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Refuging behaviour in the nursehound *Scyliorhinus stellaris* (Chondrichthyes: Elasmobranchii): preliminary evidence from acoustic telemetry

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The tendency for marine fish to refuge in natural and artificial structures underwater is well documented, but the incidence of this behaviour among predatory sharks is not widely known. A sub-adult male nursehound *Scyliorhinus stellaris* was tracked by intermittent acoustic telemetry over 168 days in a tidal sea lough. This individual, in-between undertaking nocturnal foraging excursions, refuged in at least five different narrow-entrance holes. Refuge location was validated by underwater and surface observations during which time other nursehounds (sub-adult male and female), were also seen refuging, sometimes together. This indicates nursehound display philopatric behaviour centred on aggregation in 'home' refuges that, in this case, were labyrinthine rock systems.

INTRODUCTION

Periodic use of the structural physical environment for shelter from adverse conditions, protection from predators, avoidance of conspecifics, or for resting, is a behaviour exhibited by nearly all animals at least during some portion of their lives. Refuging behaviour in nests, holes and caves is extremely common among terrestrial taxa, but its importance to marine animals is less well understood, especially among predators. The tendency for marine fish predators to use structural refuges has been documented extensively for intertidal (Gibson, 1982) and coral-reef fish (Ebeling & Hixon, 1991), but the prevalence and function of this behaviour for larger predators such as sharks remains poorly known by comparison. A better understanding of how frequently refuging occurs among different fish species may yield useful insights into the function and evolution of this behaviour.

Refuging behaviour has been observed in only a few species of sharks to date (Sims, 2005) and appears to be undertaken principally by females, which often aggregate in specific refuges such as deep holes or more open caves (McLaughlin & O'Gower, 1971; Sims et al., 2001). Generally, individuals remain inactive within the refuge during the day prior to leaving to go on nocturnal or crepuscular foraging excursions. The factors leading to refuging behaviour in sharks remain unknown, but they often result in spatial segregation of the sexes (Sims, 2005). Sexual segregation as a consequence of refuging behaviour is therefore an important consideration in the context of marine fisheries, because it influences spatio-temporal patterns of species abundance and distribution. This may have implications for fisheries management if refuging behaviour skews habitat usage between the sexes, altering the ratio of males and females in a specific fishing area.

Persistent refuging behaviour in 'home' caves occurs in female lesser spotted dogfish (*Scyliorhinus canicula*) (Sims et al., 2001), but it has not been described in any of the other 90 or so members of the Scyliorhinidae. The nursehound, *Scyliorhinus stellaris*, grows to a much larger size (1.6 m total length (L_T), ~9.5 kg), but is much less abundant in the coastal seas of Britain (Rogers & Ellis, 2000), than its sister species *S. canicula* (0.8 m L_T, ~1.4 kg). Because it is encountered relatively infrequently, very little is known about its basic biology, including movements and behaviour. This paper describes the first acoustic tracking of a nursehound, with underwater observations of this and other individuals using refuges in deep, rocky holes that form part of labyrinthine rock systems.

MATERIALS AND METHODS

Study site

Lough Hyne (Ine) is a 0.8 km^2 tidal sea lough in the far south-west of Ireland (51.50°N 09.30°W). Although part of the lough reaches a depth of 47 m, it is connected to the Atlantic Ocean via a narrow and shallow 'rapids' (width <20 m, depth 1–3 m) with a distinct raised sill (Kitching & Ebling, 1967), which acts to limit fish movements into and out of the lough (Figure 1).

Acoustic telemetry

A sub-adult male nursehound (0.84 m L_T, 2.74 kg) was captured with a gill-net in <10 m depth on the western shore of Lough Hyne on 1 May 2004 (Figure 1). The fish was anaesthetized (ethyl p-aminobenzoate, Sigma; 5 g in 100 cm^3 of ethanol as a carrier, with 10 cm^3 of this solution added per litre of seawater in an anaesthetic bath) and fitted with an acoustic transmitter (16 mm diameter, 65 mm long, weight in water 10 g; Vemco, Nova Scotia Canada). The transmitter was placed intraperitoneally through a 2-cm long incision in the abdominal wall. The

