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Fish ecological assessment of an Austrian impoundment (HEPP Freudenau, Vienna) with cluster and discriminant analysis implicating dominances after TISCHLER (1949)

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Abstract. According to the demands of the European Union Water Framework Directive, natural structures and habitats were implemented during the construction of the hydropower plant Freudenau. Ecological data were processed and evaluated from the years 1999 to 2000 as well as from the years 2003 till 2004. The study area was divided into five parts, which were further divided into 19 habitats. The statistical software SPSS (© SPSS Inc. 2007) was used for statistical analysis. The dominances after Tischler were calculated and consulted for further analysis. In the context of this project an increase in the number of fish species from 1993 to 2004, showing a peak before and after the power station construction, was demonstrated. The CPUE values proved high magnitudes in the habitats B, D and I. The lowest number of individuals shows the Free Flowing Stretches. Both juvenile and adult fish could be proved in many habitats. A more exact analysis with the dominances after Tischler confirmed previous results. Nevertheless the change in the current spectrum of fish species points out interventions to the habitats. Anthropogenically created habitats are only substitutes for natural habitats.

Keywords: Hydraulic engineering, Hydrobiology, Watermanagement.

Resumo. Avaliação ecológica dos peixes de uma represa austríaca (HEPP Freudenau, Viena) com cluster e análise discriminante implicando dominâncias após TISCHLER (1949). Devido às demandas da Directiva Quadro da Água da União Europeia, estruturas naturais e habitats foram implementados na represa durante a construção da usina hidrelétrica Freudenau. Dados ecológicos dos peixes dos anos 1999/2000 e 2003/2004 foram analisados e avaliados. A área de estudo na região da UHE Freudenau foi dividida em cinco seções e estas subdivididas em 19 habitats. O programa estatística SPSS (© SPSS Inc. 2007) foi usado para análises estatísticas. A dominância de Tischler foi calculado para fazer comperações entre as análises. O contexto deste projeto mostrou um aumento de número de peixes entre os anos 1993 e 2004, antes e depois da construção da UHE Freudenau. Através de captura por unidade de esforço (CPUE) foi comprovado que a maioria de peixes permanace nos habitats B, D e I; o menor número de espécies foi encontrado na Zona de Corrente Livre. Tanto peixes adultos quanto os juvenís foram capturados nos hábitats artificiais e análises exatas, calculadas com a dominância de Tischler, afirmaram os resultados prévios. No entanto, as alterações na estrutura das comunidades demonstram as intervenções nos hábitats. Hábitats criados artificialmente são apenas substitutos de hábitats naturais.

Palavras-chave: Engenharia hidráulica, Gerenciamento de rios, Hidrobiologia.

Introduction

The Danube river, with the highest fish richness in Europe, was all times important in the water-supply and therefore it is frequently object of scientific investigations. Serious changes in the river system were effected by the construction of power plants, weirs and flood protection. Primarily interruptions of the flowing continuum and the lateral connectivity impede spawn migration of catadromous and anadromous species of fish.

Adverse water quality and altered thermal as well as hydrologic regimes upstream of dams often limit native fish populations in habitats downstream (Cushman, 1985). Dams and dikes cause stabilized flow regimes, reduced sediment loads, altering instream habitats, food webs and flow conditions. Therefore fishes, which were naturally adapted to turbid and fluctuating flow regimes of rivers, have declined (Cross & Moss, 1987; Pfleiger & Grace, 1987; Hesse *et al.,* 1993). The effects of hydrologic alteration on river animals are well documented. Fishes living in the main channel of floodplain rivers use naturally flooded habitats for feeding and reproduction (Guillory, 1979; Baker *et al.,* 1991; Light *et al.,* 1995).

Anthropogenically created habitats like tailwaters and reservoirs are better suited to non-native biota, or to a subset of the naturally native fauna, than to native assemblages (Starnes, 1995). Riverine species and fishes introduced to reservoirs can spread downstream and upstream into unimpounded rivers (Winston *et al.,* 1991). Introduced fish may compete with native species by predation or hybridization (Li *et al.,* 1987; Minckley *et al.,* 1991; Courtenay & Moyle, 1992).

