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1 *In situ* TS detections using two generations of echo-sounder, EK60 and EK80 : the
2 continuity of fishery acoustic data in lakes

3

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14

15 **Abstract**

16 Used for several decades and recognized today as a reliable method, fishery acoustics is
17 commonly used in scientific studies and monitoring surveys. In Europe, during the last
18 decades, the most frequently used scientific echo-sounder has been the EK60 from the Simrad
19 company (Simrad Kongsberg Maritime AS, Horten, Norway). A new echo-sounder model,
20 the EK80, has been recently developed, and it is therefore necessary to check whether the
21 results obtained by the two generations of echo-sounder (EK60 and EK80) give the same
22 results. This is of main importance in the context of time series. Recent works have already
23 addressed this comparison, focusing on S_A (nautical area backscattering coefficient) but the
24 systems' reliability to accurately measuring target strength (TS, in dB) has only been tested
25 using calibration spheres. Our work aims to test the hypothesis that, at a given frequency, the
26 TS recorded simultaneously *in situ* by an EK60 and an EK80, in CW mode, were not
27 statistically different. Data were recorded in two peri-alpine lakes using the two systems
28 sampling sequentially a similar volume. Using statistical tests, acoustics metrics were
29 compared. For TS, statistically significant differences were found between the two
30 generations of echo-sounder. However, these differences were not large enough to affect the
31 fish density used for fishery management or researches on the fish population. The continuity

32 of the time series acquired with the EK60 is ensured when one switches to the EK80 echo-
33 sounder for lake ecosystem research and monitoring.

34

35 **Highlights**

- 36 - Fishery acoustics is commonly used and reliable.
- 37 - A new echo-sounder, the EK80, has been recently developed.
- 38 - It is necessary to check *in situ* whether the results obtained by the two generations of
39 echo-sounder give same results.
- 40 - *In situ* differences on TS values were not large enough to affect the fish density results.
- 41 - The continuity of the time series acquired with the EK60 is ensured when one
42 switches to the EK80.

43

44 **Keyword**

45 Hydro-acoustics, Freshwater, Target Strength, *In situ*, Lake

46

47 1. Introduction

48 Hydro-acoustics is a non-invasive method to assess fish abundance in aquatic ecosystems
49 (Rudstam et al., 2012; Simmonds and MacLennan, 2005) and to describe their relationships
50 with ecosystem features (Koslow, 2009; Trenkel et al., 2011). It has been standardized for
51 lake surveys both on the North American continent for the Great Lakes (Parker-Stetter et al.
52 2009) and on the European continent related to the Water Framework Directive (CEN, 2014;
53 Draštkík et al., 2017). Used for several decades and recognized today as a reliable method
54 (Rudstam et al. 2012), fishery acoustics is commonly used in scientific studies and monitoring
55 surveys in lakes (Baran et al., 2021; Godlewska et al., 2016; Pollom and Rose, 2016;
56 Wheeland and Rose, 2016).

57 During the last decades, in Europe, the most frequently scientific echo-sounders used for
58 research and monitoring surveys, both in freshwater and marine environments, are from the
59 Simrad company (Simrad Kongsberg Maritime AS, Horten, Norway). The EK60 echo-
60 sounder was marketed about 20 years ago (Andersen, 2001), and a new echo-sounder model,
61 the EK80, has been recently developed. In the medium term, EK80 will replace the EK60; its
62 maintenance will be no longer assured. EK80 has the capacity to emit in CW mode
63 (continuous wave), as the EK60, as well as in broadband mode (Frequency Modulated signal)
64 (Demer et al., 2017). The broadband method is an opportunity to discriminate between
65 different targets using the acoustic spectrum, to develop new broadband school parameters to
66 classify echo-traces, and to improve size detection (Bassett et al., 2018; Benoit-Bird and
67 Waluk; 2020; Blanluet et al., 2019; Blanluet et al., 2022 ; Gugele et al., 2021).

68 In the medium term, research works and monitoring surveys using the EK60 will have
69 to migrate to the new model EK80. The components and software of the EK80 are obviously
70 different from those of the EK60 (Demer et al., 2017), and therefore it is necessary to check
71 whether the results obtained by the old (EK60) and the new (EK80) systems give similar
72 results. This is of main importance to maintain time series (Pollom and Rose, 2016; Braun
73 and Mehner, 2021).

74 Recent works (De Robertis et al., 2019; MacCaulay et al., 2018), as well as a ICES
75 (International Council for the Exploration of the Sea) report (Demer et al., 2017), have
76 already addressed this comparison, focusing on S_A (nautical area backscattering coefficient, in
77 $m^2 \cdot nmi^{-2}$) (MacLennan et al., 2002), a metric proportional to the fish abundance (Simmonds
78 and MacLennan, 2005). If they have shown some dissimilarities between EK60 and EK80
79 data, notably at low power (De Robertis et al., 2019), these differences were negligible when
80 working in normal survey conditions (strong backscatters, medium range). These works have
81 been carried out in marine environment, using several frequencies. The systems' reliability to
82 accurately measuring target strength (TS, in dB) (MacLennan et al., 2002) has only been
83 tested using calibration spheres (De Robertis et al., 2019; MacCaulay et al., 2018). This
84 metric, corresponding to a proxy of the individual fish size (Rudstam et al., 2012), allows to
85 describe the size spectra of fish population and then to calculate a biomass per unit area
86 (Simmonds and MacLennan, 2005). TS is widely used in freshwater research and surveys
87 (Draštík et al., 2017; Pollom and Rose, 2016; Wheeland and Rose, 2016).

