

Marine turtles and their barnacles from Scottish waters and adjacent seas

M. O'Reilly¹, A. Brownlow², M. ten Doeschate², D. Fenwick³ & R. Penrose⁴

¹Scottish Environment Protection Agency, Angus Smith Building, 6 Parklands Avenue, Maxim Business Park, Eurocentral, Holytown, North Lanarkshire ML1 4WQ

²Scottish Marine Animal Stranding Scheme, Institute of Biodiversity, Animal Health & Comparative Medicine, College of Medical, Veterinary & Life Sciences, University of Glasgow, Glasgow G12 8QQ

³APHOTOMARINE, <https://www.aphotomarine.com/>

⁴British and Irish 'TURTLE' Database Manager, Marine Environmental Monitoring, Penwalk, Llechryd, Cardigan, West Wales SA43 2PS

¹E-mail: myles.oreilly@sepa.org.uk

ABSTRACT

The history of marine turtles in Scottish waters and adjacent seas is reviewed. The recording and reporting schemes for stranded marine animals in Scotland and the U.K. are highlighted. Detailed descriptions are provided of strandings of a loggerhead turtle (*Caretta caretta*) at Irvine, Ayrshire in December 2015, with numerous attached goose barnacles (*Lepas anatifera*) and a leatherback turtle (*Dermochelys coriacea*) at St. Cyrus, Aberdeenshire in January 2016, with several acorn barnacles (*Stomatolepas dermochelys*). A review of U.K. marine animal strandings reports revealed additional records of *L. anatifera* and *L. hillii*, from stranded loggerheads in Carmarthenshire in 2006 and in Cornwall in 2016 respectively, as well as another leatherback with *S. dermochelys* in Cornwall in 2018. The occurrence of lepadomorph and balanomorph barnacles on turtles is discussed including historical records from the U.K. and Ireland, and adjacent waters in the Mediterranean and the north-east Atlantic. Taxonomic confusion within the genus *Stomatolepas* is clarified. Other species of barnacle that might occur on turtles reaching the waters of the U.K. and Ireland in the future are discussed along with other exotic fauna that can accompany turtles. The impact of barnacles on turtles and how turtles remove attached epibionts is summarised.

INTRODUCTION

Whales, dolphins, or marine turtles washed up on Scottish shores are routinely examined under the Scottish Marine Animal Stranding Scheme (SMASS) (Brownlow *et al.* 2016). The occurrence of whale or turtle barnacles is poorly known in British waters, so these strandings offer an opportunity to examine and provide new information on these interesting epibiont fauna. Two relatively recent finds of unusual barnacles from turtles stranded in Scotland, and examined by SMASS, prompted this investigation and a review of current knowledge on turtles and their barnacles in the waters around the U.K. and Ireland.

MARINE TURTLES

Marine turtles are rare visitors to the shores of Britain and Ireland. Historically they have received scant attention as British subjects. Smith (1951), in his volume on the British amphibians and reptiles, stated that turtles do not properly belong to the British fauna and he provided only a brief account of the five species then known from British waters with a map depicting their stranding locations throughout Britain and Ireland. Records of marine turtles in British or Irish waters have usually been scattered in fisheries articles, naturalists' journals, or press reports and have only occasionally been collated (Taylor, 1948, 1963; Brongersma, 1972), with details of Scottish records gathered by Stephen (1953, 1961), Stephen *et al.* (1963) and McInerney & Minting (2016).

In the 1960s efforts were made to better inform fishing communities about marine turtles and to encourage reporting of sightings (Brongersma, 1967, 1968a). Leatherback turtles (*Dermochelys coriacea*) are the largest living turtle species. The largest leatherback so far recorded in the U.K. stranded on Harlech beach, Wales, in 1988. It measured almost 3 m and weighed 914 kg and is now displayed at the National Museum of Wales (Hanley *et al.*, 2013). It is perhaps understandable that some previous turtle sightings of leatherbacks in Scottish waters, or elsewhere, have been mistaken for mythical beasts (Brongersma, 1968a,b,c). It is now known that the leatherback turtle is able to maintain an elevated body temperature in cooler northern seas (Frair *et al.*, 1972; Mrosovsky, 1980) and that it is an intentional summer migrant to British waters, in search of jellyfish on which it feeds (Davenport, 1998). Leatherbacks are the only turtle species able to maintain warm body temperatures in cold waters and this adaptation also allows them to dive to cooler waters of over 1,000 m depth in search of prey (Lovich & Gibbons, 2021). Hard-shelled turtles are not able to regulate their temperatures in the same

