DIPLOMARBEIT

Titel der Diplomarbeit

Stimuli for Spawning Migration of *Chondrostoma nasus* in a Danubian Tributary (Fischa) using Horizontal Hydroacoustic

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CONTENTS

1. ABSTRACT

The lower part of the River Fischa, a tributary of River Danube east of Vienna represents a important spawning habitat for several rheophilic fish species of the River Danube. Spawning migration starts at the end of February with species like pike (*Esox lucius*), followed by dace (*Leuciscus leuciscus*), nase (*Chondrostoma nasus*), barbel (*Barbus barbus*) and ide (*Leuciscus idus*) (Keckeis & Rakowitz, 2005).

In this thesis the spawning migration of the most abundant species, *Chondrostoma nasus*, was analysed. The first individuals of nase were recorded at 12th of March by the hydroacoustic method. Migration was characterised by a series of multiple peaks between mid March and beginning of May. A diurnal pattern in the spawning migration of nase with dusk and dawn as preferred migration time was also observed. The aim was to analyse the role of water temperature, water level, turbidity and solar radiation as a triggering factor for the migrating individuals. Focus laid on short term fluctuations of these abiotic variables.

Upstream migration of nase was most significantly correlated with a slight increase of water temperature in the confluence (> 0.5°C) within 1 day, a steep increase of water temperature at the spawning place (> 2.5°C) within 5 days and a decreasing water level in River Danube within 6 days. Fluctuations of the environmental factors, especially in the main river, represent relevant stimuli, which initiate and control the temporal pattern as well as the intensity of the spawning migration in nase. Fourier analysis revealed a clear diurnal pattern in the spawning migration of nase with dusk and dawn as preferred migration time.

2. INTRODUCTION

Behaviour is the outcome of internal and external cues that interact to stimulate a response (Lucas & Baras, 2001). Some species of fish show a special behaviour at the beginning of the spawning season, they migrate to the spawning sites. Despite substantial variation in the behaviour of individual fish of the same species general migration patterns may be observed, such as the tendency for upstream migration in spring and summer and downstream migration in autumn and winter (Lucas and Batley, 1996), as well as the aggregation of large numbers of fish in specific areas at certain times of the year (Duncan and Kubecka, 1996; Lucas et al., 1998b). It is very important that these migrating fish species can use their ways to the spawning places without any barriers.

Hence the loss of appropriate habitats and the interruption of fish migrations cause the decline of riverine fish populations, especially those of fluvial species which have to rely on intact connectivity to undertake spawning migrations into tributaries (Schiemer & Spindler, 1989; Schiemer & Waidbacher, 1992; Harris, 1995). Cyprinids are frequently the most numerous fish of middle and lower reaches of rivers, and play a key role in their ecology (Winfield & Townsend, 1991). One common example is Nase (*Chondrostoma nasus*), which lives in shoals in swiftly flowing streams and rivers throughout much of Europe (Lelek, 1987). It has dramatically declined in abundance and distribution during the last decade (Penaz, 1996). Where healthy populations occur the spawning migration involves a large numbers of fish and often occurs over long distances, some exceeding 100 km (Steinmann et al., 1937; Povz, 1988). In spring they migrate upriver and into tributaries to spawn (Keckeis, 2001). Large spawning migrations shoals as documented historically are rare today (Zbinden & Maier, 1996). The movement of fish within these systems is important in their life cycles and is likely to influence trophic interactions (Smith, 1991; Lucas et al., 1998a). A great amount of research has been carried out on the movements of cyprinids and migratory patterns, associated with spawning (Rodriguez-Ruiz & Granado-Lorencio, 1992; Penaz, 1996), feeding (Lelek, 1987; Liu & Yu, 1992) and refuge seeking (Huber & Kirchhofer, 1998).

The most obvious ontogenetic change in behaviour is related to spawning activity, which has a marked impact on the migratory behaviour of many fish species. The occurrence of migratory behaviour has a partial genetic basis in many freshwater-resident fish populations, although it is clear from various studies that the genetic ‘signal’ for migratory behaviour may be strongly influenced by environmental and developmental factors (Lucas & Baras, 2001).

The initiation of spawning is under control of an endogenous cycle of gonadal development and of an internal mechanism that synchronizes this cycle with environmental cues (Munro et al., 1990; Wootton, 1990). The direction, timing and extent of movements of fish within river systems may be influenced by a variety of variables including physical factors like temperature (Lucas and Batley, 1996; Slavik, 1996; Laine et al., 1998), flow (Baras, 1992; Jensen et al., 1998) and daylength (Lucas and Batley, 1996).

Among these relevant environmental factors, river flow is most frequently observed to control river entry and upstream migration of Atlantic salmon *Salmo salar* L. (Trèpanier et al., 1996). Jonsson (1991) suggested that a hierarchy of environmental factors initiates migration.

In the tilapia *Sarotherodon* (now *Oreochromis*) *aureus*, the initiation of spawning by increasing water temperature is followed by a rise in testosterone levels (Katz and Eckstein, 1974). In temperate or northern latitudes, the most frequently cited zeitgeber is photoperiod, but influences of temperature and/or water level have also been demonstrated (Wootton, 1982; Tomasson et al., 1984). Northcote (1969, 1998) proposed that temperature may act as a directional orientation cue, or function as threshold stimulus for initiating movement (Raymond, 1979), particularly in combination with other environmental stimuli such as discharge and photoperiod. Increased water level and increased water temperature have been demonstrated to be among the main factors which effect upstream spawning migration, especially in salmonids (Erkinaro et al., 1999; Jensen, 1998; Svendsen, 2004).

In temperate, lowland rivers the distribution and abundance of fish is not fixed in time, but is subject to seasonal and diel fluxes (Northcote, 1978; Lucas et al., 1998a,b). Furthermore the migration of many freshwater fish species has also been found to have a diel component (Lucas & Bately, 1996). Clough and Ladle (1997) showed that in summer adult dace (*Leuciscus leuciscus*) did not forage actively during day, moved shortly before dusk to riffle habitats, then homed at dawn to the same daytime site, where they occupied the same position in the shoal relative to other recognisable fish (Clough & Ladle, 1997). Similar cases of repeated homing behaviour day after day have been demonstrated for barbel (*Barbus barbus*) (Pelz & Kästle, 1989; Baras, 1992). Some individuals show remarkable constant departure times with respect to sunset and light intensity (Baras, 1992; 1995b).

In this study, migrating nase were monitored via a hydroacoustic online system. When starts migration of *C. nasus* in spring, how could this spawning run be characterized? What about temporal fluctuations? Maybe periodical or seasonal occurrence of spawning migration could be observed. Fluctuations of diurnal fish activity were also of interest. What about the number of migrating nase? Main topic was to analyse the influence of factors like water temperature, water gauge, turbidity and solar radiation on spawning migration of *Chondrostoma nasus*.

3. MATERIALS AND METHODS

3.1. Characteristics of the River Fischa and the Sampling Site

3.1.1. River Fischa

River Fischa is a tributary of River Danube east of Vienna, which has its source at an altitude of 229 m in the south of Lower Austria (Haschendorf/Ebenfurth) and flows north east for 35 km before joining the Danube at an altitude of 154 m (Figure 1). Together with its main tributary River Piesting, which rises at an altidude of 1200 m, the total catchment area is 549.4 km^2 with a pluvio-nival drain-regime (Mader et al., 1996). The mean annual discharge is about 7.51 m^3.sec^{-1}. Spring (March/April) and winter (November/ December) floods are common (Kresser, 1989). Water temperature rises normally not above 16°C during summer. Its hyporithral character changes into epi- and metapotamal approximately 4 km upstream the confluence with River Danube, the “transition area”, where discharge is mainly influenced by the water-gauge of River Danube. In spring several fish species undertake spawning migrations from the Danube into the River Fischa, these migration activities are composed of sequences of single species spawning events. Pike (*Esox lucius*) starts, followed by dace (*Leuciscus leuciscus*), nase (*Chondrostoma nasus*), barbel (*Barbus barbus*) and ide (*Leuciscus idus*) (Keckeis & Rakowitz, 2005). Two known spawning sites of Danube nase are located 4.5 km upstream the mouth, when River Fischa splits into several smaller branches creating a local floodplain area (figure 1). Two of these sidearms contain riffles with high current velocities and are frequented by the same individuals of nase between years during the spawning period (Keckeis, 1999; Keckeis & Rakowitz, 2006).

3.1.2. The Sampling Site

Hydroacoustic investigation was conducted at a site located 4 km upstream of the estuary with well suited cross sectional riverbed topography for fixed location horizontal beaming (figure 1). Its triangle cross-section with a gradually sloping right shore increases steeply on the left shore (Figure 3). At the site the river is 15m wide with a maximum depth of 2.15m according to water-gauge of River Danube. The bottom consists of gravel and has an even gradient with small obtrusions. Additional reasons for the suitability for hydroacoustic measurements are a site close to the spawning places with sufficient distance upstream of the mouth should guarantee investigation on the spawning migration of nase and minimise bias caused by other Danubian fish species migrating into the lower stretch above the mouth. Water level fluctuations during spring floods are less extensive than in the mouth which enables permanent recording without interruption due to disassemblage of the hydroacoustic setup.

