

SHORT NOTE

ATTRIBUTION OF ACOUSTIC ECHOES TO SQUID IN THE SOUTH ATLANTIC

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Abstract

During a research cruise of the British Antarctic Survey ship RRS *James Clark Ross* in February 1996, more than 2 000 individuals of the ommastrephid squid, *Martialia hyadesi*, were caught in a single haul made by a pelagic trawl near the Antarctic Polar Frontal Zone in CCAMLR Subarea 48.3. This paper describes the analysis of acoustic data gathered during this haul and a survey of the immediate vicinity, in order to characterise an acoustic signature that may be used to identify this species of squid. Distinctive echoes that did not occur when other, unsuccessful hauls were undertaken, were the only strong echoes recorded from the part of the water column traversed by the net. The trawl was restricted to a single depth zone which reduced the potential number of echoes that might otherwise have been attributed to the squid that were caught.

Résumé

Plus de 2 000 calmars ommastrephidés, *Martialia hyadesi*, ont été capturés dans un chalut pélagique près de la zone frontale polaire antarctique dans la sous-zone 48.3 de la CCAMLR au cours d'une campagne de recherche qui a été menée en février 1996 par le navire de recherche du British Antarctic Survey, *James Clark Ross*. Cette communication a pour but de décrire l'analyse des données acoustiques qui ont été relevées pendant le chalutage et lors d'une campagne de recherche menée dans le secteur proche de cette zone en vue de définir le caractère acoustique de cette espèce de calmar afin de pouvoir éventuellement l'utiliser pour l'identifier. Les seuls échos intenses qui ont été enregistrés dans la partie de la colonne d'eau qui traverse le filet sont des échos distinctifs qui ne se sont pas reproduits lors d'autres chalutages dans lesquels la capture de cette espèce a été nulle. L'opération de chalutage n'a été réalisée que dans une seule zone de profondeur, ce qui a réduit le nombre d'échos potentiels qui auraient autrement pu être attribués aux calmars capturés.

Резюме

В ходе научно-исследовательского рейса британского судна *James Clark Ross*, проведенного в феврале 1996 г. в Антарктической полярной фронтальной зоне Подрайона АНТКОМа 48.3, за одно траление разноглубинным тралом было выловлено свыше 2000 кальмаров вида *Martialia hyadesi*. В данной работе представлены акустические данные, полученные в ходе этого траления и съемки, выполненной в близлежащих водах, с целью определить акустические параметры, которые можно будет использовать для идентификации данного вида кальмара. Четко различающиеся эхосигналы, которых не наблюдалось в тралениях без вылова или с небольшим выловом кальмара, явились единственными сильными сигналами, зарегистрированными в толще облавливаемой тралом воды. Трал работал только на одном горизонте, что сократило возможное количество тех сигналов, которые в противном случае можно было бы приписать выловленным кальмарам.

Resumen

Durante una campaña de investigación británica efectuada con el RRS *James Clark Ross* en febrero de 1996 en la Subárea 48.3 de la CCRVMA, más de 2 000 especímenes del calamar ommastreídeo *Martialia hyadesi* fueron capturados en un arrastre realizado en aguas pelágicas cerca de la Zona del Frente Polar. Este trabajo describe el análisis de los datos acústicos obtenidos durante este arrastre y durante una prospección en aguas adyacentes a fin de determinar el perfil acústico característico que se puede utilizar para identificar esta especie de calamar. Los ecos característicos, que no ocurrieron cuando se realizaron otros lances sin éxito, fueron las únicas señales intensas registradas en la columna de agua recorrida por la red. El arrastre se limitó a un estrato de profundidad, de modo que se redujo el número potencial de ecos, que de otra manera podrían haber sido atribuidos al calamar que fue capturado.

Keywords: squid, ommastrephids, hydroacoustics, pelagic trawl, ehco attribution, target strength, South Atlantic, CCAMLR