way, hence should not normally occur in cooler British waters unless they have drifted there on currents. Therefore, the leatherback, at least, became regarded as part of the British fauna worthy of further monitoring and proper protection (Brongersma, 1982; Anon., 1984).

A Turtle Code advice sheet was produced by the Nature Conservancy Council in 1988 aimed at various seafarers. Scottish Natural Heritage (SNH, now NatureScot) undertook a review of marine turtles in Scottish waters (Langton *et al.*, 1996) and issued their own turtle code advice sheet (Davenport & Gaywood, 1997). A guide to the marine turtles in British and Irish waters was published by Gaywood (1997) and additional turtle codes were issued by the Cornish Wildlife Trust in 1997 and the Countryside Council for Wales (CCW) in 1998. A U.K. Marine Turtles Grouped Species Action Plan was produced by the U.K. Biodiversity Action Group (UKBAP, 1999) which proposed various actions on policy and legislation, species management and protection, and future research and monitoring. Thereafter, the Turtle Implementation Group was formed which comprised lead conservation agencies and research groups in the U.K. A review of turtle strandings in British and Irish waters was undertaken by Pierpont (2000) and subsequently a database of turtle records for the U.K. and Ireland was established (Pierpont & Penrose, 2002).

From 2001 marine turtles were included within the U.K. Cetacean Strandings Investigation Programme (CSIP) with information on stranded turtles included within CSIP annual reports (<https://ukstrandings.org/csip-reports/>). Turtle strandings in Scottish waters are investigated by SMASS and further information on Scottish marine mammal and turtle strandings is included in SMASS annual reports available online from 2009 (<https://strandings.org/publications/>). More comprehensive information, including distribution maps of all turtle strandings and live sightings for the U.K. and Ireland, has been separately collated since 2001 and is available in annual reports produced by Marine Environmental Monitoring (MEM) (www.strandings.com/). These include the first ever

record from the U.K. or Ireland of an olive ridley turtle (*Lepidochelys olivacea*), which was found alive in the Menai Strait, Wales, in November 2016 (BBC, 2016c; Penrose & Gander, 2017). A second olive ridley was recently reported off Seaford beach, East Sussex (BBC, 2020). However, subsequent examination revealed this specimen to be a Kemp's ridley turtle (*L. kempii*). The British and Irish 'TURTLE' database now holds 2,881 records of sightings and strandings of turtles from 1748 to the end of 2021. An analysis of the long-term records of turtles around the U.K. and Ireland was undertaken by Botterell *et al.* (2020). A summary of the over one thousand records of turtles, from around the U.K. and Ireland over the last twenty-one years is provided in Table 1. On average there have been 50 turtle records per year. Of the 1,052 turtle records around 67% were leatherbacks, around 15% were loggerheads, and about 12% were unidentified. Kemp's ridley turtles, green turtles (*Chelonia mydas*), and olive ridley turtles represented only 3.9, 0.9, and 0.009% respectively.

A thorough review of current knowledge about marine turtles in Scottish waters is included in the volume *The Amphibians and Reptiles of Scotland* (McInerny & Minting, 2016). The authors provided detailed distribution maps of the turtles recorded from Scottish waters and indicate that from about 1750 to 2014 there were around 350 records of turtles in Scottish waters, including about 250 leatherbacks, 50 loggerheads, nine Kemp's ridley turtles, four green turtles and about 80 turtles unassigned to species. Only adult leatherbacks (length 1.8-2.9 m) appear to visit Scottish waters. Most leatherback sightings are between June and October and are live animals, though a number were found to have died following entanglement in fishing gear.