88 Therefore, our work aimed to test the hypothesis that, at a given frequency, the TS
89 values, recorded simultaneously *in situ* by an EK60 and an EK80 in CW mode, were not
90 statistically different, and finally that one can consider that data from the two generations of
91 echo-sounder are the same. Preliminary, as observed in previous works (De Robertis et al.,
92 2019; MacCaulay et al., 2018), we checked that no significant difference was observed on the
93 S_A means from the two sounders. We acquired data at two lakes using the two systems
94 sampling sequentially a similar volume, at the most used frequency in lakes (Draštík et al.,
95 2017). Data were analyzed using the same software and parameters. In this way, we tested
96 whether the data series could be continued without breakage, despite the change of echo-
97 sounders.

98

99 2. Materials and Methods

100 2.1. Study site

101 The surveys were performed in two deep peri-alpines lakes in France, Lake Annecy
102 (45°51'24"N; 06°10'20"E) (14 September 2020) and Lake Bourget (45°43'55"N; 5°52'06"E)
103 (29 and 30 September 2020), as part of annual monitoring surveys of the Observatory of
104 LAKes (OLA) (Rimet et al., 2020). The fish population in the two lakes are similar (Guillard
105 et al., 2014) and well known (Frossard et al., 2021; Jacquet et al., 2021). Furthermore,
106 methodological acoustic surveys were regularly performed in these two lakes (Blanluet et al.,
107 2020; Perrot et al., 2010; Guillard et al., 2014).

108 At the time of the surveys – end of summer (CEN, 2014) – the two lakes were stratified (Fig.
109 1) (data from OLA [http:// www6.inra.fr/soere-ola](http://www6.inra.fr/soere-ola) ©SOERE OLA-IS, AnaEE-France, INRAE
110 Thonon-les-Bains, CISALB, SILA, Eco-Informatics ORE INRAE Team). This stratification
111 between the upper (warm) and deeper (cold) layers structures the distribution of the fish
112 communities, according to their thermal preferendum (Mehner 2012; Yule et al., 2013).
113 Salmonids are in the deeper layers, while *Percidae* and *Cyprinidae* are dominant in the upper
114 layers (Guillard et al., 2006; Guillard et al., 2014). According to the thermal profiles, the two
115 layers were defined as i) the “surface layer”, set from 3 m (the volume between the surface
116 and 3 m depth was excluded to avoid near field and surface-related noise) to 14 m in Lake
117 Annecy and to 16 m in Lake Bourget ; and ii) the “deep layer”, from respectively 14 and 16 m
118 depth to the bottom. Shallow near-ground areas (bottom less than 5 m) were excluded from
119 the analyses.

120 2.2. Surveys

121 Hydroacoustic surveys were performed following the acquisition standard (CEN, 2014), using
122 a EK60 GPT and a EK80 WBT-Mini echo-sounder, respectively link to two ES120-7C
123 transducers with a theoretical open angle of 7° degrees at -3 dB (EK60 transducer Along ship:
124 6.75° / Athwart ship: 6.76°; EK80 transducer Along ship: 6.55° / Athwart ship: 6.60°) and
125 recording using the EK80 software from a unique laptop. The transducers were set one behind
126 the other, in the direction of sailing, to maximize the overlap of the sampling volume on a
127 vertically oriented frame and set 0.70 m below the surface. This setup has already been used
128 in previous methodological surveys to test the impact of frequencies and pulse length on fish
129 stock assessments (Guillard et al., 2014; Mouget et al., 2019). The two echo-sounders, driven
130 by the same computer and acquisition software, emitted sequentially at 120 kHz, with a pulse
131 length set at 0.256 ms (Godlewska et al., 2011), a ping rate at 5 Hz and a transmission power

132 of 50 W for the EK80 and 100 W for the EK60 records. These parameters are the ones most
133 used in lakes (Draštík et al., 2017).

134 The surveys, georeferenced by a GPS connected to the echo-sounder, followed a zigzag
135 course at a navigation speed of about 8 km.h⁻¹ in calm to moderate wind conditions (CEN,
136 2014; Draštík et al., 2017). The surveys were performed at night, approximately 1 h after
137 sunset, to sample the fish when their distribution is as dispersed as possible within the water
138 column (Girard et al., 2020). Calibrations were performed using the EK80 software for both
139 echo-sounders according to the standard protocol of Foote et al. (1987) (Demer et al., 2015)
140 and the manufacturer's manual. For the EK80, the calibration was performed in a "calibration
141 tank" at Ifremer (Brest, France), and for the EK60, the calibration was performed *in situ*. To
142 overcome the variability inherent in *in situ* calibrations, the echo-sounder was calibrated three
143 times, and the results averaged following recommendations of De Robertis et al. (2019).