The Danube river in Austria was formerly allocated to a braided river system with numerous mainstreams and tributaries. The main arm of the river was the inhabitancy for most of the Danube fish fauna (Waidbacher *et al.,* 1996).

Artificial structures and habitats were implemented in the impoundment during the construction of the hydropower plant Freudenau. Due to the European Water Framework Directive from the year 2000 it is necessary to reach a "Good Status" till 2015 and to restore in all water bodies. The directive obliges all member states of the European Union to adhere to the requirements and represents a great challenge for the Austrian water management (Stigler *et al.,* 2005).

Ex ante to this scientific work an assessment of the Institute of Hydrobiology and Aquatic Ecosystem Management, University for Natural Resources and Applied Life Sciences, Vienna, of the ecological functionality of anthropogenically created habitats upstream the hydropower plant Freudenau was performed (Tarkus, 2008).

The ecological functionality is characterized by the maintenance of the ecological integrity between waters and its occurring organisms in the surrounding area, according to the natural characteristic of the respective water body type (Admicka *et al.*, 1992).

The principal aim of this work was to evaluate the fish ecological functionality of anthropogenic shore structures in the impoundment of the hydropower plant Freudenau by analysis of dominances after Tischler.

Materials and Methods

Study Area

The first large and most modern run of river power station of the world in a metropolis was the hydropower plant Freudenau, built between 1992 and 1998. The volume of the impoundment is approximate 55 million cubic meters. The head amounts to 8.5 m and the average mean water level flow is 1700 m^3/s. The annual generation of electricity reaches one billion kWh (Information Center Freudenau, Österreichische Donaukraft AG, Folder 1998).

The study area (Stream kilometer 1914.50 to 1994.60) was divided into five sections for further investigations (Ginzler, 2002). Those five river sections are: Tailwater (strkm. 1914.50 to 1921.05), Impoundment (strkm. 1921.05 to 1928.00), Transition Zone (strkm. 1928.00 to 1935.00), Head of Reservoir (strkm. 1935.00 to 1945.50) and Free Flowing Stretches (strkm. 1945.50) (Figure 1). Various habitat structures, located on the left river side, are situated in the mentioned sections.

Nine artificial habitats (A – I) were implemented during the construction of the power plant to simulate natural shore structures like tributaries and bays. Habitat A including A Channel (strkm. 1921.90 to strkm. 1922.40), B including B Channel (strkm. 1923.90 to strkm. 1924.50), C_1 including C_2 (strkm. 1926.20 to strkm. 1926.70) and D (strkm. 1927.35 to strkm. 1927.50) are located in the Impoundment. The Transition Zone is characterized by the habitats E (strkm. 1928.80 to strkm. 1928.90), F (strkm. 1929.90 to strkm. 1930.10) and G (strkm. 1930.90 to strkm. 1931.10). Habitat H (strkm. 1932.20 to strkm. 1932.50) and I (strkm. 1934.80 to strkm. 1935.50) are situated in the Head of Reservoir.

E-fishing

Fish react to an externally created electric applied DC field in the water, which is the principle of E-fishing. Due to the electrotype taxis the individuals, situated in the electric field lines, approach the anode and are narcotized (electrotype narcosis). E-fishing is a quantitative and species selective fishing technique (Cowx & Lamarque, 1990).

The procedure of the captured fish was: in situ determination, measuring and weighing. Especially the determination of juvenile individuals form sometimes a problem therefore those were fixed in a 4% formalin solution and afterwards examined under stereomicroscope. The basic unit was determined by the "CPUE" (Catch Per Unit Effort) and calculated by the number of individuals per ten minutes of fishing.

Data Analysis

Ecological fish data from the years 1999 to 2000 as well as from the years 2003 till 2004 were evaluated and analyzed.

The applied databases were "Freudenau" (1999/2000) and "FIDON" (2003/2004) of the Institute for Hydrobiology and Aquatic Ecosystem Management. They were refined for following statistical bi- and multivariate analysis. Solely fish data of the E-fishing were used to calculate binary data, frequencies, dominances and "Catch Per Unit Effort" (CPUE). Bi-and multivariate calculations such as midpoint, cluster and discriminant analysis were computed with the statistical software SPSS.

Applying dominances after Tischler enables posterior comparisons to the various analysis. The dominance of the species was calculated for each investigation section. The calculation after Tischler concerns to the procentual contingent of species related to the total count.

