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Influence of diurnal behaviour rhythms and water-level fluctuations on the migratory activities of fish in a backwater of the River Danube: a hydroacoustic study

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Abstract − This paper reports the results from three fixed-location acoustic surveys carried out in August and September 1996 to analyse the influence of diurnal behaviour rhythms and water-level fluctuations on the migratory activities of fish in the mouth of the Regelsbrunn-arm east of Vienna, Austria. A BioSonics 105 dual-beam echosounder (420 kHz), with a circular transducer (6°/15°) beaming nearly horizontal across the arm was used, with acoustic ranges of between 20 and 30 m. All surveys were conducted during day and night. The fish density was highest during the first observation period with low water level, lowest during the second sampling period with increasing water level, and intermediate during the third period with decreasing water level. The fish density was always higher during night than during day. Diurnal behaviour rhythms influenced the fish density as well as the size-frequency distribution. Increasing or decreasing water-gauge superposed the influence of diurnal behaviour rhythms on the size-frequency distribution for immigrating fish of certain length classes. Fish within the length group 10–15 cm tended to migrate upstream during decreasing water-gauge. Fish above 400 mm total length tended to move upstream during increasing water-gauge. © 2000 Ifremer/CNRS/INRA/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS

hydroacoustics / fixed-location survey / Danube / fish migration

Résumé − Influence des rythmes de comportement diurnes et des fluctuations de niveau de l'eau sur les activités migratoires des poissons d'un bras du Danube : étude hydroacoustique. Cette étude présente les résultats de 3 campagnes acoustiques effectuées au moyen d'un sondeur fixe à double faisceau, en août et septembre 1996 pour analyser l'influence des rythmes de comportement diurne et les fluctuations du niveau de l'eau sur les activités migratoires des poissons dans l'embouchure du bras de Regelsbrunns, à l'est de Vienne, en Autriche. Un échosondeur à double faisceau annulaire ('dual beam') Biosonics 10 (420 kHz) doté d'un transducteur circulaire (6°/15°) a été utilisé horizontalement pour obtenir une portée acoustique de 20 à 30 m. Toutes les campagnes ont été conduites à la fois de jour et de nuit. La densité des poissons était supérieure durant la 1re période d'observation avec un faible niveau de l'eau, la plus basse densité lors de la 2e période d'échantillonnage lors de l'augmentation du niveau de l'eau et intermédiaire lors de la baisse du niveau. La densité de poissons a toujours été plus élevée durant la nuit que durant le jour. Des rythmes de comportement diurne influencent la densité des poissons aussi bien que la répartition en taille. L'augmentation ou la baisse du niveau de l'eau se superpose à l'influence des rythmes de comportement sur la distribution de fréquences de tailles de poissons migrants de certaines classes de taille. Des poissons compris entre 10 et 15 cm ont tendance à migrer vers l'amont durant la baisse de niveau. Des poissons de tailles supérieures à 40 cm ont tendance à migrer vers l'amont mais lors de l'augmentation du niveau. © 2000 Ifremer/CNRS/INRA/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS

hydroacoustique / système acoustique fixe / Danube / migration des poissons

1. INTRODUCTION

Backwaters are an important habitat for the riverine fish fauna. High hydrological dynamics and connectivity with the main channel are characteristic for open arms such as the Regelsbrunn-arm (Schiemer, 1994). It is located within the southern parts of the floodplains of the 'Donauauen' national park east of Vienna,

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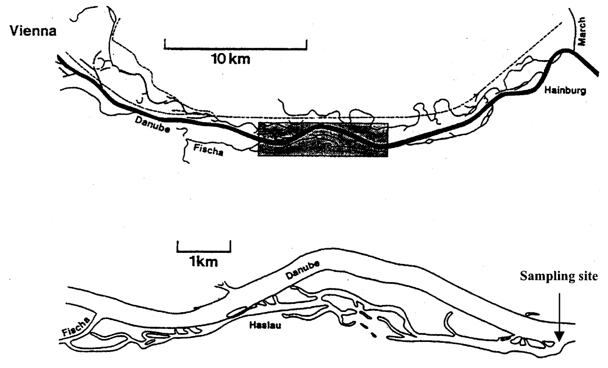

Figure 1. Map of the River Danube east of Vienna and the Regelsbrunn-arm with the location of the sampling site.