The distribution of leatherbacks in relation to their gelatinous prey was examined, for the Irish Sea by Houghton *et al.* (2006) and for the north-east Atlantic by Witt *et al.* (2007). The hard-shelled turtle species that occur in Scottish waters are usually juveniles, which are carried by currents from warmer seas. They are often found dead but many are still alive, albeit cold-stunned and consequently lethargic. Previous records of hawksbill turtles (*Eretmochelys imbricata*) from Scotland are considered erroneous (McInerny &

Country	Leatherback	Loggerhead	Green	Kemp's Ridley	Olive Ridley	Unidentified
Scotland	113	36	3	8		14
Ireland	227	45	1	3		22
England	254	56	2	17		84
Wales	115	22	4	13	1	12
Totals:	709	159	10	41	1	132

Table 1. Records of sightings or strandings of marine turtles in the waters around the United Kingdom and Ireland from 2001 to 2021.

Minting, 2016), and currently there is only a single confirmed record of a hawksbill turtle from the U.K. or Irish waters, caught in a herring net off Cork in 1983 (O’Riordan *et al.*, 1984; King & Berrow, 2009).

Some historical Scottish turtle records include fascinating anecdotes (McInerney & Minting, 2016). In 1829 a live turtle (suspected loggerhead) was captured at Southernness, Dumfries and Galloway, and was sent to a hotel in Dumfries to make soup; in 1861 a turtle (suspected loggerhead) was captured alive at Rowardennan in Loch Lomond, presumably having swum up the River Leven. In 1959 a leatherback was captured in Kilbrannan Sound, Firth of Clyde, and was transported alive to Calderpark Zoo in Glasgow. It subsequently died, but a cast of the specimen is now in Paisley Museum and the head is held in the Kelvingrove Art Gallery and Museum, Glasgow (Reg. No. Z.1959.138.2).

The Kelvingrove Museum also has a cast of a leatherback found entangled in creel ropes in Luce Bay, Kirkcudbrightshire, in 1975 (Reg. No. Z.1975.118), and National Museums Scotland, Edinburgh hold a semi-modelled head of a leatherback collected from Annan, Dumfriesshire, in 1959 (Reg. No. 1959.49.1.1), and a full cast of a leatherback collected from Crail, Fife, in 1967 (Reg. No. NMS.Z.1967.81.1). The leatherback cast on display in the Hunterian Zoology Museum (Graham Kerr Building, University of Glasgow) was purchased in New York in 1916 and shipped across the Atlantic. In the midst of World War 1 this would have been a perilous journey for a replica turtle compared with the transatlantic migrations of its living counterparts in the wild.

TURTLE BARNACLES

Although poorly known by many naturalists, barnacles, with their highly transformed crustacean morphology, are an ideal case study for evolutionary biologists and they were extensively investigated over many years by Charles Darwin (Darwin, 1851, 1854; Stott, 2003; Jagt, 2020). It is advantageous for barnacles if they can attach to marine turtles. The turtle provides a mobile feeding platform with enhanced feeding currents and an absence of barnacle predators. However, the turtle has apparently little to gain and growth of barnacles or other epifauna impedes their motility and is a hindrance to be avoided. While considerable interest has been shown in turtles occurring in British and Irish waters, little has been published about the unusual barnacles that they sometimes host. The first Linnean Society synopsis of British Barnacles (Bassindale, 1964) does not mention any barnacles from turtles. However, the revised synopsis of the British barnacle fauna (Southward, 2008) has records of three sessile acorn barnacle species from turtles in British waters and cites a potential fourth species.

In the winter of 2015/16 two turtles stranded on Scottish shores within a month, each harbouring some unusual barnacles. This communication examines these

new Scottish records of turtle barnacles and reviews some other recent records from England and Wales. Historical records of turtle barnacles from the U.K. and Ireland are considered along with other barnacles which might be expected on turtles entering British or Irish waters. Unless stated otherwise the scientific names used herein for barnacles and other species follow the World Register of Marine Species (WoRMS, <https://www.marinespecies.org/>).

