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An assessment of biases associated with inshore acoustic cod surveys

by

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Abstract

We assess biases in survey methods for demersal fishes in coastal environments by comparing visual observations from submersible transects to surface-made acoustic density estimates of Atlantic cod, in Placentia Bay, Newfoundland, during fall 1996. Daytime acoustic density estimates were significantly greater than those made at night. A strong nighttime preference for close proximity to the bottom and rocky substrates likely reduced the probability of distinguishing fish from the bottom acoustically, thereby lowering acoustic densities at night. Repeated passes of acoustic transects suggested no active boat avoidance by the cod. Acoustic density estimates were correlated with the assumed 'ground truth' density measurements made by visual transects (Spearman's $r=1.0$, $p<0.01$, $n=3$). Submersible transects showed a higher density of redfish (Sebastes spp.) than estimated from acoustic surveys, but there was no evidence that cod density estimates were biased by the presence of redfish. In general, our results suggest that acoustics can provide a useful and accurate means of estimating inshore cod density provided that diel movements are considered.

Résumé

Nous avons évalué les biais des méthodes de relevé des poissons démersaux dans les milieux côtiers en comparant les résultats d'une observation visuelle à partir d'un submersible à ceux d'estimations acoustiques des densités de morue réalisées en surface dans la baie Placentia (Terre-Neuve) à l'automne de 1996. Les densités acoustiques estimées le jour étaient significativement plus élevées que celles obtenues la nuit. Une forte préférence pour la proximité du fond et les substrats rocheux la nuit réduit sans doute la probabilité de distinguer les poissons du fond par technique acoustique, de sorte que les valeurs estimées s'en trouvent réduites. La répétition des virées acoustiques porte à croire à l'absence d'évitement actif du bateau par les morues. Les estimations acoustiques des densités ont été corrélées aux mesures de densité supposées « vérifiées sur le terrain » des observations visuelles (Spearman - $r = 1,0$, $p <0,01$, $n = 3$). Les virées par submersible indiquent une densité de sébaste (*Sebastes* spp.) supérieure à celle des relevés acoustiques, mais rien n'indique que les densités de morue estimées étaient biaisées par la présence des sébastes. De façon générale, nos résultats portent à croire que les relevés acoustiques constituent un moyen utile et exact d'estimer la densité des morues en zone côtière si l'on tient compte des déplacements nycthéméraux.

Introduction

There is a need to develop effective survey methods for Atlantic cod in the inshore areas of Newfoundland, as traditional approaches used in offshore research may be inappropriate to the coastal environment. We assess biases associated with inshore acoustic cod surveys by comparing ship-made acoustic density estimates to observations made *in situ* with a Canadian Navy submersible. The biases addressed by our study focused on distinguishing fish from the sea-bed (Mitson 1984), which is thought to be particularly important in the rocky and steep bottoms typical of inshore Newfoundland. We also examined whether cod actively avoided the survey vessel, thereby reducing our abundance estimates (Olsen et al. 1983). Third, we considered the accuracy of our acoustic density estimates in comparison to the `true´ density of cod in the area. Finally, we determined whether the presence of other species with acoustic signatures similar to cod, specifically redfish, artificially inflated our cod acoustic density estimates. The effect of target strength estimation on acoustic density measurements, while important, was not addressed by this study.

Methods

Our study area was a half nautical mile line transect in Placentia Bay, Newfoundland. This location was chosen due to its complex bottom and steep slopes in order to pose the maximum challenge possible to our acoustic techniques. The acoustic system involved two Biosonics single beam digital echosounders (38 and 120 kHz) mounted on a towed body deployed from either the MV Innovation or MV Mares (Marine Institute of Memorial University). Acoustic data were echo-integrated using FASIT (Fisheries Assessment and Species Identification Toolkit) software under development at Memorial. A scaling factor of -32.7 dB per fish was calculated for an average cod length of 54.96 cm from the relationship: $TS = 20\log L - 67.5$ (Rose unpublished data). The average density along the entire line was calculated for each pass of the transect. An initial series of acoustic passes over the transect in late October and early November 1996 suggested diel movement of cod off the bottom during the day and back down at night. In late September and early October 1997, we therefore performed three 24 hour acoustic surveys, running the transect at least once an hour.