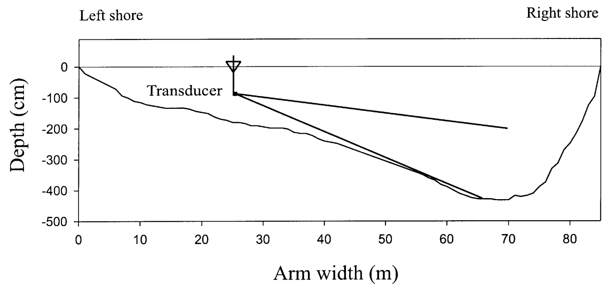

Figure 2. The cross-section of the Regelsbrunn-arm shows the fixed position of the transducer with its bottom-oriented, horizontal sound beam.

Austria (*figure 1*). Various water-level fluctuations during the year enable seasonal habitat changes and fish migrations. Many species such as nase, *Chondrostoma nasus*, and bream, *Abramis ballerus*, use the arm as a feeding habitat, spawning area, winter-refuge, and protection zone (Schiemer, 1985). During the last twenty years, the building of hydroelectric power stations caused a decline in the duration and intensity of the connectivity between backwaters and the main channel. Migration dynamics indicate the relevance of lateral connectivity for the ecological quality of riverine systems (Schiemer and Spindler, 1989; Schiemer and Waidbacher, 1992, Harris, 1995). In 1991, in the mouth of the arm, weir-basket catches indicated that immigration mainly occurred at night (Spindler, 1993).

The development of hydroacoustic technologies, especially narrow-beamed circular or elliptical transducers with low side lobes, enables to use horizontal sonar to observe fish stocks and fish migration, and possibly enables to estimate fish abundance and size composition in shallow waterbodies and large lowland rivers (Burczynski and Johnson, 1986; Duncan and Kubecka, 1994; Duncan and Kubecka, 1996; Foote, 1987; Kubecka, 1994a; Kubecka, 1994b; Kubecka, 1995; Kubecka, 1996; Kubecka and Duncan, 1994; Kubecka and Wittingerova, 1998; MacLennan and Simmonds, 1992; Ransom et al., 1998; Thorne, 1998). Horizontal sonar was used on a number of occasions for fixed-location surveys, monitoring the migratory behaviour of mostly salmonid fish (Gaudet, 1990; Mesiar et al., 1990; Johnston and Hopelain 1990; Johnson et al., 1992). This strategy gives good information on the body aspect insonified and whether the movement is upstream or downstream (BioSonics, 1985; BioSonics, 1987; Kubecka et al., 1992). It can also be used as a point-sampling method for quantitative estimates within a certain observation area (Duncan and Kubecka, 1994). The application of a horizontally-aimed sonar beam specifically appeared to provide the best means for exploring hypotheses about the migratory behaviour of fish in this backwater of the Danube:

– time of the day and water-level fluctuations are the governing factors for the activity patterns and migratory dynamics of riverine fish,

– fish of different sizes may react differently to time and water level.

2. MATERIAL AND METHODS

2.1. Topography of the sampling-area

The topography of the mouth of the arm into the River Danube is well-suited for fixed-location hydroacoustic studies to observe migrating fish. The site has a nearly ideal triangle cross-section with a gently sloping left shore whilst the right shore increases steeply (*figure 2*). The bottom consists of gravel and silt and has an even and gradual gradient, with no protrusions. A stone barrier within the mouth keeps the water level high in the arm. The maximum depth was 4.5 m according to 150 cm water-gauge Wildungsmauer on June 19, 1996 (*figure 3*). The arm and the River Danube are connected at 250 cm water-gauge Wildungsmauer. Wildungsmauer is the name for the location of a water-gauge, which is about 1 km close to the sampling site and which is permanently measuring water-level fluctuations of the River Danube.

2.2. Fixed-location study – Experimental design

In August and September 1996 there were three hydroacoustic fixed-location surveys carried out in the mouth of the Regelsbrunn-arm into the River Danube (*table I*). The first survey (August 30, 1996) lasted 22 h. The waterbodies of the arm and the river were separated by the stone barrier and the water level was slightly falling. The second sampling period (September 6–8, 1996) was characterised by connectivity between the arm and the River Danube. During the entire second survey of 40 h the overall water level was increasing with very short periods of slightly decreasing or constant water-gauge. The duration of the third survey (September 26, 1996) was 27 h. The water level was decreasing but the arm and the river were connected throughout this period.