INTRODUCTION

Analysis of the diet of albatrosses and elephant seals breeding on the South Atlantic Island of South Georgia, led scientists at the British Antarctic Survey (BAS) to realise that there must be substantial stocks of squid available within the foraging range of these predators (Rodhouse et al., 1993; Rodhouse et al., 1996). The squid taken most often by predators were not the two commonly fished species in the South Atlantic (*Illex argentinus* and *Loligo gahi*), but a third species, sometimes caught as a by-catch with *Illex argentinus*, the circumpolar ommastrephid *Martialia hyadesi*. Apart from data collected in 1989, when large numbers of *M. hyadesi* were caught by a commercial jigger during exploratory fishing trials in the Antarctic Polar Frontal Zone (APFZ) (Rodhouse, 1991), our knowledge of the distribution and life history of this species in the CCAMLR area is based only on data from catches of small numbers of individuals (Rodhouse et al., 1996), and recent data from a new fishery developing at South Georgia (González and Rodhouse, in press; Rodhouse, 1997). Excluding the commercial fishery on the Patagonian Shelf (see González et al., 1997), which is beyond the foraging range of the major Antarctic predators (other than the wandering albatross), *M. hyadesi* has been difficult to sample and, as a consequence, there is a lack of information about the acoustic characteristics of this species. A growing amount of information has been collected about the location and timing of the feeding of grey-headed albatrosses (a species known to depend heavily on *M. hyadesi*) using satellite tags; this has pointed to the APFZ as the most probable site from which birds obtain *M. hyadesi* (Rodhouse et al., 1996).

In 1996 more than 2 000 individuals of *M. hyadesi* were caught in a pelagic trawl near the APFZ during a research cruise of the BAS ship RRS *James Clark Ross*. This paper examines acoustic data gathered during this haul in an attempt to describe echochart marks that can be attributed to squid. Although the haul covered an extensive horizontal track, it was carried out at a single depth, which reduced the number of potential acoustic targets that could be attributed to the haul. No other species were caught with the squid which is an advantage for making a positive identification of echoes. An initial review of the echocharts showed fairly intense, scattered marks that are unlike the shallow aggregations, attributed to krill, usually seen in the vicinity of South Georgia. The absence of any other strong echoes during the haul at the depth fished increases the likelihood that these echoes are caused by squid. In other hauls in the area, also described here, only small numbers of squid were caught; these did not coincide with any strong acoustic echoes. If this acoustic characterisation can be confirmed, it will be possible to use acoustic surveys to further describe the distribution and behaviour of *M. hyadesi* stocks (see Starr and Thorne, in press, for a review of acoustic assessments of squid).

METHODS

In early February 1996 the RRS *James Clark Ross* traversed a region of the South Atlantic Ocean in the vicinity of the Maurice Ewing Bank where the APFZ had been located a month before (Figure 1). Satellite tags on grey-headed albatrosses in the previous year had suggested that this area was being actively targeted by foraging birds, and was therefore a probable site for *M. hyadesi* (Rodhouse et al., 1996).

