Wide band fisheries sounder; from individual echoes analysis to classification of schools at sea.

Manell E. ZAKHARIA

CPE Lyon, LISA (EP92, CNRS) / LASSSO (Laboratoire d'Acoustique, Systèmes, Signaux et SOnar)
43 Bd. du 11 Novembre 1918 ; Bat. 308 ; BP 2077, 69616 Villeurbanne cedex ; FRANCE ; zakharia@cpe.fr

Abstract: The paper deals with fish species classification using the spectral signature of wide band echoes. The case of individual fish in controlled conditions is first investigated. A brief description of a wide band prototype is followed by the results obtained on caged fish in a lake and the one obtained at sea during several cruises.

INTRODUCTION

Fish species recognition is an essential issue for both stock estimation and commercial fisheries. Several works have been carried out in the last decade concerning this subject. Some have concentrated on the use of school shapes (5), others have investigated the use of wide band signature of the echoes for both individuals (8), (9) and schools (5), (10) either in fresh waters (7) or at sea (10). This paper summarizes our work in this area since 1988.

INDIVIDUAL FISH

First experiments were conducted in a fresh water tank in order to evaluate the improvement of fish size estimation while using a wide band system (8), (9). The relation between reflected energy and fish size was investigated. The experiment was carried out in the frequency range from 50 to 75 kHz. The results are summarized in table 1. The results show the interest of widening the bandwidth: improvement of the correlation between fish size and echo energy, in particular when the fish is wild (8), (9). Bandwidth increasing can also improve the linearity of echo-integration (3)

<table>
<thead>
<tr>
<th>TABLE 1. Energy/size relationship for wide band system and single frequencies</th>
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<tbody>
<tr>
<td>number of echoes</td>
</tr>
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<td>------------------</td>
</tr>
<tr>
<td>4620</td>
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where $e = 10 \log (E)$, (E: Energy), $L = 10 \log (L)$, (L: fish length), and $a,b$ are regression coefficients.

PROTOTYPE AND PROCESSING

A wide band prototype (20 to 80 kHz) was developed for sea trials (6),(10); chirps were transmitted and pulse compression was used to improve signal to noise ratio while reducing the axial resolution (a few centimeters). For real-time processing reasons and for compatibility with other equipments, the bandwidth was split into 3 sub-bands of 20 kHz each (LF: 20-40, MF: 40-60, HF: 60-80 kHz ). Peak level in the three sub-bands was respectively, 214, 215 and 207 dB (ref 1 μPa at 1 m.). Echoes were processed using autoregressive modeling for an accurate description of the resonances of echo spectrum (1), (2), (10). The echoes were thus described by a reduced number of relevant parameters that were used for species discrimination. Classification was achieved using a neural network whose input was the spectral signature of the echoes. Part of the echoes (half) was used for the training of the network and the remaining was used for performance evaluation.
LAKE EXPERIMENTS

A series of experiments (30-60 kHz) were conducted on fish schools in controlled situations (Loch Duick, in collaboration with the Marine Lab in Aberdeen). Three fish species were studied: cod, Mackerel and Saithe (free swimming in a cage). The classification performance obtained from a single ping varied from 72 to 87% when using only the spectral parameters and from 97 to 99% when using both the spectral signature and the echo energy (2). Classification performance was highly improved when using several consecutive pings. An improvement of more than 10% while using 10 consecutive pings was obtained. This was coherent with the results obtained by the Marine Lab investigations (4).

CLASSIFICATION AT SEA

Several sea trials were conducted in Bay of Biscay from 1991 to 1994 at different seasons, in collaboration with IFREMER. Ground truth was obtained by trawling. Only monospecific schools were considered for the study. The classification performance, in the medium frequency range, are summarized in a confusion matrix (table 2).

<table>
<thead>
<tr>
<th>true species</th>
<th>estimated species</th>
<th>Sardine</th>
<th>Anchovy</th>
<th>Horse mackerel</th>
</tr>
</thead>
<tbody>
<tr>
<td>sardine</td>
<td>73%</td>
<td>12%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>anchovy</td>
<td>19%</td>
<td>64%</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>horse mackerel</td>
<td>18%</td>
<td>8%</td>
<td>74%</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

The performance obtained at sea have confirmed the relevance of using the spectral signature of wide band echoes for species classification. This result is reinforced by the improvement of size estimation and echo-integration linearity. The classification performance can still be improved by using several consecutive pings of the same fish schools for the classification (as in the lake experiment).

ACKNOWLEDGMENTS

This work was partly supported by the European Commission, DG XIV, FAR program, BIOMASS project.

REFERENCES