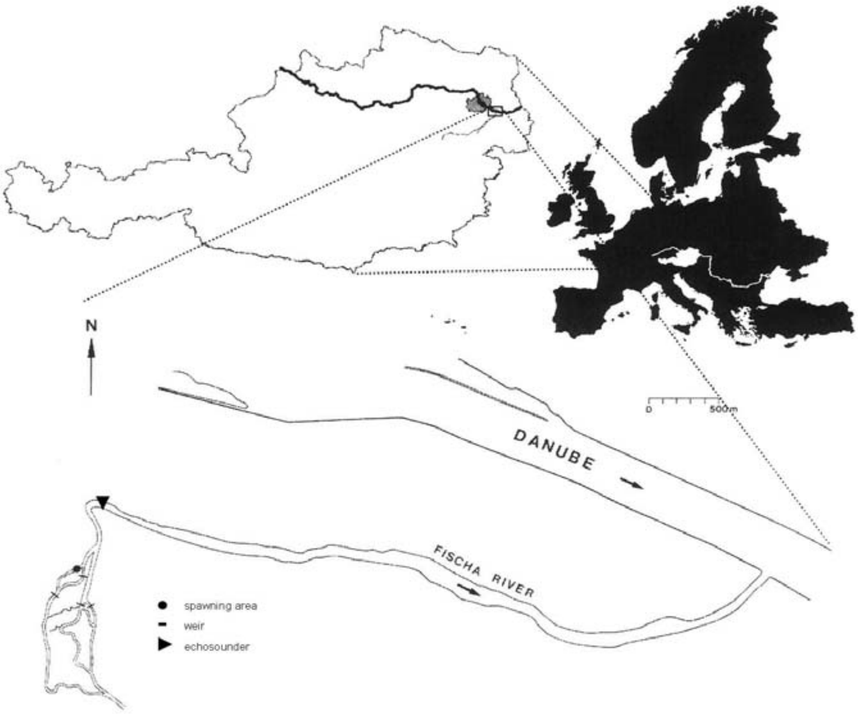
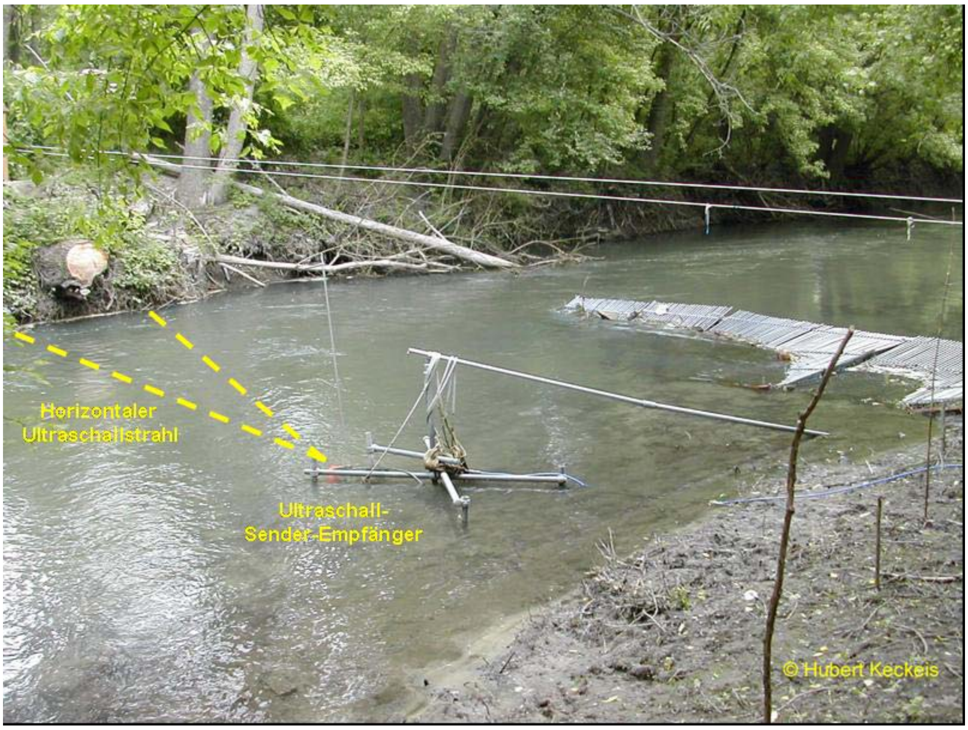


Fig. 1: The River Danube in Austria and the tributary River Fischa. The sampling site of the echosounder is indicated by a triangle.



Pic. 1: The sampling site, 4km upstream the mouth of River Fischa. The river bed has a triangular cross-section with a gradually sloping right shore, the left shore increases steeply.

Fig. 2: Cross-sectional view with bottom profile of River Fischa at the sampling site. Green lines show the supersonic beam. X-Axis represents River-width (m), Y-Axis the depth of the River (m).

3.2. Hydroacoustic Methodology

In 2005 from 12th of March till 3rd of May hydroacoustic data were collected with a portable 120 kHz digital echo sounder (Simrad, EK 60) and an elliptical (4.4° x 8.3°) splitbeam transducer (picture 2). The transducer was mounted on a tetrapod-scaffolding and adjusted horizontally across the river from the right shore towards the left shore using a dual-axis remote controlled rotator (Sub-Atlantic, 1128-MAS). A panel fence was placed downstream the transducer to guide upstream migrating fish out of the transducers nearfield and thus improve the detection rate of the echo sounder. For calibration purposes, a simple rope-ferry across the river combined with a fishing reel as a lifting device for the calibration sphere was constructed to place the sphere in any position at any range in the beam. Prior to continuous echo sounding beam mapping was conducted to adjust the horizontal beam as close to the bottom as possible in order to detect bottom oriented upstream migrating fish. Once properly oriented the echo sounder system was in situ calibrated using the tungsten-carbide standard calibration sphere (Ø = 23 mm) with a nominal target strength (TS) value of $TS = -40.4\ dB$ and kept stationary for the whole sampling period. In order to measure the sound propagation in the beam in absence of a hydrophone target strength measurements of the standard calibration sphere at different range and depth positions in the beam were carried out. This kind of soundfield measurement provided basic information about the sound propagation in the horizontal bottom aligned beam (Rakowitz & Kubecka, 2006). During monitoring sound pulses were transmitted in average with the duration of 0.1 ms, the power of 63 W, the pulse width of 0.064 ms, the bandwidth of 11.8 kHz and the pulse repetition rate of 10 pings/s^{-1}. The short range changes of the absorption coefficient dependent on changes in water temperature were neglectable. A 40 log R TVG (Time Varied Gain) function was used. The sensitivity threshold value of the detected echoes was set to -50 dB due to the level of the background noise. Low signal to noise ratio (2:1) due to horizontal beaming in a river requires less restrictive criteria for the echo sounders single echo detector to be applied than during vertical beaming. Therefore to increase the detectability in the horizontal bottom aligned beam the echo length detector was set to 0.8-1.5, the maximum phase deviation was set to 1.2 and the maximum gain compensation was enhanced to 6 dB (one-way) to accept echoes with off-axis positions out to the -6 dB beam. Signals were automatically compensated for off-axis distance. The echo sounder was in operation in average 23.55 h a day. Field tests, transducer cleaning and broken power supply occasionally interrupted the monitoring 12 times for some hours (figure 4).

date	**cause of interruption**	**time (hh:mm-hh:mm)**	**duration (hours)**
16.03.2005	cleaning	16:00-20:30	4,50
17.03.2005	cleaning	08:48-14:25	~5,75
19.03.2005	flood	20:17-24:00	~3,75
20.03.2005	flood	00:00-18:15	18,25
01.04.2005	calibration	12:43-17:55	~5
02.04.2005	calibration	09:48-14:18	~4,5
06.04.2005	system problems	16:57-22:32	~5,5
11.04.2005	damage	14:37-17:18	~2,75
13.04.2005	system problems	10:29-18:27	~8
23.04.2005	flow measurement	07:30-12:30	5,00
26.04.2005	flow measurement	07:45-11:32	~3,75
29.04.2005	damage	10:30-16:08	~5,5
03.05.2005	electro-fishing	08:41-18:50	~10

Tab. 1: Cause, time and duration of measurement-interruptions

Analog data from the transducer were digitalized in the echo sounders GPT unit (Simrad, ER 60), recorded on a laptop and stored on a hard disk. For this study 33 days of were analysed with Sonar5Pro post processing software (Balk, 2001). For the total number of upstream migrating nase the remaining 23 days respectively were interpolated by the mean of upstream migrants of the day before and the day after. After conversion of the raw data a newly developed cross-filter detector (Balk, 2001) was applied to improve fish detection and trace quality in the recordings. Upstream migrating fish in River Fischa were characterised by long traces with horizontally undulating shaped swim-pattern (figure 4).