144 2.3. Acoustic data process

145 Data were analyzed using Sonar5-Pro software (Balk and Lindem, 2021), a software regularly
146 used in freshwater studies. The TS threshold was set at -60 dB for Single Echo Detection
147 (SED) according to monitoring surveys in lakes (Draštík et al., 2017). This threshold allowed
148 fish detection greater than ~ 0.02 m using Love's equation (Love, 1971), an equation
149 commonly used in freshwater surveys (Emmrich et al. 2012; Morrissey-McCaffrey et al.,
150 2018; Tessier et al., 2020). SED was determined in Sonar5-pro using the following
151 parameters: a pulse length ratio between 0.8 and 1.3; a maximum gain compensation of 3 dB
152 (one way); and a sampling angle standard deviation of 0.3 degrees (Godlewska et al., 2011;
153 Guillard et al., 2014). The threshold of the mean volume backscattering strength, S_v (in dB re
154 1 m⁻¹), was set 6 dB lower, at - 66 dB, according to Parker-Stetter et al. (2009). The data from
155 the two echo-sounders were simultaneously processed, using the multi-frequency function of
156 Sonar5-Pro, creating two channels (Balk and Lindem, 2021). The bottom was automatically
157 detected using the software's tool, including a margin of 0.5 m and, in rare cases, was
158 manually rectified on both channels. The Elementary Distance Sampling Unit (EDSU) was set
159 to 250 m (same as applied by Guillard et al. 2014; Mouget et al., 2019) and allowed to extract
160 the mean Target Strength (calculated in the linear domain) by layers, and in the same way, the
161 S_A values (expressed in hectare acoustic scattering strength, in m².ha⁻¹). The study focusing
162 on fish surveys, to avoid analyzing unwanted non-fish echoes (Emmrich et al., 2014), the
163 Sonar5-Pro cleaning tool was simultaneously used on both echograms to remove ghost echoes,

164 bubbles, debris accumulations, ropes from gillnets/buoys, and fake bottoms. A few EDSU
165 with too many noises and artefacts (e.g., buoys) were excluded from the analysis. Finally, the
166 Sawada index (Sawada et al., 1993) was set to ensure that conditions permitted estimation of
167 TS. Thus, to overcome the presence of multiple echoes that would impact the TS estimation,
168 only EDSU with a Sawada index $<$ to 0.1 were used for the size distribution analyses
169 (Godlewska et al., 2011).

170 2.4. Statistical analysis

171 The mean values of TS were compared using the Mann-Whitney U-test, as the data did not
172 follow a normal distribution. For TS, the test was performed in the linear domain (Simmonds
173 and MacLennan 2005). Furthermore, to compare data from each EDSU, i.e., pairs of TS from
174 EK60 and EK80 for each EDSU, the procedure developed by Warton et al. (2006) was done
175 in addition to linear regression, the slopes of the data set were compared with a 1:1 line. This
176 statistical approach is recommended when the measurement error is unknown, which is the
177 case with the acoustic data set (Mouget et al., 2019). This statistical procedure was performed
178 in previous analysis of comparisons of acoustic data set (Godlewska et al., 2011; Guillard et
179 al., 2014; Mouget et al., 2019). The statistical test evaluated whether the two metrics from the
180 EK60 and EK80 meet the H_0 hypothesis that the two sets of data are the same. SED
181 distributions were tested using the Kolmogorov-Smirnov test. The Lake Annecy and Lake
182 Bourget data were merged to perform statistical tests on a larger sample. Finally, fish
183 densities were calculated for each layer and lake using Forbes and Nakken's (1972) equation
184 (Tessier et al., 2020).

185

186 3. Results

187 3.1. Data set

188 In Lake Bourget, 582 EDSU were recorded for the surface layer, 578 for the deep layer; in
189 Lake Annecy, 284 EDSU were recorded for the surface layer and 290 for the deep layer
190 (Table 1). Analyses were performed on a total of 1652 EDSU for TS analysis and 1654 EDSU
191 for S_A comparisons (Table 1) , two EDSU being excluded for TS due to an inappropriate
192 Sawada index. Echograms from the two devices appeared to be similar (Fig. 1). According to
193 previous works (De Robertis et al., 2019; MacCaulay et al., 2018) no significant difference in
194 the S_A means between the two generations of echo-sounders, regardless of the layer, were

195 found (Annex 1).