We made direct visual observations of cod density and behaviour in the study site with the Canadian Navy's submersible SDL-1, supported by the Navy vessel Cormorant. This sub work coincided with the 1996 acoustic survey and consisted of two daytime dives, and two dives that started in the early afternoon and ended during the early night. The line transect was run first using a sub-mounted echosounder, after which the sub descended to the bottom to perform a visual line transect. Running the line acoustically and visually in short succession provided density estimates from each on very comparable spatial and temporal scales. In spite of the use of artificial light, we observed no obvious avoidance behaviour by the cod other than when the sub ran directly over the fish, at which point they would swim rapidly away.

Video tapes were made of the visual transects, and were used to calculate cod density by dividing the number of fish seen on a given transect by transect length. Transect width was defined as the field of view of the video camera, and as such was constant, but unfortunately unknown. The visual measures of density reported here are thus relative only. Acoustic relative densities from the sub were calculated by counting the number of echoes on the transect's echogram that fell within the range of known target strengths for cod, then dividing by transect length. A constant, but unknown, transect width was again assumed since the submersible consistently maintained a height of 20 m off the bottom.

We also noted the type of bottom occupied by each fish observed on the videotape, in terms of the presence of cover. No cover included areas of sand, silt, and fine gravel, low cover comprised areas with some rocks but mostly sand or gravel, and high cover denoted areas with many large rocks and boulders. These bottom types were chosen as they describe both the amount of cover available to the fish in terms of avoiding predators or currents, but also because they represent increasingly difficult habitats to survey acoustically.

Results

Vertical Migration

The 1997 acoustic data showed a distinct pattern of high acoustic densities during the day, but very low at night (Fig. 1). Cod acoustic density increased sharply almost exactly at sunrise, remained high but variable during daylight hours, and then decreased at sunset. The three study days were chosen to span the full range of possible tidal phases. The consistent pattern over all three days despite these differences in tidal cycle, and the fact that densities were never high at night, suggest that the movement was associated with light conditions rather than tides. Visual inspection of echograms (Fig. 2) revealed that cod were still present on the line at night, but were too close to the bottom to be reliably distinguished using present bottom-fish separation algorithms.

We also compared the submersible-observed distribution of cod over the three bottom types to that expected if fish were randomly distributed relative to the natural distribution of the bottom types in the study area. During the day, no preference was evident for any one bottom type (χ^2=2.1, p= 0.351, n=45; Fig. 3). At night, however, there were many more cod in areas of high cover, and many fewer in areas of no cover, than was expected (χ^2=26.3, p< 0.001, n=72; Fig. 4). Videotape analysis showed that 12.5% of the cod observed during the day were well off the bottom, while at night all observed fish were in close proximity to the bottom, corroborating the acoustic trend. Cod were therefore more frequently on the bottom at night, at which time they also selected areas of high rock cover. Similar numbers of fish were observed with the sub during night and day (n=45 and 72, respectively).

Boat Avoidance

Since the surface acoustic transect was typically run twice every hour, separated by only 20 minutes, we were able to examine the question of boat avoidance by looking at the difference between densities measured on the first and second pass. Were the fish reacting to the vessel, the second pass should consistently have yielded a lower density than the first. A paired t-test indicated that the difference between the two passes was not significantly different from zero ($t=0.113$, $p=0.911$, $n=37$).

Accuracy

We verified the accuracy of our acoustic density estimates by comparing them to the visual estimates of density, where both methods were performed with the sub. A combination of having only four dives, and a frequent lack of positional information during those dives, led to our having four data points for comparison. One of these points represents a transect run at night (Fig. 5). Given the demonstrated diel vertical migration of these cod and its effects on acoustic surveys, it is not surprising that this point should show a very high visual density but a very low acoustic measurement. Excluding this nighttime transect, the remaining three points were significantly correlated (Spearman's $\rho=1.0$, $p<0.01$, $n=3$; Fig. 5).

Redfish

In analysing the videotape, we saw 113 redfish, as compared to 139 cod. Very few other species were observed, and none that might be acoustically confused with cod. Redfish target strength is likely similar to that of cod for fish of similar sizes (Gauthier and Rose, unpublished data). However, the fact that the line of figure 5 relating acoustic to visual density estimates passes nearly through the origin suggests that when no cod were observed with the echosounders, none were present. Were non-cod targets inflating our acoustic density estimates of cod, a non-zero acoustic density would be expected when the visual cod density was zero. Redfish observed during the day were found almost uniquely in areas of high rock and boulder cover where the echosounders are unlikely to have ensonified them ($\chi^2=152.6$, $p<0.001$, $n=93$).

