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MASTERARBEIT

Titel der Masterarbeit

„SED-Based vs. Track-Based Echo Integration:

A Comparison of Two Hydroacoustic Analysis Methods for Fish Abundance and Biomass Estimates”

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Content

Abstract

As the use of hydroacoustic devices in fish ecology and fisheries is steadily increasing, a gapless knowledge is needed for assuring the correctness of results from echosounding analysis. To close this gap a bit further, a study was carried out to determine whether two different approaches of echo integration yield similar results if applied to the same dataset. The main difference between the two sub-methods (SED-based and track-based) is that the SED-based approach takes the target strength (TS) of each single echo detection (SED) into account seperately, whereas the track-based approach summarizes more than one SED to form a fish track from which the mean TS is calculated. We compared data from three lakes, collected at both day- and nighttime, as well as in different seasons. No significant differences in the results of the two echo integration methods could be found. Both approaches yielded similar fish abundance and biomass results. Length classes of fish in the lakes did not differ between methods, but between day and night. The time of the data collection (time of the year, day or night) had a major impact on both abundance and biomass results. Therefore we conclude that the methods are stable in their outcomes, but the comparability of hydroacoustic surveys is strongly affected by vertical as well as horizontal fish distribution in the course of the day and the year.

1. Introduction

Hydroacoustic technology has developed vastly over the last few decades. A significant cost reduction as well as a decrease in equipment size widened the scope of applicability and lead to a widespread use of hydroacoustic technology, both in lakes and in running waters (Wanzenböck and Gassner 2001, Mehner et al. 2003, Simmonds and MacLennan 2005). The fields of application range from bathymetry and bottom classification to abundance and distribution estimates of aquatic biota, such as macrophytes, zooplankton and fish, the latter being the economically most important (Brandt 1996, Wanzenböck et al. 2003). With the development of international standards for hydroacoustic surveys (CEN 2009, Winfield et al. 2012), as well as the progress in software and hardware (Wanzenböck et al. 2003, Balk and Lindem 2007), hydroacoustics has become a freshwater application used almost routinely for estimating fish abundance and biomass by highly trained and experienced operators.

Nevertheless, there are still uncertainties about the accuracy and reliability of acoustic estimates. It has been adequately described that the time of day at which a survey is conducted has an impact on the results, because fish distribution in the pelagic changes during the phases of the day (Appenzeller 1992, Appenzeller and Leggett 1992, Simmonds and MacLennan 2005, Djemali et al. 2009, Draštík et al. 2009). These dial migrations can occur both vertically and horizontally, which is why fish staying closer to the bottom during daylight can go undetected (Guillard et al. 2004, Simmonds and MacLennan 2005), as well as those migrating between the pelagic zone and the littoral throughout the day (Kubecka 1993, Jacobsen et al. 2004). The time of year is important as well, since fish migrate between habitats (feeding, spawning and shelter habitats) during the course of the seasons, which can lead to fluctuations of biomass and abundance estimates over the year (Gassner et al. 2000, Schmidt 2006).

However, not only biotic factors can cause uncertainties. The use of analytical parameter settings and their variations is still not fully investigated, and settings are more often chosen based on the experience of the operator rather than on clear guidelines. Direct comparisons of fish density and biomass estimates obtained by different hydroacoustic systems as well as by different survey settings have only been published in the last few years (Ehrenberg and

Torkelson 1996, Rudstam et al. 1999, Wanzenböck et al. 2003, Axenrot et al. 2004, Godlewska et al. 2009). As stated in Wanzenböck et al. (2003), „non-expert users such as fishery decision-makers have to base their actions on the presumed capability and credibility of the hydroacoustic experts they commission or collaborate with in fish-stock assessments". With the implementation of the European Water Framework Directive (WFD, 2000/60/EC) into national law the demand for accurate fish stock assessments is now more important than ever, as fish are an indicator for the ecological status of a water body. This is why further understanding of the analysis methods and survey settings is needed to account for the potential variation within the results.

One of the most commonly used data analysis methods in hydroacoustics is the echo integration, also known as „sv/ts scaling" (Ehrenberg 1980, Richards et al. 1991, Wanzenböck et al. 2003, Guillard et al. 2004, Schmidt et al. 2004, Simmonds and MacLennan 2005). The volume backscattering coefficient (s_v, average of the total reflection across pings) is divided by the backscattering cross-section (σ_{bs}, mean echo intensity from individual targets) (MacLennan 2002, Winfield et al. 2012). The individual fish echo intensity (TS) therefore has to be calculated, which can be done in different ways: one way is to use all the single echo detections (SEDs) and treat each SED as a single fish, another way is to use fish tracks obtained from numerous single echoes (Balk and Lindem 2007, Winfield et al. 2012). For an easier distinction within our analysis we refer to the first sub-method as ‚SED-based‘ echo integration, to the second one as ‚track-based‘ echo integration.

As both data analysis methods are commonly used in hydroacoustic surveys, we studied the differences (or similarities) between these two approaches. Fish abundance and biomass estimates at different times (day and year) in whitefish-dominated pre-alpine lakes were analysed to determine if there are differences between the two sub-methods. The aim of this study is to clarify the influence of the two alternative analysis approaches of hydroacoustic data on the variability of abundance and biomass estimates.

2. Material and Methods

2.1. The Study Sites

Hydroacoustic data from three Austrian pre-alpine lakes (Zellersee, Irrsee and Wallersee) were collected in 1998 and 2001 (Table 1). These datasets were selected for a comparison of two different analysis approaches within the echo integration method for fish abundance and biomass, namely an SED-based echo integration versus a track-based echo integration.

Table 1: Description of surveys used in this study; transects were excluded if less than 20 single echo detections were registered

	date	***# of transects (# excluded)***	
		day	***night***
Irrsee	*18.03.1998*	*6 (1)*	*6*
Wallersee	*31.03.1998*	*10 (3)*	*10 (1)*
Zellersee	*24.08.2001*	*21*	*21*
	12.10.2001	*21*	*21*
	17.12.2001	*21 (1)*	*21 (3)*

Lake Irrsee, lake Wallersee and lake Zellersee are generally quite similar in their limnology (Table 2) and species composition. All three lakes are holomictic and dimictic and are situated in Austria, north of the Alps, lake Zellersee (N 47° 19′ 24″, E 12° 47′ 53″) and lake Wallersee (N 47° 54′ 50″, E 13° 10′ 30″) in the province of Salzburg, lake Irrsee (N 47° 54′ 44″, E 13° 18′ 25″) in Upper Austria (see Fig. 1).

All three lakes are dominated by whitefish (*Coregonus lavaretus* species complex), especially lake Zellersee. Lake Irrsee and lake Wallersee have a more diverse fish fauna (e.g. perch, roach, common bream), but during the sampling period (early spring) it is fair to assume that the dominating fish species in the pelagic are whitefish as well. This was also shown in parallel gill-net catches (Gassner et al. 2000).