Tischler (1949) defines five classes of dominances: eudominant, dominant, subdominant, recedent and subrecedent. This distinction was assumed in this project as a starting point for detailed analysis and covered with the class values of 0 (subrecedent) to 4 (eudominant). By the calculation of dominance classes extreme outliers like 0 and 4 can be detected and eliminated for further verifications.

Results

In the study area 24 680 individuals of 52 species were caught by E-fishing in the period from April 1999 to November 2000 and from July 2003 to October 2004 (Table I). Bleak (*Alburnus alburnus*, Linnaeus, 1758), Nase (*Chondrostoma nasus*, Linnaeus,

1758) and Roach (*Rutilus rutilus*, Linnaeus, 1758) were the most frequent species. The rarest community included e.g. Mediterranean Barbel (*Barbus peloponnesius*, Valenciennes, 1842), Stone Loach (*Barbatula barbatula*, Linnaeus, 1758) and Spirlin (*Alburnoides bipunctatus*, Bloch, 1782).

In general the CPUE- values demonstrated high magnitudes in the habitats B and D (Impoundment) as well as they showed a tendency towards habitat I (Head of Reservoir) (Figure 2).

By the formation of the median of the CPUE juveniles could be proved primarily in the created habitats of the impoundment. A high number of adult individuals appeared in the Tailwater. Well balanced results were given in the Free Flowing Stretches.

Binary fishdata, separated into their age categories, were used as variables for cluster analysis of the habitats. In further detailed calculations the habitats, used as cases, were summarized for each section.

Exempli gratia the Figure 3 shows the cluster analysis with juvenile fish in the habitats A-D (impoundment). Three partial clusters were identified. The tributary habitats A, B and B Channel belong to the first partial cluster. Habitat A Channel and C_2 define the second partial cluster. Partial cluster three includes the bay shaped habitats C_1 and D.

The cluster analysis, calculated without eudominant and subrecedent fish data (defined by Tischler), was classified by two partial cluster (Figure 4). The first partial cluster is composed of the habitats

B, C_1, D and B (

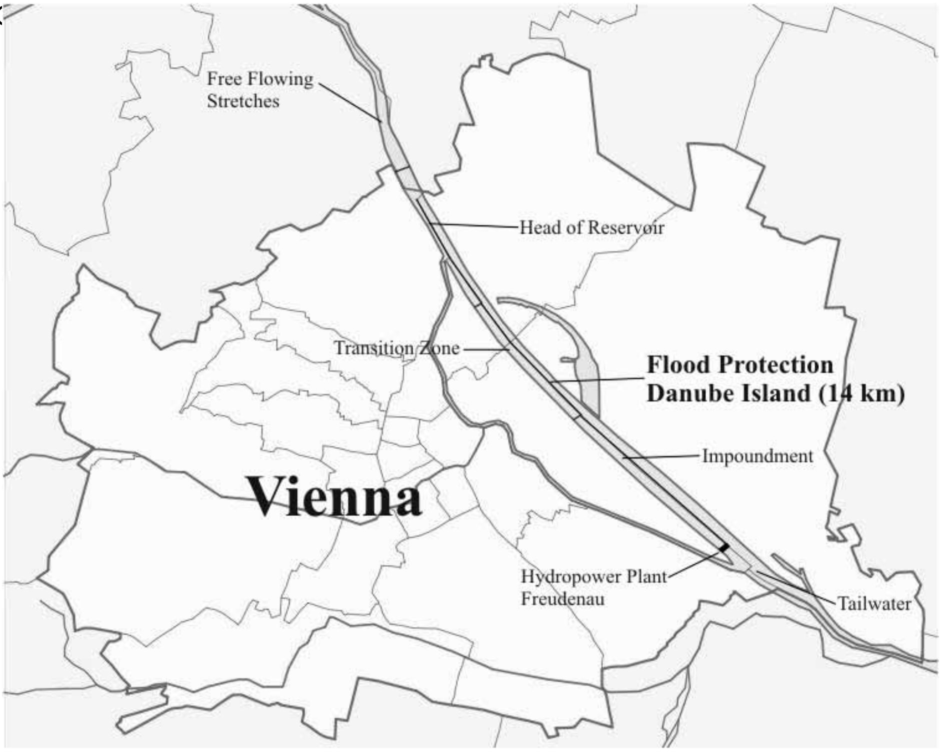

Figure 1. Map of the five sections Tailwater, Impoundment, Transition Zone, Head of Reservoir and Free Flowing Stretches in the study area hydropower plant Freudenau, Vienna, Austria.

