

Passive Acoustic Field Research on Atlantic Cod, *Gadus morhua* L. in Canada

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Introduction

The Atlantic cod is a very important commercial fish in Newfoundland and Atlantic Canada and has been a part of the culture for centuries. In the past ten years, cod stocks have been drastically depleted. In Newfoundland waters, cod is found from the coast to the continental shelf in water temperatures ranging from approximately -0.5°C to 8.5°C . They are broadcast spawners and typically spawn in large aggregations (Robichaud, 2002). The spawning season typically occurs in the spring but varies by area and is influenced by environmental factors, such as temperature (Scott and Scott, 1988). Spawning begins in the north as early as February and ends in the south as late as December. The depth at which spawning occurs varies among stocks; some may spawn in water as shallow as 20m, while others at depths over 300m (Rose, 1993). Differences in spawning behaviours among sub-stocks and among ages and sexes have been reported (Robichaud, 2002). Laboratory studies have shown that cod have elaborate courtship behaviours with males being very territorial and more aggressive males having the most success at spawning. Cod are also known to detect and produce sound and this observation has long been recognized by lab experiments (e.g. Brawn, 1961). This study is the first attempt in Canada to document the sounds made during spawning and to relate them to spawning behaviour in order to link active and passive acoustic research in behavioural field studies.

Previous and future research on Atlantic cod behaviour

Two of the largest spawning components of Atlantic cod in Newfoundland waters have been studied using active acoustics for several years. These include Placentia Bay, located on the south coast of Newfoundland (NAFO regulatory area 3Ps), and Trinity Bay, located on the north east coast (NAFO regulatory area 3L). Annual acoustic surveys using SIMRAD EK 500 echo sounders, along with the analyses of the data using FASIT (Fisheries Assessment and Species Identification Tool) (Lefeuvre et al., 2000) have provided insights into stock migrations and spawning behaviours. The echogram in Figure 1 is from April 2000 in Placentia Bay, Newfoundland, showing some of the pelagic behaviour easily observed using an echo sounder. Cod in this area have a peak

spawning period between April and June. This spawning aggregation was found in a trench, over 300 meters deep. The image in the bottom corner is an enlargement of a section of the echogram where single cod targets (white arrow) are resolved.