Table 2: Morphometric characteristics of the analysed lakes (Beiwl and Wolfgang 2010)

	Irrsee	**Wallersee**	**Zellersee**
sea level [m]	553	505	750
area [ha]	360	610	455
catchment area [km^2]	27,5	110	54,7
max. length [km]	4,7	5,5	3,8
max. width [km]	1,0	2,0	1,5
max. depth [m]	32	23	68
mean depth [m]	15	13	39
volume [Mio. m^3]	53,1	76,3	178,2
retention time	1,3 years	0,8 years	4,1 years
mixing	holomictic, dimictic	holomictic, dimictic	holomictic, dimictic
secci depth [m]	5,0	4,1	6,8
P_{total} [µg/l]	8	13	6
trophic level	oligo-mesotroph	mesotroph	oligotroph

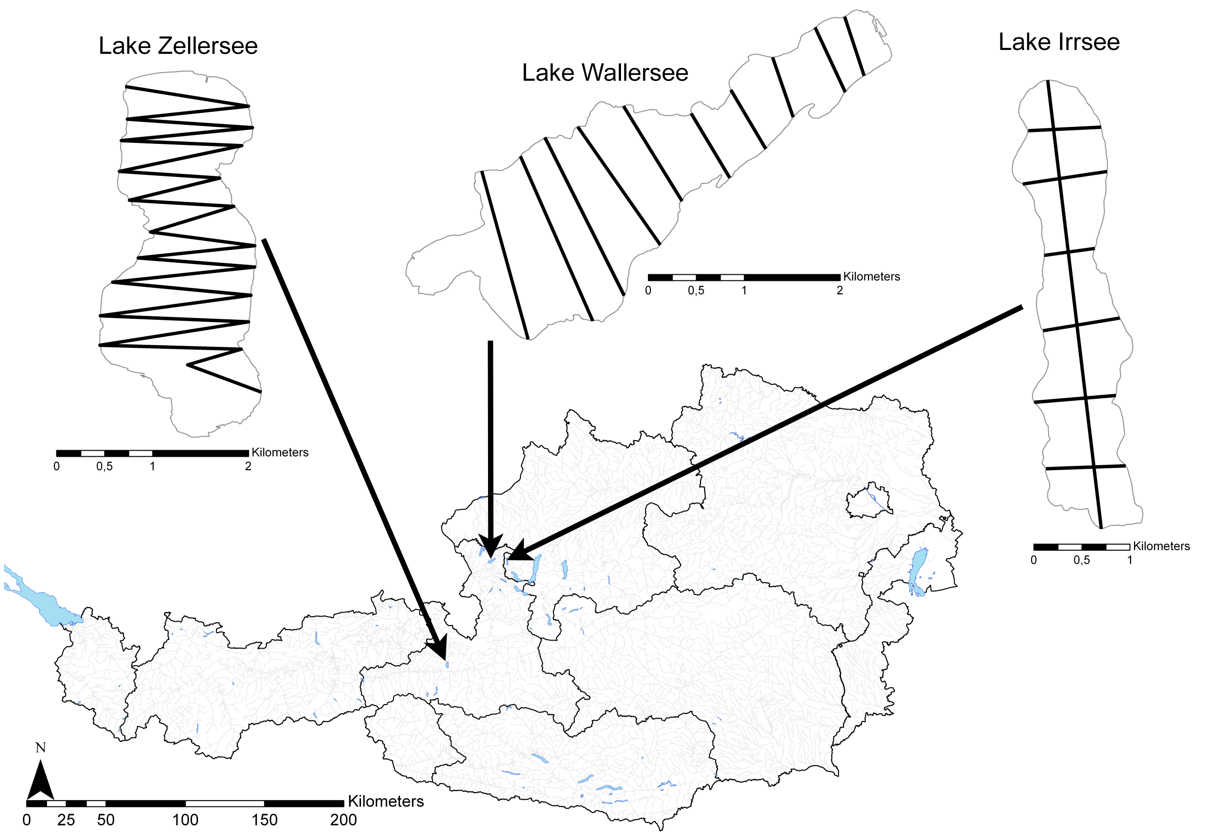


Figure 1: GPS-logs of the sailed transects at the sampled lakes in Upper Austria (lake Irrsee) and Salzburg (lake Wallersee and lake Zellersee)

2.2. Hydroacoustic Techniques

The hydroacoustic equipment consisted of a SIMRAD EY500 echo-sounder with a split-beam transducer ES120-4x10 (frequency 120 kHz, elliptical transducer, beam width 10° x 4°, pulse length 0.1 ms, maximal possible ping rate was set according to water depth with ~ 7-9 pings/sec and reduced when necessary). The transducer was mounted on a pole system at a depth of ~ 0.3 m laterally to the motorboat. Boat speed was maintained at 4–6 km h^{-1}. The system was calibrated with a standard copper sphere provided by the manufacturer using the LOBE-software (Simrad 1995). Transducer gains for TS and Sv were checked regularly. Night and day surveys were conducted during complete darkness starting one hour after sunset and around midday, respectively. They were performed with vertical beaming along a selected number of transects (see Fig. 1). Waypoints were set as starting- and endpoints and the locations were stored in a GPS (Trimble Pathfinder PRO XR). Sample angle and sample power with a base threshold of -100 dB were stored in EY on a computer and archived to CD. The data were later converted using Sonar5 post-processing software (version 6.0.1).

In Sonar5, the selected minimum TS was set to -58 dB, the relative minimum and maximum echo length 0.8 and 1.2, maximum gain compensation 4.0 dB and maximum phase deviation 6.0 phase steps (Simrad 1995). The abundance estimates were obtained using 20 log R Time Varied Gain (TVG) amplification. Each transect was cleared of noise (such as bubbles, debris or ping interferences) by setting an appropriate threshold and by manual deletion, so that only fish echos would be used for further analysis. Data from a depth within 4 m of the transducer were excluded (transducers nearfield). Layers between 4 m range and the bottom of the lake were analysed, the bottom line of the echogram was defined automatically and corrected manually.

2.2.1. SED-Based Echo Integration

For the SED-based echo integration, the target strength from all single echo detections (SED) is used to calculate mean fish echo intensity for abundance and biomass estimations. By selecting „Analysis - Analysis - 1 Set up menu - Biomass - Based on SED" in the drop down menu of Sonar5, the Biomass window was started. The method works by dividing the volume backscattering coefficient s_v (average of the total reflection across pings) by the mean reflection of signals resolved as single targets (the backscattering cross-section, σ_{bs}) (Winfield et al. 2012). The latter value is derived from single, unrelated echo detections, taking every SED into account seperately. More details on the calculation process is given in Simmonds and MacLennan (2005) as well as in Balk and Lindem (2007). Only transects with more than 20 detections were used in this study (Tab. 1). Abundance and biomass were calculated in Sonar5 and results for each transect were exported to Microsoft Excel (2010).

2.2.2. Track-Based Echo Integration

For the tracking method, the same transects were used as for the SED-based echo integration. The Biomass window was started by selecting „Analysis - Analysis - 1 Set up menu - Biomass - Advanced" in the drop down menu. In the opening dialog window, the option „Track and Biomass estimate at the same time" was selected. As with the SED-based approach, the volume backscattering coefficient s_v is divided by the mean echo intensity from individual fish tracks. In this sub-method, however, the latter value is derived from tracks constructed from a number of single echo detections.

In order for the SED tracker to recognise several SEDs as one track (= fish), the minimum track length was set to 1 ping, a maximum ping gap of 3 pings and a gating range of 0.5 meters. With these settings it was possible to receive good fish tracks in deeper water layers and, at the same time, include stand-alone SEDs in the upper water layers. Here multiple detections of one single fish are much less likely because of the physical properties of the sound beam (small hydroacoustic cone, sailing speed, fish avoidance, ...).