Conclusions

Cod acoustic densities decreased during the night by an order of magnitude as a consequence of vertical movement and a selection for coarse bottom types where separating fish from the bottom acoustically is difficult. The fact that cod were observed with the submersible at night indicates that lower density estimates from acoustic surveys at night were a sampling artifact rather than a consequence of cod actively leaving the study area. Acoustic surveys in this area should therefore be performed after sunrise and before sunset. We have observed the same trend of vertical migration elsewhere in Placentia Bay, both at other times of year and in other years. It is not known whether cod in other inshore areas of Newfoundland behave similarly. In offshore areas, the common perception is that cod migrate off the bottom at night, returning during the day (Beamish 1966). This difference between offshore behaviour and that observed in our study illustrates the plasticity of cod behaviour, and the importance of recognizing behavioural variability when designing and conducting surveys.

Although we saw no evidence of boat avoidance, our research vessels were under 42 feet. Larger, noisier boats might well cause avoidance.

Our results provide no indication that redfish affected estimates of cod density. Redfish habitat selection for high cover substrates likely excluded this species from acoustic density estimates of cod. More work needs to be done on redfish target strength and signal pattern identification.

Finally, we believe that the correlation between our acoustic and visual density estimates provides evidence of the accuracy of inshore acoustic surveying. Although the visual density is not likely an absolute measure of cod density, it may be the most accurate measurement that can presently be made and therefore provides a good basis for assessing the accuracy of acoustic measurements. This work suggests that acoustics are a useful tool for measuring cod abundance in the inshore environment.

Acknowledgments

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Figure 1 - Acoustic cod density (fish/m^2) vs. time of day at which density estimate was made, from midnight to midnight on each of the three study days. Gray background indicates nighttime, white background day.

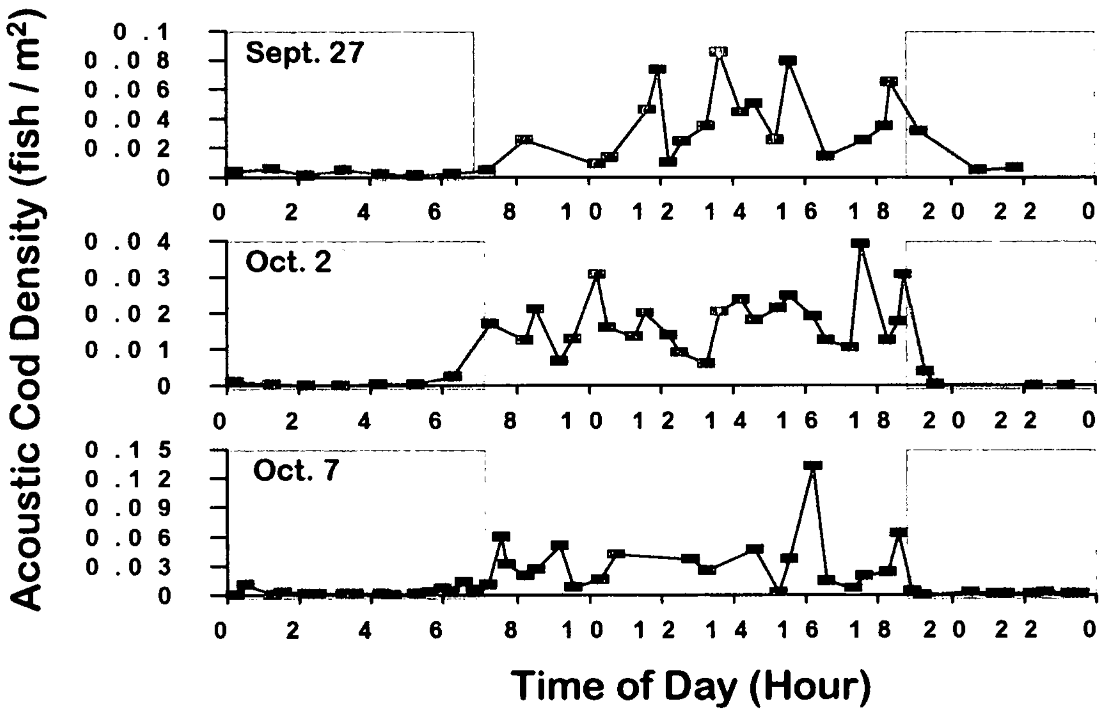

Figure 2 - Representative day and nighttime echograms of the acoustic line transect. Note that the times indicated at the top of each echogram are incorrect (7 hours must be subtracted to give the correct time of day). Inset in the night echogram is a zoomed in view of the first peak on the line, showing that cod were present but in close proximity to the bottom.

