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Movements and growth of a female basking shark re-sighted after a three year period

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Basking shark (*Cetorhinus maximus*) movement patterns and growth rates over annual cycles remain entirely unknown. Here the re-sighting of a female identified by a highly distinctive first dorsal fin, after a 3.1 year period is described. Our results show this individual foraged at the surface in coastal areas off south-west England in at least two of four summer seasons and increased in total length by 2.4 m over this period. The growth increment observed was similar to that predicted from the growth model for this species.

Basking sharks (*Cetorhinus maximus*) filter-feed on zooplankton, often at the surface, along ecologically important thermal fronts during summer months in coastal regions of the north-east Atlantic Ocean (Sims & Quayle, 1998). Despite this seasonal proximity to land enabling recent close study of foraging behaviour (e.g. Sims, 1999), other aspects of this species' basic biology and ecology such as migration, reproduction, fecundity and growth, remain largely unknown. The apparent seasonal disappearance of basking sharks from shallow sea areas outside summer months, its highly variable spatial distribution together with its probable low relative abundance has impeded systematic and sustained scientific investigations of this species' life history.

Much information has been obtained on the movements and growth of pelagic sharks as a result of tagging studies. There are numerous accounts of short-term trackings of shark movements, including *C. maximus*, using electronic tags (e.g. Priede, 1984; Nelson, 1990; Carey & Clark, 1995), but such devices have yet to elucidate seasonal movements like migration. In addition, electronic tags do not enable growth rates of sharks to be studied as deployment times are short (hours to days) and individuals are not usually recaptured. In contrast, plastic tags each with a unique identification number and/or colour, or dart tags with a message inside a capsule have been attached to individual sharks before release so that if a marked shark is recaptured the minimum horizontal distance covered and growth of the animal can be calculated (if length or weight is also reported) (NOAA, 1994). However, such tags are not easily applicable to the study of basking sharks. This is because their spatio–temporal occurrence at the sea surface where tags can be applied is difficult to predict, and their plankton-feeding habit disqualifies them from being lured to the tagging vessel by bait, or captured and immobilized for tag attachment because of their large size. Identification tags have been attached to dorsal fins or musculature using a harpoon dart technique that causes no harm to the animal (Sims et al., 1997), although this requires a specially trained tagging team. Because of these limitations relatively few tags have been attached to *C. maximus* for identification purposes.

Identifying unique body features such as fin shape, pigment discontinuities and scars has proved highly successful in tracking individual cetaceans (Katona et al., 1979; Sigurjónsson et al., 1988) but has not been used for identifying particular fish. This photo-identification technique may be an appropriate method for large-bodied sharks such as *C. maximus* however, that swim at the surface providing a clear view of the first dorsal fin. Here we report the re-sighting after a three year period of a female basking shark identifiable by a very distinctive first dorsal fin and present new information on her growth rate and movements.

During a series of surveys to investigate the distribution and behaviour of basking sharks off Plymouth, south-west coast of England between May and August 1996, a shark with its first dorsal fin apparently missing was seen surface feeding at 1100 hours on 6 June (position: 50°17.83′N 04°07.74′W) among a group of six sharks. The fin shape was very distinctive and enabled one of us (D.W.S.) in a research vessel to track visually the movements of this individual for 2.5 h while it remained feeding at the surface. The research vessel stayed within 10–50 m of the shark at all times and the vessel's position was determined every 5–10 min using a Global Positioning System (Garmin 120S). During the tracking several close views of the shark were obtained and it was identified as female and estimated (Sims et al., 1997) to be 4.9 m in total length (L_T). The entire anterior half of the fin was missing, although a wide portion of the base made up of the radial elements remained. A small subtriangular section of the posterior lower half of the fin was present (radial elements and ceratotrichia) and curled over on the right side of the shark, where it touched the fin base and dorsal surface of the shark, giving the overall appearance of a very shallow, corrugated V-shape when viewed laterally (Figure 1A).

The following day this individual (catalogued as #6696F1) was observed surface feeding at 1555 hours some 8.5 km further east-south-east (position: 50°14.06′N 03°59.77′W) in the presence of four other sharks. Close inspection of the shark over the next 5 min enabled one of us (A.M.F.) to make a second and independent total length estimate of 5.0 m.