2.3. Data Analysis

During the analysis with both methods within Sonar5, fish echoes were split into 2 cm size-classes, ranging from 2 cm to 120 cm. The Love's (1971) equation was used to estimate fish lengths from target strength. Biomass estimations were carried out in Sonar5 as well, using lake-specific weight-length regressions (see Table 3) obtained from gill-net catches (Gassner et al. 1998, Gassner et al. 2000). Results for each transect were exported to Microsoft Excel (2010), where total abundance and biomass for each lake were calculated from the transects. The data were tested for normal distribution with a Kolmogorov-Smirnov-Test (KS-Test). Estimates of total abundance and biomass for transects and surveyed lakes were tested for significant differences with non-parametric tests. The program used for the statistical analysis was IBM SPSS Statistics 20, graphs were built in SigmaPlot 11.

Table 3: Length-Weight-Regression for biomass-calculations (TW: full weight in g; TL: total fish length in cm) obtained from gill-net-catches (Gassner et al. 1998, Gassner et al. 2000)

	Regression	**r^2**	**Fish Species**
Zellersee	$TW = 0.00281 \; . \; (TL)^{3.2643}$	0,989	whitefish (n = 180)
Irrsee	$TW = 0.0044 \; . \; (TL)^{3.1860}$	0,984	whitefish (n = 352)
Wallersee	$TW = 0.0326 \; . \; (TL)^{2.6773}$	0,967	whitefish (n = 52), perch (n = 113), roach (n = 28), common bream (n = 111)

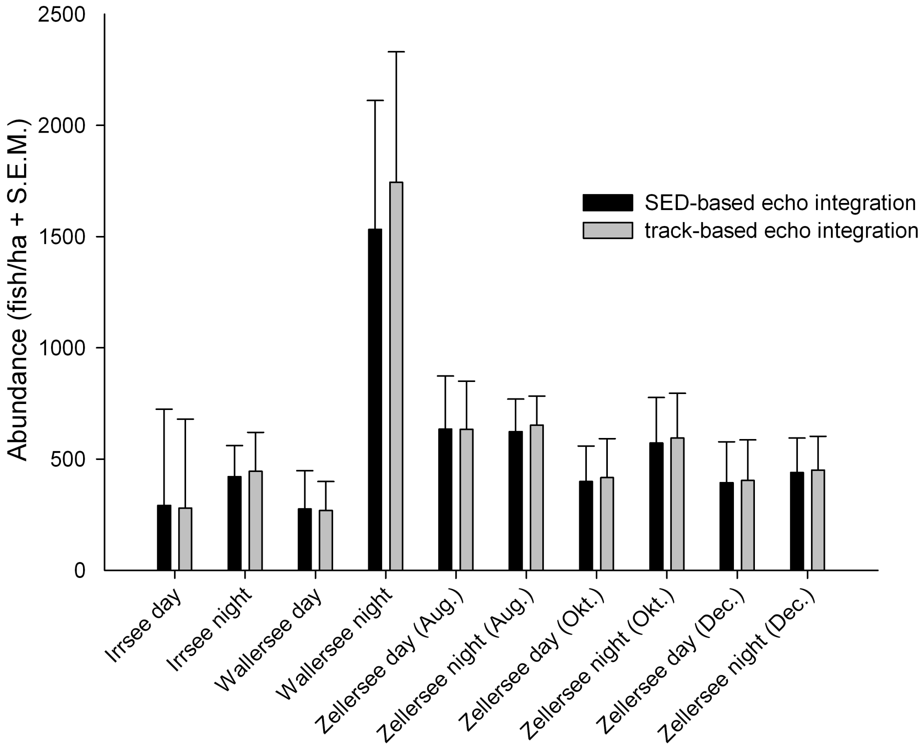
3. Results

Total abundance was not normally distributed (SED-based: n = 150, Z-value = 2.068, sig. ≤ 0.001; track-based: n = 150, Z-value = 2.229, sig. ≤ 0.001), whereas biomass estimates were normally distributed (SED-based: n = 150, Z-value = 1.148, sig. = 0.143; track-based: n = 150, Z-value = 1.242, sig. = 0.092). Since we compared total abundance and biomass estimates, non-parametric tests were used for further analysis.

The total abundance estimates for each lake had a relatively high range between transects in both methods, ranging from 65.89 fish ha^{-1} (SED-based) or 63.72 fish ha^{-1} (track-based) in lake Irrsee (March) during day to 2 438 fish ha^{-1} (SED-based) or 2 909 fish ha^{-1} (track-based) recorded in lake Zellersee (December) during day. Mean densities over all transects were not significantly different between the two methods (Fig. 2A; Mann-Whitney U-test; n = 300, Z = -0.560, sig. = 0.575). Biomass estimates (see Fig. 2B) for the transects varied between 2.57 kg ha^{-1} (SED-based, lake Irrsee during day) or 6.99 kg ha^{-1} (track-based, lake Wallersee day) and 236.66 kg ha^{-1} (SED-based) or 244.39 kg ha^{-1} (track-based) in lake Zellersee in October (night). The biomass estimates for all transects were not significantly different between the two methods (Mann-Whitney U-test; n = 300, Z = -0.336, sig. = 0.737). A significant difference between night and day was observed in both total abundance estimates, particularly at lake Wallersee (Mann-Whitney U-test; SED-based: n = 150, Z = -4.681, sig. ≤ 0.001; track-based: n = 150, Z = -4.993, sig. ≤ 0.001), as well as in biomass estimates (Mann-Whitney U-test; SED-based: n = 150, Z = -5.279, sig. ≤ 0.001; track-based: n = 150, Z = -5.242, sig. ≤ 0.001; see Fig. 2A & B).

A regression between the two sub-methods was calculated for total abundance and biomass estimates (Fig. 3). The regression between the two methods describing the results of the transects was very close to the expected line of unity for the abundance estimates ($[f\ ha^{-1}]_{tracking} = 1.105 * [f\ ha^{-1}]_{SED} - 30.782$; $r^2 = 0.979$) and did not significantly differ from the latter (ANCOVA, df = 149, F = 7066.262, sig. < 0.001). Same could be observed for the biomass estimates ($[kg\ ha^{-1}]_{tracking} = 0.950 * [kg\ ha^{-1}]_{SED} + 1.694$; $r^2 = 0.985$; ANCOVA: df = 149, F = 9573.738, sig. < 0.001).

A.)



B.)