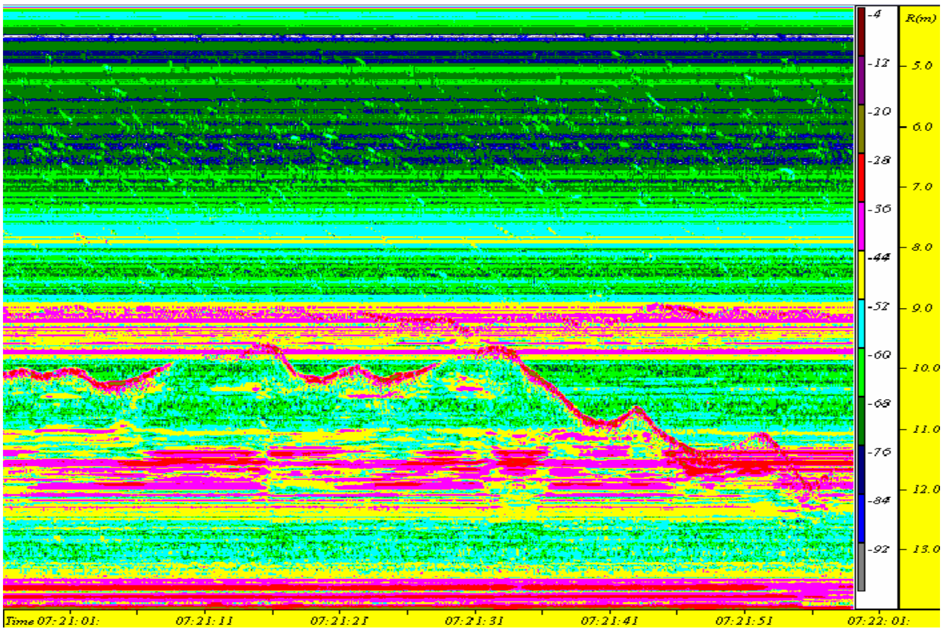


Fig. 3: Echogram showing a typical undulating swimming-pattern of an upstream moving fish. The abscissa represents daytime (hh:mm:ss), the ordinate describes distance from the shore (m).

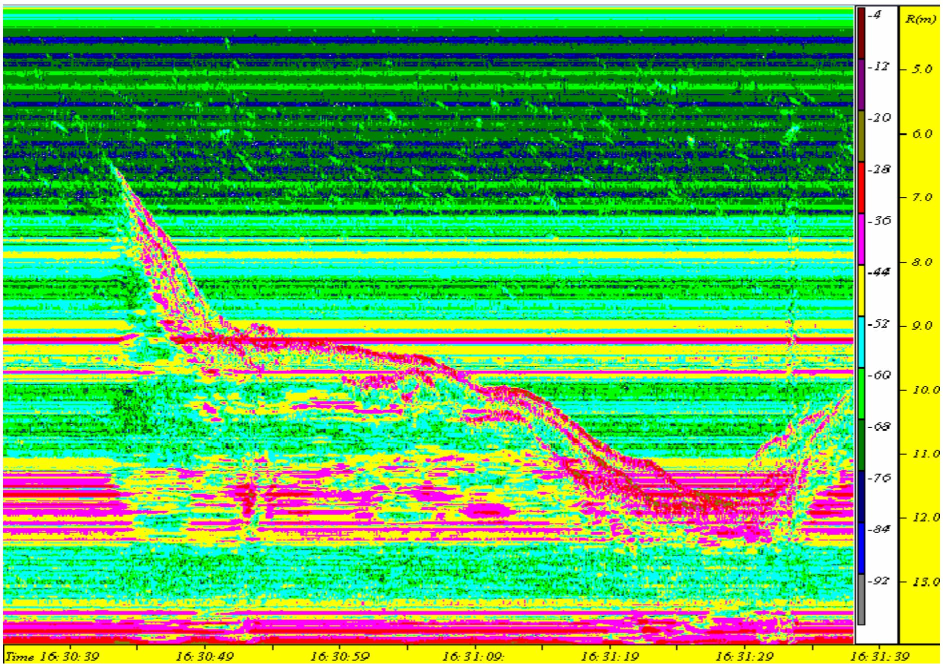
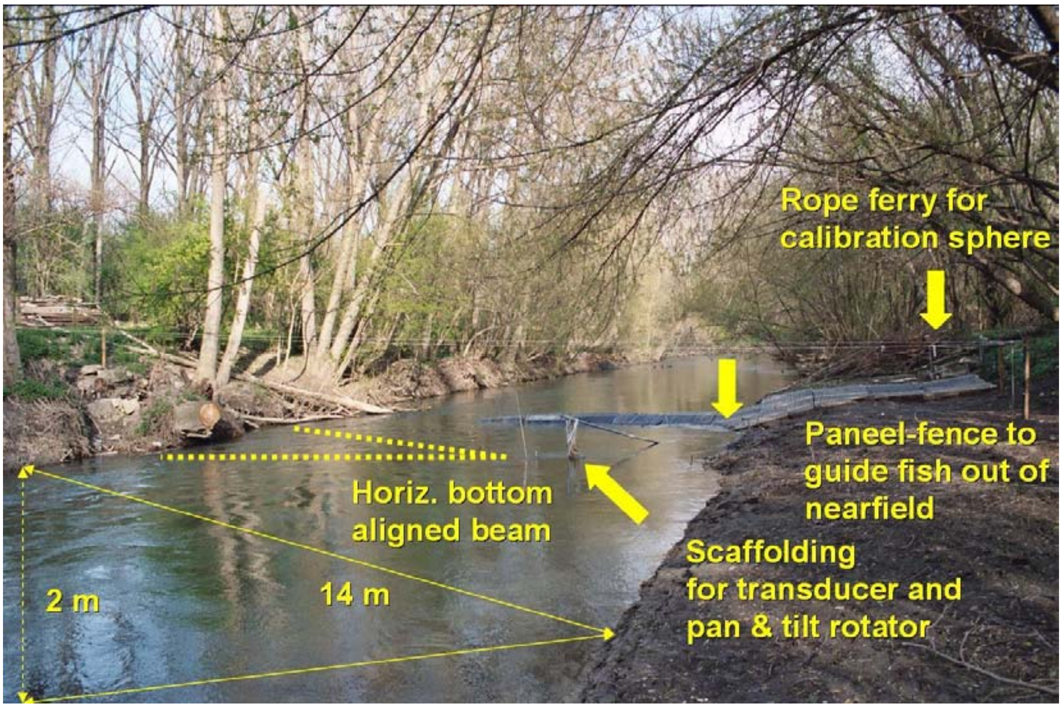


Fig. 4: Echogram showing a upstream migrating fish-trio. The abscissa represents daytime (hh:mm:ss), the ordinate describes distance from shore (m).

In order to get correct fish traces optimal choice of cross-filter parameters had to be tested. The cross-filter settings, which provided best results for tracking fish in River Fischa, were: foreground filter: height = 1/1, width = 1/1; background filter: height = 23/11, width = 7/13; Offset = +6/+6 dB. Minimum and maximum values for the track length were 1 to 250 pings and for the area 8 to 232 numbers of samples in a detected region. Automatic tracking caused sever bias mainly due to splitting the trace of one single fish into separated traces of several fish and including single echoes of the bottom or from background noise into the fish trace. Therefore, manual tracking was applied and tracked fish were stored in specific fish baskets for further statistical analysis. “Hydroacoustic nase” were separated from non-target species based on the length distribution of 80% of captured nase. The relationship between target strength (TS) and fish total length (TL) was $TS = 24.71 \times (\log_{10} \times TL) - 89.63$ (Frouzova, 2005). The hydroacoustic data enable size related separation of target fish from non-target fish in the [$TS_{nase} \leq -21.92\ dB\ and \geq -24.10\ dB$ corresponding to a total length of nase $TL_{nase} \geq 45\ cm\ and \leq 55\ cm$; $TS_{other\ species\ (excluded)} \geq -21.92\ dB\ and \leq -24.10\ dB$] in accordance with Romakkaniemi et al. and Lilja & Romakkaniemi (2000, 2003).

Pic. 2: Tetrapod-scaffolding with mounted elliptic splitbeam-transducer. The small picture shows the splitbeam-transducer which is connected with the rotator, the yellow arrows display possible movements of the rotator which sets the transducer.



Pic. 3: The sampling site in detail. In the back the panel-fence and the Rope-ferry for calibration, the Scaffolding with the Transducer in the centre of the picture.

Pic. 4: a) The calibration-sphere made of tungsten is used for in situ calibration of the supersonic beam, b) shows the GPT-Unit which digitalizes the analogue data from the transducer, c) downstream placed panel-fence guides upstream moving fish out of the transducers nearfield, d) shows the Rotator-Joystick to set the optimal Pan- and Tilt-Angle.

3.3. Environmental Parameters

During sampling period water temperature (°C), water-gauge (cm), turbidity (NTU) and global radiation (Joule cm^{-2} h^{-1}) were continuously measured. Three submerged temperature logger, one at the spawning place, one at the echosounder site and one in the confluence of River Fischa with River Danube measured the water temperature in intervals. Water level in River Fischa was red off at a water-gauge in the left spawning arm and at a water-gauge near the echo sounding site every day at the same time. Daily water level of River Danube were provided from the nearest installed water-gauge (WG) for routine environmental monitoring of the Austria Water Authority Via-Donau (WG Wildungsmauer in 2005). Turbidity was measured once a day via portable turbidimeter (Turbiquant 1000 IR) at the traps during sampling. Values of global radiation were taken from the nearest measuring station of the Austrian Central Meteorological Office (ZAMG).

Pic. 5: Water-gauge at the wooden bridge in Fischamend, between hydroacoustic and trap net sampling site after flood.

3.4. Statistical Analysis

Kolmogorov-Smirnov-Test (K-S-Test) was used to test the frequency distribution of daily upstream passage rate of nase (TL = 45-55 cm). Parametric Pearson correlations between daily passage rate of nase and environmental variables were calculated with time lags up to ± 7 days. The time series were differenced, $Y = X_t - X_{(t-1)}$, where X is the measured value at the point of time t to calculate them stationary. For each time lag the differences (one to seven days) were summed up. A correlation for a negative time lag indicates a relationship between the passage rate of nase and the alteration of environmental factors during that number of days anterior. A correlation for a positive time lag indicates a relationship between the passage rate of nase and the alteration of environmental factors during that number of days posterior. Variables with significant correlations were additionally used for multiple regression analysis in order to analyse the mode of the triggering.

