Fisheries Research 147 (2013) 154–160

Contents lists available at SciVerse ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Avoidance reactions of fish in the trawl mouth opening in a shallow and turbid lake at night

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ARTICLE INFO

Article history:
Received 12 December 2012
Received in revised form 23 May 2013
Accepted 24 May 2013

Keywords:
Lake Neusiedl
Electrified trawl
DIDSON
Fish abundance
Biomass

ABSTRACT

Fish avoidance behaviour in the trawl mouth at night was investigated in the extremely shallow and turbid Lake Neusiedl in Austria. To evaluate fish reactions, a fixed frame benthic trawl with three electricity modes (without electricity, with continuous electricity and with interrupted electricity) was used and the captured fish abundances, biomasses and size structures were compared between modes. Simultaneously, the dual-frequency identification sonar (DIDSON) monitored fish abundance and size in front of and beside the trawl mouth during all tows. White bream (*Blicca bjoerkna*), bleak (*Alburnus alburnus*) and razor fish (*Pelecus cultratus*) were dominant fish species in the trawl catches. We did not find differences in fish abundance or biomass when the tows with different electricity modes were compared. The length frequency distribution of fish was not significantly different between modes, but trawls with the two electrified modes contained a higher proportion of fish larger than 130 mm than trawls with the non-electrified mode. Additionally, the DIDSON recordings did not display any significant differences in abundance, length frequency distribution and from length–weight relationships calculated biomass between the electrical modes. Not even the two avoidance behaviour categories used as indicators of trawling error displayed significant differences between avoidance and biomass. Our results indicate that based on trawling abundance and biomass comparisons, and supported by observations by DIDSON, all electrical modes were similarly effective for all size groups of fish. The study found minimal avoidance reactions by the dominant fish species in the trawl mouth opening when a relatively small fixed frame trawl was used to sample fish in a shallow and turbid lake at night.

1. Introduction

Knowledge of the effectiveness of the sampling tool is necessary in order to estimate the basic ecological parameters of fish stocks such as abundance, biomass and length frequency distribution. Midwater trawling is an efficient method of sampling in deep open water areas of lakes and reservoirs (Schmidt et al., 2007; Emmrich et al., 2010; Rakowitz et al., 2012) while bottom trawling is also useful in benthic habitats of lakes (Krause and Palm, 2008; Yule et al., 2008). A considerable amount of research has recently focused on the avoidance behaviour of demersal fish in bottom trawls (Weinberg et al., 2002; Hoffman et al., 2009), however little is known about the overall catching efficiency of midwater trawls (Suuronen et al., 1997), particularly in freshwater.

A bottom trawl is necessary for sampling in extremely shallow lakes. However there are similarities with midwater trawling, particularly when sampling areas close to the surface of the water. Small-scale fixed frame trawls are used at night to sample fingerlings in artificial reservoirs, but it is not effective for sampling larger sized adult fish (Jůza and Kubečka, 2007). As such a special type of fixed frame trawl equipped with wheels was developed and proved to be the only useful tool for sampling the open water areas of a shallow lake (Kubečka et al., 2007). However without knowing how quantitatively valid our sampling tool is, one can not be sure about the accuracy of fish biomass and density estimates, because it is not known how many fish and of what sizes avoided the net.

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0165-7836/$ – see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.fishres.2013.05.008