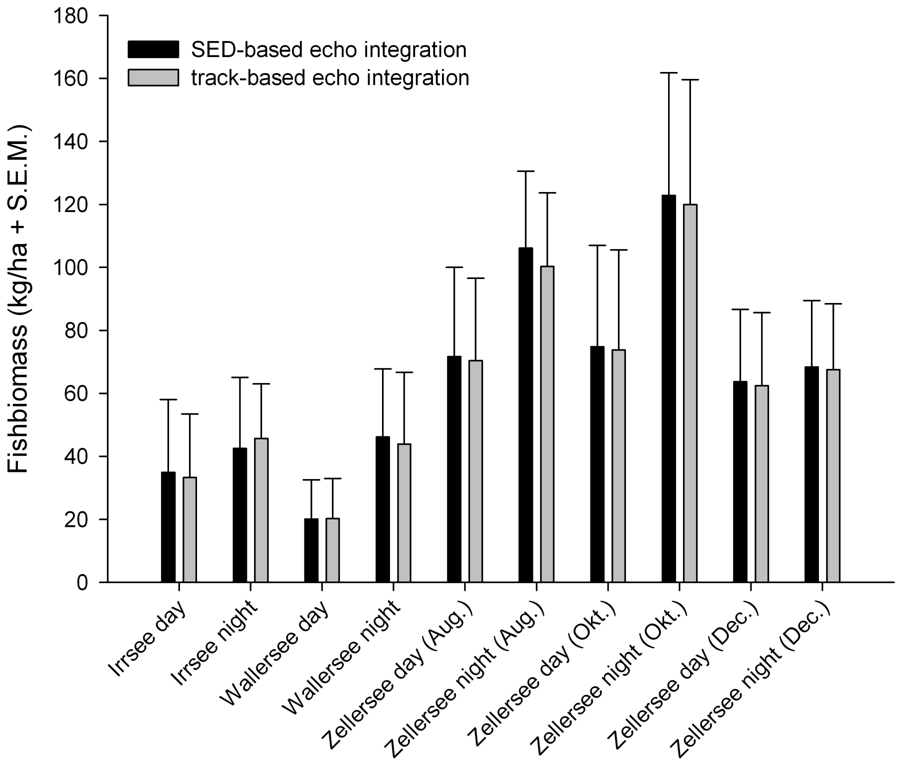
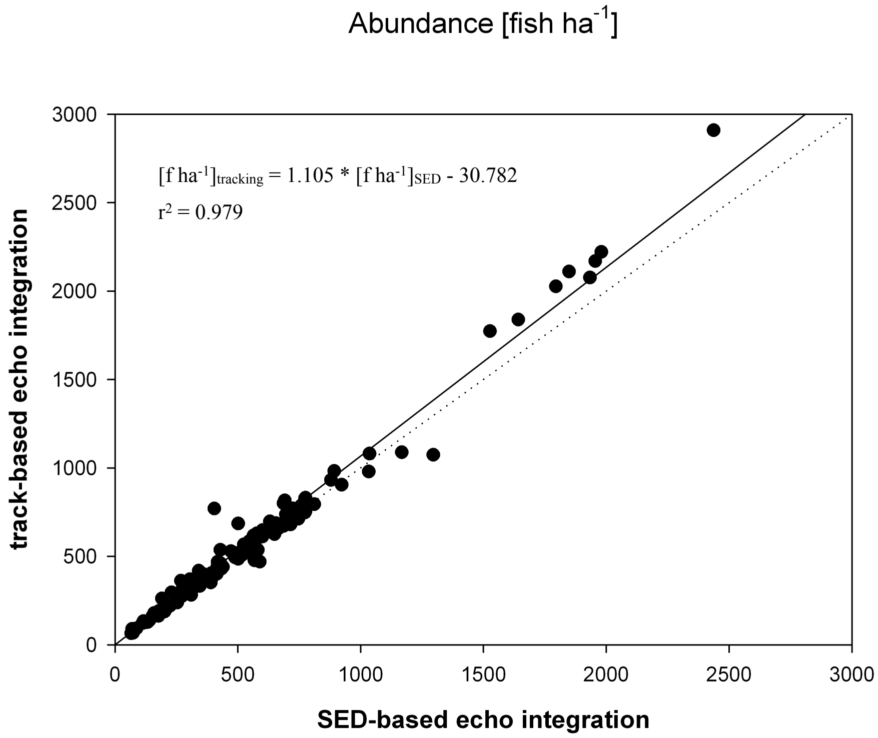


Figure 2: A.) Total fish abundance (fish/hectare) and **B.)** fish biomass (kg/hectare) during night and day surveys of three pre-alpine lakes in Austria

A.)



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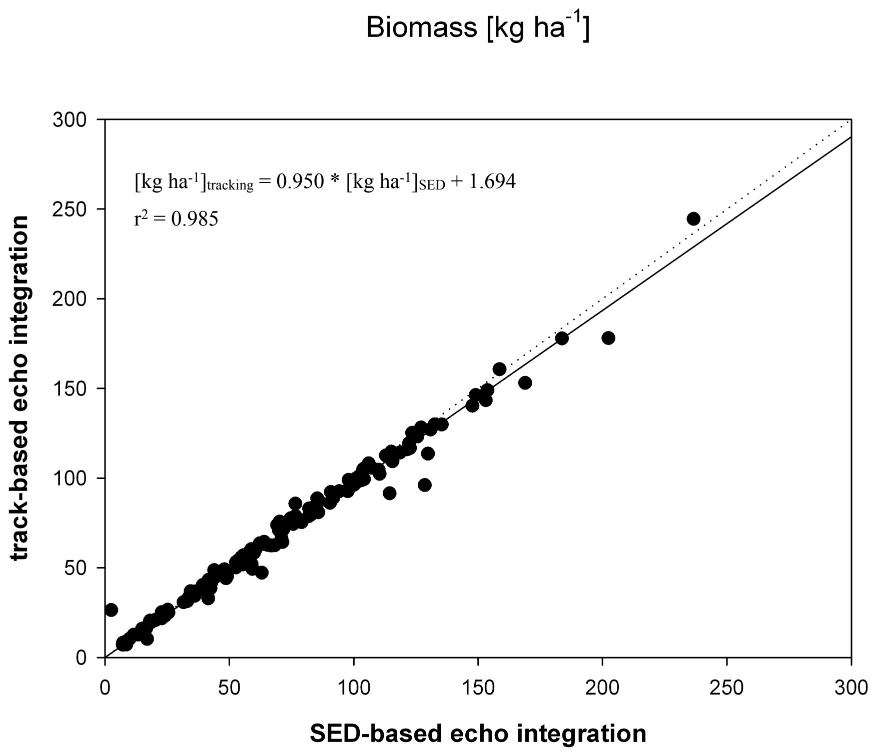

Figure 3: Regression of the two methods for total abundance (**A**) and biomass (**B**) results; the results from SED-based echo integration are the independent variable, the results from track-based echo integration the dependent variable; both regressions (total abundance and biomass) yield significant results, meaning that there are no significant differences between the two methods; the stippled lines represent the lines of unity;

Table 4: Significance levels from a Mann-Whitney U-Test between SED- and track-based echo integration for the different length classes showing non significant differences without exception; results are split between day and night

	night					day					
length class [cm]	Irrsee	Wallersee	Zellersee Aug.	Zellersee Oct.	Zellersee Dec.	Irrsee	Wallersee	Zellersee Aug.	Zellersee Oct.	Zellersee Dec.	length class [cm]
<10	0,423	0,145	0,392	0,232	0,296	0,873	0,655	0,792	0,365	0,516	<10
10-20	0,443	0,427	0,296	0,358	0,236	1,000	0,759	0,950	0,497	0,546	10-20
20-30	1,000	0,659	0,910	0,651	0,812	0,631	0,225	0,990	0,920	0,903	20-30
30-40	0,873	0,269	0,358	0,687	0,912	0,522	0,654	0,669	0,870	0,829	30-40
40-50	0,229	0,106	0,252	0,633	0,145	1,000	0,671	0,970	0,615	0,607	40-50
50-60	0,288	0,696	0,212	0,252	0,861	0,494	0,534	0,866	0,980	0,636	50-60
60-70	0,858	0,363	0,219	0,235	0,317	0,393	0,534	0,152	0,291	0,554	60-70
>70	0,528	1,000	0,961	0,152	0,908	0,798	0,917	1,000	0,593	0,971	>70

To check whether the two methods provide different length distributions, the relative frequencies of length classes within each survey between the two methods were tested.