Fourier analysis was applied on the mean hourly upstream passage rate of nase and the mean hourly global radiation to analyse diurnal migration patterns. Mean passage rate was transformed by square root transformation, period length T was 24 hours, time unit t_i was one hour. Scale of arc (W_i) was calculated according to the formula $W_i = \frac{2\pi}{T} \times t_i$ (1).

The general equation $y = c_0 + \sum_{j=1}^{\infty} \left[a_j \cdot \sin(j \cdot Wi) + b_j \cdot \cos(j \cdot Wi) \right]$ (2) was applied to calculate the oscillation of diurnal migration pattern of nase (in SPSS, version 12.01, Chicago, USA).

W_i: scale of arc (calculated with the formula: Wi = ($2\pi \times T^{-1}$) x t_i);

T: period-lenght (= 24 hours = 1 day);

t_i: time unit (=1 hour) within T;

j: number of periods (= frequency of oscillation = 1, 2, 3,…);

a_j, b_j, c_0: regression coefficients;

4. RESULTS

4.1. Abiotic

4.1.1. Temperature

During the investigation period water temperature at the spawning area ranged from 3.9 to 14.5°C. At the start of the sampling period the River Danube was 1-2°C colder than River Fischa, followed by a period of nearly same temperature levels in both Rivers and at the end of May the River Danube was approximately 2°C warmer than River Fischa.

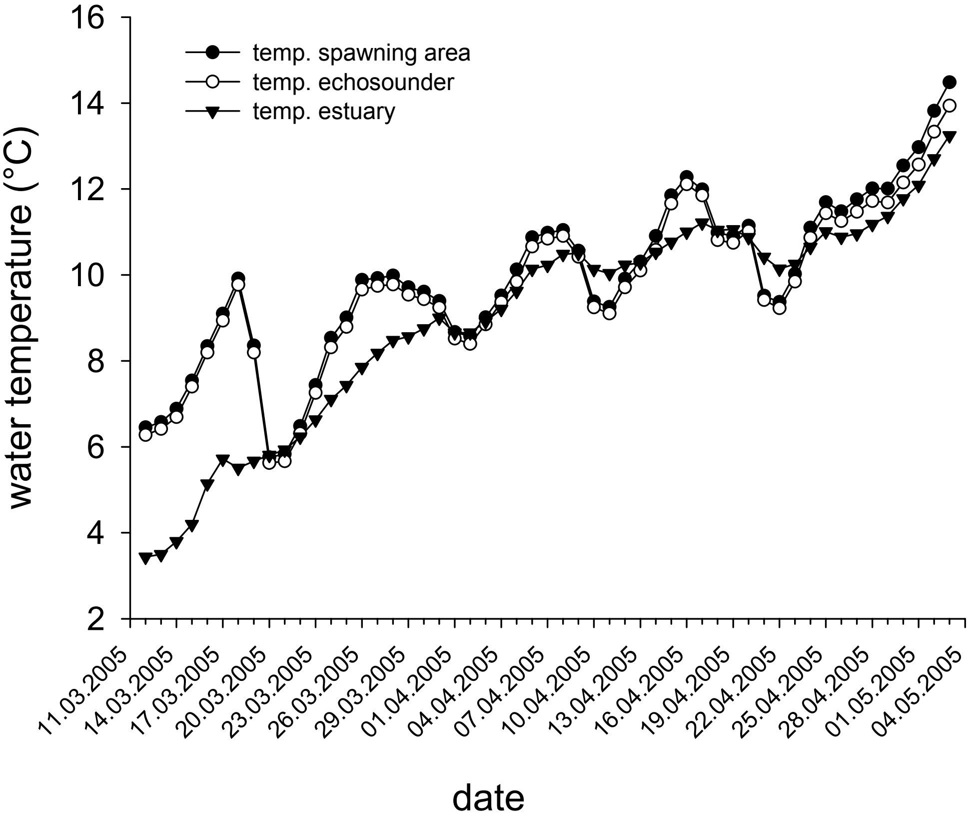


Fig. 5: Daily average water-temperature (°C) at three stations beginning on 12th of March and ending on 3rd of May in 2005.

4.1.2. Water-Gauge

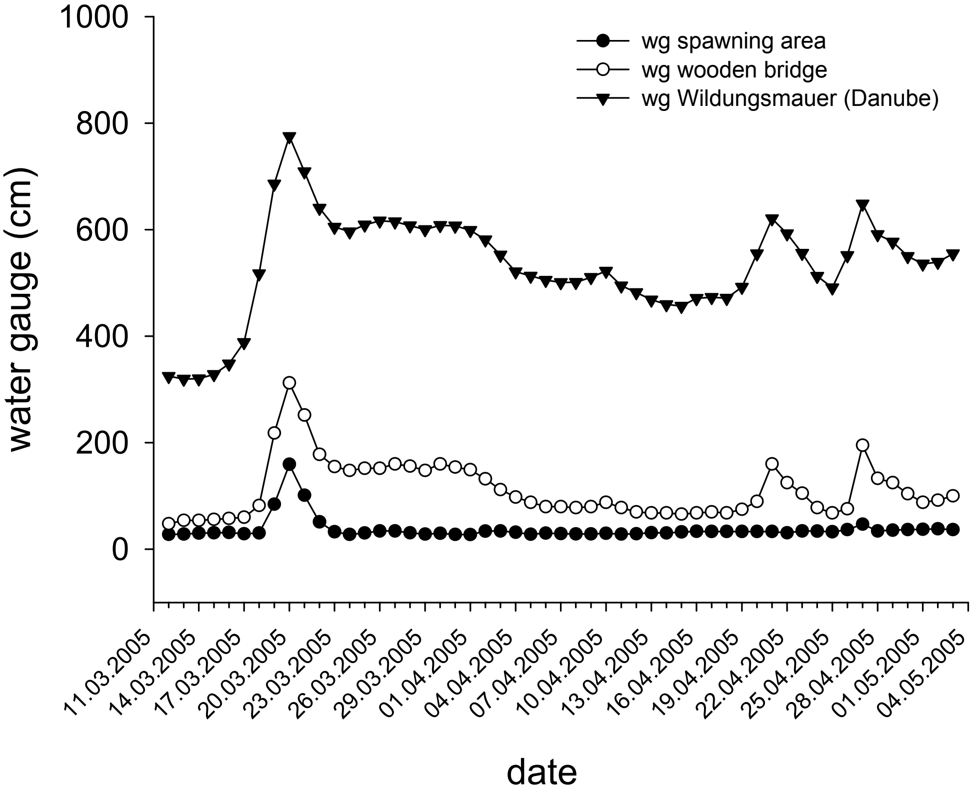


Fig. 6: Comparison of daily average water-gauge (cm) in the River Danube and the River Fischa, beginning on 12th of March and ending on 3rd of May in 2005.

Figure six shows water gauge changes at three sites (River Danube, spawning area – River Fischa, wooden bridge - River Fischa) during the investigation period. The water-level in the River Danube ranged from 319.8 cm to 775.1 cm. Three floods occurred, the maximum water-gauge of the first flood on 20th of March was recorded at 775.1 cm, the both other maximum values occurred on 21st and 27th of March (620.9 cm and 648.4 cm). Water-levels in River Fischa were generally lower and ranged from 27.5 cm (spawning area) to 312 cm (wooden bridge). The water levels of the River Danube and the station at the wooden bridge at River Fischa revealed a similar pattern of water level fluctuations resulting in a synchronised water-gauge (Spearman coefficient; r = 0.88, P < 0.001). This was not the case for the situation at the spawning site during the last but one flood peak.

4.1.3. Turbidity

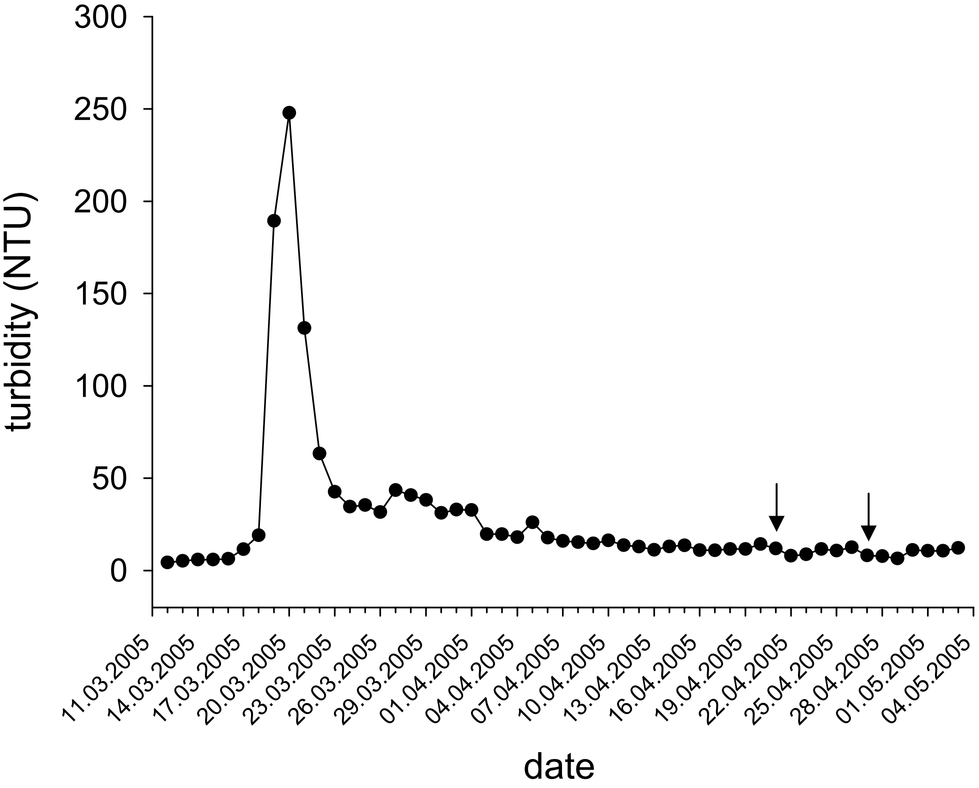


Fig. 7: Course of turbidity-values (NTU) beginning on 12th of March and ending on 3rd of May in 2005 of River Fischa.