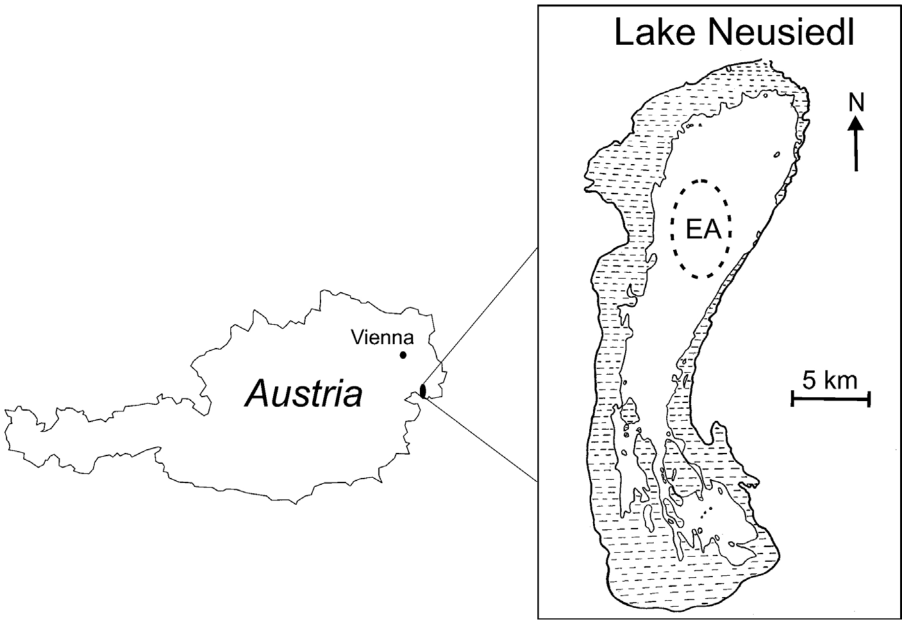

Fig. 1. Location of Lake Neusiedl in Austria and the exact position of the experiment area (EA) on the map of the lake.

The ability of fish to escape the trawl directly in the mouth opening can be influenced by the following factors: light intensity in the water (Glass and Wardle, 1989); water turbidity; body length of the fish (Wardle, 1993); size of the trawl mouth (Itaya et al., 2007; Jůza and Kubečka, 2007); and speed of trawling (Itaya et al., 2007; Winger et al., 2010). Except observations using different sized trawls (Itaya et al., 2007; Jůza and Kubečka, 2007; Jůza et al., 2010), the avoidance reactions of fish in the trawl mouth can be investigated by direct video observations (Graham et al., 2004, Trenkel et al., 2004) or hydroacoustics (Handegard et al., 2003, Schmidt, 2009). Another possibility of how to evaluate the avoidance reactions of fish is to compare the efficiency of electrified and non-electrified sampling methods (Bayley et al., 1989; Freedman et al., 2009). Electric currents have the ability both to attract and to incapacitate fish so we can hypothesize that the electrified trawl would be more efficient than a non-electrified one (Willemsen, 1990; Freedman et al., 2009). This hypothesis is valid only in the event of active avoidance behaviour in front of non-electrified trawl.

Comparison of the effectiveness of trawls with and without the application of electricity is only indirect proof of avoidance/non avoidance reactions of fish, so a direct observation technique also needs to be implemented simultaneously. The DIDSON (Dual frequency identification sonar) multibeam acoustic camera, which produces near video images of fish behaviour, has great potential for gear avoidance studies (Handegard and Williams, 2008; Rakowitz et al., 2012) especially in turbid or dark freshwater environments, where video or photographic observations are not effective.

The main aim of this study is to evaluate avoidance reactions of fish in the trawl mouth in an extremely shallow and turbid lake, analyze the effectiveness of using three different modes of electricity while trawling at night and to compare these results with simultaneous direct observations taken by DIDSON. Small-scale night trawling in an extremely shallow and turbid lake with a muddy bottom is a novel technique of fish sampling and this study provides a first step towards understanding its effectiveness. Understanding the effectiveness of a sampling method is the basic premise for study of fish ecology and for estimates of abundance.

2. Materials and methods

2.1. Study area

The study took place in the Austrian part of Lake Neusiedl (47°50′ N 16°45′ E), a mesotrophic, well-mixed steppe lake located 50 km southeast of Vienna on the Austrian-Hungarian border (Fig. 1). All experiments were done in the central part of the lake between Illmitz and Podersdorf (Fig. 1). The lake is 36 km long and 6–12 km wide from east to west, with a maximum depth of 180 cm and mean depth of 110 cm only. Considering its size, this lake is one of the shallowest large lakes in the world. The altitude of the lake is 115 metres above the sea level and the water level of the lake is controlled by precipitation (500–700 mm per year) and evaporation (Reitner et al., 1999). The open water zone (143 km^2) is characterized by the high concentration of suspended solids, which are stirred up from the bottom by wind actions. Due to the almost perpetual motion of the lake water, the high pH values of greater than 9.0, and low dissolved Ca^{2+} concentrations, the mineral particles form suspended colloids, which are responsible for the high turbidity of the lake ("white water", Krachler et al., 2009). The lake is surrounded by a reed belt (*Phragmites communis*), which is very important for water balance (Nobilis et al., 1991) and covers an area of 178 km^2 (Akbulut, 2000). The open water fish community of the lake is dominated by white bream (*Blicca bjoerkna*), bleak (*Alburnus alburnus*) and razor fish (*Pelecus cultratus*; Kubečka et al., 2007).

