05
A. sapa	0,1	0,11	3,42	0,44	3,73	84,78
L. idus	0	0,1	2,73	0,34	2,98	87,76
A. brama	0,1	0,11	2,65	0,47	2,89	90,65

Groups SA & GB
Average dissimilarity = 96,45%

Species	SA Av.Abund	GB Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,9	0	10,91	1,35	11,31	11,31
N. gymnotrachelus	0,9	0	10,24	1,5	10,62	21,93
A. ballerus	0,69	0	9,59	1,01	9,94	31,87
A. bjoerkna	0,68	0	9,39	1,09	9,74	41,61
B. barbus	0	0,61	8,73	0,86	9,06	50,66
N. kessleri	0,66	0,25	7,62	1	7,9	58,56
G. albipinnatus	0	0,48	6,23	0,73	6,46	65,03
V. vimba	0	0,46	6,17	0,73	6,4	71,43
A. brama	0,47	0,11	6,07	0,75	6,29	77,72
Z. streber	0	0,37	4,54	0,64	4,71	82,42
P. fluviatilis	0,39	0	4,04	0,74	4,19	86,61
S. glanis	0,24	0	2,43	0,56	2,52	89,13
Z. zingel	0	0,21	2,2	0,5	2,28	91,4

Months

Groups Juni & Juli
Average dissimilarity = 77,57%

	Juni	Juli				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,81	0,97	14,11	1,02	18,19	18,19
N. kessleri	0,06	0,57	7,98	0,98	10,29	28,48
A. bjoerkna	0,19	0,43	7,11	0,82	9,16	37,64
A. brama	0,29	0,29	6,61	0,77	8,53	46,17
B. barbus	0,24	0,17	6,54	0,63	8,43	54,6
N. gymnotrachelus	0,14	0,25	4,8	0,64	6,19	60,79
Z. streber	0,13	0,21	4,56	0,59	5,88	66,68
G. albipinnatus	0,16	0,13	4,49	0,49	5,79	72,46
Z. zingel	0	0,22	3,73	0,53	4,8	77,27
A. ballerus	0,14	0,11	3,66	0,5	4,72	81,99
S. glanis	0,12	0,11	2,99	0,49	3,85	85,84
G. schraetser	0,06	0,11	2,4	0,44	3,09	88,93
V. vimba	0	0,18	2,16	0,45	2,78	91,72

Groups Juni & August
Average dissimilarity = 81,83%

	Juni	August				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,81	0,89	15,39	0,95	18,81	18,81
N. kessleri	0,06	0,63	9,31	0,93	11,38	30,19
B. barbus	0,24	0,24	7,35	0,63	8,98	39,17
A. brama	0,29	0,17	5,89	0,65	7,2	46,37
N. gymnotrachelus	0,14	0,3	5,37	0,59	6,56	52,93
V. vimba	0	0,24	5,25	0,5	6,41	59,35
A. bjoerkna	0,19	0,27	4,99	0,67	6,1	65,44
P. fluviatilis	0	0,37	4,3	0,77	5,26	70,7
G. albipinnatus	0,16	0,07	3,76	0,43	4,6	75,3
A. ballerus	0,14	0,19	3,55	0,5	4,33	79,63
A. sapa	0,06	0,15	3,39	0,46	4,14	83,77
Z. streber	0,13	0	2,46	0,36	3	86,78
S. volgensis	0	0,18	2,2	0,42	2,69	89,46
S. glanis	0,12	0	1,88	0,34	2,3	91,76

Groups Juli & August
Average dissimilarity = 75,34%

	Juli	August				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
N. melanostomus	0,97	0,89	12,03	1	15,96	15,96
N. kessleri	0,57	0,63	8,54	1,01	11,34	27,3
A. bjoerkna	0,43	0,27	6,27	0,81	8,32	35,62
N. gymnotrachelus	0,25	0,3	5,33	0,69	7,08	42,7
B. barbus	0,17	0,24	5,2	0,6	6,91	49,61
V. vimba	0,18	0,24	5,04	0,61	6,69	56,3
P. fluviatilis	0,11	0,37	4,2	0,81	5,58	61,88
A. brama	0,29	0,17	4,08	0,66	5,42	67,3
Z. zingel	0,22	0	3,17	0,5	4,21	71,5
A. ballerus	0,11	0,19	3,04	0,52	4,03	75,54
G. albipinnatus	0,13	0,07	2,57	0,39	3,41	78,95
Z. streber	0,21	0	2,55	0,44	3,39	82,34
A. sapa	0	0,15	2,19	0,39	2,9	85,25
G. schraetser	0,11	0,07	2,08	0,44	2,76	88
S. volgensis	0	0,18	1,87	0,42	2,48	90,48

Curriculum Vitae

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AUSBILDUNG:

1991 - 1995	VS Klam
1995 - 2003	Europagymnasium Baumgartenberg, Matura
02.2004 - 02.2005	Zivildienst beim Roten Kreuz Grein
seit Februar 2005	Diplomstudium der Biologie/ Studienzweig Ökologie
Seit 10. 2009	Diplomarbeit
04.2011	Teilnahme an Konferenz „World's Large Rivers“

SPRACHKENNTNISSE

Deutsch	Muttersprache
Englisch	Wort und Schrift
Französisch	Grundkenntnisse
Spanisch	Grundkenntnisse

SONSTIGE QUALIFIKATIONEN

Führerschein (B)
Schiffsführerpatent - 10m
Elektrofischereikurs
EDV und Statistik Kenntnisse