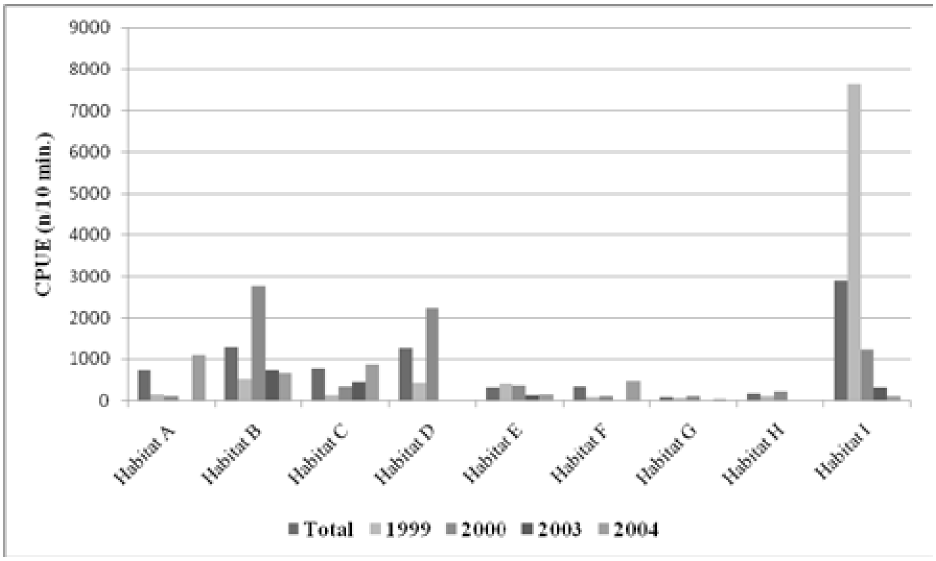

Figure 2. Fish frequency by CPUE in each habitat of the research area.

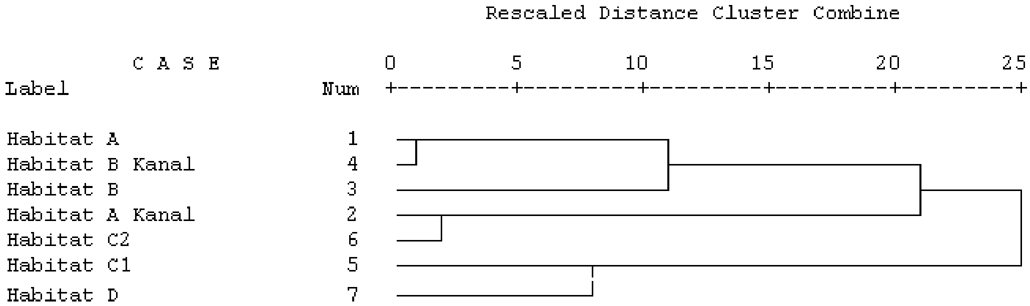

Figure 3. Cluster Analyses with juvenile fish in the habitats A-D (impoundment): Habitat A Kanal refers to Habitat A Channel and Habitat B Kanal refers to B Channel.

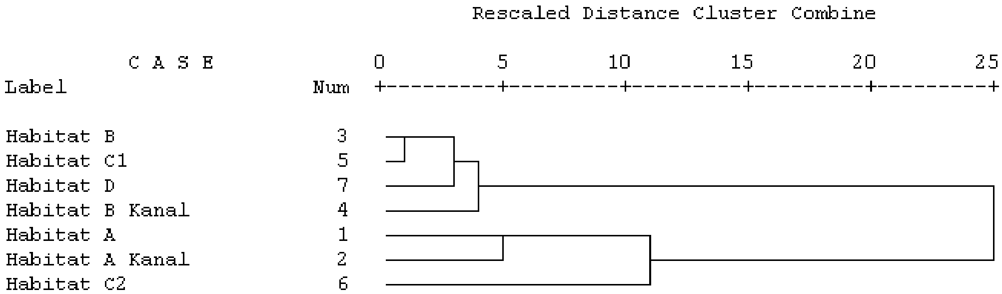

Figure 4. Cluster Analyses with juvenile fish in the habitats A-D (impoundment), calculated without eudominant and subrecedent fish data (defined by Tischler): Habitat A Kanal refers to Habitat A Channel and Habitat B Kanal refers to B Channel.