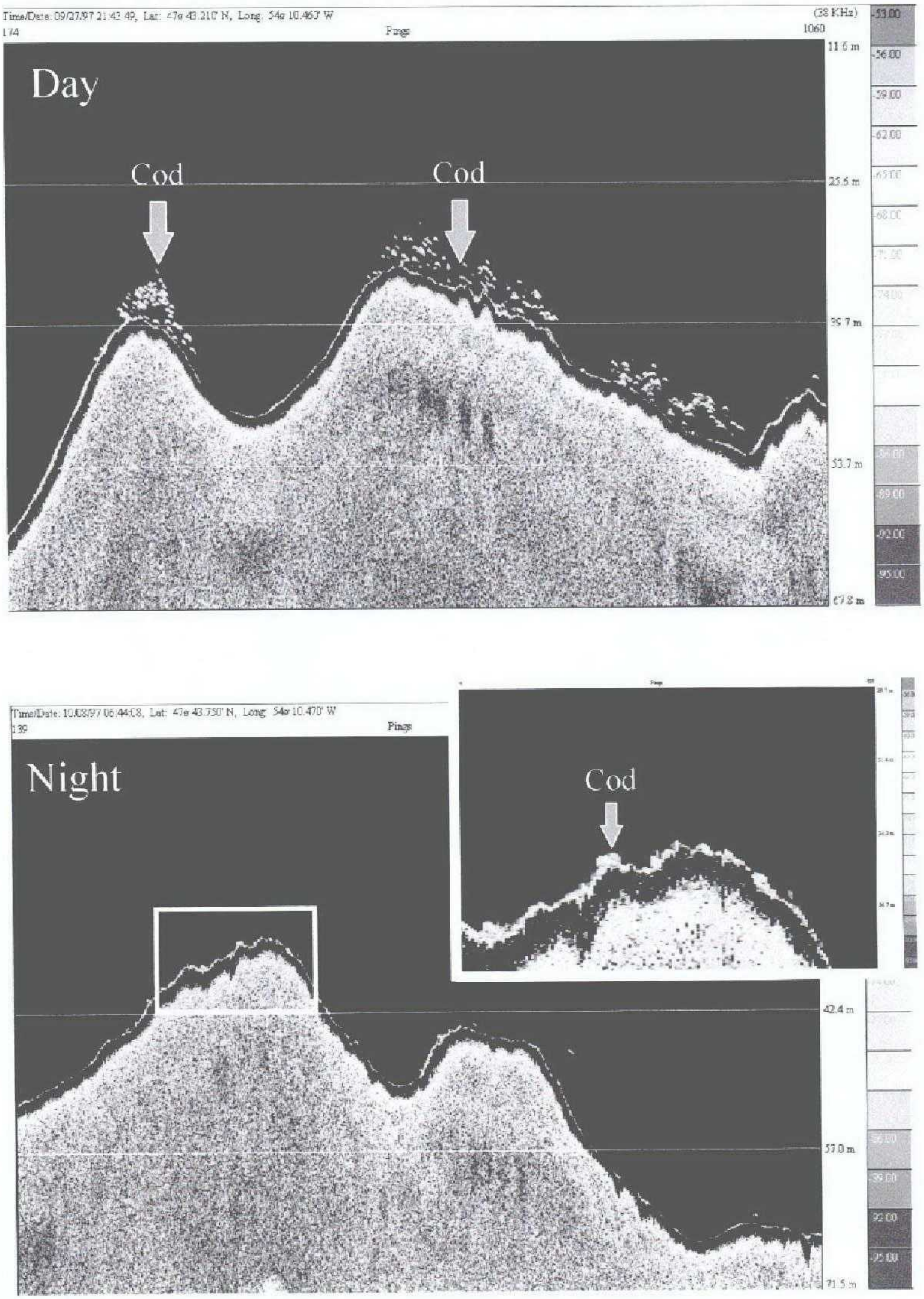

Figure 3 - Cod habitat preference during the daytime, plotted as number of cod observed and expected vs. bottom type (high, low, no cover). Observed distribution was not significantly different from that expected if the fish were distributing themselves randomly relative to the natural distribution of bottom types in the area (χ^2=2.1, p= 0.351, n=45)