Although dedicated research cruises to investigate the behaviour of *C. maximus* were operated in 1997–1999 off Plymouth and other locations around the south-west peninsula, this easily identifiable shark was not seen. In an independent study however, a shark with a distinct first dorsal fin was videotaped feeding at the surface between 1400 and 1430 hours on 23 July 1999 in Harlyn Bay, north Cornwall coast (position: 50°32.50′N 05°00.00′W). During the 30 min observation

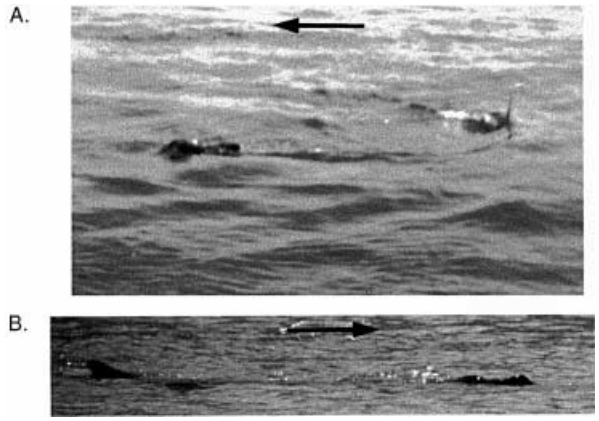

Figure 1. Photographs of the first dorsal fin and caudal fin tip of #6696F1 taken on 6 June 1996 (A) and 23 July 1999 (B). Swimming direction denoted by arrows. The individual photographs shown here were taken from different angles of elevation.

close-up photographs were taken and the shark was identified as female and estimated to be 7.3 m L_T. The fin shape of this particular shark very closely resembled that of #6696F1 seen three years earlier on the south Devon coast. The first dorsal fin of the Harlyn Bay shark was essentially missing but there was a broad anterior base and a posterior trailing edge that curled over to the right side giving an overall shallow, corrugated V-shape when seen in profile (Figure 1B). Therefore, on account of this close match between fin shape and associated fin features, independent observations that the shark's sex was female, it was concluded that these sightings 3.1 years apart were most likely of the same individual.

In the period between 6–7 June 1996 and 23 July 1999 which included four summer feeding seasons, the female *C. maximus* increased in length by approximately 2.4 m. The growth rate of basking sharks is not known with any certainty, but Parker & Stott (1965) attempted to construct a von Bertalanffy growth curve from length–frequency data derived from 93 individuals from fishery catches. The latter authors showed there was a shift in length–frequency of smaller sharks between a summer (May–July) mean length of 3.09 m and a winter (Oct–Feb) mean length of 3.52 m. This difference in length they ascribed to summer growth and using these two points, and assuming a length asymptote of 11.0 m L_T, Parker & Stott (1965) constructed a growth model for basking shark length at age. The growth increment of #6696F1 in the present study fits this model very well if it is assumed, as seems probable, that *C. maximus* reaches a length of 4.9–5.0 m in the fifth winter (or fourth year) after parturition. Accepting this limitation, the growth curve has been remodelled by least squares nonlinear regression as a starting point for future analysis. The growth increment data for #6696F1 were used together with the 3.09–3.52 m length increase over 0.5 y obtained by Parker & Stott (1965), included an assumed size at parturition of 1.5 m L_T and a fixed maximum length asymptote (L_∞) of 11.0 m L_T (Parker & Stott, 1965). The regression coefficient (r^2) of the modelled relationship was 0.99 ($0.001 < P < 0.002$), while the von Bertalanffy growth model constants for both models were similar [Parker & Stott (1965): K, 0.120; t_0, −1.250. This study: K, 0.131; t_0, −1.045].

This study serves as an example of how unique fin shapes can be used to identify individual basking sharks. The recent incorporation of a CD-ROM database containing photographs of dorsal fins of individual basking sharks (based at the National Marine Aquarium, Plymouth) provides a new focus for the development of photo-identification studies in this species.

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