Figure seven displays the course of turbidity values during the investigation period recorded for River Fischa. Turbidity-values ranged from 4.4 NTU on 12th of March to 247.8 NTU on 20th of March.

The peak on 20th of March was caused by a spring flood. The main flood peak of River Fischa led to a steep increase in turbidity of approximate 10 times of the average value. The two arrows, marking 21st and 27th of April show, that turbidity in River Fischa was barely influenced by the two floods in the Danube at the end of April.

4.1.4. Solar Radiation

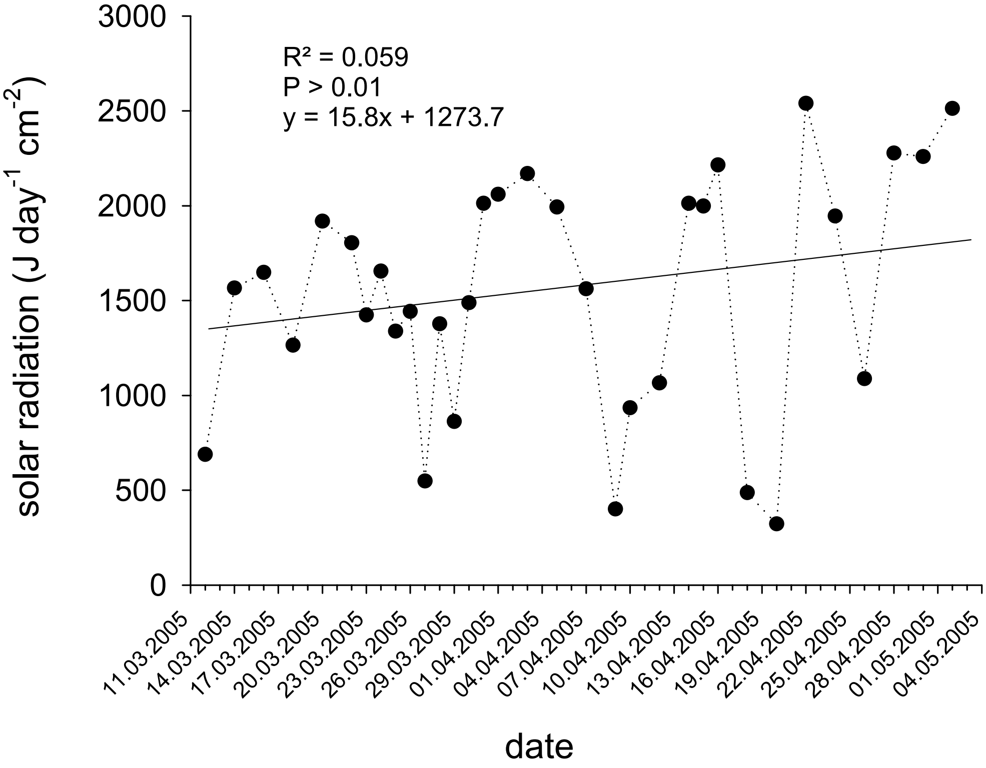


Fig. 8: Course of solar radiation during the investigation period beginning on 12th of March to 3rd of May in 2005.

According to a typical course for a central European spring-season mean solar radiation increased during the investigation period from 12th of March to 3rd of May which is shown in figure 8 by a regression line with a coefficient of determination (R²) of 0.059 and a non-significant P (>0.01). The values ranged from 322 on 20th of April to 2540 on 22nd of April (Joule $day^{-1}cm^{-2}$). Decreasing values are results of weather-changes when sunshine alternates with cloudiness, and vice versa.

The diurnal cycle of solar radiation is characterised by maximum values in the noon, minimum values at night. Mean daily values over the investigation period were combined with daytime (Fig. 9). The horizontal bar on top of the figure separates a cycle of 24 hours in night (black), dusk and dawn (grey) and day (white).

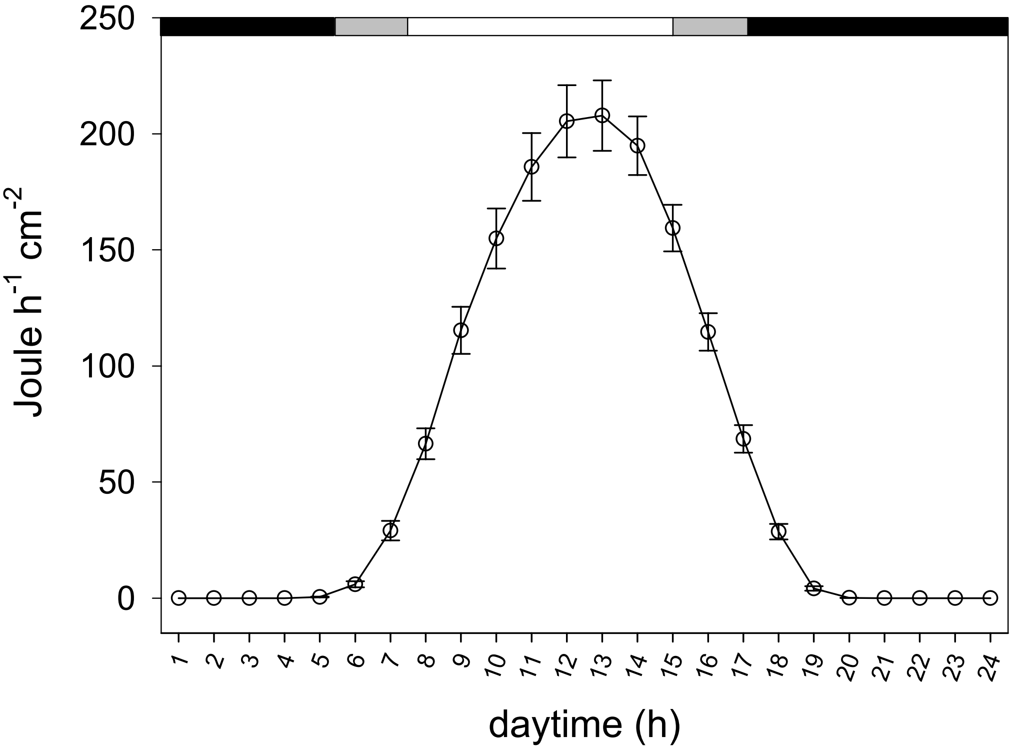


Fig. 9: The diurnal cycle of hourly average values for solar radiation (Joule $hour^{-1}cm^{-2}$) calculated from the investigation period within 12th of March and 3rd of May in 2005. The calculated mean standard error (S.E.M) is displayed by the error bars.

4.2. Biotic

4.2.1. Migration of nase

Daily spawning migration in nase was characterised by an oscillating pattern with several distinct peaks. The first individuals were recorded on 12th of March. The average passage rate was about 31 (±16) Ind. day^{-1}. Observed were three main peaks in nase spawning migration. The first immigration peak was on 16th of March (48 nase), the second on 26th of March (60 nase) and the third on 7th of April (81 nase).

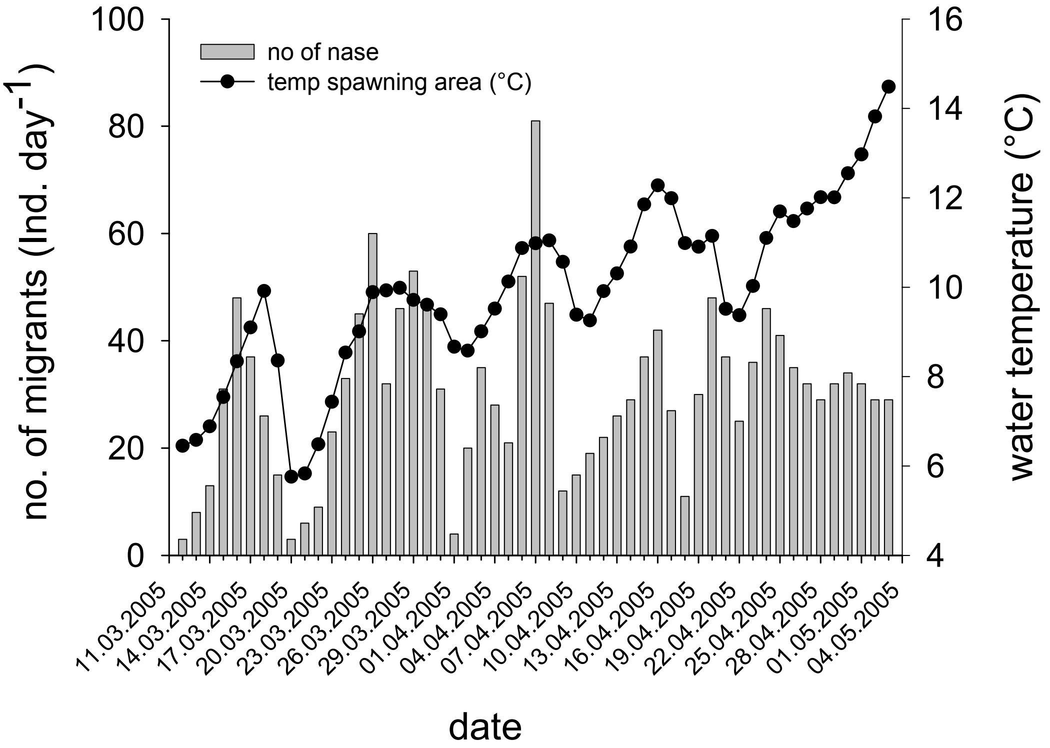


Fig. 10: Migration of nase from 12th of March till 3rd of May in 2005. The quantities nase per day (grey bars) are shown with water temperature at the spawning area.