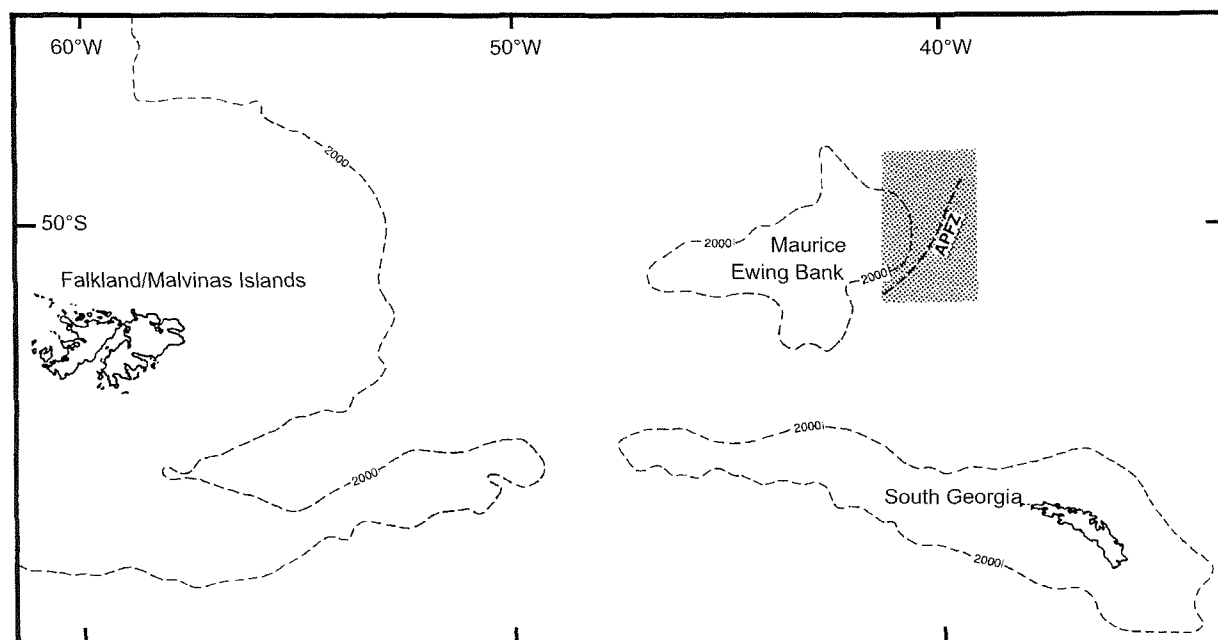


Figure 1: Map of the South Atlantic Ocean showing the context of the squid study, the Antarctic Polar Frontal Zone (APFZ) and study area (stippled).

The aims of the acoustic study were, firstly, to help determine the location of suitable targets for squid fishing and secondly, to characterise the echosignals of any squid caught in a pelagic net. The pelagic trawl, towed at between three and four knots, was designed for catching small fish, and has been described previously by Rodhouse et al., 1996. Some modifications had been made to the net before the present survey, to increase the net opening to 25–30 m in height. A depth sensor was attached to the net and this was used to estimate the net depth using an acoustic link (Roe and Shale, 1979).

A Simrad EK500 echosounder (software v.4.01) operating at 38 kHz, 120 kHz and 200 kHz was used during a series of transects and net hauls within the survey area (stippled in Figure 1). Echosounder settings are summarised in Table 1.

Table 1: Echosounder settings.

Sounder Data Simrad EK500		
Frequency, kHz	38	120
Ping rate, s	4	4
Pulse length, ms	1.0	1.0
Band width, kHz	3.8	1.2
Beam angle, °	7.02	9.10
Threshold dB	-100	-100
Noise margin, dB	0	0
Echochart minimum, dB	-75	-75

Integration of acoustic backscatter down to 1 000 m was carried out using 5 m depth layers and 100-second horizontal bins (resets). The echo strength data are expressed in cubic metres as mean volume backscattering strength (MVBS) in dB//1 m for each bin. The sounder was calibrated using three sizes of copper sphere suspended around 20 m below the ship's hull in accordance with a standard method (MacLennan and Simmonds, 1992 and Simrad EK500 operator manual). Calibrations were carried out in a deep, sheltered inlet at South Georgia on two occasions in mid-January and mid-February 1996, and average values were used for the gain settings. Sound speed and absorption coefficient settings were calculated for the conditions encountered in the waters around South Georgia but no changes were made during the cruise to simplify data collection. Integrated data were processed to add these calibration corrections but no additional corrections have been made for the elevated temperatures encountered in part of this fishing area because of the complex oceanographic conditions there, although these would be necessary if the acoustic data were being used to estimate biomass. TVG-amplified noise was removed from the integrated results using the visualisation package AVS as described by Socha et al. (1996) and Watkins and Brierley (1996).

RESULTS

During the night of 11/12 February 1996 the pelagic trawl was fished across the area at a depth of 25 m for 12 hours and caught an estimated 2 300 *M. hyadesi* (Table 2). No other species were recorded in this haul. The average mantle length of squid in this catch was 228.6 mm \pm 21.8 (standard deviation). The echocharts recorded at 38 kHz and 120 kHz during part of this haul are reproduced as Figure 2. Most of the haul (the first seven hours) was through an area notable for the strongly speckled layer on the echocharts (subsequently referred to as speckles) between the surface and 50 m. The charts from the two frequencies were recorded using the same colour minimum (-75 dB), so that the level of the weakest visible echoes, and the level indicated by each colour range, are the same for both. However, calibration constants from a calibration carried out in the UK had been used during the survey period, so that it was necessary to make adjustments of +0.92 dB for 38 kHz and +2.5 dB for 120 kHz to the raw data. Thus the true intensity range for the 120 kHz chart starts about 1.6 dB below that of the 38 kHz chart. Taking this into account, it is evident from the charts that this layer scattered more weakly at 120 kHz. After dawn, the speckles cleared away and no more targets were seen.

The only other class of marks seen during the trawl is also illustrated in the sections of chart in Figure 2: slightly more compact, extending between about 40 m and 240 m in depth and of varying density, these loose aggregations are only marginally stronger on this 38 kHz chart than on the 120 kHz chart. After adjustment, echo-integrator values from the vicinity of these marks are about +1 dB higher at 120 kHz than at 38 kHz.