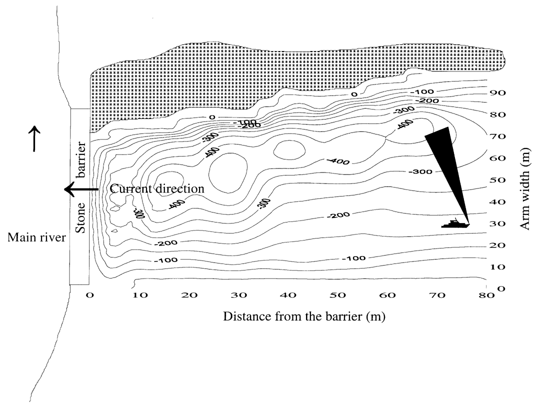

Figure 3. Horizontal map of the mouth of the Regelsbrunn-arm, showing the position of the boat relative to the stone barrier, the sound beam with its deviation from a sonar direction perpendicular to the current, the current direction during high water levels and the stone barrier between the main river and the arm.

The sonar system was a BioSonics portable dual-beam echosounder model 105 operating at a frequency of 420 kHz, a BioSonics tape recorder interface model 171 and a circular transducer with a narrow-beam angle of 6° and a wide-beam angle of 15° (6°/15°). The boat with the hydroacoustic equipment was anchored within the mouth of the arm in order to ensure stable position parallel to the current in the arm (*figure 3*). The boat was able to rise with the increasing and decreasing water level. The transducer was attached to a mechanically adjustable pan and tilt head, which was rigidly mounted in front of the boat by means of scaffolding. The transducers depth was 80 cm. The sonar beam was directed from the left shallow shore towards the steep right shore. By adjusting the tilt with a mechanical system, the transducer was aimed sideways to maximise the insonified range with minimum interference from bottom- and surface-generated reverberation. In order to record most fish from their side aspect, beaming sideways perpendicularly to the current provided exact information on the individual fish. It was expected that fish would move parallel to the current, upstream or downstream (Kubecka and Duncan, 1994; Kubecka, 1996). The following two equations used for the relationship of target strength of known aspect versus fish size are based on Kubecka's $\cos^3 2\alpha$ model (Kubecka and Duncan, 1998; Kubecka, 1994b). The criteria of a trajectory slope of < 3 mm·ping^{-1} (that is, the change in range per ping) was used to identify fish in side aspect. The all-species regression equation $Y = aX + b$ was used to transform target strength (*TS*) values of side aspect tracked fish into total length (Y = side-aspect target strength of the recorded fish in dB (420 kHz); $X = \log_{10}$(total length); a = 27.4857; b = –96.159). To enable us to use the change-in-range technique (BioSonics, 1987), to decide about the swimming direction, the horizontal sonar beam was oriented at about 20° deviation of the direction perpendicular to the current of the arm (*table I*). Fish tracked with a trajectory slope of > 3 mm·ping^{-1} and < 1.5 mm·ping^{-1} had to be recalculated by application of the equation:

$$TS = [\,(a_{side} \times \log l_{side} + b_{side}) - (a_{all} \times \log l_{all} + b_{all})\,] \times \cos^3 2\alpha + (a_{ll} \times \log l_{all} + b_{all}) \qquad (1)$$

