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Convergence and divergence between two multibeam sonars (SIMRAD SM20 and RESON SeaBat 6012) used to extract the spatial, morphologic and energy parameters of fish schools

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ABSTRACT

In situ three-dimensional (3D) fish school descriptors were compared using two multibeam sonars, a Simrad SM20 200-kHz and a Reson SeaBat 6012 455-kHz, deployed together in a lake to observe same fish schools simultaneously. School-specific 3D parameters observed by SeaBat and SM20 were extracted using the SBIViewer software for the Reson, and a customized IRD Matlab algorithm (IMA) for the SM20. This study shows that for most of the school parameters considered (school length, width, height, surface, volume, mean energy, energy standard deviation), the estimates from the SeaBat and SM20 sonars converged. The divergences observed for three other school parameters (school roughness, number of holes, and hole volume) may have been due to differences between the instrumental and/or the extraction methods. The source of each divergence was identified, and its impact discussed.

1. Introduction

Vertical multibeam sonar systems have been used for several years to complement and enhance conventioned vertical scientific echo-sounders in fisheries acoustics (Rudstam et al., 2009) by providing 3D information about fish schools, and by increasing the sampling volume as well as the efficiency and precision of acoustic surveys (Fernandes et al., 2002; Gerlotto et al., 1999; Mayer et al., 2002). Multibeam sonars are powerful tools for remote three-dimensional (3D) observations (Gerlotto and Paramo, 2003; Guillard et al., 2006a; Paramo et al., 2007), and for characterizing the spatial distribution, internal structure (Gerlotto et al., 2010) and kinematics of fish schools (Gerlotto et al., 2006). Data from these systems are useful in several domains of fisheries research particularly: (i) to investigate fish school behaviour (Gerlotto et al., 2004a,b; Guillard, 1998; Guillard et al., 2010; Hafsteinsson and Misund, 1995; Soria et al., 1996, 2003), and predator–prey interaction (Axelsen et al., 2001; Benoit-Bird, 2009; Cox et al., 2009; Nøttestad and Axelsen, 1999), (ii) to enhance acoustic methods used to estimate fish biomass (Gerlotto et al., 2000; Misund and Coetzee, 2000; Trenkel et al., 2008), and more widely, (iii) to provide measurements of the different acoustic descriptors used for monitoring fish schools. School tracking using horizontal insonification with multibeam omnidirectional sonar is also very informative when monitoring fish schools. Recently-developed school tracking techniques were used to identify the schools and estimate dynamic school descriptors (Brehmer et al., 2006a, 2007; Trygonis et al., 2009).

Since 1995, IRD has been using the 455-kHz RESON SeaBat 6012 multibeam sonar in several different research programs (Brehmer et al., 2003, 2006b; Gerlotto et al., 1998, 2006; Gonzalez and Gerlotto, 1998). Specific software, the SBIViewer, has been developed to extract the 3D descriptors defined by Gerlotto et al., 1999 (position, morphology, energy, density, holes) of each fish school recorded from SeaBat multibeam images (Hamitouche-Djabou et al., 1999; Lecornu et al., 1998). In 2007, IRD purchased a 200-kHz SIMRAD SM20 multibeam sonar, which was intended to replace the ageing SeaBat sonar. To ensure that future studies using the SM20 were comparable with existing data, it was necessary to check the consistency between data collected by these two sonar systems. The consistency of the data was evaluated by estimating the level of correlation between the 3D fish school parameters obtained using the two sonars.

This paper presents the results of a comparison of the 3D fish school parameters estimated from the SeaBat and SM20 sonars. The convergences and divergences between the two sets of estimates of sonar parameters are identified and discussed, and their source and their impact on fish school characteristics determined. Two different sets of reasons for divergence were: those attributable to

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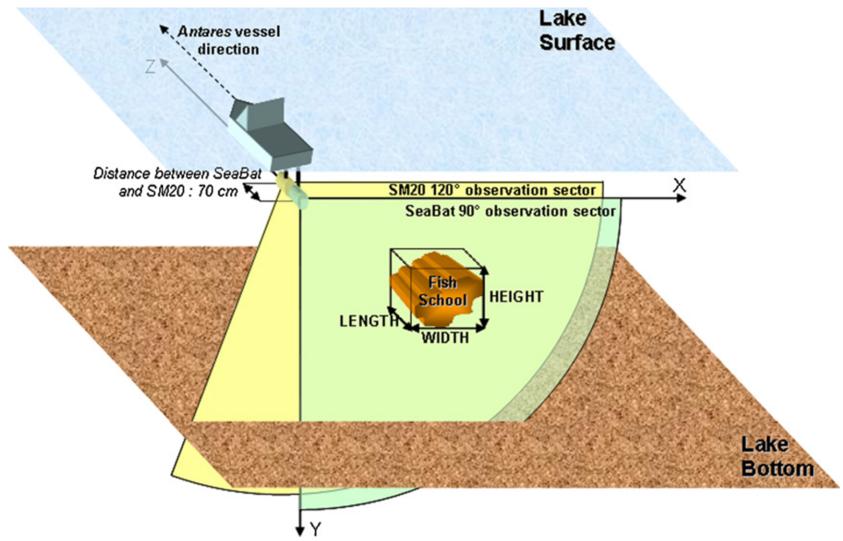

Fig. 1. Positions, insonification sectors, and definitions of the Cartesian coordinate system and the fish school parameters: length, width and height for the SeaBat 6012 and SM20 sonars.

instrumentation differences and those attributable to differences in the extraction methods.