The echoes caused by squid during daylight may appear very different on the charts from the near-surface speckled marks of Figure 2. Figure 3 shows a chart collected in the fishing area at dusk on which strong aggregations, which had been regularly seen in midwater during daylight hours in the area, appear to migrate upwards and dissipate, leaving the speckled layer as seen at night in Figure 2. The loose (+1 dB) aggregations also developed on this occasion as the sun set, but it is not clear which of the daylight marks (if any) can be attributed to the same source.

Five other hauls carried out in the study area with the pelagic trawl that caught only small samples of *M. hyadesi* (less than 40 individuals) (details in Table 2) did not pass through either night-time speckled layers or the daytime compact marks as shown on the charts in Figure 2. The presence of some squid in these nets suggests that

Table 2: Haul data.

Net	Date Time (GMT)	Latitude Longitude	Depth (m) Duration (h:mm)	<i>Martialia hyadesi</i>	Other Squid
1	11 Feb 96 11:10	50°12.85'S 40°47.18'W	210 – 300 02:10	0	0
2	11 Feb 96 23:00	50°16.98'S 40°37.27'W	25 12:10	2 310	0
3	13 Feb 96 01:51	50°09.58'S 40°43.51'W	20 01:30 100 02:25	30	4
4	13 Feb 96 17:52	49°32.03'S 39°56.08'W	130 01:45 80 00:30 20 01:55	28	5
5	14 Feb 96 08:40	49°36.35'S 39°49.83'W	150 01:30	7	0
6	16 Feb 96 00:30	49°41.60'S 39°31.86'W	60 00:45 20 02:00 70 – 100 02:10	36	6 Extensive net damage sustained