2.2. Data collection

2.2.1. Electrified trawling

Benthic trawling was conducted over one night from 18 to 19 August, 2010. A fixed-frame benthic trawl, with an opening of 2 m high and 4 m wide, towed with four nylon bridles was used for fish sampling. The mesh size of the trawl was 6 mm from knot to knot in the main belly and 4 mm in the codend. The trawl was equipped with a funnel, which prevented fish from escaping (Jůza and Kubečka, 2007). To keep the lower frame of the trawl in a desirable distance from the bottom, i.e. not digging into the mud and not lifting too high above it, a "wheeled trawl" (Kubečka

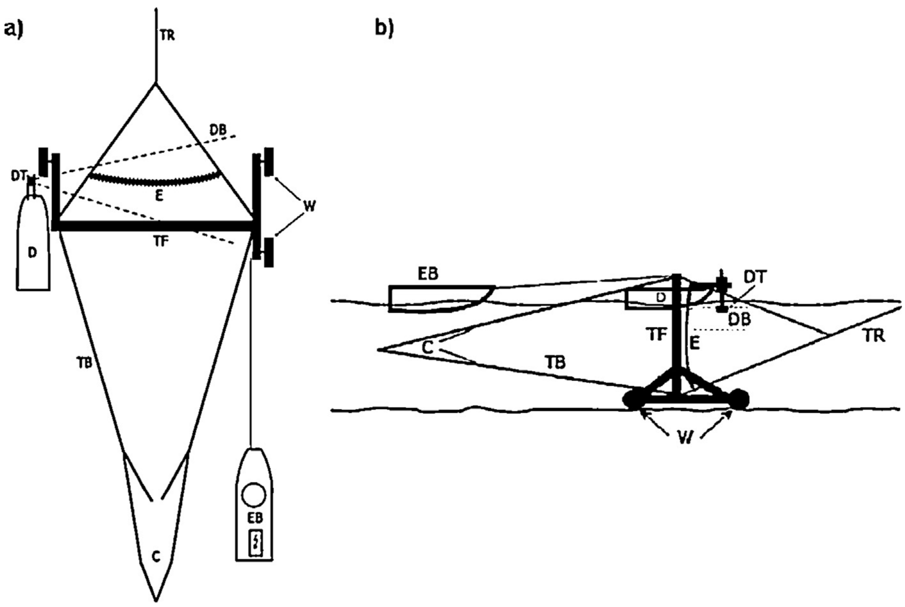

Fig. 2. The top (a) and side (b) views illustration of synchronized sampling with electrified wheel-trawl and DIDSON. TR = towing rope; D = DIDSON, acoustic barque; DT = DIDSON transducer; DB = DIDSON beam; E = electrified anode; EB = electro-fishing boat; W = wheels; TF = trawl frame; TB = trawl bag; C = codend.

et al., 2007) rigged with an iron bar and two plastic wheels was used. The trawl was towed approximately 100 m behind the boat for 10 min duration at the towing speed of around 1 m s^{-1}. The trajectory of pulling was not completely straight so the sampled area was outside the area disturbed by the boat. For each haul the trajectory was charted by GPS to calculate the water volume sampled.

A 6 m long, 1.4 m wide aluminium flat bottom boat equipped with an electro-shocker (EL 65 II GL; Hans Grassel GmbH; 13 kW; 300/600 V) was fixed to the frame of the trawl with a 7 m long rope so that the boat was towed alongside the codend of the trawl (Fig. 2a and b). A copper wire (6 m long, 7 mm in diameter) was used as the anode and was fixed around the bridles approximately 1.5 m in front of the mouth opening of the trawl (Fig. 2a and b). The flat bottom hull of the boat served as a cathode. Sampling was conducted with 60 Hz pulsed direct current and 600 V were applied into the water. The impact of the electricity on the trawl's effectiveness was tested in three different modes. In mode OFF the electro-shocker was turned off during the tow. In mode INT the electricity was interrupted every three seconds during the tow (3 s On and 3 s Off) and the reason for the interruption was to give an unexpected electric shock every 3 m of the trawl trajectory. Lastly, in mode CON the electro-shocker was turned on continuously during the entire tow duration. Five tows were done in each mode (OFF, INT and CON) with the modes alternated regularly. In total 15 tows were conducted during the survey.