No significant differences could be found in any survey (Mann-Whitney U-test, significance levels summarised in Table 4). There was, however, a significant difference in most lakes concerning single length classes between night and day surveys (see Fig. 4, significance levels in Table 5). Differences were tested for both analysis methods, but significance levels were more or less the same in both. Generally, the relative frequency of the length classes varied between day and night. Only in lake Irrsee the relative frequency of each length class did not vary significantly between night and day surveys.

Table 5: Significance levels from a Mann-Whitney U-Test between night and day surveys for the different length classes; significant values are written in bold letters; results are split between the two methods, but significances are mostly found at the same length class in each survey

	SED-based					track-based					
length class [cm]	Irrsee	Wallersee	Zellersee Aug.	Zellersee Oct.	Zellersee Dec.	Irrsee	Wallersee	Zellersee Aug.	Zellersee Oct.	Zellersee Dec.	length class [cm]
<10	1,000	0,064	**0,000**	0,725	**0,000**	1,000	**0,004**	**0,000**	0,687	**0,001**	<10
10-20	0,096	0,271	0,148	**0,000**	**0,018**	0,159	0,909	0,580	**0,000**	**0,004**	10-20
20-30	0,873	**0,013**	**0,001**	0,428	0,136	0,749	**0,007**	**0,004**	0,178	0,105	20-30
30-40	0,109	**0,003**	**0,001**	0,080	**0,000**	0,150	0,098	**0,001**	0,080	**0,000**	30-40
40-50	0,522	0,485	**0,015**	**0,007**	**0,004**	0,378	0,847	0,110	**0,017**	**0,001**	40-50
50-60	0,328	0,847	0,382	0,162	**0,006**	0,732	0,816	0,749	0,687	**0,020**	50-60
60-70	1,000	0,847	0,061	0,956	0,662	1,000	0,783	0,076	0,935	0,343	60-70
>70	0,592	0,257	0,152	1,000	0,532	0,181	0,257	0,152	0,317	0,492	>70

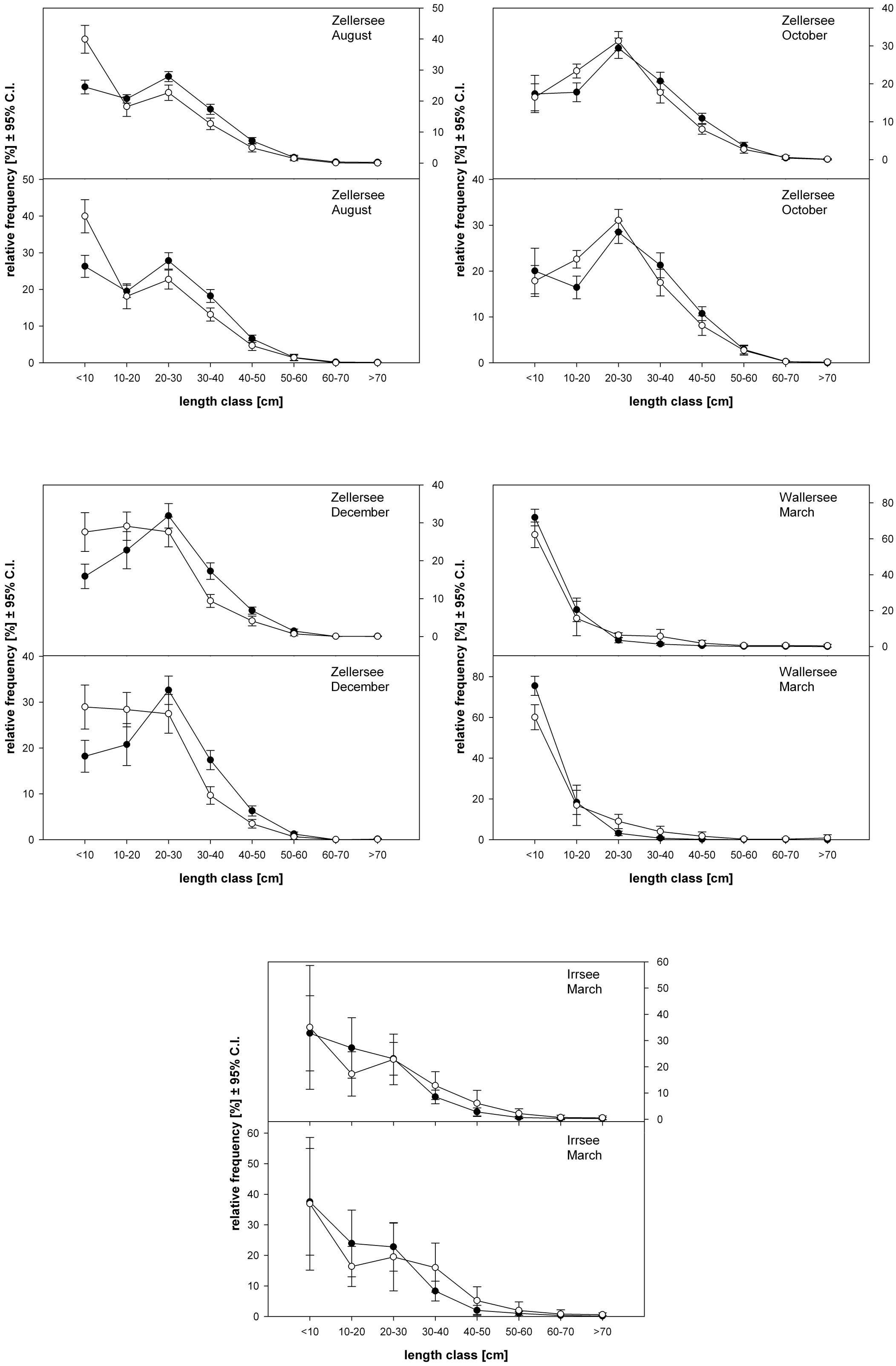

Figure 4: Relative frequencies of total length in 10-cm classes comparing proportions in each survey. Differences between the two methods SED-based (upper graph) and track-based echo integration (lower graph) are not significant; differences between night (black dots) and day (white dots) are significant in several surveys; Error bars indicate a 95% confidence interval