Recent records of turtle barnacles

Many of the stalked (lepadomorph) or sessile (balanomorph) barnacles commonly found on turtles have cosmopolitan distributions and illustrated keys for their identification are provided by Monroe & Limpus (1979) and Zullo (1979). The lepadomorph barnacles attach to almost any floating objects, including turtles. Most of the balanomorph barnacles found on turtles are more specialised chelonophilic barnacles which occur only on turtle hosts.

On 5th December 2015, in the wake of Storm Desmond, a loggerhead turtle was washed ashore on Irvine beach in the Firth of Clyde, Scotland (M408/15 in SMASS database, National Reference number T2015/02). The turtle was found alive, but moribund, by participants from a nearby cycling event, and the British Divers Marine Life Rescue and Scottish SPCA were alerted. The turtle, a young female, 72 cm in length and weighing 28 kg, had a malformed right front flipper and was heavily infested by goose barnacles on the upper right side (Fig. 1). The turtle was transferred to the Scottish Sea Life Sanctuary at Oban for rehabilitation. The goose barnacles were removed but unfortunately the turtle died a few days later (Scottish Sea Life Sanctuary, 2015). The turtle was subsequently necropsied by SMASS and the cause of death was considered most likely to have been cold shock (Brownlow *et al.*, 2016).



Fig. 1. Loggerhead turtle (*Caretta caretta*) (frontal view) stranded on Irvine Beach, Scotland, December 2015. (Photo: Andy Martin, SEPA)

Although the goose barnacles were not retained, various photographs show them *in situ* (BBC, 2015b; Penrose & Gander, 2016; Deaville *et al.*, 2016), (Fig. 2), or being removed by the sanctuary staff (Figs. 3 and 4). The goose barnacles can be identified from the photographs as *Lepas anatifera*, due to their relatively large size, their smooth shell plates (without obvious



Fig. 2. Loggerhead turtle (*Caretta caretta*) (dorsal view) stranded on Irvine Beach, Scotland, December 2015. (Photo: Scottish SPCA)



Fig. 3. Removal of goose barnacles (*Lepas anatifera*) from loggerhead turtle (*Caretta caretta*) from Irvine Beach, Scotland, December 2015. (Photo: Anna Price, Scottish Sea Life Sanctuary)



Fig. 4. Loggerhead turtle (*Caretta caretta*) from Irvine Beach, Scotland, after removal of goose barnacles (*Lepas anatifera*). December 2015. (Photo: Anna Price, Scottish Sea Life Sanctuary)

radial ridges), the narrow gap between the carina and scutum plates, and the absence of any rust-coloured band at the top of the peduncle (Broch, 1959; Southward, 2008). It can be estimated from the photographs and the turtle image with a scale shown in Brownlow *et al.* (2016) that the largest barnacles were around 10 cm long, and it appears that around 80 to 100 were attached to the turtle. It is probable that the deformed flipper restricted the turtle's swimming

manoeuvrability. This would have slowed movement of the turtle and may have limited its ability to abrade its shell on the seabed to remove growths. Hence, the goose barnacles were able to colonise and grow unhindered with these adding a burden to the turtle, further impairing its propulsion.

Barely a month later, on 8th January 2016, a leatherback turtle was found washed up dead on the beach at St. Cyrus Nature Reserve, Aberdeenshire (Anon., 2016, M24/16 in SMASS database, National Reference number T2016/01). The turtle was an immature male with overall length of 179 cm. It was removed from the beach and brought to the SMASS laboratory for examination (Fig. 5). The turtle weighed 209 kg and the subsequent necropsy suggested the cause of death was probably hypothermia (Brownlow *et al.* 2017; Penrose & Gander, 2017). It seems likely that the turtle may have been a victim of the then recent Storm Frank.



Fig. 5. Leatherback turtle (*Dermochelys coriacea*) from St. Cyrus, Scotland, being weighed prior to necropsy. (Photo: SMASS)

Twenty barnacles were found on the turtle, embedded in its skin. They were mostly located on or around the base of the front fins: eight ventrally between the base of neck and the base of left front fin (Fig 6a,b); one dorsally on base of same fin; five ventrally near base of right front fin; five dorsally behind base of same fin; and one ventro-laterally about half way along the body.