$a_{side\ aspect} = 27.4857$; $a_{mean\ all\ aspect} = 22.3974$; $b_{side\ aspect} = -96.159$; $b_{mean\ all\ aspect} = -94.255$ (Kubecka, 1995). According to different pan-angles during the three surveys α was 19°, 21°, and 22°. Fish with a trajectory slope > 1.5 mm·ping^{-1} were assumed to move too obliquely through the horizontal sonar beam. They were excluded from the fish-size reconstruction analysis but included in fish-density estimations. Upstream- as well as downstream-swimming fish were classified into nine size classes defined by the total length (TL) of the fish: 50–100 mm, 100–150 mm, 150–200 mm, 200–250 mm, 250–300 mm, 300–350 mm, 350–400 mm, 400–450 mm, and 450–500 mm. The total sampling period was subdivided into 31 three-hour sampling intervals for more detailed analysis. Within each three-hour sampling interval, the size-frequency distribution (%) was calculated for upstream- as well as for downstream-swimming fish. The instrument was calibrated in situ before each survey (Johanesson and Mitson, 1983; Foote et al., 1987; BioSonics Inc., 1989) using a 21.2-mm diameter tungsten-carbide sphere as standard target with a *TS* of –43.5 to –43.7 dB following the procedure of Duncan and Kubecka (1994). A short pulse duration of 0.4 ms with a frequency bandwidth of 5 kHz was set for the resolution of single targets (Kubecka, 1995). Because of the relatively short ranges of the targets of interest of about 20–30 m, the pulse repetition rate was set to 10 pings·s^{-1}. For the fixed-location survey data was collected with time varied gains (TVG), which is the correction for spreading loss of the sound, of 40 log*R*

Table I. Selected features of all three sampling periods.

Date	Start	End	Duration (h)	Water-gauge (cm)		Temperature (°C)		Deviation from a sonar direction perpendicular to current
				Start	End	Start	End	
Aug. 30–31, 1996	17h43	16h11	22h28	253	230	20.2	20.2	19°
Sept. 6–8, 1996	19h43	12h00	40h17	288	312	15.1	13.5	21°
Sept. 26–27, 1996	12h00	15h00	27h00	296	260	11.8	12.5	22°

for dual-beam echocounting and sizing of every single target, and processed in real time on the boat using a BioSonics 281 dual-beam processor. Because noise levels in lowland rivers are generally quite high and ranges are rather short, noise thresholds were set separately at a threshold-to-noise ratio of 3:1 for a series of horizontal strata, which means that different thresholds were set for different range intervals (Duncan and Kubecka, 1994). Noise-restriction analysis gave the probabilities of recording targets of known size under different noise thresholds associated with different environmental noise levels during the surveys. These probabilities were calculated using an EXCEL spreadsheet specially designed to calculate beam cross sections where various-sized targets can be detected just over the imposed threshold. The analysis gives information, whether the recording of a target of certain size and within a certain range was highly probable or not. If the probability of recording a target was high under the influence of the applied threshold within this range, this target was accepted for further analysis. If the probability was too low, the target had to be eliminated. It was estimated better to sacrifice the smallest fish that can be defined rather than to accept noise as fish targets. Only targets within the intervals of the beam pattern factor (BPF) between 0 dB (on-axis) and –4 dB from the acoustic axis of the transducer were included in the identification of individual fish and used for fish-density estimation and TS calculation. The value –4 dB for the cut-off point was defined during analysis and is slightly higher than the nominal beam angle of –3.29 dB. In case of a RHBNC 6°/15° circular transducer, –3.29 dB is equivalent to 6° nominal angle. This beam angle of –4 dB and ranges of about 20–30 m according to certain noise levels defined the volume of the sampled beam cones (Kubecka et al., 1994). The total sampled volume was calculated by addition of the beam cones of all pings during the total sampling period.