Table 1. Fish frequencies in the investigation area, Danube River, Vienna, Austria.

Species	Rheophilic Grade	Frequency
Barbus peloponnesius (Valenciennes, 1842)	Rheophile	1
Negobius syrman (Nordmann, 1840)	Rheophile	1
Barbatula barbatula (Linnaeus, 1758)	Rheophile	2
Carassius carassius (Linnaeus, 1758)	Stagnophil	2
Alburnoides bipunctatus (Bloch, 1782)	Rheophile	2
Abramis ballerus (Linnaeus, 1758)	Rheophile	2
Gobio gobio (Linnaeus, 1758)	Rheophile	3
Hucho hucho (Linnaeus, 1758)	Rheophile	3
Anguilla anguilla (Linnaeus, 1758)	Stagnophil	4
Lepomis gibbosus (Linnaeus, 1758)	Stagnophil	4
Silurus glanis (Linnaeus, 1758)	Eurytopic	4
Ctenopharyngodon idella (Valenciennes, 1844)	Stagnophil	5
Zingel streber (Siebold, 1863)	Rheophile	5
Ameiurus nebulosus (Lesueur, 1819)	Stagnophil	5
Abramis sapa (Pallas, 1814)	Rheophile	7
Oncorhynchus mykiss (Walbaum, 1792)	Rheophile	8
Salmo trutta forma fario (Linnaeus, 1758)	Rheophile	10
Carassius auratus (Linnaeus, 1758)	Eurytopic	11
Gobio kessleri (Dybowski, 1862)	Rheophile	12
Pelecus cultratus (Linnaeus, 1758)	Rheophile	13
Gymnocephalus cernuus (Linnaeus, 1758)	Eurytopic	24
Gobio albipinnatus (Lukash, 1933)	Rheophile	24
Gymnocephalus baloni (Holcik & Hensel, 1974)	Eurytopic	44
Scardinius erythrophthalmus (Linnaeus, 1758)	Stagnophil	55
Zingel zingel (Linnaeus, 1766)	Rheophile	69
Rhodeus sericeus (Pallas, 1776)	Stagnophil	77
Cobitis taenia (Linnaeus, 1758)	Rheophile	80
Cyprinus carpio (Linnaeus, 1758)	Eurytopic	88
Carassius gibelio (Bloch, 1782)	Eurytopic	94
Tinca tinca (Linnaeus, 1758)	Eurytopic	94
Sander lucioperca (Linnaeus, 1758)	Eurytopic	111
Neogobius melanostomus (Pallas, 1814)	Rheophile	138
Gymnocephalus schraetser (Linnaeus, 1758)	Rheophile	141
Rutilus pigus (La Cepède, 1803)	Rheophile	142
Lota lota (Linnaeus, 1758)	Eurytopic	179
Vimba vimba (Linnaeus, 1758)	Rheophile	220
Abramis brama (Linnaeus, 1758)	Eurytopic	261
Cottus gobio (Linnaeus, 1758)	Rheophile	285

continuação da Tabela 1

Species	Rheophilic Grade	Frequency
Blicca bjoerkna (Linnaeus, 1758)	Eurytopic	291
Esox lucius (Linnaeus, 1758)	Stagnophil	307
Neogobius kessleri (Günther, 1861)	Rheophile	387
Proterorhinus marmoratus (Pallas, 1814)	Eurytopic	402
Gasterosteus aculeatus (Linnaeus, 1758)	Stagnophil	513
Leuciscus leuciscus (Linnaeus, 1758)	Rheophile	513
Aspius aspius (Linnaeus, 1758)	Rheophile	606
Barbus barbus (Linnaeus, 1758)	Rheophile	746
Leuciscus idus (Linnaeus, 1758)	Rheophile	1062
Perca fluviatilis (Linnaeus, 1758)	Eurytopic	1218
Leuciscus cephalus (Linnaeus, 1758)	Rheophile	1542
Rutilus rutilus (Linnaeus, 1758)	Eurytopic	3259
Chondrostoma nasus (Linnaeus, 1758)	Rheophile	4151
Alburnus alburnus (Linnaeus, 1758)	Eurytopic	7453
Total		24680