196 3.2. TS values according to the echo-sounders

197 The number of SED detected by each echo-sounder was very close. The EK60 detected
198 43,631 SED for the two layers compared to 43,726 for the EK80, a difference of 0.2%. This
199 difference was mainly due to a higher number of targets detected by the EK80 in the deep
200 layer: 19,490 SED for the EK80 against 18,779 SED for the EK60, i.e., a difference of 3.6%.
201 In the surface layer, the number of SEDs recorded by the EK80 is slightly lower, with 24,236
202 against 24,852 for the EK60, a difference of 2.5%. For the surface layer, there is a slight shift
203 in the main mode of the TS distribution, - 47.8 dB for EK60 values against -47.3 dB for the
204 EK80 values. There was no offset for the secondary mode (-59.3 dB) (Fig. 2). For the deep
205 layer, the distributions were similar, with the same modes for the two echo-sounders (main
206 mode: -37.6 dB; secondary mode: -52 dB), even if there were significant statistical difference
207 between the SED distributions using the Kolmogorov-Smirnov test ($p < 0.01$).

208 There was no significant difference in mean TS (Table 2) using Wilcoxon's nonparametric
209 test to compare the two types of echo-sounder for the surface layer (p -value > 0.05), but this
210 difference was significant for the deep layer (p -value = 0.0004). When the layers were merged,
211 there was still a slightly significant difference between the means (p -value = 0.02) (Table 2).
212 The box plots of the TS values (Fig. 3) also show the similarities between the datasets
213 acquired by the EK80 and the EK60, regardless of the layer. When the mean TS values were
214 compared by pairs for the same EDSU via the Warton et al. (2006) test, no difference between
215 the EK80 and the EK60 was observed on the whole sample (Fig. 3).

216 3.3. Fish density

217 Regarding fisheries and ecosystem management, it is meaningful to express the acoustic
218 metrics in fish density, i.e., number of fish by surface. Thus, the fish densities per layer
219 obtained with the two generations of echo-sounders were calculated. Results were very close
220 between the two echo-sounders : for the surface layer, 1203 (EK60) and 1183 (EK80) fish.ha⁻¹
221 and 583 (EK60) and 529 (EK80) number of fish.ha⁻¹ for the deep layer.

222

223 4. Discussion

224 The previous works done in marine environment (Demer et al., 2017 ; De Robertis et al., 2019;

225 MacCaulay et al., 2018) have addressed the comparison of the two generations of echo-
226 sounder and thus made it possible to validate the continuity of the data for time series.
227 However, these previous works focused mainly on S_A (nautical area backscattering
228 coefficient), the TS intercalibration between the two sounders was only done using calibration
229 spheres. So, our work completes the previous ones with *in situ* data. Our comparison being of
230 main importance for lake fishery studies, we choose the most used parameters (frequency,
231 pulse length, power) in lakes (Draštík et al., 2017). Bonar and Hubert (2002) have highlighted
232 that standardized methods ensure robust estimates. To facilitate comparisons between datasets
233 acquired using different equipment, inter-calibration is needed. The main goal of this study
234 was to evaluate the difference on TS recorded *in situ* by two generations of echo-sounder,
235 EK60 and EK80. This approach is necessary to inter-calibrate the echo-sounders due to the
236 discontinuation of the production of the EK60. Many long-term monitoring surveys have been
237 performed with EK60 in freshwater ecosystems (Draštík et al., 2017; Ostrovsky et al., 2014;
238 Pollom et Rose, 2016) and the continuity of the series is of paramount importance (Bonar and
239 Hubert, 2002). The previous comparisons (Demer et al., 2016 ; Macaulay, et al. 2018, De
240 Robertis et al. 2019) showed that there is a deviation between the two echo-sounders, a ratio
241 $EK80/EK60 < 1$, mainly due to a slight over-amplification of low-power signals by the EK60.
242 This difference would be related to the linearity of the echo-sounders, especially for the EK60,
243 which differs for weak targets and targets located at long distances to the echo-sounder. This
244 over-amplification biases abundance estimates because it modifies the assumption inherent in
245 echo-integration (Foote, 1983). However, according to the authors, for depths not exceeding
246 100 m, over-amplification is not present. Furthermore, the authors highlighted that the impact
247 is relatively small for data from strong scatters, i.e., fish with swimbladders. Therefore, our
248 results, focusing on *in situ* TS complement previous works, in a lake context, where the
249 depths are shallower (max Bourget depth: 145 m; Annecy max depth: 82 m), and fish are
250 rarely located below 100 m depth and have a swimbladder (Yule et al., 2013).

251 We confirm that the echo-integration measurements from the EK80 are slightly higher than
252 those of the EK60 on the entire water column for a frequency of 120 kHz, but the ratio
253 $EK80/EK60$ remains very close to 1. The Warton et al. (2006) test showed that the acoustic
254 response between the EK60 and EK80 echo-sounders was similar for data from the surface
255 layer. Whereas the test showed a significant difference for data from the deep layer, with
256 higher values for the EK80 echo-sounder, but ultimately had a very small impact on the
257 overall dataset results. This difference, which was not highlighted by the Wilcoxon test on

258 averages, is small and thus not noticeable for fish management or research perspectives.