3. RESULTS

3.1. Fish-density distribution versus change of water-gauge

During the total sampling period of more than 89 h 72×10^6 m^3 water was sampled and 85 000 fish were detected. Fish-density estimates of all three hydroacoustic surveys were achieved by echocounting. The 85 000 detected fish were included in the fish-density estimates. Average fish densities were 2.2×100 m^{-3} during the first survey, 0.6×100 m^{-3} during the second survey, and 1.2×100 m^{-3} during the third survey. During the night, fish-density estimates were always higher than during the day, independent of water-level fluctuations (*figure 4*). When the arm and the river were disconnected, the fish density during the night was much higher (median = 3.2×100 m^{-3} and 0.3×100 m^{-3} for night and day respectively, *figure 4a*). In *figure 4b* two night-time and two daytime samples represent the total sampling period of the second survey with increasing total water level. During the second night lower fish densities (median = 0.7×100 m^{-3}) were detected than during the night before (median = 1.6×100 m^{-3}). This was caused either by a 'dilution-effect' due to the increasing water level or inflowing water, 'washing' the fish away from the observation area. *Figure 4c* shows two daytime samples and one night-time sample during the third survey. Higher densities during the second daytime sampling period (median = 1.4×100 m^{-3}) compared to the first daytime sampling period (median = 0.9×100 m^{-3}) were probably caused by a 'condensation effect' of the decreasing water-gauge. Outflowing water was bringing fish in the observation area, and inhibited fish passage due to lower water levels could have forced downstream-swimming fish to concentrate in front of the stone barrier. As the total number of detected fish, upstream- and downstream-swimming fish showed the same pattern of density distribution during night and day. For a more detailed analysis, fish-density estimates were analysed separately for all 31 three-hour sampling intervals and correlated by means of linear regression with the percentage change of water-gauge. The percentage change in water-gauge is defined as the change over the three-hour sampling period relative to the beginning of the period. The regressions showed no correlation ($R^2 = 0.06$). Residuals of the regressions were plotted against time. High residual values during the night indicate that the activity was higher during the night than was expected from the water level. Low residual values during the day indicate the opposite trend. The periodical change of the residual values during night (higher values) and day (lower values) of each survey illustrates that the diurnal aspect had a strong influence on the fish-density distribution.

3.2. Size-frequency distribution versus change of water level

In general upstream-swimming fish were smaller (average TL = 229 mm) than downstream-swimming fish (average TL = 259 mm) (*table II*). Upstream-swimming fish during a decreasing water-gauge were smaller (average TL = 220 mm) than upstream-swimming fish during an increasing water-gauge (average TL = 245 mm). Downstream-swimming fish showed also a slight difference in the average TL according to decreasing (average TL = 252 mm) or increasing (average TL = 270 mm) water-gauge. To study the flux of fish in and out of the arm 32 542 fish from the two surveys, which were characterised by a connectivity of waterbodies between the arm and the River Danube, were used for a further detailed analysis of the relationship between the size-frequency distribution and the water-level fluctuations. Within these two relevant surveys 75% of the upstream-swimming fish and 66% of the downstream-swimming fish belong to the size class of 150–300 mm TL. Fish

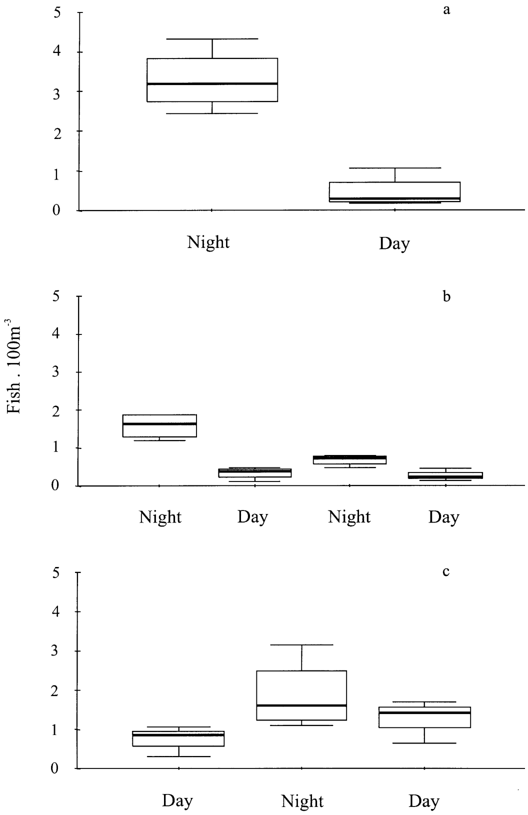

Figure 4. Diurnal pattern of average fish-density distribution of all three hydroacoustic surveys. a) August 30, 1996, waterbodies were disconnected. b) September 6–8, 1996, waterbodies were connected and the water level was increasing. c) September 26, 1996, waterbodies were connected and the water level was decreasing. Bold horizontal lines indicate the Medians. The box includes 50% of the observations. Vertical lines indicate the ranges.