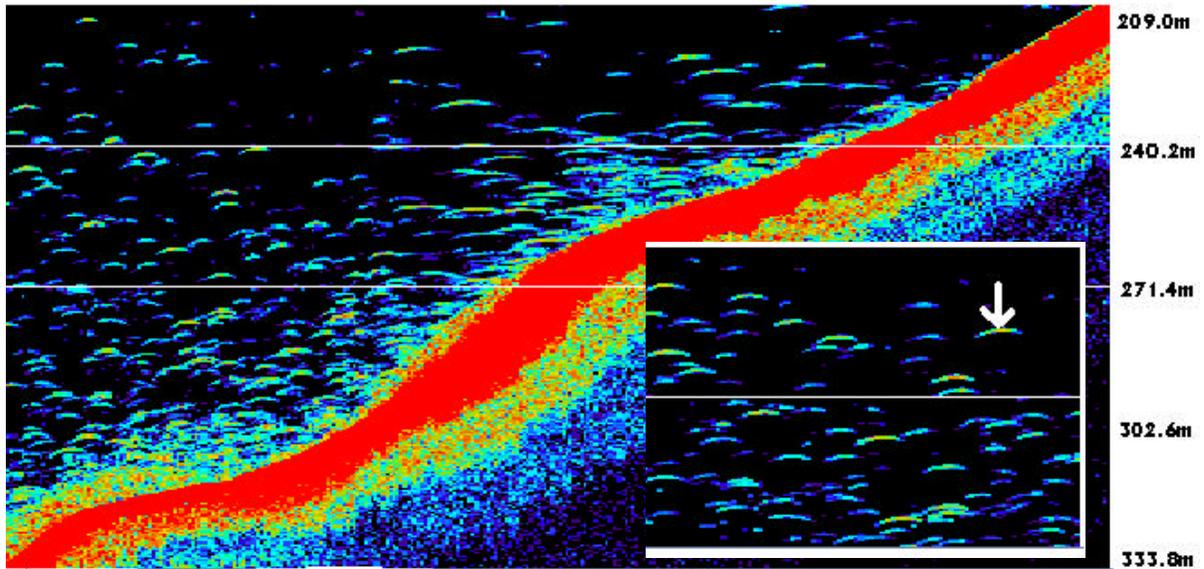


Figure 1: Echogram of a spawning cod aggregation in Placentia Bay, Newfoundland 2001

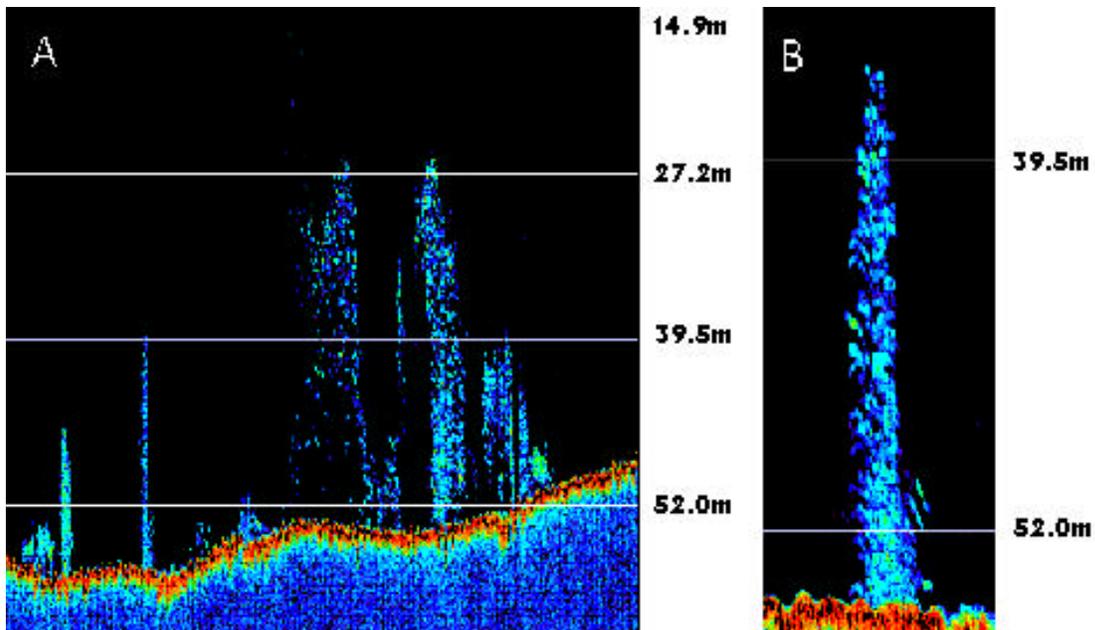


Figure 2: Cod spawning column in Placentia Bay in 1997

The use of active acoustics has led to observations of different spawning aggregation structures. Figure 2 is an echogram of spawning columns observed in shallow waters of

Placentia Bay in 1997 at a depth of approximately 50m (Rose, 1993). In section A, several columns are shown. Section B is an enlargement of one of these columns, which extends approximately 20m off the ocean floor.

Throughout their range, cod occur in distinct stocks as well as sub-stocks, and spawning behaviour within specific sub-stocks is of interest. Sonar tagging studies have been conducted to investigate the homing ability of Atlantic cod to specific spawning grounds. Long-term sonar transmitting tags (Lotek CAFT16_3 Acoustic Transmitters) were implanted in female and male cod at a spawning ground in Placentia Bay, Newfoundland in April 1998. Homing of cod back to the spawning ground from which they were taken was observed. Approximately 50% of the tagged cod returned to the same spawning ground (capture site) in subsequent years and 25% of the tagged cod returned 3 years in a row (Robichaud and Rose, 2001). This study provides some of the first direct evidence that cod undertaking long-distance feeding migrations may home to a specific spawning location in consecutive years. Present tagging work that has begun this year also will involve the identification of distinct spawning populations using acoustic surveys; cod have been released within their “home” populations as well as within other groups. Results of this study hope to provide valuable insight into the Atlantic cod’s homing properties.