4.2.2. Controlling factors

Table two shows Pearson Correlation coefficients between environmental factors and the number of migrating nase. TEMP_SPA = temperature at the spawning area, TEMP_ECHO = temperature at the echosounder site, TEMP_MOUTH = temperature at the mouth of river Fischa into Danube, WG_SPAREA = water-gauge at the spawning area, WG_ECHO = water-gauge at the echosounder site, WG_WILD = water-gauge at measuring point Wildungsmauer (Danube), TUR = turbidity.

Highly significant correlations between daily upstream passage rate and environmental parameters like water temperature except for the estuary (TEMP_MOUTH), water-gauge and turbidity were detected. The most significant correlations for the different parameters used for further analyses were yellow-marked.

TIME LAG	TEMP_SPA	TEMP_ECHO	TEMP_MOUTH	WG_SPAREA	WG_ECHO	WG_WILD	TUR
-1	0,327	.347(*)	-0,023	-0,081	-0,035	-0,006	-0,043
-2	.421(*)	.440(*)	0,022	-0,024	-0,121	-0,096	-0,081
-3	.475(**)	.480(**)	0,218	-0,122	-0,221	-0,222	-0,083
-4	.456(**)	.456(**)	-0,004	-0,269	-0,333	-0,341	-0,236
-5	.478(**)	.482(**)	0,060	-.387(*)	-.427(*)	-.408(*)	-.375(*)
-6	.416(*)	.417(*)	0,014	-.417(*)	-.474(**)	-.433(*)	-.482(**)
-7	0,226	0,222	-0,141	-0,342	-.377(*)	-.354(*)	-.414(*)
0	0.430(*)	0.438(*)	0,261	-0,292	-0,108	0,041	-0,259

*Tab. 2: Pearson Correlation coefficients environmental factors and the number of migrating nase. N = 33; **.Correlation - significance at level of 0.01 (2-sided), *.Correlations - significance at a level of 0.05 (2-sided).*

Temperature

For the spawning area and the echosounder site highest correlations between water temperature and the average daily number of migrating nase (no. of migrants (Ind. day^{-1})) were detected for an increasing water temperature with a time lag of -5 days.

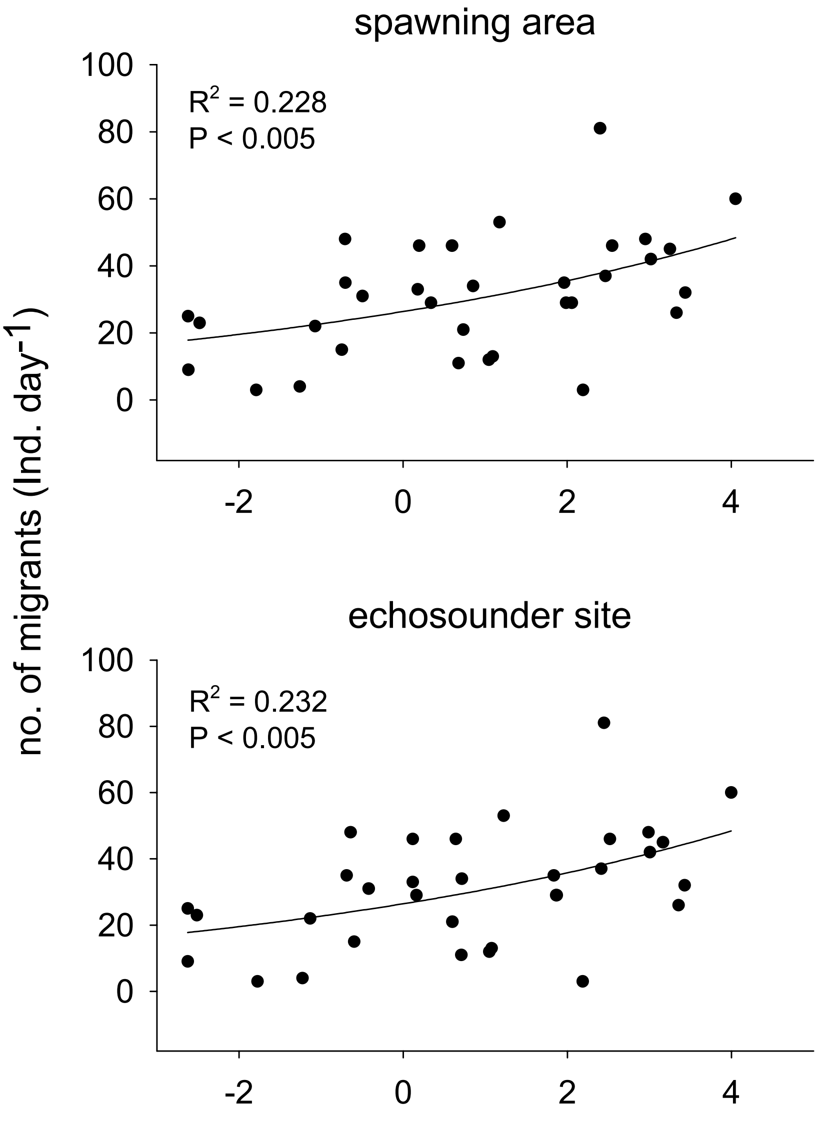


Fig. 11: Relationship between temperature change and the average number of daily migrants with a time lag of -5 days at the spawning area (R^2 = 0.228, $P < 0.005$) and the echosounder site (R^2 = 0.232, $P < 0.005$).

At the estuary of River Fischa into the Danube water temperature and the average daily number of migrating nase (no. of migrants (Ind. day^{-1})) showed no significant correlation with time lags from -1 to -7 days.

Water Gauge

A time lag of -6 days for a changing, decreasing water gauge (cm) and the average daily number of migrating nase (no. of migrants (Ind. day^{-1})) showed the highest correlations for all three sites, spawning area – River Fischa, echosounder site – River Fischa and Wildungsmauer – River Danube, were water gauge was measured (Fig. 12a - c).

At the spawning area the first high correlation between changing water gauge and the migrants could be observed at a time lag of -5 days (R^2 = 0.15, $P < 0.05$). A time lag of -6 days (Fig. 12a) showed highest correlation (R^2 = 0.17, $P < 0.05$). The highest variability of no. of migrants could be observed at marginal changes in water gauge.

The echosounder site showed the second highest correlation at a time lag of -5 days (R^2 = 0.18, $P < 0.05$), the highest correlation (Fig. 12b) showed the calculation for a -6 days time lag (R^2 = 0.23, $P < 0.01$). After a decreasing water gauge over seven days also high significance could be observed (R^2 = 0.14, $P < 0.05$).

The result of the time lag model for the water gauge measuring Point at Wildungsmauer-Danube (Fig. 12c) was, that the highest correlation between changing, decreasing water gauge and mean daily values of migrants into River Fischa occurred after a decreasing water gauge over six days (R^2 = 0.19, $P < 0.05$). The time lag models for -5 (R^2 = 0.17, $P < 0.05$) and -7 days (R^2 = 0.17, $P = 0.05$) showed also high significance between the observed parameters (Tab. 2).