> 500 mm represented less than 1% of the total fish. Upstream swimming fish of the 100–200 mm TL class contributed a higher percentage than downstream-swimming fish of the same length class. Upstream-swimming fish of the 250–500 mm length class had lower percentages than downstream-swimming fish of the same length class. The highest percentage of upstream-swimming fish was observed in the 100–150 mm length class, whereas the highest percentage of downstream-swimming fish was represented by the 200–250 mm length class (*table III*). The percentage of each size class of upstream- and downstream-swimming fish was set against the percentage of the change in water-gauge during the three-hour sampling interval by means of linear regression (*figures 5, 6, 7*). In five out of nine regressions a weak correlation between the changes in water level and the percentage of fish was found. For upstream-swimming fish the importance of small fish (100–150 mm TL) and large fish (400–450 mm TL and 450–500 mm TL) showed opposite trends, middle-sized fish were not indicative. The percentage of upstream-swimming fish with TL 100–150 mm was higher during decreasing water levels (> 27% fish) than during increasing water levels (< 20% fish) (*figure 5*). By way of contrast upstream-swimming fish of TL 400–450 mm and TL 450–500 mm had a higher percentage during an increasing water-gauge (> 3% fish) than during a decreasing water-gauge (< 1%) (*figures 6, 7*). Downstream-swimming fish of the same size classes show no significant correlation between the percentage of fish and the changes in water level. Middle-sized downstream swimming fish of 250–300 mm TL and 300–350 mm TL illustrated a weak correlation between the percentage of fish and the change in water-gauge, but this was not analysed in detail. To demonstrate the effect of diurnal activity patterns on the migration of the fish, the average residuals from the regression of the fish percentage versus water-level changes were plotted (*figures 8, 9, 10*). Each three-hour sampling interval recurred three times during the sampling period of the two relevant surveys. To achieve the average residual for one three-hour sampling interval, all three different residuals of this interval were averaged. In the 100–150 mm TL-size class, high residual values occur during the night, indicating that migration was higher than expected by water-level changes. Large fish of the 400–500 mm TL-size class showed the opposite trend. High residual values during the day indicate that migration was higher during day than expected by the water-level changes.

4. DISCUSSION

It is well established that fish migration is an essential indicator for the ecological integrity of a riverine system (Schiemer, 1985). Our studies show that fish-density estimates were mainly influenced by the time of the day rather than by changing water-gauge during the sampling periods. Fish densities were always higher during the night than during the day. The same diurnal pattern of fish-density distribution could be proved for upstream- as well as for

Table II. Average total length (TL, mm) of upstream and downstream of swimming fish according to changes in water-gauge (WG).

TL (mm)	Upstream	Downstream	Upstream		Downstream	
			Decreasing WG	Increasing WG	Decreasing WG	Increasing WG
	229	258	220	245	252	270

Table III. Average percentage of upstream- and downstream-swimming fish of all nine length classes during decreasing or increasing water-gauge (WG) of the last two surveys.

TL (mm)	Fish upstream (%)		Fish downstream (%)	
	Decreasing or constant WG	Increasing WG	Decreasing or constant WG	Increasing WG
50–100	4.3	4.0	1.6	3.4
100–150	27.5	19.8	13.4	13.0
150–200	18.0	18.6	14.6	15.5
200–250	19.6	17.4	20.7	19.1
250–300	14.3	15.6	19.8	17.0
300–350	8.1	7.6	12.9	10.6
350–400	3.9	5.1	7.2	7.9
400–450	1.7	3.7	3.9	4.1
450–500	0.8	2.8	2.3	3.0

downstream-migrating fish. Fish densities were highest during the first observation period (low water level), lowest during the second sampling period (increasing water level), and in between during the third period (decreasing water level). During the second survey a 20% increase in water volume compared to the water volume during the first survey was set against a 71% decrease in average fish density. The 12% more water volume during the third survey is opposed to a 46% decrease in the average fish density. Therefore it seems that the increase in water volume is not the only explanation for a decrease in the average fish densities. A decrease in the average temperature of 5.45 °C and 7.6 °C, respectively during the second and third survey, relative to the first survey is a possible explanation for the decrease in swimming activity (*table I*). The mouth of the Regelsbrunn-arm into the River Danube is supposed to be an important spot for seasonal habitat changes and fish migrations (Spindler, 1993). The fact that more downstream-swimming than upstream-swimming fish were detected could be caused by the method employ. Upstream-swimming fish are bottom oriented, whereas downstream-