On deck of the boat, all captured fish were immediately identified and most of them were measured for standard length (SL) to the nearest 1 mm (0+ fish) or to 5 mm (older fish) and released back to the lake. After measuring a few hundred 0+ fish of one species, which provided a representative picture of the length frequency distribution of the cohort, the remaining fish were then counted without being measured. To present the length frequency distributions of fish total lengths (TL), the SL/TL ratios were used (the SL/TL ratios were taken from Herzig et al., 1994). For each fish the weight was calculated using the length–weight relationship for individual species in Lake Neusiedl (Herzig et al., 1994). For each haul, total fish abundance related to the sampling area (ind ha^{-1}) and total fish biomass per sampling area (kg ha^{-1}) was calculated. The abundance of fish in a tow was calculated as

$$A = \frac{10,000 \times N}{4 \times S}$$

where A is fish abundance per hectare, N is number of fish captured in the appropriate tow and S is trajectory of tow in metres. The fish biomass was calculated as

$$B = \frac{10 \times W}{(4 \times S)}$$

where B is fish biomass in kilograms per hectare, W is total weight (g) of fish captured by the appropriate tow and S is trajectory of the tow in metres (measured by Garmin 60 CSx GPS). The number 4 in both equations represents the width of the trawl that was 4 m.

2.2.2. DIDSON observations

DIDSON was used simultaneously with 12 trawl tows (4 tows with each mode) to directly observe fish avoidance behaviour towards the benthic trawl. Because the trawl sampled practically the entire water column of the lake (the only possibility for fish to escape in the vertical direction was swimming beneath the lower rim of the trawl between the wheels), the lateral (sideways) potential avoidance behaviour was considered. DIDSON was fixed on another motor barge, which was attached to the left edge (in direction of trawling) of the vertical iron frame of the benthic wheeled trawl (Fig. 2a and b). This application guaranteed sufficient stability during recording and allowed for beam adjustments as the sampling situation required. The DIDSON acoustic camera operated in high frequency mode. In this mode DIDSON emits the ultrasound of 1800 kHz in 96 beams to form a horizontal fan approximately 29 geometrical degrees wide. The geometrical dimensions of every beam in this fan are approximately 0.3°. The vertical dimension of the fan beam is approximately 14°.

Real time recordings were stored in the hard disc of a laptop. The fish records were manually analyzed using Sonar5-Pro software (Balk and Lindem, 2010). By fish abundance it is meant the number of recorded fish per one minute of trawling (ind min^{-1}) and by fish

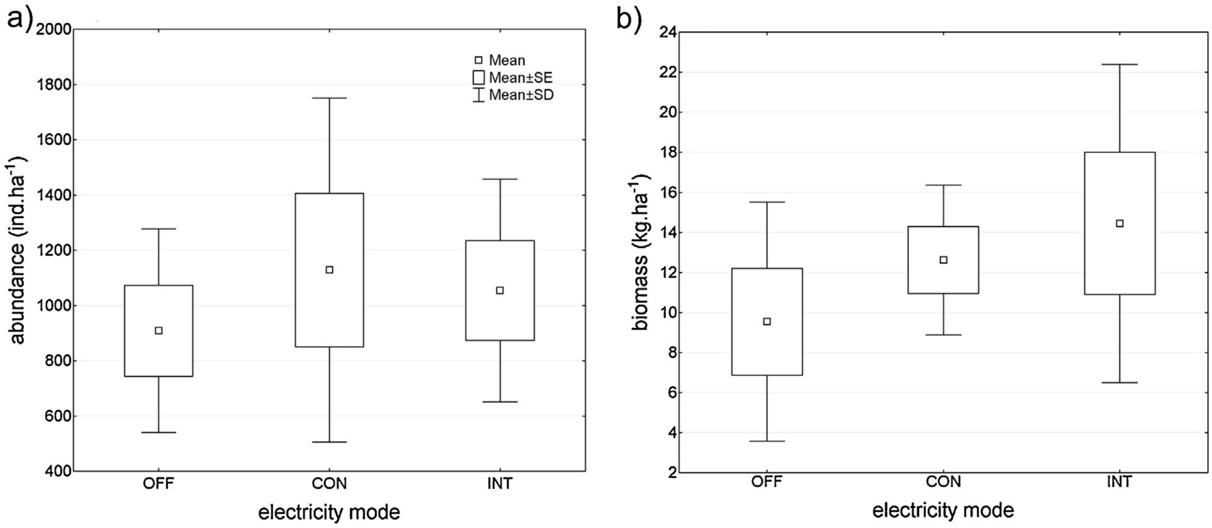

Fig. 3. Comparison of abundance (a) and biomass (b) reached by trawl with different electricity modes.

biomass it is meant total weight of recorded fish per one minute of trawling (kg min^{-1}). The biomass reached by DIDSON was calculated directly from fish length on images using length–weight relationship for weight calculation.