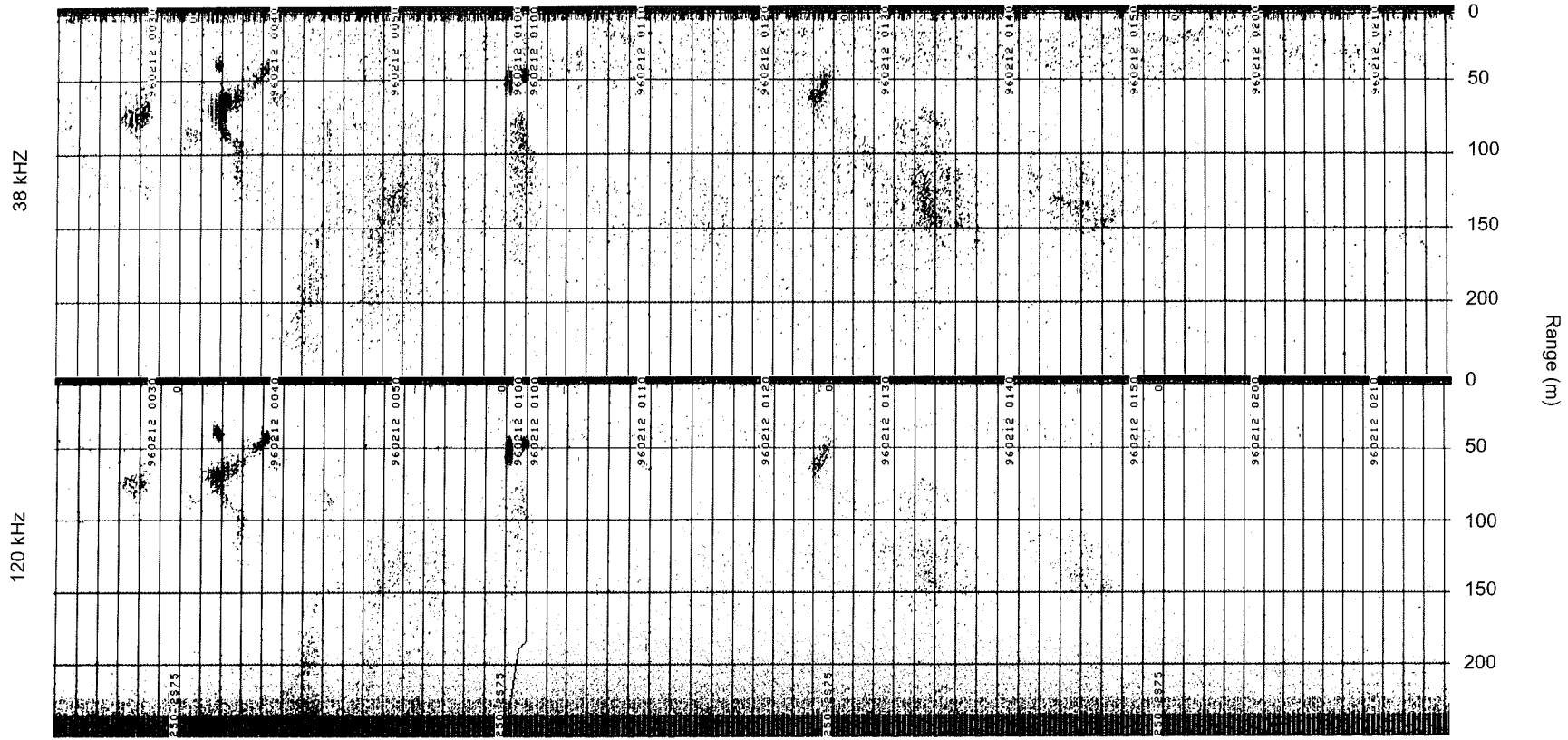


Figure 2: Echocharts recorded at 38 kHz and 120 kHz during part of the pelagic haul in which the major catch of *M. hyadesi* was taken.

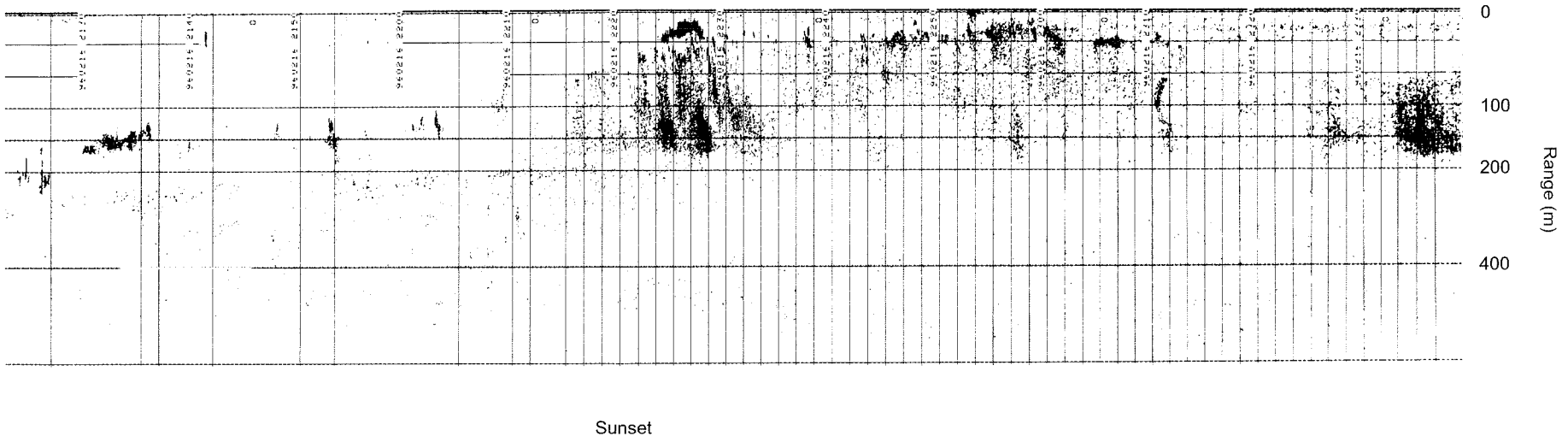


Figure 3: Echochart recorded at 38 kHz in the fishing area at dusk.

the fishing was in the same area as *M. hyadesi* aggregations, but that major concentrations had been bypassed. Clear targets where TS at 38 kHz was higher than 120 kHz were visible during the section of the first transect that preceded the first haul. However, during the daytime tow the strong marks stayed below the 300 m maximum fished by the net for all but a very short portion of the haul. The second haul was the successful night haul described in the preceding paragraph. During the third, night-time haul, the speckled layer was replaced by a concentrated +1 dB layer, at around 40 to 50 m water depth. During the latter part of this haul at 100 m the net probably passed through acoustic targets represented by diffuse irregular +1 dB patches. The fourth daytime haul was towed at 130 m, 80 m and 20 m, but all of these sections of the haul were probably too shallow to catch the targets causing the only strong marks that appeared on the echocharts, which were between 150 m and 250 m. Similarly, the only strong marks around the fifth night-time tow appeared before deployment and after the net had been hauled in. During the final haul the net suffered extensive damage, thus the size of the catch cannot be related to the acoustics, but the catch of *M. hyadesi* provides additional confirmation of its presence in the area.