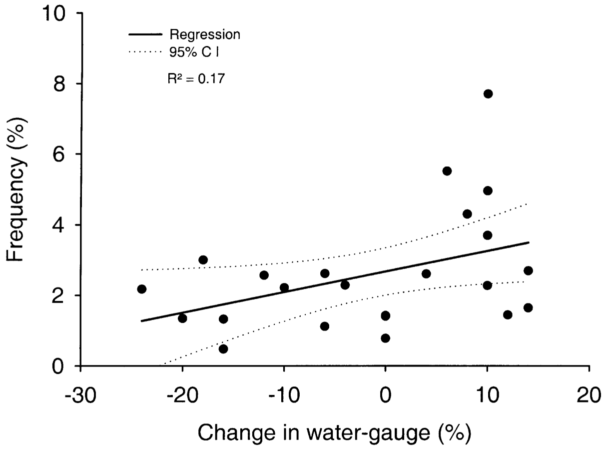

Figure 6. Relationship between the percentage of upstream-swimming fish of size class 400–450 mm TL and the percentage of change in water-gauge. The percentage of change in water-gauge is defined as the change over the three-hour sampling period relative to the beginning of the period. The bold line indicates the regression, dotted lines indicate the 95% confidence interval. R^2 = 0.17; P = 0.05. Each point represents one of the 23 three-hour sampling intervals of the last two surveys.

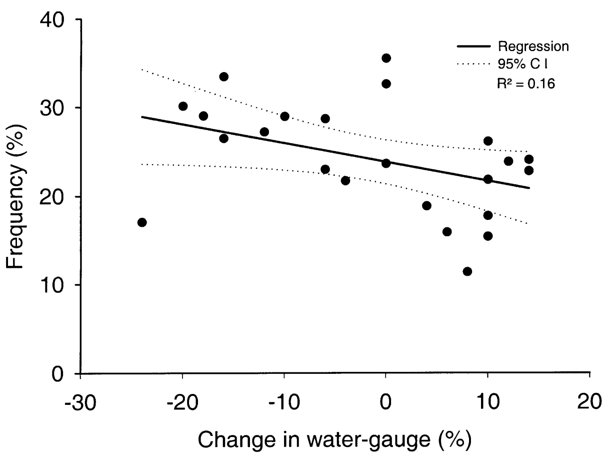

Figure 5. Relationship between the percentage of upstream-swimming fish of size class 100–150 mm TL and the percentage of change in water-gauge. The percentage of change in water-gauge is defined as the change over the three-hour sampling period relative to the beginning of the period. The bold line indicates the regression, dotted lines indicate the 95% confidence interval. R^2 = 0.16; P = 0.05. Each point represents one of the 23 three-hour sampling intervals of the last two surveys.

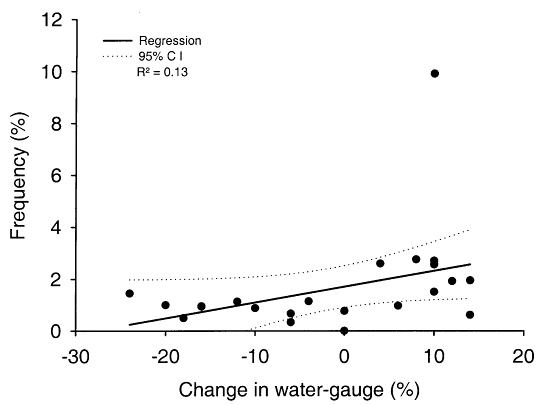

Figure 7. Relationship between the percentage of upstream-swimming fish of size class 450–500 mm TL and the percentage of change in water-gauge. The percentage of change in water-gauge is defined as the change over the three-hour sampling period relative to the beginning of the period. The bold line indicates the regression, dotted lines indicate the 95% confidence interval. R^2 = 0.13; P = 0.08. Each point represents one of the 23 three-hour sampling intervals of the last two surveys.

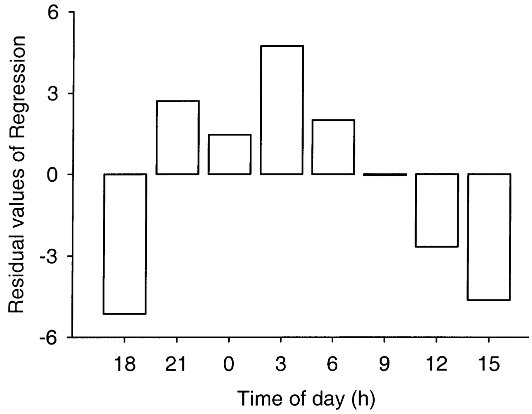

Figure 8. Residuals of the regression in *figure 5* were averaged within time-of-day intervals for the total sampling period of the two last surveys.