In order to analyze the lateral (sideways) avoidance behaviour fish were divided into those recorded laterally inside the trawl and those recorded laterally outside the trawl with the right (in the direction of trawling) vertical trawl frame as the threshold range at 4.4 m. In addition, this threshold range provided equal beam cone areas for quantitative comparison. Two categories of fish were considered to highlight the potential trawling error. First, fish that were swimming inside the wheeled trawl or were attracted by the anode from outside (beyond 4.4 m) into the trawl and were caught by the trawl. Second, fish that avoided the wheeled trawl by swimming from inside (within 4.4 m) the trawl outwards as quick or quicker than the trawling speed, forward in direction of pulling or were chased away from the anode outwards the trawl and were not caught by the trawl.

2.3. Statistical analysis

To compare the effectiveness of trawling with different modes (both for real trawl catch and DIDSON observations), a one-way analysis of variance (one-way ANOVA; Statistica software) was performed with the three electrical modes (OFF, CON, INT) whereby the analysis was the independent variable and abundance (biomass) was the dependent variable. Between each mode a one-way analysis of variance was used also to evaluate the effects of chasing fish laterally from inside the trawl outwards beyond the trawl mouth and by contrast attracting fish from the outside the trawl into the trawl. The abundance or biomass of fish attracted from outside the trawl inwards or conversely chased away from inside the trawl outwards were the dependent variables and the three electricity modes were independent variables for the analysis. For comparisons of fish length distribution a one-way analysis of variance was also performed. Results from the electricity modes were entered as the independent variable and the number of fish per one metre of tow (standardization per one metre of tow was done because of slight differences in lengths of individual tows) in four size groups (20–55 mm, 60–125 mm, 130–160 mm and 165–220 mm) was entered as the dependent variable. The range of size groups were chosen based on main peaks in the length frequency distribution plot. The standard significance level ($\alpha = 0.05$) was used.

3. Results

3.1. Species composition of the trawl catches

Altogether 4178 fish were captured in 15 tows in Lake Neusiedl. Bleak (49.7%), razor fish (21.9%) and white bream (17.8%) dominated the catch in abundance. In biomass white bream was the dominant species (52%) followed by bleak (23%) and razor fish (16%) Less abundant species in the open water area of the lake were pikeperch (*Sander lucioperca*, 6.5%), ruffe (*Gymnocephalus cernuus*, 4.1%) and eel (*Anguilla anguilla*, 0.1%). The mean fish abundance was 1030 ind ha^{-1}, and the mean fish biomass was 12.2 kg ha^{-1}.

3.2. Comparisons between modes of direct catch abundance, biomass and size distribution

The lowest mean abundance was found during trawling in OFF mode, while the highest mean abundance was found in CON mode (Fig. 3a). Abundance was not significantly different between modes (ANOVA; $p = 0.76$, $F = 0.27$). The lowest mean biomass was found in OFF mode, while the highest mean biomass was achieved in INT mode (Fig. 3b). Biomasses were not significantly different between modes (ANOVA; $p = 0.46$; $F = 0.82$).

In the length–frequency distribution the catch of all modes was created by two clearly separated peaks (fish of 20–55 mm TL (mostly 0+ bleak and white bream) and fish of 60–125 mm TL (0+ pikeperch and razor fish, 1+ bleak and white bream)) and the relative proportion of these sizes of fish was similar in all three modes (Fig. 4) without significant differences (ANOVA; $p = 0.85$, $F = 0.16$ for fish of 20–55 mm TL and $p = 0.75$, $F = 0.29$ for fish of 60–125 mm TL). Minor, but still important for biomass estimates, were fish larger than 130 mm. Fish of 130–160 mm TL (white bream and razor fish) were more abundant in both electrified modes (CON and INT) than in the OFF mode but differences were not significant ($p = 0.65$, $F = 0.45$). Fish larger than 165 mm TL were also captured particularly in the INT mode (Fig. 4) but again without significant differences between modes (ANOVA; $p = 0.43$, $F = 0.90$).