Table 6: Mean dB-Values and associated fish length for each survey and each method; significance values in the last column refer to Mann-Whitney U-tests for differences in dB-values between day and night (day and night surveys were not significantly different for lake Irrsee, but for all other surveys);

survey	method	month	day/night	mean length [cm]	mean dB	std. deviation	std. error mean	sig.
Irrsee	SED	March	night	19,86	-39,06	1,17	0,48	0,153
			day	22,73	-37,94	2,95	1,12	
	tracking		night	19,36	-39,27	1,64	0,67	0,116
			day	23,00	-37,84	2,92	1,10	
Wallersee	SED	March	night	10,41	-44,42	1,25	0,40	**0,001**
			day	16,69	-40,50	2,62	0,83	
	tracking		night	9,64	-45,05	1,13	0,36	**0,000**
			day	16,41	-40,64	2,56	0,81	
Zellersee	SED	August	night	25,21	-36,03	0,53	0,12	**0,000**
			day	21,50	-37,40	1,05	0,23	
		October	night	28,03	-38,20	0,98	0,21	**0,007**
			day	26,33	-38,72	0,65	0,14	
		December	night	26,08	-40,80	0,77	0,17	**0,000**
			day	21,14	-42,54	1,66	0,36	
	tracking	August	night	24,64	-36,27	0,45	0,10	**0,000**
			day	21,66	-37,43	0,97	0,21	
		October	night	27,40	-38,39	0,98	0,21	**0,019**
			day	26,04	-38,81	0,71	0,15	
		December	night	25,64	-40,94	0,70	0,15	**0,000**
			day	21,04	-42,58	1,53	0,33	

As shown in Figure 4, juvenile fish (<10 cm in total length) or larvae seemed to be more abundant in the pelagic water column during the day, at least in summer (August) and winter (December) surveys at lake Zellersee. Fish communities observed during day and night showed similar results between the two methods (regarding length distribution). Table 6 summarizes the mean target strength and associated mean fish length observed during day and night. Mean TS during the day was significantly different from the mean TS during the night, with exception of lake Irrsee. One has to keep in mind, however, that only 6 transects were recorded there, making a significant difference harder to detect. The pattern observed for mean TS was also visible for assocciated mean fish length. At lake Wallersee and Irrsee the mean fish length was higher during the day surveys compared to the night surveys. Contrary to lake Wallersee and Irrsee, the mean fish length during the day was lower than during the night at lake Zellersee. Similar tests were carried out for differences between the methods as well, but no significant differences between SED-based and track-based echo integration could be observed.

A generalized linear model showed that the variables ‚lake‘ (Wald Chi^2 = 48.24; sig. ≤ 0.001), ‚month‘ (Wald Chi^2 = 16.599; sig. ≤ 0.001) and ‚day/night‘ (Wald Chi^2 = 30.16; sig. ≤ 0.001) affected abundance estimates in hydroacoustic surveys. However, the two sub-methods of echo integration did not influence the results significantly (Wald Chi^2 = 0.412; sig. = 0.521). Similar results were found for biomass, where ‚day/night‘ (Wald Chi^2 = 106.147; sig. ≤ 0.001) and ‚month‘ (Wald Chi^2 = 116.849; sig. = ≤ 0.001) showed a significant model effect, whereas ‚lake‘ (Wald Chi^2 = 0.812; sig. = 0.368) and ‚method‘ (Wald Chi^2 = 0.309; sig. = 0.578) did not affect biomass estimates significantly.

4. Discussion

In our analysis we were not able to find any significant differences between the two approaches, namely SED-based vs. track-based echo integration. In the three whitefish-dominated pre-alpine lakes in Austria, both sub-methods resulted in comparable estimates of fish abundance and biomass. No significant differences in the relative frequencies of length classes within each survey were found between the two approaches. The main difference between the two sub-methods is the way they use the single echo detections. The SED-based approach takes the target strength of each echo detection into account seperately, whereas the track-based approach summarizes (if available) more than one SED to form a fish track, from which the mean TS is calculated. This means that if a fish is hit ten times, ten observations are included in the TS-distribution with the SED-based approach, whereas it only counts as one within the track-based approach. In other words: the second sub-method (tracking) performs weighting of SEDs according to their affiliation to individual fish.
This does affect the abundance estimates from echo integration and consequently biomass calculations due to shifts in the length distribution, especially if length classes are distributed heterogeneously over different depths.

To visualize this problem, let us assume that fish in deeper water layers are bigger than in upper water layers (Fig. 5). In this example only two fish individuals are present: a big fish and a small one. The big fish in the depth is hit 9 times by the hydroacoustic wave (in consecutive pings), the smaller one is observed at a much lower depth and is only hit one single time. The track-based approach reproduces the relative frequencies correctly by stating that there are 50% big and 50% small fish, because each fish - no matter how often it was hit by the beam - is seen as one fish.

The SED-based approach on the other hand would suggest that there are 90% big and 10% small individuals because it takes into account each single echo detection seperately. Therefore the SED-based approach would give a wrong impression of relative frequencies. As fish populations rarely consist of only two individuals, we could add many more fish to this example, but as long as the variation in length over depth stays the same (big fish near the bottom, small fish near the surface) the systematic error persists.

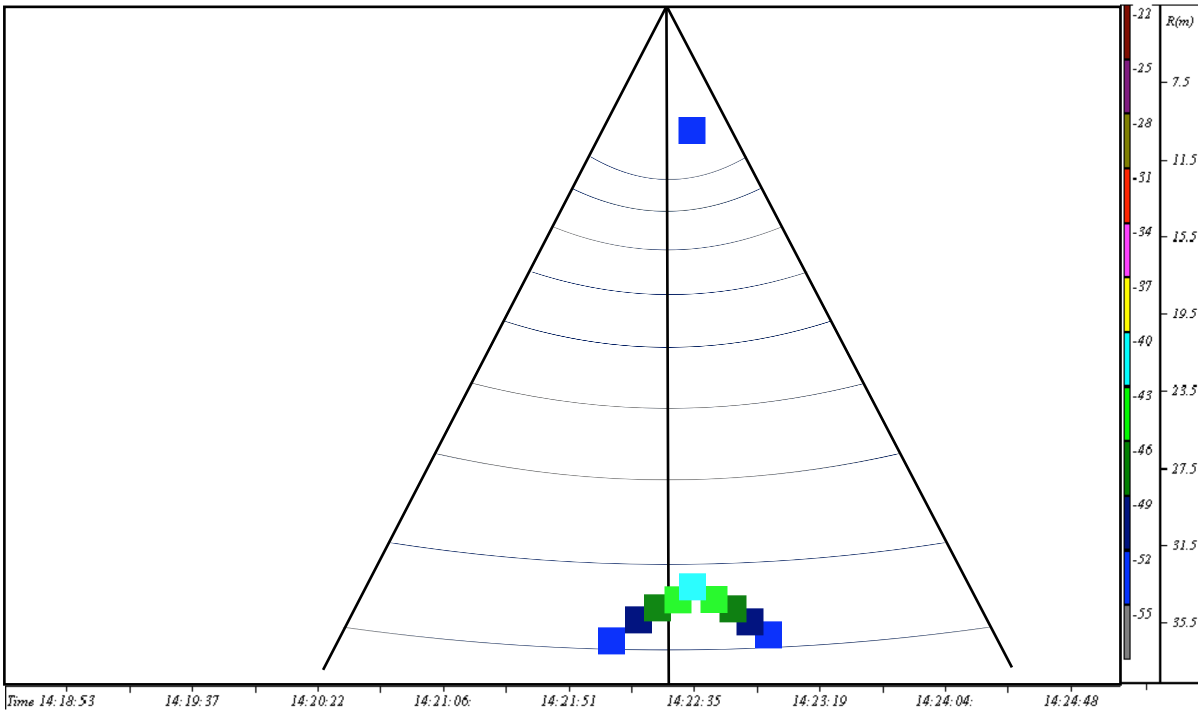

Figure 5: Hypothetical example; small fish stay in the upper layers, big fish in deeper layers; due to the propagation of the beam, fish near the surface are only hit one single time (one SED), whereas fish in the depth are hit more often (in this example 9 SEDs); colored dots represent the single echo detections, black lines represent the hydroacoustic beam, y-axis is the depth, x-axis is the time; colors of the SEDs represent the measured dB-values (second x-axis);

To conclude the problem: fish in deeper layers are always hit more often than fish in shallow layers. This might induce a bias to the fish abundance estimates in the SED-based approach, if the length distribution of fish differs between depth layers. This might also be a problem in multi-species lake systems where different species with different length classes are found in different depth layers. Howerver, trawling in different depths in lake Hallstättersee (also a whitefish-dominated pre-alpine lake in Austria) showed that size distribution of whitefish did not significantly change with depth (unpublished data, Wanzenböck, Kubecka & Frouzova). Therefore we assume that this problem is minimized for the SED-based approach in our surveys as well.