Integrated acoustic results were used to derive the quantity δ MVBS: the number of decibels remaining when MVBS at 38 kHz is subtracted from MVBS at 120 kHz. Figure 4a shows the frequency distribution of this quantity for all the integrator observations between 20 m and 50 m for the main part of the haul that contained targets. Figure 4b shows the frequency distribution for a subset of these observations; this subset was chosen by referring to the echocharts, and selecting a portion of the tow when speckles were the only evident mark.

Observations During Transects

The first long transect during the survey began with similar acoustic layers to earlier transects made to the north of the APFZ: a deep layer visible on 38 kHz charts, extending through much of the area, at depths of 500 to 600 m. The width of the sounder beam at this depth means that little horizontal or vertical detail can be detected. At night, north of the APFZ, the shallow, speckled layer, characteristically stronger on 38 kHz than 120 kHz, and seen during the major squid haul, extended down to 50 m on a number of transects. During the daytime, diffuse +1 dB patches below

50 m were common, having a characteristically even intensity. Interspersed patchily with these marks were small, dense, irregular aggregations with a similar frequency difference to the night-time, near-surface speckles.

Squid Target Strength (TS)

A summary of previously published data on squid TS is given in Table 3. Because squid do not have a swim bladder, their TS is low in comparison with fish of equivalent size possessing swim bladders. Arnaya et al. (1988, 1989a) distinguished between intensity TS and energy TS, the former representing peak values, and the latter, integrated values of the whole echo. They recommend the use of energy TS because this will take into account variations with pulse length and wave length; this type of measurement is thought to be more accurate than the intensity TS. These authors present separate regression equations for the two types of TS versus mantle length at two frequencies, but they also state that a linear relationship between the two types of measurement could not be established. Their intensity TS values have been cited in Table 3 to allow comparison with earlier peak-based measurements. A number of TS estimates of various squid species have shown the importance of using live, free-swimming specimens for this purpose; Arnaya et al. (1989b) recorded much lower values with live squid than they had using dead specimens in their earlier studies, making their results comparable with those recorded by Jefferts et al. (1987) for *Loligo opalescens*. Arnaya et al. (1988, 1989a, 1989b, 1989c) and Arnaya and Sano (1990a, 1990b) have studied the effect of aspect and swimming speed on TS, and in the last paper in the series compare their latest results with predictions from a scattering model, achieving good agreement between their observations and predictions. Because of the similar size (230 mm) of the squid and the fact that live, encaged squid were used, the results of Arnaya et al. (1989c) are considered the most appropriate for the squid caught in this survey. Until TS measurements of *M. hyadesi* become available, this would suggest a TS around -46 dB at 38 kHz.

DISCUSSION

Speckled marks that dominated the echotraces during the haul in which large numbers of squid were caught are thought to be caused by *M. hyadesi*. The δ MVBS (MVBS at