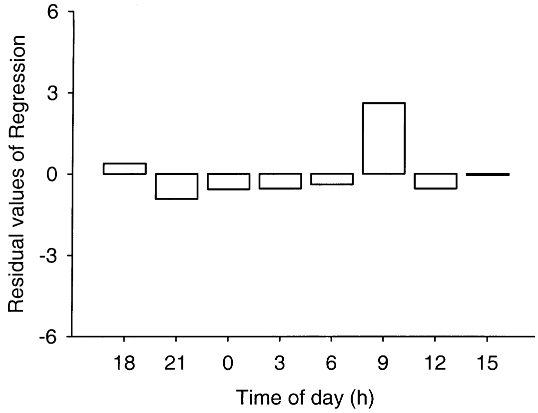

Figure 10. Residuals of regression in *figure 7* were averaged within time-of-day intervals for the total sampling period of the last two surveys.

swimming fish are more evenly distributed (Ransom et al., 1998). A transducer with 6°/15° circular beams is not the best application for detecting bottom-oriented upstream-swimming fish. Low side-lobe transducers with elliptical split beams of $4 \times 10°$ or $3 \times 10°$ are more useful for this application, because splitbeam gives also information on the vertical distribution of the fish.

The differentiation in size classes and direction of movement during the analysis enabled establishing various trends in the migratory behaviour of fish in this area. Changing of the water-gauge had influence on the size-frequency distribution of upstream-swimming fish. Ranges and *P*-values of upstream- and downstream-swimming fish showed a weak significant correlation between the size frequency and the change of water-gauge within five size classes. From *table III* it is evident that small-sized fish (100–150 mm TL) differed in their reaction to the changing water-gauge

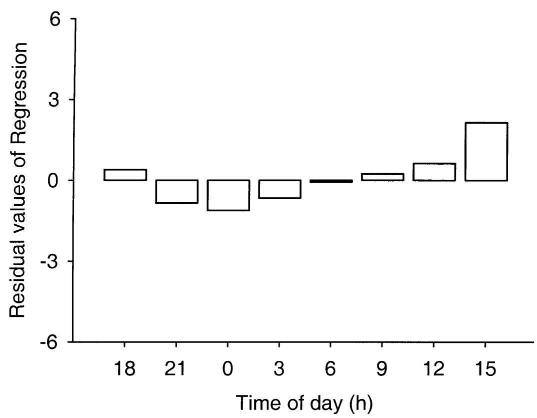

Figure 9. Residuals of the regression in *figure 6* were averaged within time-of-day intervals for the total sampling period of the last two surveys

compared with big-sized fish (400–450 mm and 450–500 mm TL). Fish in the length group of 100–150 mm TL tended to immigrate into the arm during decreasing water-gauge. Even during the second hydroacoustic survey, which was characterised by an increasing all-over water-gauge, small fish took advantage of short periods with decreasing or constant water-gauge to immigrate.

Fish of 400–450 mm TL and 450–500 mm TL tended to immigrate into the arm during an increasing water-gauge. It is well established that bigger fish need a minimum attraction current to find passage for upstream migration (Böhmer et al., 1998). It seems that conditions for the upstream migration of big fish were good whenever the water-gauge had increased to the highest levels during the observation periods. Whether different size classes consisted of different species or of adults and juveniles of the same species (or a mixture of species) could not be verified, because no gill netting or weir-basket catches were carried out.

5. CONCLUSION

During the total sampling period diurnal behaviour rhythms influenced the fish density as well as the size-frequency distribution. But changing of environmental conditions during the surveys, such as increasing or decreasing water-gauge, superposed the influence of diurnal behaviour rhythms on the size-frequency distribution for immigrating fish of certain length classes. The results about fish densities and the migratory behaviour of fish achieved during this study by a hydroacoustic methodology indicate the relevance of high hydrological dynamics and lateral connectivity for the ecological quality of this area.

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