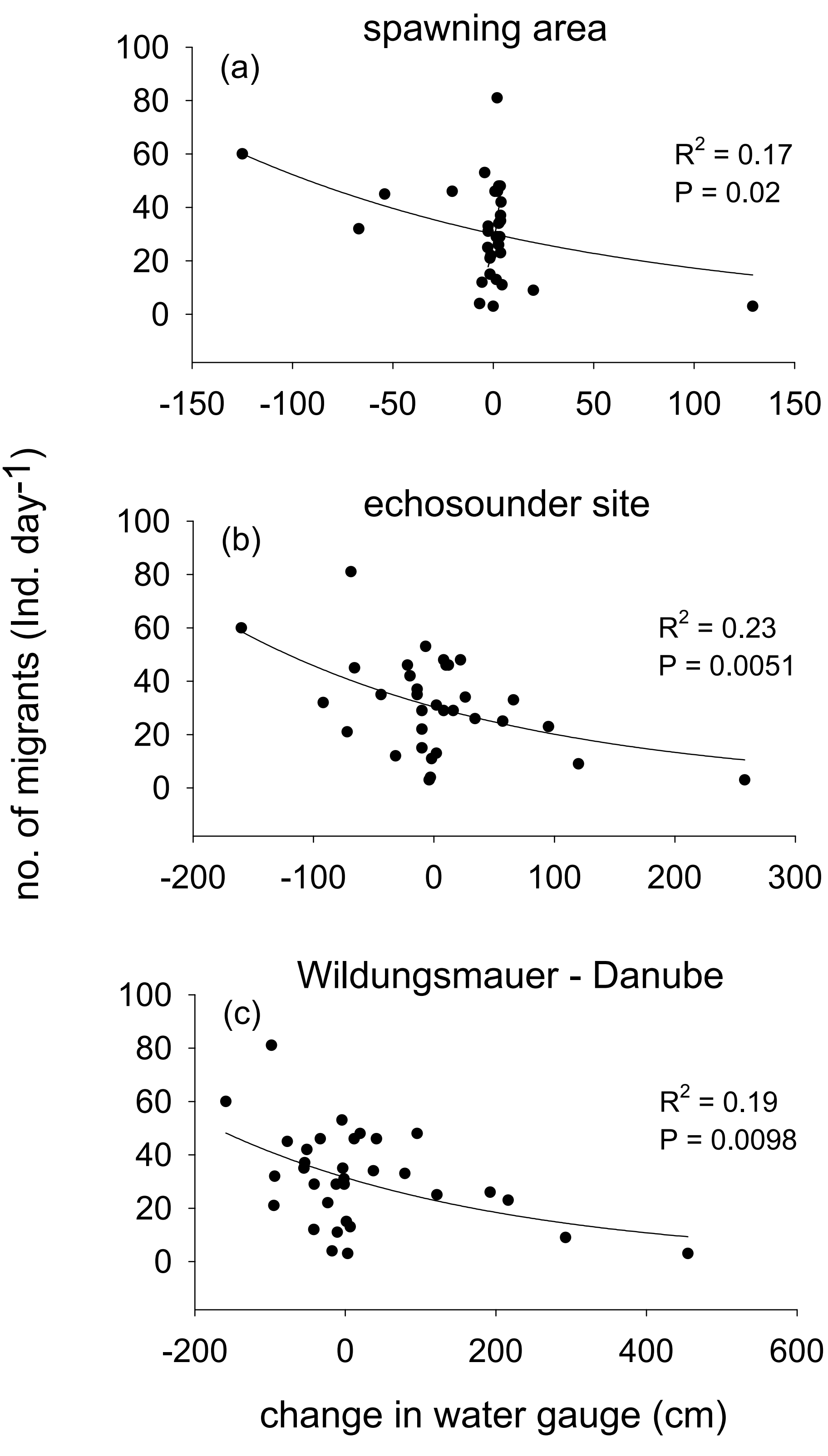


Fig. 12: Relationship between changing water-gauge with a time lag of -6 days and the average daily number of migrants at (a) the spawning area, (b) the echosounder site and (c) the Danube.

Turbidity

Decreasing turbidity in River Fischa with a time lag of -6 days ($R^2 = 0.23$, $P < 0.01$), mainly caused by decreasing water level, showed the most significant correlation with the number of migrants (Ind. day^{-1}). The highest variability of no. of migrants could be observed at marginal changes in turbidity dependent on water gauge.

Time lags of -5 ($R^2 = 0.14$, $P < 0.05$) and -7 days ($R^2 = 0.17$, $P = 0.05$) showed also significance between changing turbidity and the average daily number of migrating nase (Tab. 2).

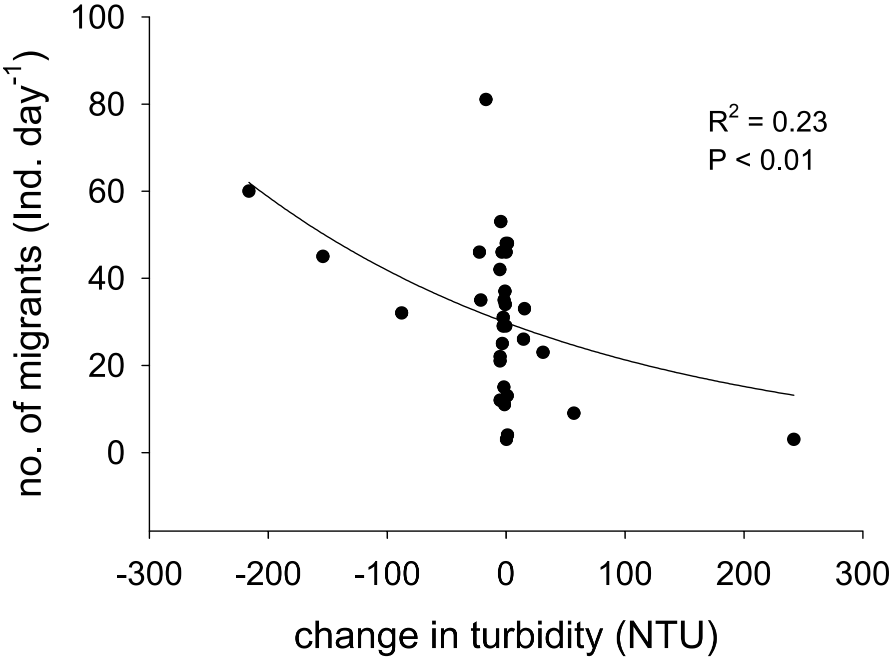


Fig. 13: Relationship between changing turbidity with a time lag of -6 days and the daily average number of migrants.

4.2.3. Diurnal activity

The Fourier-Analysis was performed to predict the mean passage rate (Indiv. h^{-1}) for the course of the day in relation to mean daily solar radiation (dashed line in Fig. 14).

The bar on the top of figure 14 displays the night (black), dusk and dawn (grey) and day (white).

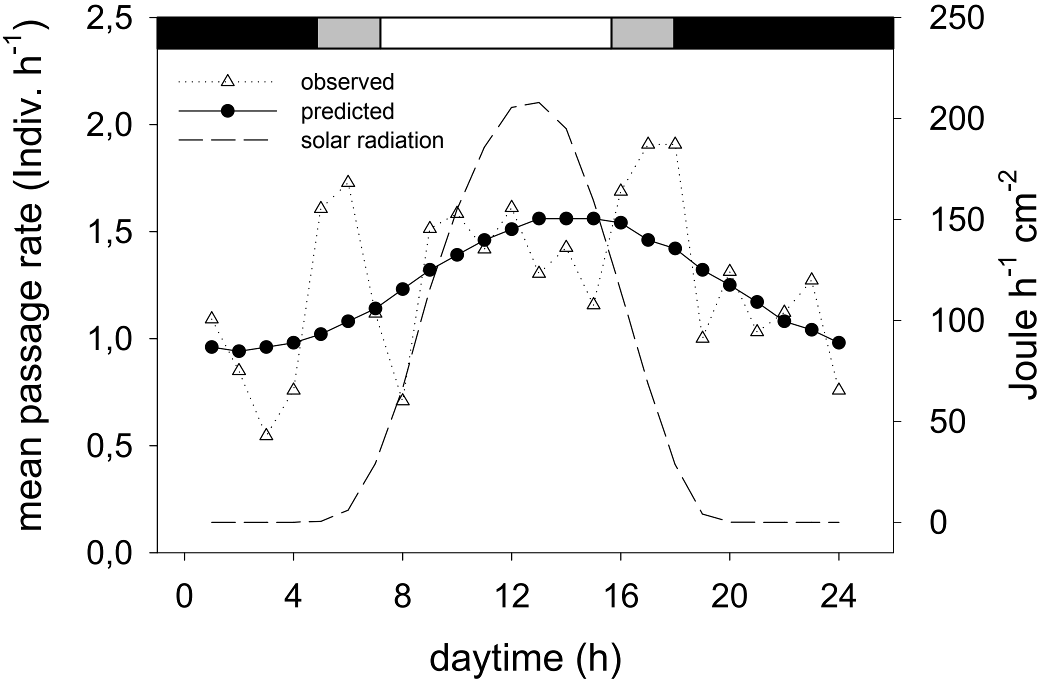


Fig. 14: Daily cycle of predicted passage rate (solid line with black dots), shown with mean daily solar radiation (Joule h^{-1} cm^{-2}) and the cycle of the observed values (dotted line) for mean passage rate (Indiv. h^{-1}).

The model`s ground oscillation predicted an increase of mean passage rate from midnight to noon, a decrease from noon to midnight and the highest migration abundance for the noon during highest solar radiation.

The observed migration activity cycle showed a diurnal pattern with highest migration abundances for dusk and dawn.

Migration increased in the dawn at 03:00 p.m. to its first peak at 06:00 p.m., decreased till 08:00 p.m. and increased to a mean passage rate value about 1.5 during noon again, the second peak. Dusk started at 15:00 a.m. with an increase of the mean passage rate to a maximum level about 1.8 at 17:00 a.m.. After sunset migration activity decreased to a value about 1.0. During the night mean passage rate was characterized by an up and down pattern which ended with a decrease in activity during 01:00 a.m. and dawn, starting at 03:00 a.m.. Observed and predicted values correlate significant (Pearson-Correlation; $R^2 = 0.323$, $P < 0.01$ two-sided).

5. DISCUSSION

Changes in water temperature, water gauge and turbidity within short periods and a daily cycle dependent on solar radiation were the main environmental cues for the spawning migration of Danube nase to initiate and conduct with spawning migration into the River Fischa.

The investigated migration period in 2005 was characterized by three main migration peaks. An important factor for the initiation of the spawning migration of nase was an increase of the water temperature within over a period of five days. Similar results were documented after observations at the beginning of the 20th decade. Keckeis (2001) documented high abundances of rheophilic nase at the spawning places in River Fischa when the water temperature increased within four to five days from 7,5°C to 11,5°C, 9°C to 13°C and from 10°C to 14°C. The preferred thermal optimum for spawning nase was reported to range from 8° to 12°C (Penaz et al., 1984). An increase of water temperature had the most significant effect on the spawning run of cyprinids was also shown in the fish migration study of Hladik & Kubecka (2003). They studied fish migration in the tributary zone of the Rimov Reservoir (CZ). Weather changes were responsible for interruption of the spawning migration of nase. Fish activity declined with a two days time lag from the maximum fish abundance to nearly zero as a consequence of a cold weather period (Hladik & Kubecka, 2004).