3.3. Comparisons between modes of fish abundance, biomass and size distribution based on DIDSON observations

The lowest mean abundance was observed by DIDSON inside the trawl during trawling in CON mode, the highest in INT mode (Fig. 5a). Abundances were not significantly different between

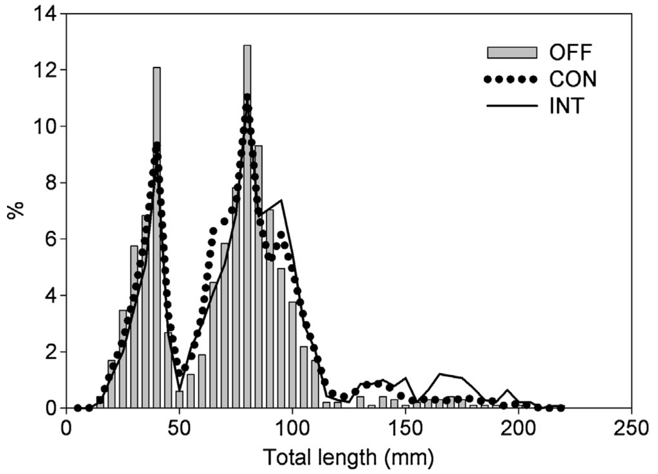

Fig. 4. Length–frequency distribution of fish captured by trawl with different electricity modes. Fish larger than 220 mm were very rare in all modes so they are not included.

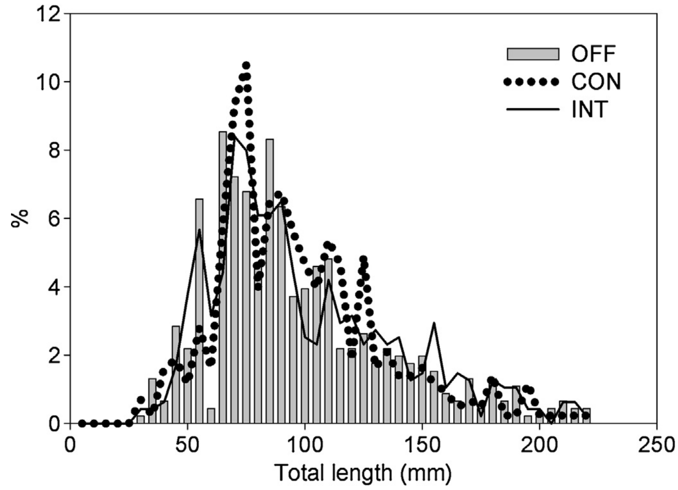

Fig. 6. Length–frequency distribution of fish recorded by DIDSON in different electricity modes. Fish larger than 220 mm were very rare in all modes so they are not included.

modes (ANOVA; $p = 0.94$, $F = 0.06$). The lowest mean biomass was displayed in CON mode and the highest at INT mode (Fig. 5b). Biomasses were not significantly different between modes (ANOVA; $p = 0.65$; $F = 0.45$).

In the length–frequency distribution the main peak recorded by DIDSON was created by fish between 50 and 130 mm TL, and a relative proportion of fish of this size was similar in all three modes (Fig. 6). As well, in the case of direct trawl catches the number of fish per one metre of tow in each modes was not significantly different for any size group (ANOVA; $p = 0.43$, $F = 0.93$ for fish of 20–55 mm TL, $p = 0.98$, $F = 0.02$ for fish of 60–125 mm TL, $p = 0.86$, $F = 0.15$ for fish of 130–160 mm TL and $p = 0.48$, $F = 0.8$ for fish of 165–220 mm TL).

Differences in attracting fish from laterally outside to inside the trawl were not significant for fish abundance between modes (ANOVA; $p = 0.73$, $F = 0.33$). The highest abundance (±SD) of fish attracted from laterally outside the trawl into the trawl was recorded by DIDSON in INT mode (0.63 ± 0.56 ind min^{-1}), the lowest in OFF mode (0.34 ± 0.62 ind min^{-1}). The abundance from outside to inside the trawl in CON mode was 0.44 ± 0.31 ind min^{-1}.

The highest fish biomass being attracted from laterally outside to inside the trawl was also recorded by DIDSON in INT mode (0.07 ± 0.07 kg min^{-1}). For OFF and CON modes the amount of biomass attracted from laterally outside the trawl into the trawl was similar (0.02 ± 0.04 for OFF mode and 0.02 ± 0.01 for CON mode). Also for fish biomass the differences were not significant between modes (ANOVA; $p = 0.21$, $F = 1.9$).

The highest abundance of fish being chased away from inside the trawl outwards was recorded by DIDSON in OFF mode (0.73 ± 1.3 ind min^{-1}), and the lowest was recorded in CON mode (0.15 ± 0.13 ind min^{-1}). Fish abundance chased away from inside the trawl in INT mode was 0.36 ± 0.33 ind min^{-1}. Between modes differences in abundance of fish chased from inside the trawl outwards were not significant between modes (ANOVA; $p = 0.57$, $F = 0.61$).