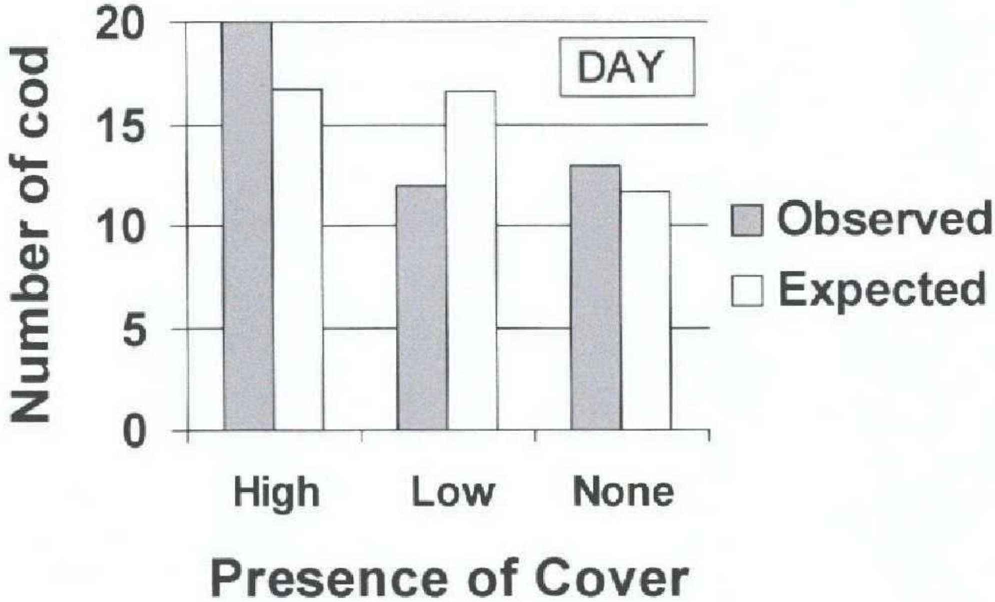

Figure 4 - Cod habitat preference during the night. Observed distribution was significantly different from that expected (χ^2=26.3, p< 0.001, n=72)

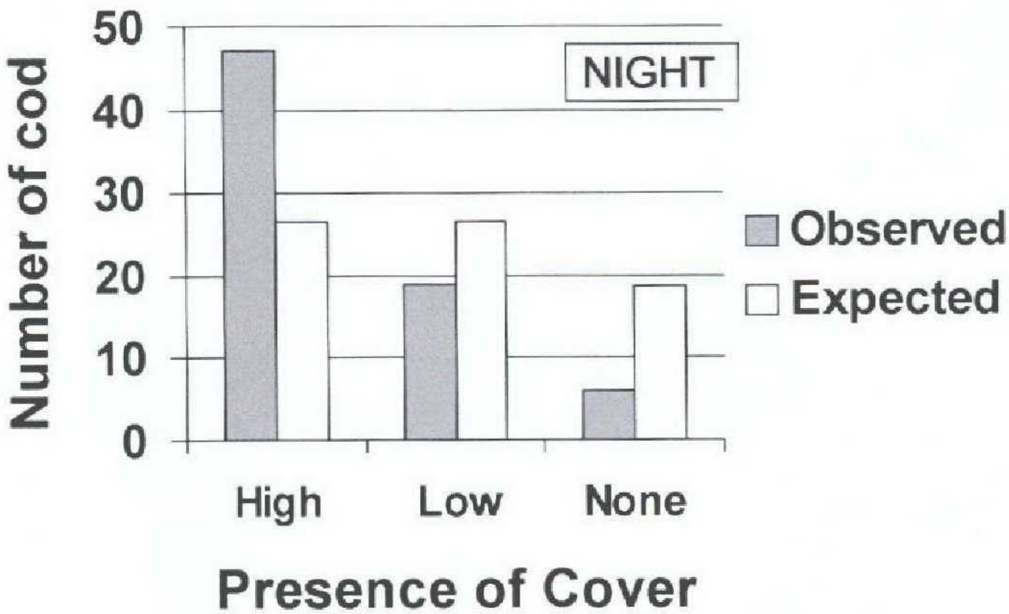

Figure 5 - Cod density measured acoustically vs. that measured visually, where both were made via submersible. Excluding the outlying nighttime data point, the estimates from the two methods of measuring density were significantly correlated ($\rho=1.0$, $p<0.01$, $n=3$).