Generally, fish in upper layers are underrepresented in both sub-methods. One reason is the beam propagation. The area of the beam in 4 m depth (transducer opening angle 4°x10°) is only ~ 1 m^2. Another reason is the avoidance reaction of fish, mostly due to sounds from the moving boat (Draštík and Kubečka 2005, Guillard et al. 2010). These systematic errors affect both methods similarly.

In this study we set the minimum number of SEDs for a track to only one SED in order to be able to compare results between the two different approaches. The next step should be a comparison between a set of surveys within the track-based approach with differing minimum number of SEDs for track recognition. Subsequently, other lake-types and fish communities should be compared with the focus on the question, whether the two approaches yield different results when the length distribution is heterogeneously distributed over the study area.

This study also showes, that the time at which a survey is conducted has an impact on the results. This does not only apply to the time of day, but also to the time of year in which the survey is carried out. We found significant differences between night and day surveys with regard to the observed fish communities (change in observed length classes, change in mean length of fish) and total abundance and biomass estimates. Differences in abundance and biomass were also observed for seasons, especially for lake Zellersee. All together, this study underlines once more the importance of multiple surveys for an accurate prediction of fish abundance and biomass in lakes .

Overall, the method of echo-integration yields valueable results for fish abundance and biomass estimation in whitefish-dominated pre-alpine lakes in Austria. The methodical approach (echo-integration) gives similar results, regardless of the used sub-method (SED- or track-based). Other factors such as the time of the day and year have a much stronger influence on the results than the used sub-method does. It can be concluded that acoustic methods are a valuable tool for both private and public matters, whether it is used for stock management or evaluation of the ecological status of a lake for the Water Framework Directive.

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6. References

Appenzeller, A.R. 1992. On the application of hydroacoustic methods to analyses of the distribution and abundance of pelagic fishes: behavioral and statistical considerations, Nationallibrary of Canada, Department of Biology, McGill University, Montreal, Quebec.

Appenzeller, A.R., and Leggett, W.C. 1992. Bias in Hydroacoustic Estimates of Fish Abundance due to Acoustic Shadowing: Evidence from Day–Night Surveys of Vertically Migrating Fish. Canadian Journal of Fisheries and Aquatic Sciences **49**(10): 2179-2189.

Axenrot, T., Didrikas, T., Danielsson, C., and Hansson, S. 2004. Diel patterns in pelagic fish behaviour and distribution observed from a stationary, bottom-mounted, and upward-facing transducer. ICES Journal of Marine Science: Journal du Conseil **61**(7): 1100-1104.

Balk, H., and Lindem, T. 2007. Sonar4 and Sonar5-Pro post processing systems (operating manual). Lindem Data Acquisition, Oslo: 427 S. .

Beiwl, C., and Wolfgang, R. 2010. Natürliche und künstliche Seen Österreichs größer als 50 ha. Schriftenreihe des Bundesamtes für Wasserwirtschaft.

Brandt, S. 1996. Acoustic assessment of fish abundance and distribution (2nd ed.). *In* Fisheries Techniques. pp. 385–419.

CEN. 2009. Water quality - Guidance on the estimation of fish abundance with mobile hydroacoustic methods (BS EN 15910). European Committee for Standardization.

Djemali, I., Toujani, R., and Guillard, J. 2009. Hydroacoustic fish biomass assessment in man-made lakes in Tunisia: horizontal beaming importance and diel effect. Aquatic Ecology **43**(4): 1121-1131.

Draštík, V., and Kubečka, J. 2005. Fish avoidance of acoustic survey boat in shallow waters. Fisheries Research **72**(2-3): 219-228.

Draštík, V., Kubečka, J., Čech, M., Frouzová, J., Říha, M., Juza, T., Tušer, M., Jarolím, O., Prchalová, M., Peterka, J., Vašek, M., Kratochvíl, M., Matěna, J., and Mrkvička, T. 2009. Hydroacoustic estimates of fish stocks in temperate reservoirs: day or night surveys? Aquat. Living Resour **22**(1): 69-77.

Ehrenberg, J. 1980. Echo counting and echo integration with a sector scanning sonar. Journal of Sound and Vibration **73**(3): 321-332.

Ehrenberg, J.E., and Torkelson, T.C. 1996. Application of dual-beam and split-beam target tracking in fisheries acoustics. ICES Journal of Marine Science: Journal du Conseil **53**(2): 329-334.

Gassner, H., Riedlsperger, R., Patzner, R., and Jagsch, A. 1998. Das Wachstum der Renken (Coregonus lavaretus) des Irrsees und des Zeller Sees. Österreichs Fischerei(51): 14-19.

Gassner, H., Wanzenböck, J., Tischler, G., Hassan, Y., Lahnsteiner, B., Jagsch, A., and Patzner, R. 2000. Projektsendbericht - Fischbestände und die ökologische Funktionsfähigkeit stehender Gewässer. ÖAW - Institut für Limnologie, Mondsee. p. 121.

Godlewska, M., Colon, M., Doroszczyk, L., Długoszewski, B., Verges, C., and Guillard, J. 2009. Hydroacousticmeasurements at two frequencies: 70 and 120 kHz – consequences for fish stock estimation. Fisheries Research **96**(1): 11-16.

Guillard, J., Balay, P., Colon, M., and Brehmer, P. 2010. Survey boat effect on YOY fish schools in a pre-alpine lake: evidence from multibeam sonar and split-beam echosounder data. Ecology of Freshwater Fish **19**(3): 373-380.

Guillard, J., Lebourges-Dhaussy, A., and Brehmer, P. 2004. Simultaneous Sv and TS measurements on Young-of-the-Year (YOY) freshwater fish using three frequencies. ICES Journal of Marine Science **61**(2): 267-273.

Jacobsen, L., Berg, S., Jepsen, N., and Skov, C. 2004. Does roach behaviour differ between shallow lakes of different environmental state? Journal of Fish Biology **65**(1): 135-147.

Kubecka, J. 1993. Night inshore migration and capture of adult fish by shore seining. Aquaculture Research **24**(5): 685-689.

Love, R.H. 1971. Dorsal-Aspect Target Strength of an Individual Fish. The Journal of the Acoustical Society of America **49**(3B): 816-823.

MacLennan, D. 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science **59**(2): 365-369.