259 To complement the previous comparison works, we studied the difference in TS obtained
260 from the two generations of echo-sounder. The fish size distribution is important to calculate
261 fish density by unit area (Rudstam et al., 2012; Simmonds and MacLennan, 20) and to
262 monitor fish size spectra (Wheeland and Rose, 2016), a reliable metric of fish population
263 evolution (McKenzie et al., 2021). Working *in situ* on fish populations is a reliable approach
264 to compare systems (Blanluet et al., 2020; Draštk et al., 2019; Guillard et al., 2004;) and will
265 serve as references for lake fishery studies. Statistical differences were observed in the deep
266 layer when comparing the TS values obtained between EK60 and EK80. This was true on the
267 mean test and using Warton et al. (2006) test, which showed a deviation to the line 1:1 when
268 comparing the TS by pairs. The difference in TS between the two generations of echo-sounder
269 was weakly significant in the upper layer and was not observed when the dataset was
270 considered as a whole. If we referred to the mean TS per layer, the difference in dB between
271 the two generations of transducers could be considered as small, < 0.5 dB. The mode of
272 digitization differs between the EK80 and the EK60 could be at the origin of this variability
273 observed between the two generations of echo-sounders. The number of SEDs was not the
274 same (Demer et al. 2016).

275 For this kind of approach, to minimize potential biases related to the acquisition chain, the
276 EK80 software was used to record the data and perform the calibrations. A strict comparison
277 of the echo-sounders should have been made with the same transducer, as in De Robertis et al.
278 (2019), but it requires a specific electronic installation not accessible during our surveys. In
279 this case, we overcome the differences specific to the use of two independent transducers,
280 which do not have the same characteristics, the equivalent beam angle is not characterized by
281 the standard calibration method, and then can be a major source of uncertainty in echo-
282 integration measurements (De Robertis et al., 2019). In our configuration, the difference can
283 be due to the own characteristics of the transducers and obviously from calibrations, which
284 despite the care taken, imply variability.

285 For a more global approach, other tests using different frequencies, power parameters, pulse
286 lengths, etc. should be done in the future but overall, our work highlights that the two
287 generations of echo-sounder give very close results, using the most used configuration in
288 lakes. The differences between EK60 and EK80 are likely to be smaller than errors related to
289 other factors (Simmonds and MacLennan, 2005) as behaviour, sampling, navigation

290 conditions, uses of different transducers, and calibration procedures. Our findings agree with
291 the hypothesis put forward by De Robertis et al. (2019). Therefore, we can assert that the data
292 acquired in shallow environment (< 100m) using the same frequency (120 kHz) by the two
293 generations of echo-sounder, namely the EK60 and the EK80, are similar and that detection of
294 changes over time in fish abundance and size spectra can be achieved using this method.

295 In a nutshell, as already shown for the S_A , no significant difference was observed for the
296 means. For the first time at our knowledge, *in situ* TS from EK60 and EK80 were compared
297 and if statistical significant differences were found between the TS from the two echo-
298 sounders, these differences were not large enough to affect the fish density used in fish
299 management studies or researches in lakes. The continuity of the time series acquired with the
300 EK60 is ensured when one switches to the EK80 echo-sounder for lake ecosystem research
301 and monitoring surveys, obviously keeping the need to continue to acquire data using the
302 recommendations developed in the standards (e.g., seasons, night-time, boat speed, weather
303 conditions) and performing regular calibrations. Further works are needed to better
304 understand the observed differences on individual targets.

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459 *Credit author statement*

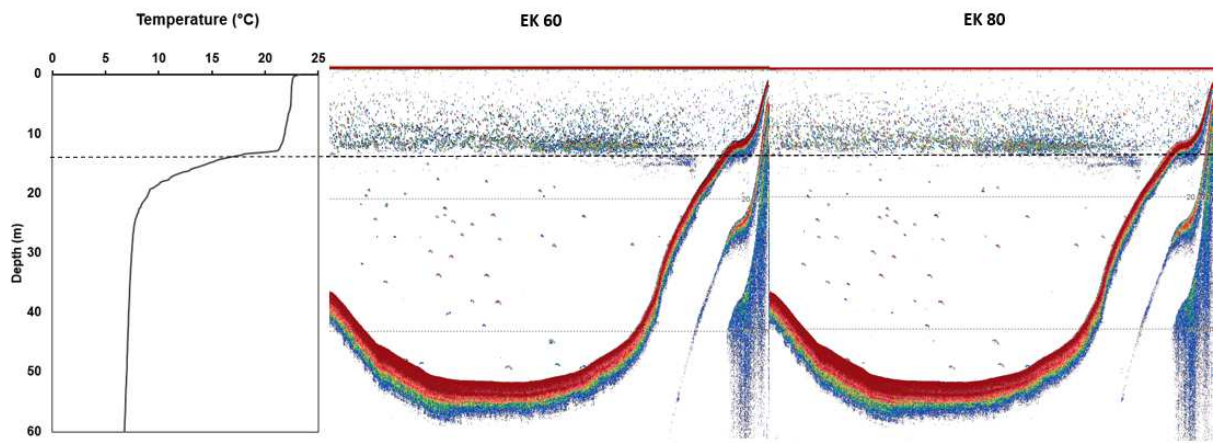
460 Clément Rautureau : Methodology , Investigation, Data curation, Writing - Reviewing