During the investigation of upstream migrating cyprinids and percids in the Äijälänsalmi channel Lilja et al. (2003) observed that an increase of water temperature about +4.5°C was associated with the largest catch per unit effort. Water temperature could also be identified as an important environmental factor for upstream migration and migration speed of cyprinids in the Guadalete River in Spain (Rodriguez-Ruiz & Granado-Lorencio, 1992). The following citation shows that this phenomenon was also observed 70 years ago. Conclusions after mark-recapture experiments in the River Danube, River Rhine and its tributaries in Austria, Germany and Switzerland within 1923 and 1934 (Steinmann et al., 1937) were that migration of cyprinids was mainly influenced by increasing water temperature and decreased considerably during cold weather periods.

The second important stimulus for spawning migration of *Chondrostoma nasus* in this study was a change in water gauge. The time series analysis showed that a decrease of the water level stimulated nase to migrate upstream from River Danube to the spawning areas in its tributary River Fischa. A time lag of six days was observed. Flow conditions directly after flood peaks were preferred because an optimal water gauge guaranteed the reachability of the spawning sites which is a requirement for spawning.

High water flow was detected by several authors (Northcote, 1984; Hawkins & Smith, 1986) to stimulate upstream movement of many temperate fish, especially salmonids. During the spawning season in the backwaters of the River Rhine most of migrating roach (R*utilus rutilus*) were caught during a decrease of water gauge immediately after flood events but another cyprinid fish, white bream (*Abramis bjoerkna*) preferred an increasing water gauge (Molls, 1999). A study on Atlantic salmon (*Salmo salar*) showed that this species avoided the maximum flow rates by a delay in peak migration (Lilja & Romakkaniemi, 2003). Upstream migration of roach (*Rutilus rutilus*) started in early May during medium or falling water levels (Vollestad, 1987). In the River Garonne a decrease in water flow corresponded with an increase in passages and vice versa for the passage rate of Allice shad (*Alosa alosa*). The high water gauge acted as an inhibitor on the shad migration (Bellariva & Belaud, 1998).

To summarize, as described in the citations above, most fish species started with spawning migration after flood or high water periods. In accordance with these facts, the exact analyses of this study based on daily water level fluctuations, shows that the period after a flood peak seems to be an optimal point in time for migrating upstream. One explanation is that the water level is still high enough to overcome obstacles and to reach appropriate spawning habitats and it might be less energy demanding to get there (Rakowitz et al, 2008).

The third relevant environmental factor was turbidity, which is change was closely correlated with water level fluctuations. High significance between the number of migrants per day and a decreasing turbidity was found. Nase seemed neither to prefer very high turbidity, as usual during flood events, nor very clear water conditions for their spawning migration (Rakowitz et al, 2008).

A Fourier model was calculated which shows a diurnal pattern thus Nase in river Fischa preferred dawn, noon and dusk for spawning migration. A diel component in movements of nase off the spawning season was analysed by other authors, but so far it was not described for the spawning migration of nase itself (Rakowitz et al., 2008).

For nase was found that furthest distances were covered during dusk and dawn (Huber & Kirchhofer, 1998). Diel movements are the expression of circadian rhythms synchronised by marked variations of light intensity at sunrise or sunset or the adaptive response to particular light levels with associated foraging benefits or predator risks (Lucas & Baras 2001). There is evidence that fish adapt their diel patterns to light level e.g. during overcast weather or the lunar cycle (Baras et al., 1998; Baras & Nindaba, 1999a, Mason, 1975).

Rakowitz et al (2008) mentioned that the preference for dusk and dawn although flow and turbidity conditions differed much between consecutive years 2004 and 2005. Why preferred nase dusk, noon and dawn for migration activity? Especially the high activity about noon was interesting, maybe a high turbidity level correlated with decreasing floods and so nase felt more secure during the day, using turbid water as coverage to minimise predator risks which is also another aspect for the peaks in migration activity during dusk and dawn.

Adult Atlantic salmon (*Salmo salar*), tend to migrate in rivers at night, often enter estuaries and migrate upstream during daytime in turbid water, frequently associated with high flows (Hellawell et al., 1974; Potter, 1988).

I conclude that spawning migration during twilight or increased turbidity minimises the risk of being preyed upon by visual predators like pike or catfish, especially when moving to shallow tributaries. Hence a proper migration time increases energetic efficiency for the energy demanding spawning run over many kilometres and for the stay in high currents at the spawning place, which can last for several weeks (Keckeis, 2001).

An optimal stimulus for the spawning migration in nase is reduced to a combination of only two variables, namely a slight increase of water temperature in the main habitat River Danube, synchronized with a steep increase of water temperature at the spawning site in the tributary, in combination with falling water level after flood peaks. During spawning season the warmer water of the tributary causes a small constant temperature difference between the confluence and the River Danube and might also act as a stimulus to maintain spawning migration into the tributary (Rakowitz et al, 2008).

The conclusion of this study is, that an increase of water temperature combined with a decreasing water gauge with certain time lags are the stimuli for nase to start with the migration to the spawning sites.

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7. ZUSAMMENFASSUNG (DEUTSCH)

Der Unterlauf der Fischa, ein Nebenfluss der Donau östlich von Wien, stellt für viele Fischarten der Donau ein wichtiges Gewässer für die Reproduktion dar. Die Einwanderung der laichreifen Fische beginnt Ende Februar. Der erste Einwanderer ist der Hecht (*Esox lucius*), gefolgt von Hasel (*Leuciscus leuciscus*), Nase (*Chondrostoma nasus*), Barbe (*Barbus barbus*) und Nerfling (*Leuciscus idus*) (Keckeis & Rakowitz, 2005). In der vorliegenden Arbeit wurde die Laichwanderung der Nase (*Chondrostoma nasus*) in die Fischa hydroakustisch untersucht. Die ersten Individuen konnten am 12. März 2005 erfasst werden. Die gesamte Wanderungsperiode war von mehreren Aktivitätsspitzen geprägt, besonders in der zweiten und dritten Märzwoche (16.3., 26.3.). Zwar konnte man danach immer wieder stärkere Wanderaktivität beobachten, diese fiel aber gegen Anfang Mai hin immer schwächer aus.

Hauptaugenmerk wurde bei der Untersuchung auf die Zusammenhänge der Einwanderungsraten von *Chondrostoma nasus* mit den abiotischen Faktoren Wassertemperatur, Wasserstand, Trübe sowie Sonneneinstrahlung/Lichtstärke gelegt. Die Einwanderung der Nasen korrelierte am höchsten mit schwach ansteigender Temperatur im Mündungsbereich (> 0.5°C) innerhalb eines Tages, mit starker Erwärmung am Laichplatz (> 2.5°C) innerhalb von fünf Tagen und einem fallenden Wasserspiegel der Donau innerhalb von sechs Tagen. Mittels der Fourier-Analyse konnte ein deutlich diurnales Muster der Nasen-Laichwanderung festgestellt werden, wobei die Morgen- sowie die Abenddämmerung

bevorzugt wird. Schwankungen der abiotischen Faktoren (Temperaturanstieg, fallender Wasserstand), besonders in der Fischa, stimulieren die Wanderung von *Chondrostoma nasus*, was sowohl das zeitliche Muster sowie die Intensität der Einwanderung prägt.

8. FIGURES

9. PICTURES

10. TABLES

11. ACKNOWLEDGEMENTS

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Jagenbach, January 2009

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Professional Career

Since 1999	**Fishery Inspector and Fishing Guide** at the Kamp Reservoirs, Windhag´sche Stipendienstiftung, Forstamt Ottenstein
Since 2006	**Fishing basic course instructor** for pupils (6 to 18 years, partly handicapped kids), Windhag´sche Stipendienstiftung, Forstamt Ottenstein
Since 2007	**Course Instructor** at “Experiment Wasserstraße” for pupils; education in basics of water chemistry and life in the water; Windhag´sche Stipendienstiftung, Forstamt Ottenstein
Since 2004	**Journalist for sports and culture** at a regional press, NÖN Zwettl
2006 – 2008	Employe at **“Flussbauliches Gesamtprojekt“**, Hydroacoustics with Mag. Georg Rakowitz, University of Vienna
2005 – 2006	Employe at **“FIDON”**, University of Vienna; Hydroacoustic data analysis, electro fishing, trap net fishing; basis for diploma thesis;

Since 2005	Employe at diverse **national fish ecological surveys** (LIFE Project, Spittelauer Arm 2005/06,…)

Educational Career

1986 – 1990	**Primary School**, Zwettl (Lower Austria)
1990 – 1998	**Grammar School**, Zwettl (Lower Austria) Science Sector including Chemistry, Physics and Biology
1998 – 2000	**Study of Jazz Trumpet** (incomplete), Jazz Conservatory Vienna
1999 – 2001	**Study of Veterinary Medicine** (incomplete), Veterinary University of Vienna
2000 – 2008	**Study of Biology**, University of Vienna Special field: Fish Ecology, especially Hydroacoustics, Fish Anatomy

Hobbies

- Sport Fishing
- Aquaristics
- Photography
- Travelling
- Musician (trumpet) at the “Zwettler Big Band Formation”, the “Zwettler Junior Big Band” and some other ensembles.
- Sports (Skiing, Hiking, Icehockey)

Jagenbach, January 2009

Bernhard Berger