Mehner, T., Gassner, H., Schulz, M., and Wanzenböck, J. 2003. Comparative fish stock estimates in Lake Stechlin by parallel split-beam echosounding with 120 kHz. Ergebnisse der Limnologie: 227-236.

Richards, L.J., Kieser, R., Mulligan, T.J., and Candy, J.R. 1991. Classification of Fish Assemblages based on Echo Integration Surveys. Canadian Journal of Fisheries and Aquatic Sciences **48**(7): 1264-1272.

Rudstam, L.G., Hansson, S., Lindem, T., and Einhouse, D.W. 1999. Comparison of target strength distributions and fish densities obtained with split and single beam echo sounders. Fisheries Research **42**(3): 207-214.

Schmidt, M., Kühlmann, M., Gassner, H., and Meyer, I.E. 2004. Hydroakustische Untersuchungen zum Fischbestand der Hennetalsperre. Landesfischereiverband Westfalen und Lippe e.V., Münster.

Schmidt, M.B. 2006. Benefits from hydroacoustics in fisheries managment and behavioural studies of coregonids, Faculty of Biology, University of Münster, Münster.

Simmonds, E.J., and MacLennan, D.N. 2005. Fisheries acoustics: theory and practice. Blackwell Science.

Simrad. 1995. Simrad EY500 Portable Scientific Echosounder. Instruction Manual.

Wanzenböck, J., and Gassner, H. 2001. Assessment of fish biomass distribution in Austrian lakes and visualization in a 3D GIS.

Wanzenböck, J., Mehner, T., Schulz, M., Gassner, H., and Winfield, I.J. 2003. Quality assurance of hydroacoustic surveys: the repeatability of fish-abundance and biomass estimates in lakes within and between hydroacoustic systems. ICES Journal of Marine Science **60**(3): 486-492.

Winfield, I.J., Emmrich, M., Guillard, J., Mehner, T., and Rustadbakken, A. 2012. Guidelines for standardisation of hydroacoustic methods. Water bodies in Europe: Integrative Systems to assess Ecological status and Recovery.

Anhang

Zusammenfassung

Hydroakustik spielt eine immer bedeutendere Rolle in Fischökologie und kommerzieller Fischerei. Um die Genauigkeit von hydroakustischen Analysen gewährleisten zu können ist eine breite Wissensbasis notwendig, welche möglichst wenige Lücken enthalten sollte. Diese Studie befasst sich mit der Fragestellung, inwieweit zwei unterschiedliche Sub-Methoden der Echo Integration ähnliche (oder eben unähnliche) Ergebnisse liefern, wenn diese an denselben Daten angewendet werden.

Der Hauptunterschied zwischen den beiden Sub-Methoden besteht darin, dass erstere (SED-basierte) Methode jede einzelne Detektion (SED) des Echolots und deren Signalstärke (TS) in ihre Berechnung miteinbezieht, während zweitere (Track-basierte) Methode mehrere Detektionen zu einem Track, also einer Spur, zusammenfasst und von dieser Spur die mittlere Echostärke berechnet und für weitere Analysen verwendet.

In dieser Studie werden Daten von drei Seen verglichen. Die Echolotdaten wurden bei Tag und Nacht sowie in unterschiedlichen Jahreszeiten aufgenommen. Beim Vergleich der beiden Sub-Methoden der Echo-Integration konnten keine signifikanten Unterschiede in den Ergebnissen festgestellt werden. Beide Methoden liefern ähnliche Ergebnisse bezüglich Fischabundanz und Biomasse. Die Längenklassen der Fische in den drei Seen unterscheiden sich nicht hinsichtlich der Auswertemethode, sehr wohl aber zwischen Tag und Nacht. Die Zeit (sowohl Tageszeit als auch Jahreszeit) hat einen großen Einfluss auf die Ergebnisse der Abundanz- und Biomasseanalysen. Wir kommen aufgrund dieser Ergebnisse zu dem Schluss, dass die beiden Methoden stabile Ergebnisse liefern, die Vergleichbarkeit von hydroakustischen Untersuchungen aber stark durch tages- und jahreszeitliche Fischmigrationen in der Vertikalen sowie in der Horizontalen beeinträchtigt wird.

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- MITHILFE BEI WISSENSCHAFTLICHEM PROJEKT AN DONAU und SCHWECHAT (QUANTIFICATION OF DRIFTING PLASTIC-PELLETS IN THE RIVER SCHWECHAT AND IN THE MAIN CHANNEL OF THE RIVER DANUBE - §27 Project FA 572016)

The entry of plastic pellets into the River Schwechat and River Danube is quantified by means of drift measurements at different discharge regimes. The sampling design enables the analyses of the type and quantity of the input, and potential sources. Additionally the temporal mode of transport from the entry into the tributary and in the main channel of the Danube is analysed. The aim of the study is to get detailed information on the type, size and quantity of drifting plastic granulate at a fine temporal scale along the inshore zone of the two Rivers, in order to get more information to develop further mechanisms for prevention of release measures (Keckeis-Lab.

- MITHILFE BEI WISSENSCHAFTLICHEM PROJEKT AM GRUNDLSEE (P_143100_12 - 2009/2010)

Im Zuge des Projektes „Untersuchung der Hechtbandwurm-epidemie im Grundlsee" der Universität Salzburg unter der Leitung von Prof. Robert Schabetsberger wurden 2009/10 Befischungen des Hechts am Grundlsee durchgeführt. Das Projekt versuchte, den Hechtbandwurm *Triaenopherus crassus* durch die Abfischung des im Grundlsee nicht heimischen Hechtes einzudämmen. In der Laichzeit wurde der Hecht mit Reusen und Kiemennetzen befischt und die gefangenen Exemplare protokolliert.

- TUTOR, ÜBUNG ZUR FUNKTIONELLEN ÖKOLOGIE - Biodiversität und Funktionalität von verbauten und unverbauten Flußabschnitten am Beispiel der Wien (SS'11)

Anhand eines verbauten und unverbauten Abschnittes des Wienflusses werden an 3 Freilandtagen wichtige Biodiversitäts- und Funktionalitätsparameter erhoben, die das Wesen eines funktionierenden Fließgewässerabschnittes erlebbar machen. Auswertungen: Erstellung von Taxalisten der Makrophyten des Uferstreifens, der Algen, des Makrozoobenthos und der Fische mittels eigener Bestimmungsskripten oder empfohlener Bestimmungsbücher; Berechnung gängiger Diversitätsindices, Feststellung der funktionellen Ernährungstypen; Auswertung der Freilandexperimente und -messungen, Anleitung zur Präsentation (Grafik- und Tabellenerstellung). Die Einzelergebnisse illustrieren die Bedeutung intakter Fließgewässerabschnitte für die Selbstreinigung, die Retention großer Wassermengen und für die ökologische Funktionsfähigkeit.

- TUTOR, ROVINJ-EXKURSION DER UNI SALZBURG (2009/2010/2011/2012)

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Schülergruppen sollen anhand der oberen Adria verschiedene marine Lebensräume nähergebracht werden. Unter der Leitung von Dr. Angelika Götzl lag der Aufgabenbereich dabei im Halten von Vorträgen über verschiedene Themenbereiche (z.B. Lebensformen in der Adria, Felslithoral, Verlandungszone, Seegraswiese, ...).

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ARBEITEN

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