461 Chloé Goulon : Methodology, Investigation, Validation, Reviewing and Editing

462 Jean Guillard : Conceptualization, Methodology, Investigation, Validation, Writing-

463 Reviewing and Editing, Supervision

464



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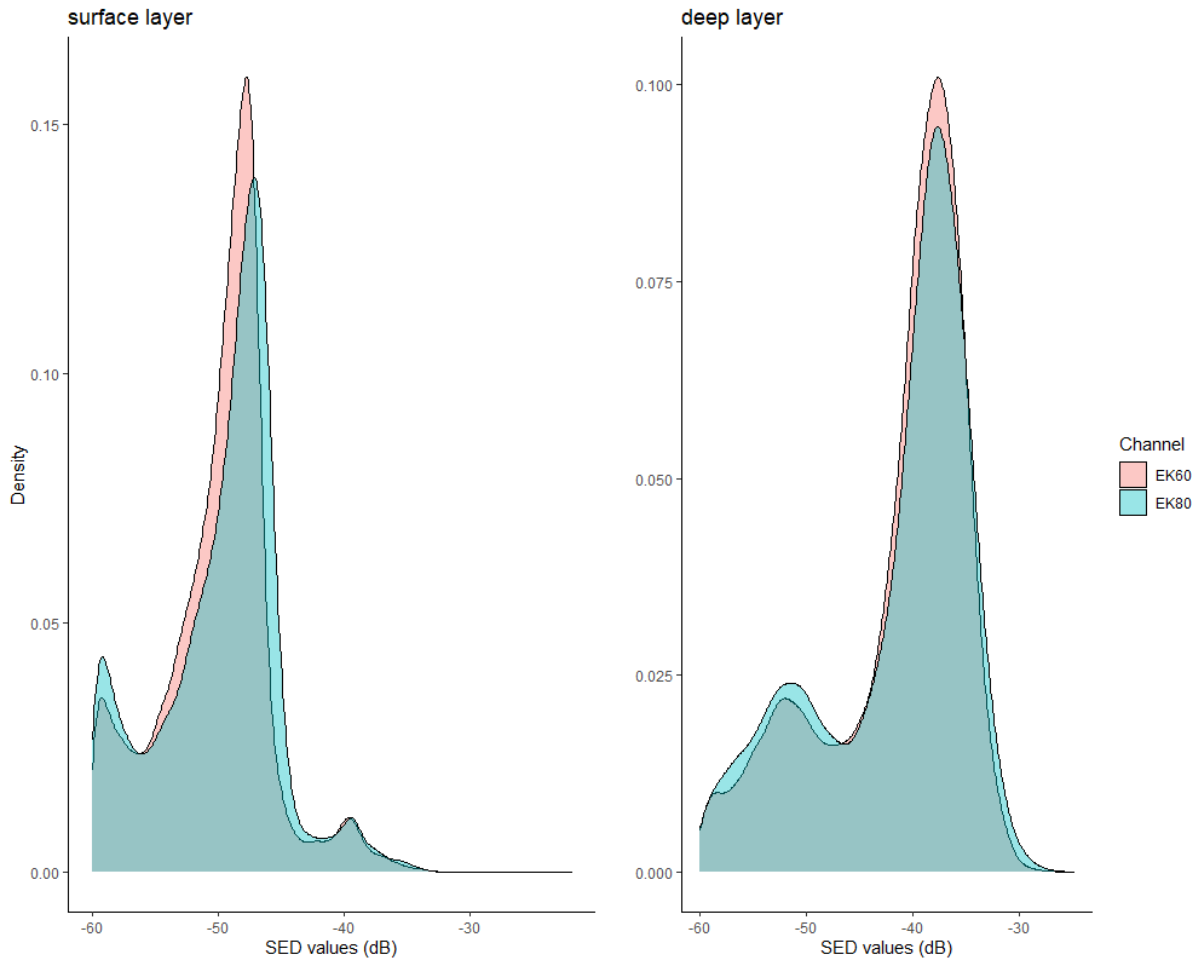
466 Figure 1. Left side -Temperature profile acquired in the Lake Annecy (14 September 2020).

467 Right side – echograms, at left EK60 and at right EK80, using a -66 dB threshold in Amp-

468 echogram recorded in the Lake Annecy ; the dashed line shows the separation between layers.