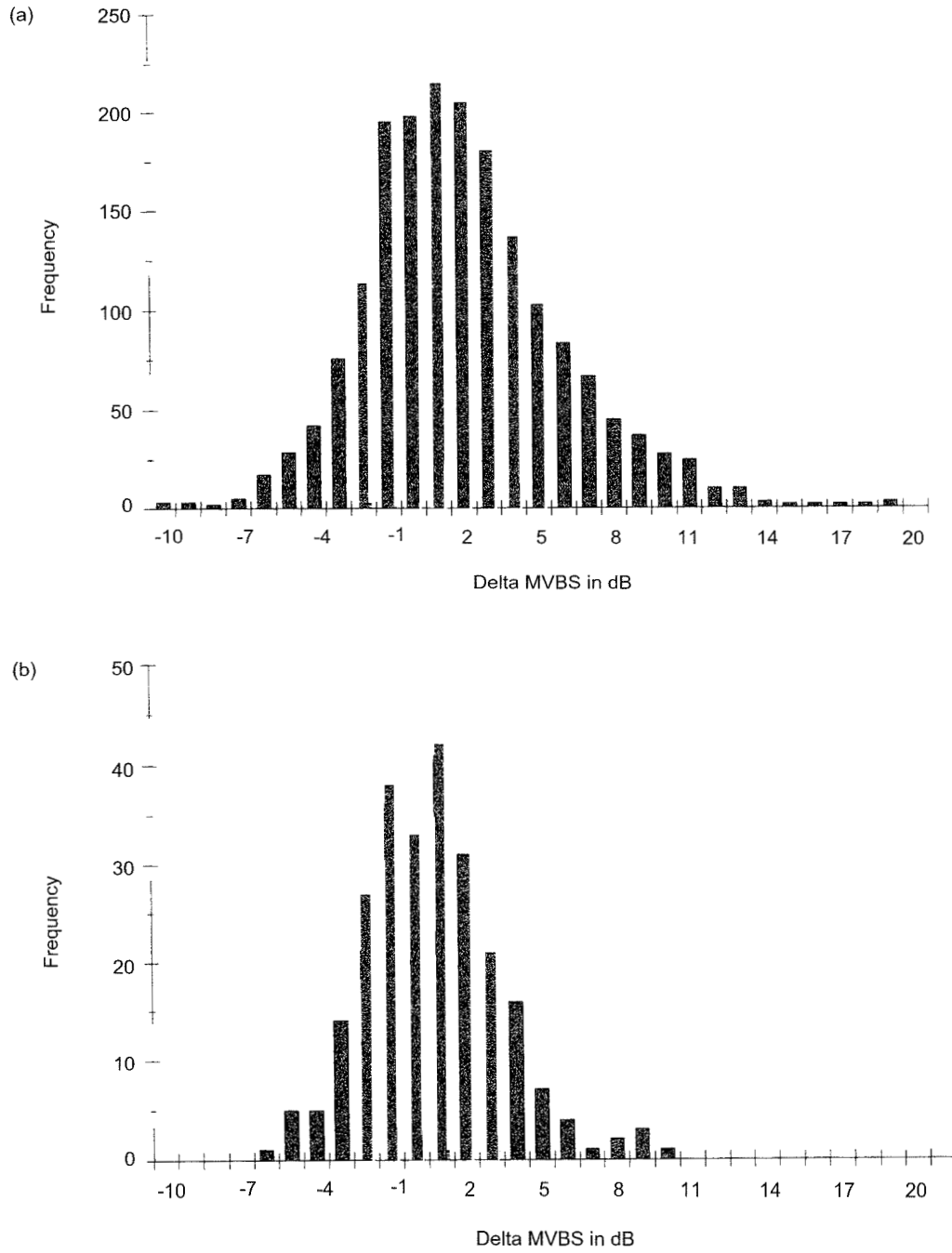


Figure 4: (a) Frequency distribution of δ MVBS during the major catch of *M. hyadesi*.
(b) Frequency distribution of δ MVBS of speckle subset.

Table 3: Squid target strength from published sources.

Species	Lengths (dorsal mantle length in cm)	Frequency (kHz)	TS in dB (max. and min. where two values are given)	Source
<i>Loligo opalescens</i> (frozen and thawed)	4.5 – 16.0	200	-49.3 -38.3	Vaughan (1978)
<i>Loligo opalescens</i>	11.6	50	-58.6 -58.7	Jefferts et al. (1987)
<i>Todarodes pacificus</i>	14.8 – 29.2	50	-46.3 -32.3*	Arnaya et al. (1988)
<i>Ommastrephes bartrami</i> (frozen and thawed)	15.2 – 28.1	200	-42.4 -30.0*	Arnaya et al. (1989a)
<i>Todarodes pacificus</i> (live)	16.0	28.5 96.2	-51.35 -54.60	Arynaya et al. (1989b)
<i>Todarodes pacificus</i>	23.67	28.5 50 96.2 200	-45.66 -46.53 -48.04 -47.62	Arnaya et al. (1989c)
<i>Ommastrephes bartrami</i>	20*	28.5	-41*	Kajiwara et al. (1990)
<i>Loligo edulis</i> (dorsal aspect)	4 – 16	200	-53.20 -40.70	Lee et al. (1991)
<i>Loligo edulis</i> (in situ, dual-beam)	4 – 9 10 – 15	420	-69.5 -57.5 -55.5 -45.5	Lee et al. (1992)

* Inferred from published regression equation

120 kHz - MVBS at 38 kHz) values measured when these marks predominate is largely between -3 dB and +1 dB, which leads us to conclude that the layer is composed of scatterers larger than krill (see Madureira et al., 1993, for a description of the frequency difference in backscattering strength among different classes of scatterers). The +1 dB δ MVBS values predominate in the overall frequency distribution shown in Figure 4a, but there is a shoulder on the negative side of the peak of the distribution, which is reflected as a separate peak (δ MVBS = -1) in the speckle-only subset (Figure 4b). These observations are consistent with the targets being composed of a mixture of two size classes of organism, for example squid and small fish.

The description of night-time echoes thought to be caused by *M. hyadesi* in this paper corresponds very well with the appearance of night-time echoes, on charts produced with similar equipment (Simrad EY500, operating at 38 kHz) in surveys off the coast of Peru, that have been attributed to *Dosidicus gigas* (Ommastrephidae) (Torero, Instituto del Mar del Peru, pers. comm.).

The overall levels of MVBS throughout fishing were low, only rarely exceeding -70 dB at 38 kHz. If the TS of squid is around -46 dB, this would suggest a very low density indeed, but the extent of the marks and the duration of the haul makes the attribution of the marks feasible for the size of

catch. In spite of the long duration of the haul in which *M. hyadesi* were caught, no other marks were visible; this is also taken as confirmation of this identification.

The +1 dB aggregations are not thought to be caused by squid because these marks only lasted for the first two or three hours of the major haul, and many of the individuals in the catch were in very good condition, still pulsating when brought on deck – which is not thought to be likely if they had been in the trawl for 10 hours. A possible source of the marks may be the myctophid prey of the squid, also caught in the area on this survey using a 25 m², rectangular midwater trawl. The decibel difference for this class is marginally less than the +2 dB minimum used to identify krill (Madureira et al., 1993). Other marks recorded during the search for squid had a positive difference in the integrated backscattering levels at 120 kHz and 38 kHz; these are thought to have been produced by *Euphausia frigida* (cf. Brierley et al., in press).

Assuming that squid in this area are the source of the speckled layer at night, and are more aggregated during the day, as suggested by the echoes in Figure 3, there are three major advantages of detection at night. The first is that distributions recorded at night are shallow, which is a fundamental advantage for hull-mounted or near-surface transducers because

interference from background noise, amplified by the time-varied gain of the sounder, is at a lower level than at greater depths. Near-transducer distributions are also more precisely mapped than those at a distance from the transducer where the beam has spread, increasing the volume of the basic echo sample. The second is that diffuse layers are more widespread than compact aggregations, and are therefore more frequently encountered for a given survey distance. The third useful feature of the echoes seen here is their distinctiveness; compact aggregations seen during the daytime would need to be distinguished from krill and possibly fish. Searching and characterisation of squid echoes is therefore expected to be most effective at night. Once detection and identification have been achieved, acoustic stock assessment might be carried out during the daytime so that no individuals are excluded because they are shallower than the transducers (at least in standard configurations) or because they are too diffuse to be detected.

CONCLUSIONS

A single large haul of *M. hyadesi* was caught during the survey at night; a number of features of the haul enabled echoes observed while it was under way to be attributed to the squid with a good degree of certainty. These are that:

- no other species were caught with the squid;
- the haul was made at a single, shallow depth. Many echoes appearing on the charts in this area were confined to a particular depth horizon, and by fishing at a single depth the number of potential candidate echo-types was reduced to two;
- one of the potential echo-types that may have been caused by squid was only recorded at the start of the very long haul. Squid caught at that time would have been in very poor condition when they were landed, but the squid actually caught were very fresh;
- the difference in echo strength at two acoustic frequencies confirmed that echoes causing the most likely echo trace also had acoustic characteristics appropriate for this size of target organism; and
- a number of additional small catches of *M. hyadesi* made during the survey were made in places and at depths where the characteristic echoes were not present.

The characterised echo traces were not observed during the daytime, although compact, deeper marks not seen at night were observed. Further fishing to identify daytime echo traces and to confirm the attribution of echoes recorded at night would be very valuable.

A review of the published target strengths estimated for squid demonstrated the variability of this quantity, and the importance of making new estimates, especially for *M. hyadesi*. Using a published target strength value for squid of a similar size to those caught in this survey suggested that the squid caught had been in a well dispersed layer, but that the extent of the layer was sufficient to produce the size of catch actually observed.

ACKNOWLEDGEMENTS

We acknowledge the assistance of Peter Boyle, Heather Daly and of the master, officers and crew of RRS *James Clark Ross*. The comments from two referees were also helpful.

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