Thirteen barnacles were removed and preserved for closer examination (Fig. 7). They ranged in length from 7 to 11 mm and in thickness from 2.5 to 5 mm. The barnacles were bowl-shaped with a flat-topped aperture and a slightly inward curving shell with numerous small protrusions enabling them to embed in the host epidermis. These features readily allowed the barnacles to be ascribed to the genus *Stomatolepas*, and their host, and their location on the host, indicate they should be referred to *Stomatolepas dermochelys* as described by Monroe & Limpus (1979). The barnacles from the St. Cyrus leatherback are deposited in the National Museum of Scotland (Reg. No. NMS.Z.2022.9).

A review of the MEM annual reports (2001-2020) on turtle strandings and sightings in the U.K. and Ireland revealed two additional photographs of loggerheads infested with goose barnacles.

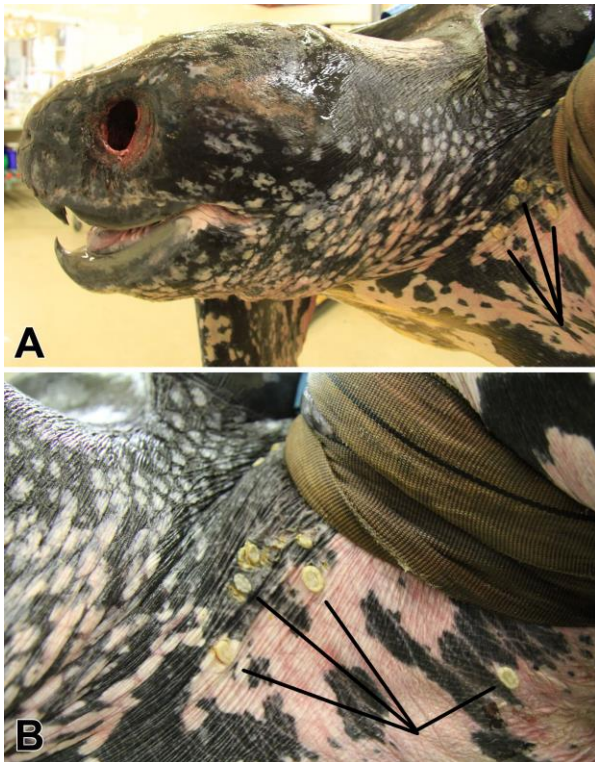


Fig. 6. Leatherback turtle (*Dermochelys coriacea*) from St. Cyrus, Scotland. (A) Acorn Barnacles (*Stomatolepas dermochelys*) (black lines) at base of neck. (B) Closer view of barnacles. (Photos: SMASS)



Fig. 7. Acorn Barnacles (*Stomatolepas dermochelys*) from St. Cyrus leatherback turtle (opercular view; longest barnacle to the right is 11 mm in length). (Photo: Myles O'Reilly)

The first, in December 2006, a live loggerhead (length 84 cm, weight 36.5 kg) was found on Cefn Sidan Sands, Pembrey Country Park, Carmarthenshire, Wales, during strong south-westerly storms (Ref. No. T2006/39; Penrose & Gander, 2007). Most of the front left flipper was missing but this had healed indicating it was an old injury. Around six *Lepas anatifera* goose

barnacles are shown attached at the rear on the underside of the carapace. This turtle was sent to the Weymouth Sea Life Centre for rehabilitation but died in February 2007. A post-mortem examination revealed lesions consistent with a severe chronic bacterial bronchopneumonia and tracheitis (Penrose & Gander, 2008).

The second, in January 2016, a juvenile loggerhead was found stranded alive, by David Fenwick, at Gwithian beach, Hayle, Cornwall, England (Ref. No. T2006/39; BBC 2016a,b; Penrose & Gander, 2017). There were around 30 goose barnacles attached to the rear of the carapace (Fig. 8) which were identified as *Lepas hillii*.