The highest biomass of fish being chased away from inside the trawl to the lateral outside of the trawl was recorded by DIDSON in OFF mode (0.05 ± 0.09 kg min^{-1}), the lowest in CON mode (0.004 ± 0.003 kg min^{-1}). Fish biomass chased away from inside the trawl outwards in INT mode was 0.02 ± 0.01 kg min^{-1}. Differences in biomass of fish chased from inside the trawl to the outside of the trawl were not significant between modes (ANOVA; $p = 0.47$, $F = 0.83$).

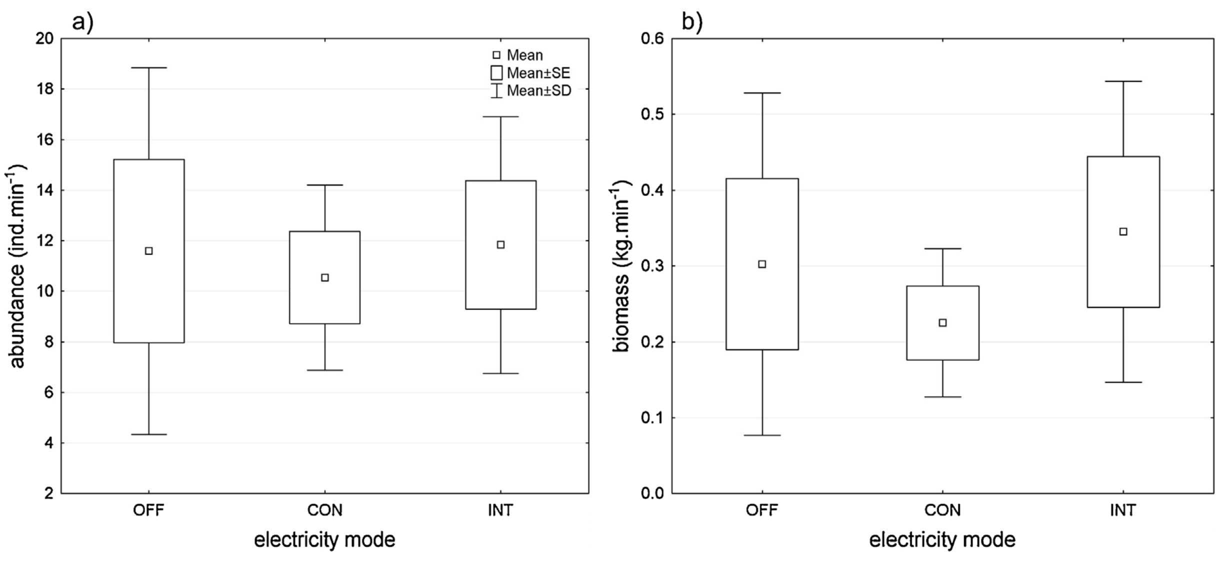

Fig. 5. Comparison of abundance (a) and biomass (b) recorded by DIDSON in different electricity modes trawls.

4. Discussion

In this study different modes of electricity were used directly in the mouth of a fixed frame benthic wheeled trawl to evaluate avoidance behaviour of fish in a shallow and turbid lake. We are aware that there can be alteration in the fish behaviour prior to the trawl arrival caused, for example, by warps or vessel noise (Handegard and Tjøstheim, 2005; Ona et al., 2007), however it was not included in this study. We attempted to conduct each haul in the same manner and therefore if there was any prior avoidance reaction it would be the same for all trawl configurations. An important assumption for the validity of this study is the homogenous distribution of fish in the sampled area, which was proved by horizontal hydroacoustical observations (Draštík and Kubečka, 2011).

Direct comparisons of the effectiveness of electrified and non-electrified active sampling techniques are scarce in literature. In the marine environment for instance, Kreutzer (1963) found an electrified trawl to be up to 30 times more efficient than a non-electrified one with a higher proportion of large fish captured. In another study on three rivers in Pennsylvania, an electrified trawl was significantly more efficient than a non-electrified one, capturing higher numbers of species and quantities of fish, as well as larger individuals (Freedman et al., 2009). Furthermore an electrified beach seine was significantly more efficient in species richness and numbers of fish captured in streams, than a non-electrified one (Bayley et al., 1989). Similarly in our experiment, the objective was to electrify the area in front of the net to prevent the escape of the fish from the moving trawl. We therefore assumed that electrified hauls, conducted in interrupted and continuous modes, would be more efficient. However, that the different electrical modes proved to be similarly effective in catching fish indicates that fish in Lake Neusiedl demonstrate minimal avoidance reactions in front of the trawl. For this comparison only five tows were performed using each electricity mode, which can influence the statistical strength. However between modes differences in abundance were less than 10%, which is lower than in previous studies giving insignificant results (see Jůza and Kubečka, 2007).

