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A short note on the applicability of hydroacoustic methods for demersal fish counting and abundance estimations

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Introduction

The fundamental requirement for counting is the capability of the sensor (in this context the combination of the hydro-acoustical apparatus and the received echo signal processor) to resolve or distinguish between the objects to be counted and then to perform the counting function.

This note will address the general situation concerning target resolution as it affects the counting of demersal fish targets.

Target Resolution

The resolution of objects, or targets, is a combination of two components: range resolution and angle resolution.

Range resolution refers to the separation of targets at the same angle referenced to a coordinate origin, and is expressed in terms of the distance between them.

Angle resolution refers to the angular separation of targets at the same range and is expressed in terms of the angle between them.

It can be shown by simple geometry that the minimum separation or distance between two hydroacoustically identical targets, employing pulsed hydroacoustical transmissions, is defined by the following expression:

$$d = \left[R_1 R_2 \phi^2 + \left(\frac{c\tau}{2}\right)^2\right]^{\frac{1}{2}}$$

where

- c = velocity of propagation of sound in sea water
- τ = time interval of the transmitted hydroacoustical pulse (pulse length)
- R_1, R_2 = range to the insonified targets referenced to the hydroacoustical transducer
- ϕ = angle between the targets referenced to the hydro-acoustical transducer.

This expression illustrates the interaction of the basic considerations in the determination of resolution and, therefore, ultimately the ability to count targets.

Practical Considerations of Target Resolution

In addition to the basic considerations of target resolution given above, there are additional vital practical factors that must be recognized, especially when the targets of interest are aquatic animals.

The following conditions must be considered in evaluating the capability of hydroacoustical apparatus and methods employed to count demersal fish targets.

1. The maximum received echo signal from a single insonified target can vary a factor of from two to three, from the absoluted maximum, depending upon the location of the target relative to the axis of symmetry of the transducer directivity function. This condition is a consequence of the response of the transducer varying with direction relative to its acoustic axis. (A detailed discussion of this condition can be found in Refs. 1.)

2. The absolute maximum received echo signal from a single insonified fish target, with a buoyancy regulating organ, can vary a factor of from 2 to 4 depending upon a small difference in the pitch attitude of the target relative to the insonifying pressure wave. (A discussion of this condition can be found in Ref. 2, 4, and 5.)

3. The minimum distance between the targets to be counted must be known to be greater than the resolution capability of the hydroacoustical apparatus and the received echo signal processing technique or method. (A discussion of this condition is contained in Ref. 2.)

4. The minimum distance between a target to be counted and the sea bottom must be known to be greater than the resolution capability of the hydroacoustical apparatus and received echo signal processing technique. (A discussion of this condition is contained in Ref. 3.)

Practical Limitations and Uncertainties

It is evident from the previous section that the combination of conditions 1 and 2 introduces considerable uncertainty in a subsequent target count, unless condition 3 is met.

For purposes of this duscussion, then, the fish targets can be considered "scattered."

For example, if: $\phi \simeq 6$, $\tau \simeq 0.4$ms and R_1 and $R_2 \simeq 100$ and 105 meters, respectively, then $d \simeq 10$ meters.*

The combination of all conditions, 1, 2, 3 and 4, dictate that the individual fish targets to be counted not only be several meters apart, but also be at a finite distance above the sea bottom.

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*Note, however, the selection of ϕ is based upon complex technical and physical considerations, such as the received signal to received noise ratio, the received signal detection threshold and the quantization or conversion uncertainties in the processing of the received echo signal. The angle cannot be considered constant due to conditions 1 and 2 specified in the previous section. Generally the so-called half power beamwidth angle of the transducer is selected for the angle ϕ.

For example, the minimum practical range resolution for the hydroacoustical apparatus given above is approximately 0.6 meters when the targets of interest are not in the vicinity of the sea bottom.

The proximity of a smooth nearly specular reflecting sea bottom increases the minimum practical range resolution to approximately 0.9 meters. The 0.3 meter loss in range resolution is due to technical considerations inherent in the implementation of automated echo signal processing.

The proximity of a less than ideal sea bottom, e.g., sloping, slightly undulating and varying density (backscattering characteristics) will, in all probability, increase the loss in range resolution an additional 0.5 to 1 meters approximately.

The net effect of these considerations is that targets within 1.5 to 2.0 meters of the sea bottom will not be detected, much less counted.

Summary

The following is given in the light of the preceding discussion.

1. It is likely that simple counting of demersal fish targets can be achieved, but only under conditions of considerable <u>a priori</u> knowledge of the environment.

2. It is not likely that useful information concerning the density of the counted targets can be obtained since the variation in sampling volume is a complex function of resolution and target attitudes at the time of insonification.

3. It is highly improbable that useful information concerning the size of the counted targets can be obtained since this is a complex function of resolution and target attitude at the time of insonification.

4. It is highly improbable that efforts to statistically combine hydroacoustically derived demersal fish target counts with concurrent trawl net counts will be valid, due to uncertainties in the respective sampling volumes and animal behavior in the presence of the hydroacoustical pressure field and in the presence of the trawl net.

Conclusion

It should be recognized that the extraction of useful information concerning demersal biomass from hydroacoustical data, acquired under the most favorable conditions, demands complex hydroacoustical apparatus and echo signal processing capabilities considerably beyond those available to the fisheries research community.

Therefore, at the present and forseeable state of hydroacoustical methods it is not feasible to estimate demersal fish abundance with any degree of confidence. Attempts to enhance well-established and effective trawl net sampling methods with hydroacoustically derived "information" may only lead to confusion and diversion of valuable vessel and scientific resources.

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