Using active acoustics in surveys and sonar tagging studies, we have learned a great deal about cod spawning aggregations and migratory behaviour. As spawning is the first step towards recruitment and rebuilding cod stocks, there is a continuing interest in the specific behaviour of spawning. Brawn (1961) documented many interesting features of cod spawning behaviour. Cod are known to have specific social behaviours related to spawning. Brawn (1961) observed distinct courtship behaviours performed by males toward females, as well as aggressive behaviour of males toward males. Both sexes in cod have been observed to produce sound, although it is the males whose sound production is thought to play an important role in spawning, such as attracting females and holding territories (Brawn, 1961). In cod, the drumming muscles surrounding the swim bladder are thought to be related to sound production.

Present field studies will observe the acoustic properties of spawning aggregations over two spawning seasons. These studies are interested in both the production and reception of sound by cod, its role in spawning behaviour, and also the influence of ambient noise in the ocean environment on these behaviours. We have chosen two main research areas, which have been studied for the past number of years using active acoustics and sonar tracking. Placentia Bay and Trinity Bay both have relatively large coastal spawning populations. However, Placentia Bay is becoming increasingly industrialized while Trinity Bay is not. With use of a small vessel specially equipped for the work, cod spawning aggregations will be located using a Biosonics DE 70 kHz echosounder with digital data storage. Once located sounds from the aggregation are detected, they will be recorded using a hydrophone (ITC 8212) with a Stanford Research System pre-amplifier (model SR560). Data will be in the form of WAV files and stored on a hard drive of a lap-top computer and analyzed using Avisoft SASLab Pro software. Video recordings will be made using an underwater video camera (J.W. Fishers MFG. Inc., TOV-1). A

parallel study will be conducted on fish from the same stocks kept in the lab at the aquaculture facility at Memorial University of Newfoundland.

Summary

This study is the first of its kind in Canada, and is attempting to document the sounds that cod make during spawning at sea and to relate these to spawning behaviour. The work attempts to link active acoustic research with passive acoustics and to use real-time video to study cod spawning behaviour. From past acoustic research, we have learned much about the state of cod stocks, spawning aggregations, migrations, and homing. With the addition of passive acoustic tools, we hope to learn more about the spawning behaviour of individual cod.

Acknowledgments

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References

- Brawn, Vivien M. 1961. Aggressive behaviour in the cod (*Gadus callarias* L.). Behaviour 18: 108-145.
- Brawn, Vivien M. 1961. Reproductive behaviour of cod (*Gadus callarias* L.). Behaviour 18: 177-198.
- Brawn, Vivien M. 1961. Sound production by the cod (*Gadus callarias* L.). Behaviour 18: 239-245.
- Chapman, C.J. and A. D. Hawkins. 1973. A hearing study in the cod, *Gadus morhua* L. Journal of Comparative Physiology 85: 147-167.
- Lefeuvre, P., G.A. Rose, R. Gosine, R. Hale, W. Pearson, and R. Khan. 2000. Acoustic species identification in the northwest Atlantic using digital image processing. Fisheries Research 47: 137-147
- Nordeide, J.T. and E. Kjellsby. 1999. Sound from cod at their spawning grounds. ICES Journal of Marine Science. 56:326-332.
- Robichaud, D. 2002. Homing, population structure and management of cod, with emphasis on cod spawning at Bar Haven in Placentia Bay, Newfoundland. Ph. D. thesis. Biology Department, Memorial University of Newfoundland.
- Rose, G.A. 1993. Cod spawning on a migration highway in the north-west Atlantic. Nature 366: 458-461.
- Scott W.B., and M.G. Scott. 1988. Atlantic Fishes of Canada. University of Toronto Press, Toronto.