2. Materials and methods

2.1. Study area

The study was undertaken in Lake Annecy, one of the largest and deepest Alpine lakes in France, situated at an altitude of 446 m. The lake is 13.7 km long, has a maximum width of 3.1 km and a total area of 24.5 km^2. It is divided into two basins with a maximum depth of 65 m. This lake had the advantage of containing many fish schools that had already been described by numerous acoustic surveys (Guillard et al., 2004, 2006a) in a familiar ecosystem (Guillard et al., 2006b; Masson et al., 2001). The thermocline caused strong vertical partitioning in the distribution of fish according to species. At the end of summer, schools of only two main species (juvenile perch, *Perca fluviatilis* and roach, *Rutilus rutilus*) were present above the thermocline during daylight hours (Appenzeller, 1996; Guillard, 1991; Guillard and Gerdeaux, 1993; Guillard et al., 2004). These schools disperse at sunset for trophic reasons (Masson et al., 2001), and reform at sunrise. Thus, the existing knowledge available about fish school populations, distribution, morphology and behaviour in this lake made it ideal for comparing fish school observations from our two multibeam sonars.

2.2. Multibeam sonars (MBS) and acoustic surveys

The Reson SeaBat 6012 and the Simrad SM20 multibeam sonars operated at frequencies of 455 and 200 kHz, respectively. As both systems are narrow band devices (20 kHz maximum bandwidth for each), there was no inter-system interference so the equipment did not have to be synchronized. With an estimated sound speed of 1516 m/s, based on temperature profiles carried out during the survey, the parameters of the acoustic systems were as follows:

- for the Reson SeaBat, a TVG (Time Varying Gain) law in 20 Log *R*, a pulse length of 0.06 ms, a range resolution of 4.55 cm, a range limited to 50 m (Guillard et al., 2006a) (with 1024 samples per beam), a ping rate of 14 pings/s, and an 8-bit data storage resolution (or 48-dB nominal dynamic range),
- for the Simrad SM20, a TVG law in 20 Log *R*, a pulse length of 0.3 ms, a range resolution of 22.74 cm, a variable range of observation up to 110 m (with variable numbers of samples per beam depending on the user range and sample rate), a ping rate of 4 pings/s, and a 12-bit data storage resolution (or 72-dB nominal dynamic range).

To observe fish schools simultaneously, the multibeam sonars were pole-mounted on the same side of a small boat (Antares, 6.4 m long), submerged to a depth of 1 m, at a distance of 0.7 m on the alongship axis, and transmitting athwartship in vertical planes with sectors of 90° (a fan of 60 beams with one single beam of 1.5° × 17°) for SeaBat, and 120° (a fan of 128 beams with one single beam of 2° × 2°) for SM20 (Fig. 1). Thus, with a ship speed of 1.5 m/s, a given fish school was observed by the SeaBat 0.45 s later than by the SM20. The last beam of SeaBat was perpendicular to the bottom, whereas the last beam of SM20 was situated at minus 30° relative to the bottom. For both sonars, the third dimension was obtained from the succession of pings along the vessel course. Both sonars were manufacturer-calibrated, and checked before the survey using known targets, but they were not calibrated *in situ* due to the difficulty of carrying out the procedure recommended by Foote et al. (2005) and Melvin et al. (2003) in the field. The acoustic survey was conducted during daylight on September 23, 2008 along transects of the northern part of the lake, using a protocol described in Guillard et al. (2006a) designed to optimize the probability of encountering fish schools during the experiment. Using the Bellhop trace programme (Porter and Bucker, 1987), we checked that there was no impact on the course of the direct rays for either sonar in this environment.

2.3. 3D characterisation of fish schools

The fish school 3D image segmentation (Hamitouche-Djabou et al., 1999) is based on a region-growing method in which, from an initial seed point inside the school previously selected by the operator, neighbouring points on the image are examined in all three directions, and assigned to a region class according to a given criterion (a threshold proportional to the seed point level). This process is repeated until no further newly detected pixel complies with this criterion. For SeaBat data, 3D descriptors of fish schools were calculated using the SBIViewer software (Hamitouche-Djabou et al., 1999; Lecornu et al., 1998). Since the SM20 data were incompatible with the SBIViewer software, a Matlab algorithm (IMA) was developed specifically to extract fish school parameters similar to