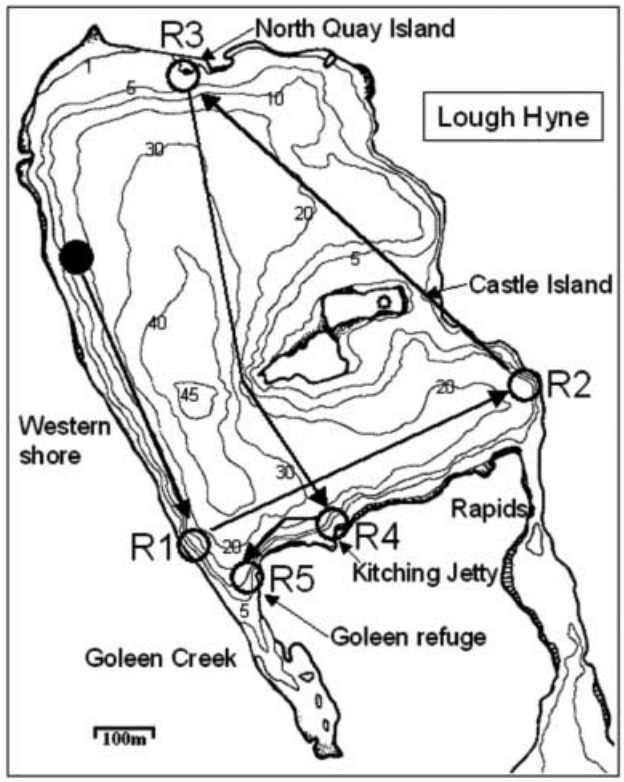

Figure 1. Bathymetric map of Lough Hyne showing locations named in the text and the capture/release position (filled circle), refuge locations (open circles) and shifts in refuge location (large arrows) by a sub-adult male nursehound *Scyliorhinus stellaris* tracked by acoustic telemetry over a 168-day period. Refuge (R) 1 occupied between 2–3 May 2004; R2, 3–12 May 2004; R3, 19–24 July 2004; R4, 28–30 July 2004; R5, 3–16 October 2004. Numbers on contours are depths in metres.

incision was closed with one permanent (2/0 Mersilk, Ethicon, Belgium) and four absorbable sutures (4/0 Vicryl, Ethicon). A coloured, numbered Floy tag was inserted subcutaneously in the dorsal surface above the pelvic fins for external identification. The transmitter-insertion procedure was completed within 10 min of initial anaesthetic administration. The fish was recovered by being moved continuously through clean seawater in the lough until normal, strong gill and swimming movements returned. The fish was released at the point of capture after approximately 1.5 h of observation to check normal swimming movements and ventilation rates were maintained.

Movements of the nursehound were tracked intermittently by fixing its geographical position approximately once per day during each of three 14-day visits to the study site over the next 5.5 months (1 May–16 October). The transmitter was located by ground-zero of the signal using an underwater, pole-mounted directional hydrophone and an acoustic receiver (V10 hydrophone, VR60 receiver; Vemco). The transmitter produced acoustic energy at a frequency of 78 kHz frequency with 60 pulses per min at a power output of 153 dB re 1 μPa at 1 m. The hydrophone was slowly turned in a broad horizontal arc about 1 m below the sea surface to determine the direction of the strongest signal. Signal strength was assessed by listening to the audio output of the receiver. A 5 m boat was used to move in the direction of the strongest signal, and a ground-zero of the transmitter's position was achieved when the same signal strength occurred in all directions when the hydrophone was turned through 360°. The location was then fixed using the Global Positioning System and verified using permanent shoreline markers spaced every 10–100 m around the lough (Kitching & Ebling, 1967). Ground-zero locations were made as often as weather conditions would allow during each field visit. Hence, the movements of the sub-adult male were tracked intermittently on 38 days over the period from 1 May to 16 October 2004.

Direct observations

Transmitter ground-zero locations were validated by underwater observation using SCUBA on two occasions (2 May and 4 October 2004). To determine the main activity times of nursehound in the lough, two observers monitored the occurrence of nursehounds at the Goleen refuge site in each of three study visits (see Figure 1). The number and behaviour of nursehounds were recorded when they passed through an 8×3 m area, extending from the surface to about 3 m depth, immediately adjacent to the Goleen refuge site. Non-overlapping, discrete observation periods, each lasting about 2 h were undertaken during each study visit such that at the end of each visit the duration of observation encompassed a complete diel cycle and totalled 24 h. Viewing boxes with a 0.28×0.28 m window were used when surface conditions were not calm. Illumination of the refuge area at night was provided by a single underwater torch to reduce the possibility of disturbance.

RESULTS

During the tracking period, 64 ground-zero locations were obtained (mean, 1.7 d^{-1} during study visits). The transmitter-tagged nursehound, after release at 0215 h (2 May 2004), moved steadily south along the western shore and by 0328 h was located in shallow water close to shore near the mouth of Goleen creek (Figure 1). At 0950 h the fish was still present at this location and a direct observation using SCUBA at 1750 h showed it to be refuging in a small, narrow-entrance hole within the boulder-scree rock matrix, with the numbered tag clearly visible above the pelvic fins. The hole entrance was 0.2×0.2 m in dimension and was at least 1 m deep. This individual moved east into the south basin at 0824 h the following day (3 May 2004) and by 1140 h was located at the base of Whirlpool Cliff (R2; Figure 1), where it remained for the next nine days until we left the study site.