469 Data from OLA, Observatory of LAkes (<http://www6.inra.fr/soere-ola> ©SOERE OLA-IS).

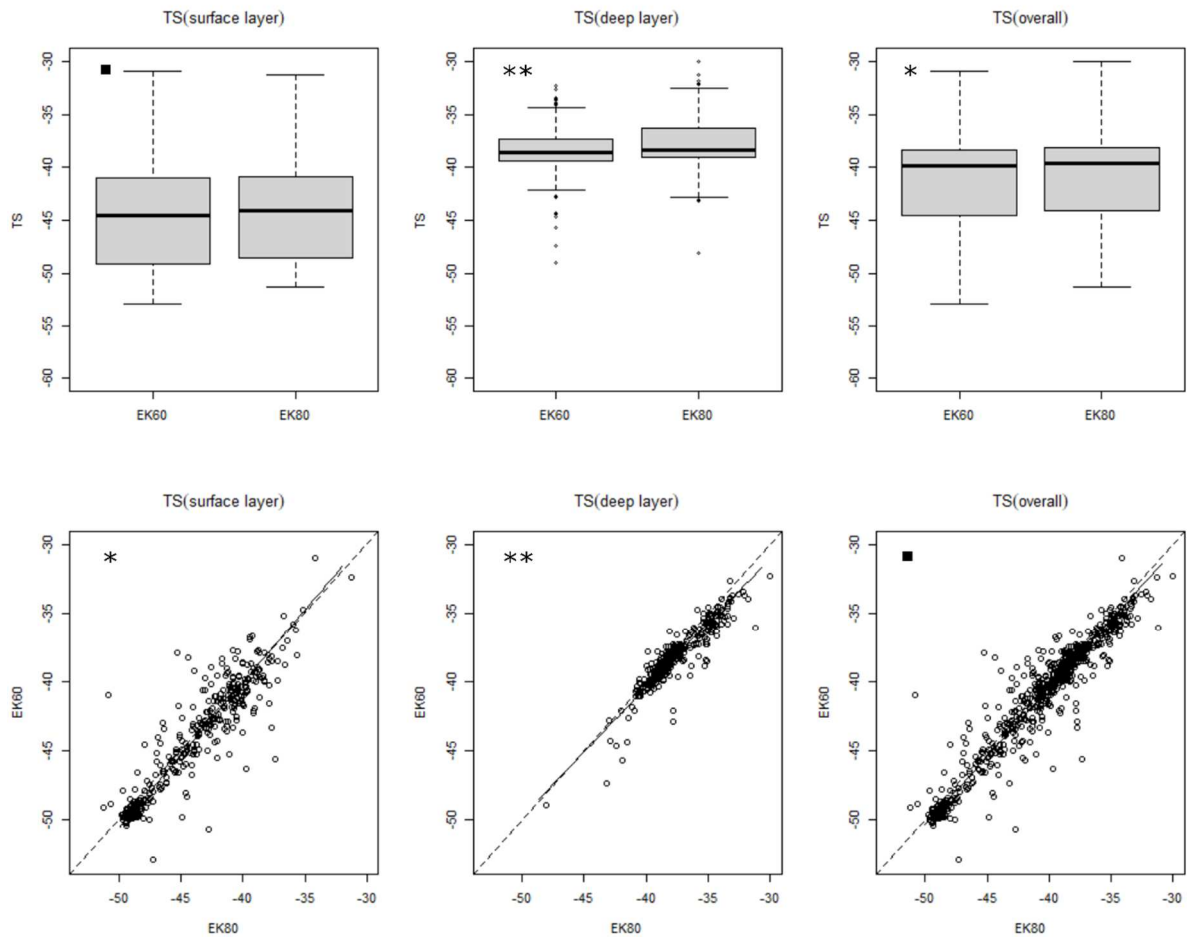
470



472

473 Figure 2. TS distribution of the Single Echo Detection (SED) for the two layers. Pink for the
474 EK60 values, green for the EK80 values.

475



476

477 Figure 3. Mean TS (dB) and boxplots values for the two layers and the total dataset.

478 Comparison by pairs of TS from EK60 and EK80 for the two layers and for the total dataset.

479 Statistical tests on the mean values and between the 1:1 line (black) and the linear regression

480 model (dotted line) were : not significantly different = ■; significantly different results p-

481 value < 0.05 = *; highly significant p-value < 0.01 = **.

482

483

484 Table 1. ESDU data set.

	Lake Annecy		Lake Bourget	
	Surface layer	Deep layer	Surface layer	Deep layer
Number of EDSU	284	290	582	578
ESDU with noises or/and artifacts		8	46	26
Sawada Index > 0.01			2	
Total for				
SA analysis	284	282	536	552
TS analysis	284	282	534	552

485

486 Table 2. Mean TS values, calculated in the linear domain, according to the layers
487

Mean TS (dB)	EK60	EK80	p-value
Global	-39.5	-39.0	0.02
Surface layer	-42.5	-42.4	0.06
Deep layer	-37.8	-37.1	0.0004