Discussion

According to Zweimüller *et al.* (2000) 62 species were detected in the Austrian Danube river. The endemic species, e.g. **Danube Roach** (*Rutilus pigus virgo,* Heckel, 1852), Zingel (*Zingel zingel,* Linnaeus, 1766) or White Finned Gudgeon (*Gobio albipinnatus,* Lukash, 1933), belong to the group of 52 autochthonous species (Schiemer & Waidbacher, 1998).

The investigated habitats in the areaof the hydropower plant Freudenau show a high acceptance by the fish species which could be confirmed by all analysis. Juvenile and adult fish were caught in all habitats. Detailed analysis with the dominances after Tischler verify previous results.

The differentiated spectrum of species allows to deduce to a good co-housing. Species such as Acipenseridae could not be proved anymore. In this case it is worth mentioning Beluga (*Huso huso,* Linnaeus, 1758) and Ship Sturgeon (*Acipenser nudiventris,* Lovetzk, 1828). Instead alien species were confirmed as dominating group in some habitats.

The Catch Per Unit Effort (CPUE) values in figure 2 demonstrate that most fish were caught in the Transition Zone (Habitat B, D) and in the Head of Reservoir (Habitat I), because of good oxygenic conditions and reproduction spaces. Previous investigations confirm these results (Rezner, 2001).

Primarily euryoecious types dominate the spectrum regarding to the list of fish species (Table I) and its guild membership. Important factors like flow velocity, shore vegetation, water temperature, increased food supply, spawning grounds, reproduction spaces and shelters are crucial requirements for complete life cycles.

During the examination 36 species were registered in the Transition Zone and 41 fish species in the Head of Reservoir. Not only the Transition Zone is an important section, but also the impoundment with 39 fish species is worthy of mention. The reduction of flow velocity after the hydropower plant construction was decisive for a shift of guild membership. Instead of rheophilic guilds now euryoecius guilds are predominant. Especially the tributary formed habitats exhibit a high acceptance by euryoecius species. Those structures provide excellent food supply, biotopes and reproduction spaces.

The cluster analysis with juvenile fish in the habitats A-D (Impoundment) was important because of the high density of shore structures in this section (Figure 3). To prove stable populations the detection of juveniles is necessary. Partial cluster one shows similar characteristics regarding the structure of the habitats. These three habitats are tributary shaped. The channel structured habitats A Channel and C_2 define the second partial cluster. The partial cluster three can be summarized by low flow velocity because of the bay formed habitats.

The cluster analysis after Tischler dominances with juvenile fish in the habitats A-D (impoundment) can be verified by two partial clusters (Figure 4). Although habitat A Channel and B Channel feature similar conditions, they do not appear in the same partial cluster. Habitat B and B Channel are a unit and define with habitat C_1 and D the first partial cluster. The unit of Habitat A and A Channel with habitat C_2 form the partial cluster two. These units itself present a high variability in food supply and reproduction spaces.

Analysis of fish data with dominances after Tischler confirmed most of the previous results with binary data. Nevertheless it came to new conclusions. Adults and juveniles show similar habitat preferences. Mentionable is the fact that different shaped habitats are being frequented by juvenile fish in almost same numbers. This fact is explainable by predation.

The behavior of adult fish species depends on the abiotic factors and can be confirmed by the rheophilic grade. The river habitat connection is another important fact. The more accesses exist, the higher the habitat preferences by the adults are.

In principle, a high acceptance of the micro habitats (proved by dominance analysis after Tischler) has to be judged positively. Nevertheless the change of the current spectrum of fish species compared to the historical one clarifies the drastic interventions according to the habitats.

Although anthropogenically created habitats are only substitutes for natural habitats, nevertheless, these should be taken into consideration as an option in areas of heavy modified rivers.

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