On 19 July 2004 the nursehound was located at a tiny island in the North Basin of the lough, North Quay Island (NQI) (Figure 1). After remaining stationary for much of the day, it left this position at 2327 h and was tracked moving within the North Basin, prior to heading back towards NQI at 0443 h (20 July 2004). This pattern of daytime location in NQI and nocturnal movements in the North Basin continued until 28 July 2004, when the nursehound moved to a new daytime location near Kitching jetty (Figure 1). It remained there until the study visit ended (30 July 2004). About two months later (3 October 2004, 1300 h), the same transmitter-tagged nursehound was found to be stationary, close to shore at the Goleen

refuge (Figure 1). Diver observation confirmed that this fish was refuging in shallow water of ~4 m depth, within a deep, narrow hole formed between rocks. During the day this fish remained at the Goleen refuge site, but was active at night. On 5 October at 2033 h, the fish was observed swimming north past the Goleen refuge site, circling back before heading north again. Similarly, on 7 October at 0100 h a faint, moving signal was detected to the north, indicating the fish was active. This pattern of daytime refuging at Goleen and night-time activity was maintained until 16 October 2004 when we left the study site.

Direct observation showed other nursehounds were also refuging in the same location as the tagged individual. On 4 October 2004 at the Goleen refuge site, a female nursehound, of similar size (0.7–0.8 m L_T) to the transmitter-tagged male, was seen during daytime laying beside it, nose-to-tail, in a hole just large enough to accommodate them both. About 10 m to the south of them, a second male nursehound was located refuging in water 1–2 m deep, in a narrow hole reaching back at least 1 m. The surface observations also showed nursehounds to be active at this site, with three solitary individuals seen swimming past the Goleen refuge on different nights; two were heading south towards the refuge during daytime on separate days (1558 h, 6 October 2004; 0724 h, 9 October 2004), while the other, a large 1.2-m long individual, swam north into deeper water at night (0415 h, 15 October 2004).

DISCUSSION

Despite the nursehound being the largest species of the Scyliorhinidae family in British waters, surprisingly little is known about important aspects of its biology, including habitat use and behaviour. Around southern shores of the UK it occupies rough, rocky ground, mostly between 20 and 65 m (Wheeler, 1969; Whitehead et al., 1984). Mature females are known to enter shallow water close to shore between March and September to lay eggs (Ford, 1921; Orton, 1926), but refuging by individuals in narrow, labyrinthine holes has not previously been documented. The results of the current study show that an immature male used rock refuges primarily during the day and moved into deeper water to forage at night, with additional observations confirming immature females also showed this behaviour. Further studies of more nursehounds will verify the generality of these preliminary observations, but the tracked individual displayed no apparent abnormal behaviours consistent with post-tagging-procedure effects (Sims et al., 2001). Taken together with the direct observations of refuging in nursehounds that were not subjected to tagging procedures, there is no reason to think the behaviour of the tracked nursehound reported here was atypical.

The use of different habitats within a home range between light and dark phases of the diel cycle is common among adult and sub-adult sharks (Sundstrom et al., 2001; Sims, 2003; Simpfendorfer & Heupel, 2004), however the use of rock refuges by benthic sharks has not been widely studied. The behaviour has been observed in a few species, including the horn shark, *Heterodontus portusjacksoni* (McLaughlin & O'Gower, 1971), and lesser spotted dogfish, *Scyliorhinus canicula* (Sims et al., 2001). Nonetheless, the reasons for refuging by nursehounds, as for other species, is not completely understood, although it has been suggested to occur due to numerous factors, including avoidance of predators, minimizing disturbance by sexually mature conspecifics, or for thermoregulation (Economakis & Lobel, 1998; Sims, 2005).

The transmitter-tagged, sub-adult male nursehound occupied at least five different refuges within the lough over the 168-day tracking period, two of which it used consistently for a number of days between night-time foraging excursions in deeper water. This suggests a degree of homing behaviour or philopatry to particular home refuges by nursehounds and is the same behaviour as that shown by adult female dogfish in Lough Hyne (Sims et al., 2001). Furthermore, the refuge locations selected by the nursehounds are in the precise places where female dogfish prefer to refuge (Sims et al., 2001; Sims, 2003, 2005), which may reflect the paucity of suitable refuging habitat within the lough. Over broader temporal scales it is apparent that nursehounds, like dogfish, also show philopatry to the lough, because the tagged nursehound used it for at least 5.5 months, whilst dogfish may remain for up to at least seven years (Sims, 2003). Our observations demonstrate an interesting convergence in behaviour between these sister species.

The refuging behaviour we have observed in the nursehound and dogfish occurs on open coasts as well as in Lough Hyne. We observed a 1.5-m long adult female nursehound refuging in a small cave at 14 m depth off Plymouth, south-west Britain in April 2004, whilst refuging in dogfish has been observed off Plymouth, Anglesey in north Wales, and off western Scotland (D.W. Sims, V.J. Wearmouth and D. Morritt, unpublished observations). The existence of refuging behaviour in both sheltered and open-coast environments by *Scyliorhinus canicula* (Sims, 2005), and now *S. stellaris* suggests this strategy may be more widespread among benthic sharks, especially within Scyliorhinidae, than presently realized. The role this behaviour has in temporally structuring the movement patterns and foraging searches of nursehounds and dogfish identifies these species as useful animal models for studying central place foraging and philopatry in marine vertebrates.

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