488

489

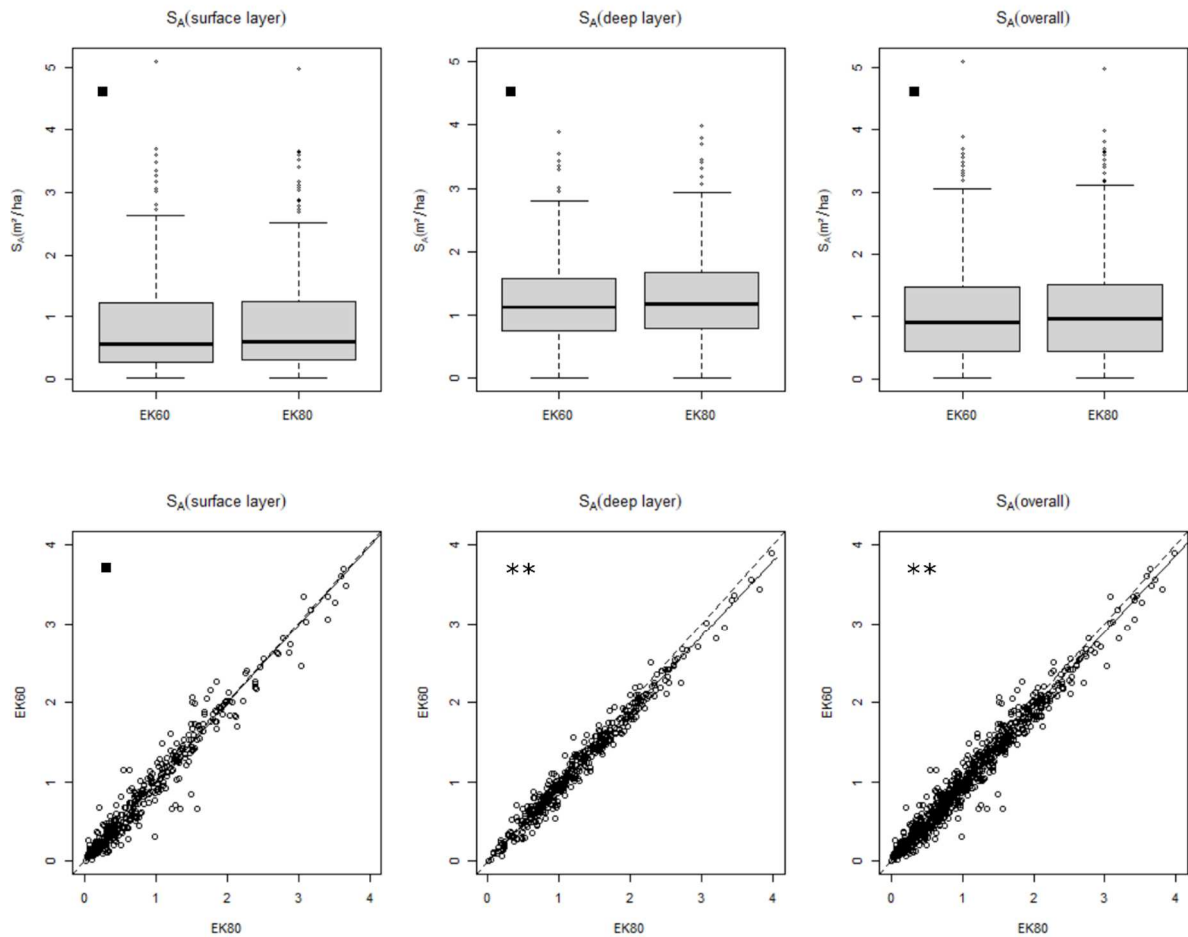
490 *Annex*

491

492 S_A values according to the echo-sounders

493 No significant difference in the S_A means between the two generations of echo-sounder,
494 regardless of the layer, were found (Table 1 - Annex). The box plots of the S_A values (Fig. 1 -
495 Annex) also showed the similarities between the datasets acquired by the EK80 and the EK60,
496 regardless of the layer. Using the procedure of Warton et al. (2006), the data were compared
497 by EDSU (Fig. 1 - Annex). For the surface layer there was no difference between the line of
498 the major axis and the 1:1 relationship (p-value = 0.7). For the lower layer, there was a
499 significant difference with the line 1:1 (p < 0.05), as for the overall dataset (p-value p < 0.05).
500 This resulted in slight deviance between the two echo-sounder for a few high values.
501 Following De Robertis et al. (2019), a ratio (S_A EK80 values / S_A EK60 values) between the
502 two echo-sounders' values was computed : the backscattered energy recorded by the EK80 is
503 slightly higher than the one recorded by the EK60, the ratio being very close to 1 for the
504 whole data set (1.07) or by layer (surface layer 1.08, deep layer 1.06).

505



506

507

508 Figure 1- Annex. Mean S_A ($m^2 \cdot ha^{-1}$) and boxplots values for the two layers and the total
 509 dataset. Comparison by pairs of S_A from EK60 and EK80 for the two layers and for the total
 510 dataset. Statistical tests on the mean values and between the 1:1 line (black) and the linear
 511 regression model (dotted line) were : not significantly different = ■; significantly different
 512 results p -value < 0.05 = *; highly significant p -value < 0.01 = **.

513

514 Table 1- Annex: Average values of S_A ($m^2 \cdot ha^{-1}$) according to the layer.

Mean S_A ($m^2 \cdot ha^{-1}$)	EK60	EK80	p-value
Global	1.04	1.08	0.35
Surface layer	0.85	0.85	0.83
Deep layer	1.22	1.29	0.15

515