Avoidance reactions in front of the trawl are influenced by the ability of fish to detect the net. This ability is dependent especially on light intensity in the water (Glass and Wardle, 1989; Misund et al., 1999) and therefore the choice of sampling period (day or night) can influence trawl efficiency. Significantly higher avoidance behaviour was observed during the day than at night in another study (Rakowitz et al., 2012). Another important parameter influencing avoidance behaviour of fish is water clarity (Buijse et al., 1992). In turbid conditions, visible range may be very short and fish may have little time to react to the approaching net. Under these circumstances, response thresholds are generally expected to be higher, reaction distance shorter and probability of being captured more likely (Glass and Wardle, 1989; Winger et al., 2010). In Lake Neusiedl, frequent resuspension of the sediment caused by winds and currents results in a high concentration of suspended solids in the water column with the usual Secchi depth lower than 0.2 m (Reitner et al., 1999). Extremely low water transparency is the most probable factor responsible for passivity and minimal avoidance reactions from fish in front of the approaching trawl. During lake monitoring in 2007 (Kubečka et al., 2007), fish were captured by identical non-electrified trawls during the day, indicating that fish avoidance behaviour is extremely limited in conditions of such low water transparency even during the day. However, the night catches were generally higher in 2007, and this was the rationale for comparing night trawling results.

Since swimming capacity is strongly dependent on fish size and larger fish are better able to avoid the net (Wardle, 1993; Videler and He, 2010), length frequency distribution of fish also plays an important role during sampling in large lakes and at sea. The number of specimens from individual size groups found in each tow was not significantly different between modes and the general length frequency distribution was also similar in different modes in DIDSON observations. This indicates no differences in size selectivity of trawling with different electricity modes. Fish larger than 130 mm TL were more abundant (but not significantly) in catches in CON mode, and in particular in INT mode but in general larger fish were relatively rare in trawl catches and DIDSON observations in the open water area of the lake.

The size distribution of fish caught by the trawl and observed by DIDSON was relatively similar for fish larger than 55 mm total length. The only difference was the lower proportion of 0+ fish (20–55 mm total length) in DIDSON observations. According to our results it seems that fish smaller than 50 mm TL are not clearly detectable during mobile DIDSON observations or that they are strongly underestimated in the acoustical beam. Baumgartner et al. (2006) have highlighted that DIDSON is inefficient for fish smaller than 75 mm and a comparison of size distribution of trawl catches and DIDSON observations in our study revealed that fish smaller than 50 mm are beyond the resolving power of DIDSON giving a strongly underestimated picture of these small fish populations during a mobile survey.

The study clearly showed that trawling with different electricity modes was similarly effective with respect to fish abundance, biomass and length structure, and this was proven by direct catch comparisons and comparison of DIDSON recordings. At least for the size structure of the dominant fish in the lake (20–160 mm) the three electrical modes used in the sampling found similar results. All sampling methods are selective to some extent (Olin and Malinen, 2003; Prchalová et al., 2008), which is a general problem of sampling fish communities in large lakes. To obtain a "true picture" of the fish stock it has been recommended to use more than one sampling technique and compare the results (Dahm et al., 1992; Bonvechio et al., 2008; Kubečka et al., 2009). Similar effectiveness in different electricity modes as well as in DIDSON recordings provided much stronger evidence for fish passivity in Lake Neusiedl at night than if only one sampling method was used. In lakes and reservoirs with a much higher Secchi depth, this small-scale trawling appeared to be quantitatively valid for small fish (especially YOY) only whereas larger fish are able to avoid the trawl (Jůza and Kubečka, 2007; Jůza et al., 2012). The results of this study showed that night sampling using a fixed frame trawl is an appropriate method to use in shallow, turbid lakes for dominant fish sizes and gives a reliable picture of the pelagic fish community in the lake.

Acknowledgments

We would like to thank Jiří Pechinger for constructing the "wheeled" trawl, Zdeněk Prachař for help during field work, Leslie Tse for English correction and the two anonymous referees for valuable comments on the manuscript. The study was supported by the National Park Neusiedler See-Seewinkel, Burgenland, Austria, Institutional Support RVO: 60077344 and the project CZ.1.07/2.3.00/20.0204 (CEKOPOT) co-financed by the European Social Fund and the State Budget of the Czech Republic.

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