Fig. 8. Loggerhead turtle (*Dermochelys coriacea*) with goose barnacles (*Lepas hillii*), Gwithian Beach, Cornwall, England, January 2016. (Photo: David Fenwick)

As the Gwithian turtle was only around 20 cm long, and the individual barnacles each about 4-5 cm, the mass of goose barnacles must have been a significant impediment to its swimming. The turtle was rehabilitated at Newquay's Blue Reef Aquarium and the goose barnacles removed. It was subsequently repatriated by the Irish Navy close to the entrance to the Mediterranean.

In addition to the above records, in August 2018, a dead leatherback was found washed up near Marazion, Cornwall, England (Fig. 9, Ref. No. T2018/01; Wilkinson, 2018; Penrose & Gander, 2019). Nine sessile barnacles were removed from the underside of the front fins and have been identified as *Stomatolepas dermochelys*. An aperture view and underside view are shown here (Figs. 10 and 11) and further detailed images of these barnacles are available at the APHOTOMARINE website (<https://www.aphotomarine.com/>).

Turtles as hosts to lepadomorph goose barnacles

Although turtles are not mentioned as hosts of the lepadomorph goose barnacles in Southward's (2008) synopsis of British barnacles, their occurrence on turtles is not unexpected. The family Lepadidae contains several goose barnacles with cosmopolitan distributions in oceanic waters which attach to various



Fig. 9. Leatherback turtle (*Dermochelys coriacea*) at Marazion, Cornwall, England, August 2018. The underside has been opened for necropsy. (Photo: David Fenwick)



Fig. 10. Acorn Barnacle (*Stomatolepas dermochelys*) from leatherback turtle (*Dermochelys coriacea*), Marazion, Cornwall, England, August 2018 (opercular view from which the feeding cirri protrude). (Photo: David Fenwick)



Fig. 11. Acorn Barnacle (*Stomatolepas dermochelys*) from leatherback turtle (*Dermochelys coriacea*), Marazion, Cornwall, England, August 2018 (underside view showing protrusions used to embed the barnacle into the turtle). (Photo: David Fenwick)

floating objects. In British waters they are well known from ship hulls and flotsam (MBA, 1957; Evans, 2000) and are frequently cast ashore, especially on the western and south-western coasts of Britain and Ireland (Trehwella & Hatcher, 2015). They can be transported considerable distances by oceanic currents such as the

Gulf Stream and North Atlantic Drift which bring them to British and Irish waters.

In 1977 a metal buoy found washed ashore near Dingle (south-west Ireland) with *L. anatifera* goose barnacles attached, also harboured some attached bivalves (*Brachiodontes exustus*) whose normal distribution is the coastal waters of the south-east U.S.A. and the West Indies (O’Riordan & Holmes, 1978). In November 2015 a large piece of rocket debris from Florida was recovered near Tresco, Scilly Isles, having acquired thousands of *L. anatifera* goose barnacles on its trans-Atlantic voyage (BBC, 2015a). The Faroe-Shetland current may carry goose barnacles onwards towards the west coast of Norway and up to northern Norway well above the Arctic Circle (Nilsson-Cantell, 1978). The proliferation of man-made flotsam may act as a habitat and vector for lepadid goose barnacles, and other rafting fauna, increasing their prevalence in oceanic waters (Minchin, 1996; Whitehead *et al.*, 2011; Kiessling *et al.*, 2015; Rech *et al.*, 2018; Mesaglio *et al.*, 2021). Images of numerous different transatlantic rafting species that have arrived in south-west England can be viewed on the APHOTOMARINE website (https://www.aphotomarine.com/trans_atlantic_rafting_species.html).

The natural habitat of most lepadid goose barnacles is floating objects such as tree trunks or branches, seed pods, coconuts, seaweed, pumice, feathers, cuttlebones, shells of Nautilidae squid, ram’s horn squid (*Spirula spirula*) or of the violet sea snail (*Janthina janthina*), or floating corals (Thiel & Gutow, 2005; Whitehead *et al.*, 2011). However, they are opportunistic hangers-on and some also occur as facultative epibionts on whales (Clarke, 1966; