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DIRECT HYDROACOUSTIC OBSERVATIONS OF CHOKKA SQUID *LOLIGO VULGARIS REYNAUDII* SPAWNING ACTIVITY IN DEEP WATER

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Unusual and distinct hydroacoustic targets were observed in November 1996, May 1998 and November 1998 during routine pelagic biomass surveys off the south coast of South Africa. During the November 1996 survey, seven such targets were observed near the bottom at depths of 115–125 m, directly south of the traditional inshore spawning grounds of chokka squid *Loligo vulgaris reynaudii* at Cape St Francis. The targets were close to prominent seabed ridges and extended 30–40 m off the bottom. In May 1998, three similar targets were observed at depths 55–80 m off Plettenberg Bay, another well-known squid spawning site. The shallowest target was identified, by means of a midwater trawl, as a mixture of mature male and female chokka. During the November 1998 survey, nine similar targets were again observed on the squid spawning grounds at Cape St Francis, also adjacent to seabed ridges. Drawing on fisheries hydroacoustic experience and knowledge of chokka squid spawning behaviour, the targets are believed to be aggregations of spawning squid.

Key words: chokka squid, hydroacoustic targets, spawning aggregations

Confirmation of deep (>60 m) spawning grounds for chokka squid *Loligo vulgaris reynaudii*, using egg recoveries from research bottom trawls (Roberts *et al*. in prep.) has several potentially important ramifications. One of these questions the validity of the accepted life history model described by Augustyn *et al*. (1992, 1994), which suggests that chokka squid use shallower, warm embayments along South Africa's south coast for spawning. The existence of deep spawning, however, means that spawning occurs in two contrasting bottom environments; the warm inshore and cold mid-shelf (Roberts and Sauer 1994). This is an unexpected spawning strategy considering that the low temperatures have been shown to be detrimental to egg development (Oosthuizen *et al.* 2002). Another ramification could be a change in fishing strategy by the fleet, perhaps compromising the resource. Despite the apparent sub-optimal benthic conditions, it is believed that spawning in deep water may provide a buffer against the high levels of fishing pressure exerted on inshore spawning aggregations, because depths >60 m are beyond the range of hand-held jigs and vessel anchors. However, the recent use of "parachute" sea drogues has enabled vessels to drift slowly and use their lights to attract squid to shallower water, so catching possible deep spawners.

To assess these ramifications, it is necessary to gain further insight into the spawning process on the deep spawning grounds. However, undertaking studies at such depths is problematic. A number of methods have been successfully used to characterizing spawning of squid on the inshore grounds. These included making use of the commercial fishing fleet, which targets spawning aggregations, to locate and accurately record positions of spawning sites (W. H. H. Sauer, Rhodes University, and MJR, unpublished data). These data, however, are limited to water shallower than 60 m. The efficiency of hand-held jigs decreases beyond this depth, and so does the effectiveness of commercial echosounders (200 kHz) to detect squid egg beds. Hydroacoustic observations have shown that undisturbed spawning aggregations of chokka squid are typically "mushroom-shaped" (Sauer *et al*. 1992, Lipiński *et al*. 1998). Researchers have also undertaken hundreds of SCUBA dives on spawning sites, and with the assistance of hand-held underwater video cameras have studied spawning behaviour *in situ* (e.g. Hanlon *et al*. 1994). Swimming movements in relation to egg beds have been studied using acoustic micro-electronic transmitters implanted in squid and tracked via 3-D radio-linked acoustic positioning telemetry (O'Dor *et al*. 1996, 1998, Sauer *et al*. 1997).

Most of these methods are either impractical or would be severely limited on the deeper spawning grounds, so other methods need to be explored to acquire accurate positions of spawning sites and behavioural information. This note presents a number of hydroacoustic observations made from research vessels, which are believed to be aggregations of spawning chokka squid. It is hoped that the results

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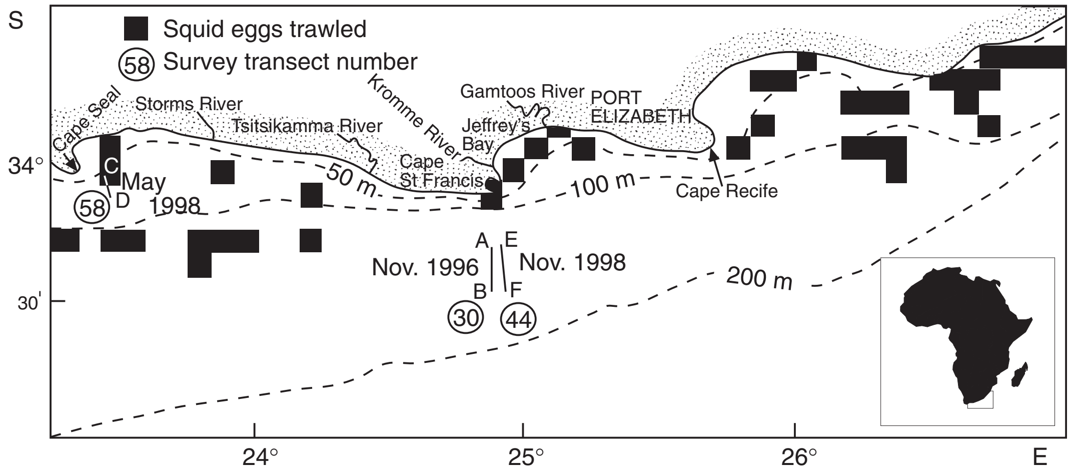

Fig. 1: Map of the Eastern Agulhas Bank illustrating where chokka squid eggs have previously been trawled during research surveys (indicated by shaded 5´ × 5´ squares). The date and transect number along which unusual hydroacoustic targets were observed in this study are shown

will initiate more detailed studies into the spawning process on the deep spawning grounds.

HYDROACOUSTIC OBSERVATIONS

Marine & Coastal Management (MCM) routinely undertake two hydroacoustic surveys per year, in June and November, to estimate the biomass and length composition of anchovy *Engraulis capensis* and sardine *Sardinops sagax*. The survey design consists of 40–60 randomly selected transects perpendicular to the coast in several strata between the Orange River in the north and to Port Alfred on the South-East Coast (Jolly and Hampton 1990). The targets of interest in this study were observed during the November 1996, May 1998 and November 1998 surveys (Fig. 1). A 38-kHz Simrad EK 400 echo-sounder, calibrated by the standard sphere method, was used on the November 1996 survey and a Simrad EK 500 was used on the May and November 1998 surveys.

Figure 2a shows a 20.2 km long segment of the acoustic echogram recorded in the early morning (07:05–08:54) taken on 14 November 1996, and along Transect 30 off Cape St Francis between positions A (34°18.84´S, 24°52.65´E) and B (34°28.17´S, 24°53.36´E; Fig. 1). The depth along this segment varied between 110 and 125 m, and the bottom trace showed a series of cross-shelf ridges up to 15 m high. The "inclined-exposed bedding plane" type profile of the ridges suggests that there were exposed outcrops of quartzite (Birch and Rogers 1973, K. Lord and K. Redding, Geological Survey, pers. comm.). Bottom temperatures along this segment ranged from 8.3°C (A) to 7.9°C (B). Of interest are the seven tall, slender

Table I: Positions of unusual hydroacoustic targets (potential spawning sites of deep chokka squid)

Target number	Depth (m)	Latitude	Longitude
	Echogram A–B		
1	112	34°22.24´S	24°53.23´E
2	118	34°22.73´S	24°53.32´E
3	118	34°23.33´S	24°53.30´E
4	117	34°24.94´S	24°53.55´E
5	116	34°26.34´S	24°53.76´E
6	118	34°27.56´S	24°53.95´E
7	118	34°28.83´S	24°53.97´E
	Echogram C–D		
1	58	34°05.28´S	23°30.22´E
2	83	34°08.07´S	23°30.58´E
3	84	34°08.20´S	23°30.61´E
	Echogram E–F		
1	122	34°29.95´S	24°53.72´E
2	120	34°29.41´S	24°53.58´E
3	116	34°28.87´S	24°53.45´E
4	118	34°28.32´S	24°53.37´E
5	113	34°26.85´S	24°53.24´E
6	114	34°25.24´S	24°53.10´E
7	114	34°24.73´S	24°53.07´E
8	116	34°23.42´S	24°52.94´E
9	112	34°22.64´S	24°52.75´E

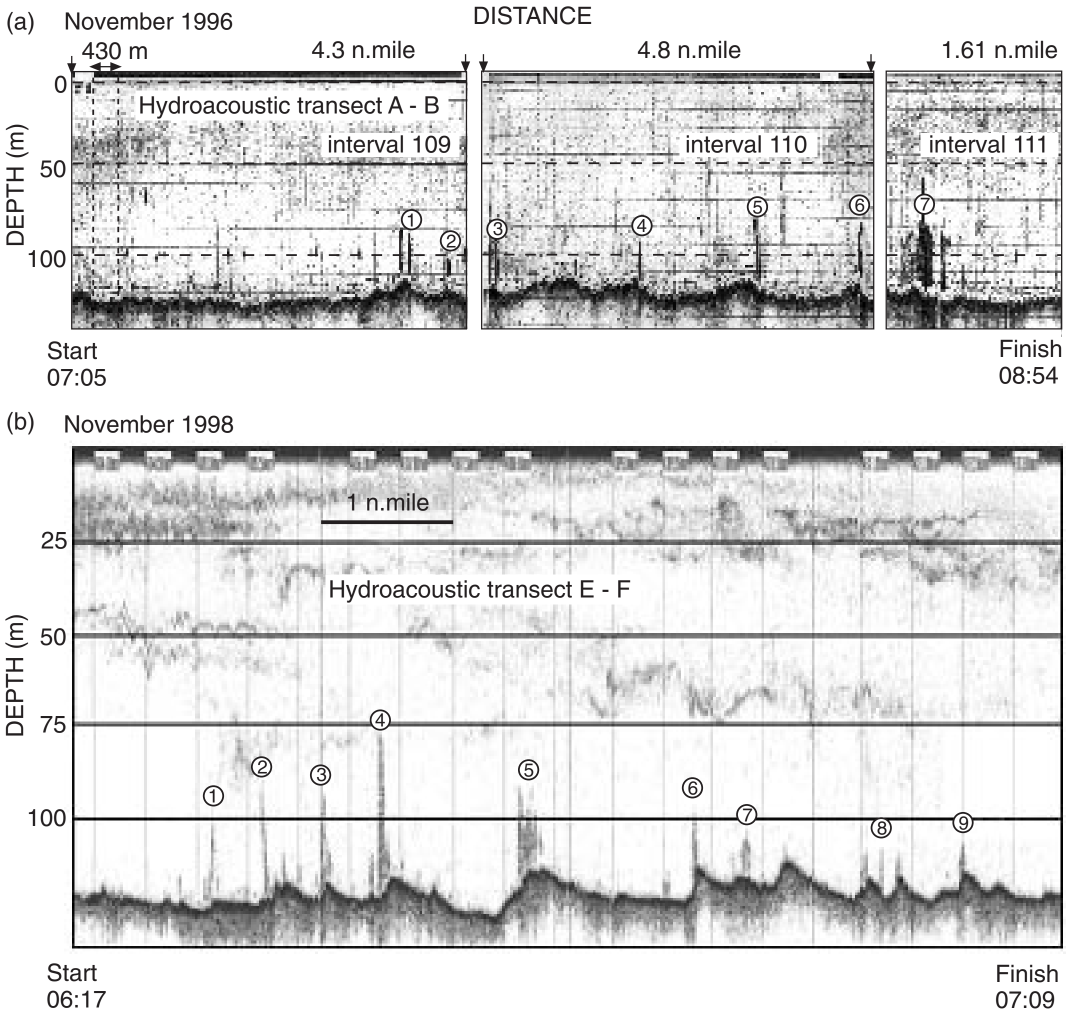

Fig. 2: Echograms showing unusual hydroacoustic targets observed during (a) November 1996 along Transect A–B and (b) November 1998 along Transect E–F. The proximity of the transects to each other is shown in Figure 1

targets positioned either on the shoulder or apex of the rocky ridges. Targets 1–6 were between 20 and 35 m high, and 30–50 m wide. Target 7 was larger in both height (35–60m) and width (350–450 m). All seven targets were considered unusual because of their close association with seabed discontinuities and their relatively low backscatter strength compared to schooling fish common to the area (from -58 to -53 Sv (dB) v. from -55 to -28 Sv (dB) for anchovy, sardine, round herring *Etrumeus whiteheadi* and horse mackerel *Trachurus trachurus capensis*). Unfortunately, the targets were not sampled. Their positions are given in Table I.

On 8 June 1998, along Transect 58 off Plettenberg Bay (Fig. 1), three echo-traces with similar characteristics to those observed between positions A and B were recorded between 05:00 and 06:24, at positions C (34°07.3´S, 23°30.2´E) and D (34°09.7´S, 23°31.1´E; Fig. 3). These observations were close to the coast, in an area where bottom trawls have previously retrieved squid eggs. The echo-trace shows a smooth seabed, probably consisting of shelly-sand (Admiralty

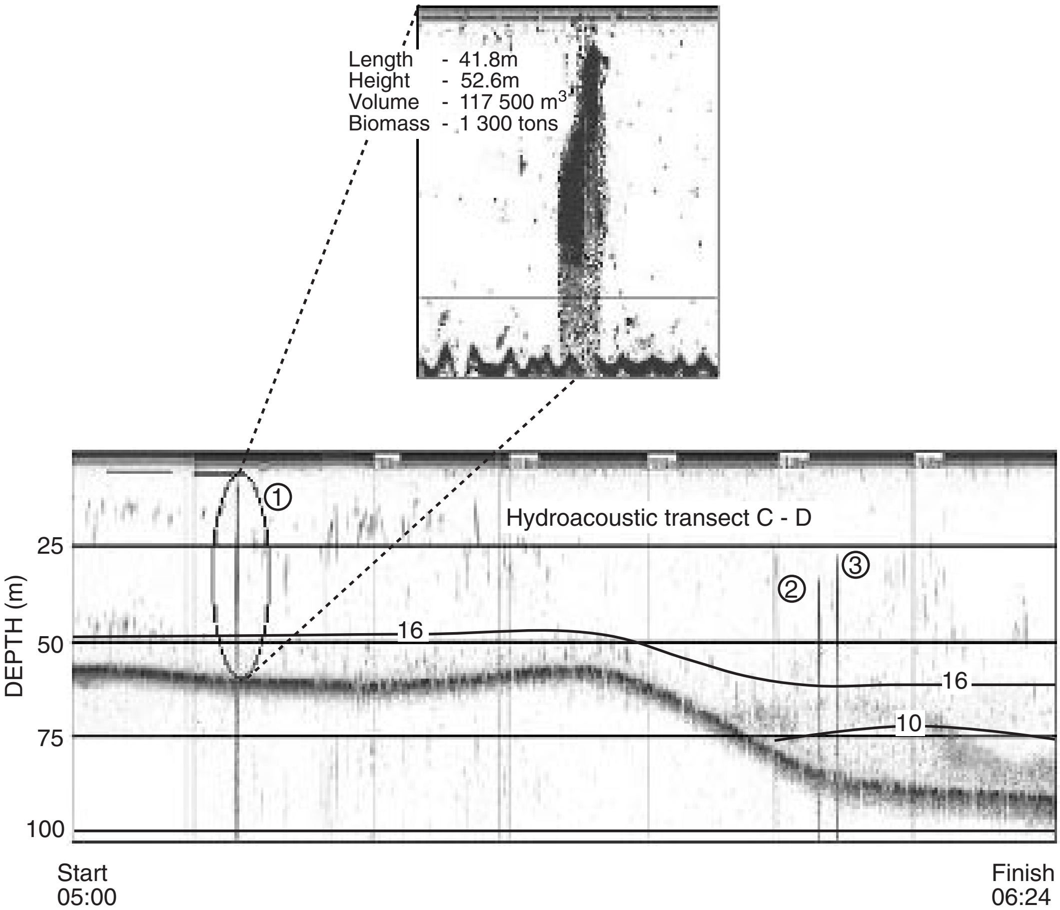

Fig.3: Echogram showing unusual hydroacoustic targets observed during May 1998 along Transect C–D. Temperature and an expanded view of Target 1 are shown

Chart, South African Navy 125). Target 1 was 60 m deep, almost spanning the whole water column (dimensions 53 m high and 42 m wide). Targets 2 and 3 were of similar dimension to Target 1, but were positioned midwater. All three targets extended above a strong thermocline about 50 m deep. Their target strength was stronger than those recorded for the November 1996 bottom targets and for fish. An Engels 308 midwater trawl fished through Target 1 yielded a catch of 201 kg of chokka squid: the biomass of the target was estimated to be about 1 300 tons. From this, 71 animals were sampled (Fig. 4). Some 92% of the males and 84% of the females were mature, with 3% spent, and all females were fertilized.

On 29 November 1998, nine "squid-like" echo-traces (Fig. 2b) were again recorded in the early morning (06:17–07:09) in almost the same position as those observed during the November 1996 survey (Transect 44; Positions E–F; Fig. 1). The positions were 34°31.2´S, 24°54.0´E (E) and 34°21.7´S, 24°52.6´E (F), 14.8 km apart. The depths along this transect varied between 112 and 125 m, and the bottom trace depicted the same series of cross-shelf ridges as those found during previous surveys (Fig. 2a). The targets were close to the seabed on the steeper side of the inclined ridges (Table I). Those between positions E and F had a greater height range (6–40 m) than between A and B. The widths of the targets between E and F ranged between 50 and 300 m. These targets, however, were not sampled.

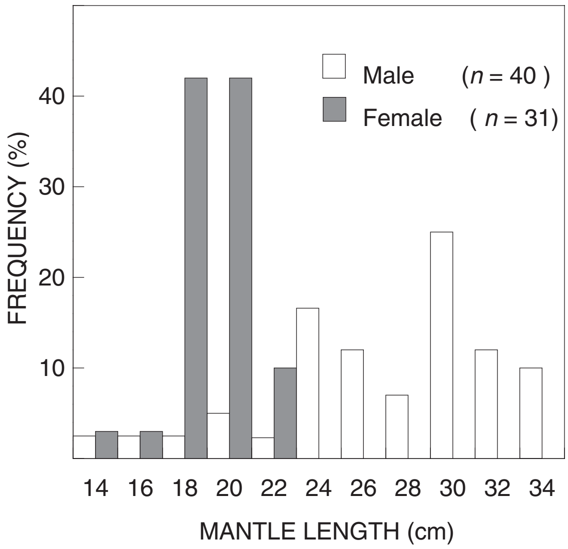

Fig. 4 Length frequency and sex of chokka squid collected at Target 1 along Transect C–D

DISCUSSION

The low intensity of the echoes and the location of the deeper targets close to the bottom seabed ridges are not typical of shoaling fish such as clupeoids or horse mackerel. Moreover, these unusual targets have not been observed acoustically outside the chokka squid spawning grounds, despite the large number of survey transects undertaken during the past 10 years (see Hampton 1992, Barange *et al*. 1998, 1999).

Target 1 on echogram C–D was positively identified as a mixed-sex shoal of mature and fertilized chokka squid, concentrated in a similar manner to those found in inshore spawning aggregations (Sauer *et al*. 1992, Lipiński 1994, Lipiński *et al*. 1998). Targets 2 and 3 on the same echogram had similar characteristics, so they too may represent large aggregations of spawning squid. The identity of the deeper targets along transects A–B and E–F, however, is the challenge to be addressed here. A significant difference to bear in mind between the deeper and the three shallower targets (echogram C–D) is that the shallower targets were in warm water above the thermocline, with Targets 2 and 3 in midwater. The similar hydroacoustic properties of the deep targets, such as time of observation, geographical position, location adjacent to the seabed ridges, shape and size, suggest that these were all the same species. The shape, size, time and sometimes echo intensity of these are similar to that of the shallower targets. When this information is combined with the fact that chokka squid eggs have regularly been trawled from the midshelf (Roberts *et al*. in prep.), it is inescapable to conclude that these deeper targets could have been spawning aggregations of chokka squid.

Further supporting evidence for this argument is seen in the spawning behaviour of chokka squid. According to Sauer *et al.* (1992), immature male and female chokka squid over the shelf are usually in separate, small, widely scattered concentrations. On reaching maturity, the shoals mix in the vicinity of the spawning grounds. Video observations by SCUBA divers on the shallow (<40 m), inshore spawning grounds show that, in the early morning, males and females form dense aggregations, up to thousands of individuals (Roberts 1998). Jostling, pairing and mating take place in the water column, and pairs near the seabed deposit egg strands on the substrata (Sauer *et al.* 1992). Egg beds range in size and configuration, from small clusters of connected strands (100–1 000 strands) to dense beds several metres in diameter (Sauer *et al*. 1992, Roberts 1998). It is common to observe eggs deposited on sand in the vicinity of reefs (Wallace 1984, Augustyn, 1990, Sauer *et al*. 1992, Sauer and Smale 1993, Sauer 1995a, b). Scattered egg beds can extend over an area of diameter as large as 200 m. Spawning sites are commonly re-used.

In view of this behaviour and the time of observation of Target 1 on transect C–D (i.e. 05:25), it is likely that egg laying in this case had not commenced, which could explain why the shoal was still above the seabed and that the "mushroom shape" of the aggregation had not yet completely formed. Certain of the above-described characteristics are also appropriate to the deeper targets. The dimensions of the deep shoals are the same as those of the inshore spawning aggregations (and Target 1). The shoals are also similarly close to the seabed on hard (rocky) substratum and extend into the water column. Given these similarities, it is possible that the echo-traces observed on the deep spawning grounds are in fact spawning squid aggregations. If this is the case, then this will be the first direct observation documented for loliginids. *Loligo pealei* (longfin squid) over the continental shelf off the east coast of the USA, Gulf of Mexico and Caribbean Sea can spawn as deep as 100 m (Mesnil 1977) but this statement is based on only a few recoveries of egg clusters. *Loligo forbesi* and *L. vulgaris* are thought to spawn mainly in shallow water up to 65 m deep (Guerra and Rocha 1994), but few specific data are available. The deep-water loliginid *L. gahi* shows a trend of increased maturity with depth, but it is believed to spawn in shallow water only (Hatfield *et al*. 1990).

To conclude, it is possible that the unusual hydroacoustic targets observed in these surveys are aggregations of spawning chokka squid. If this is the case, then 19 accurate positions of spawning sites in deep water have been found and can be used for future investigations. Furthermore, it appears that the hydroacoustic technique described here can be used to obtain behavioural information of the spawning process in these deeper waters.

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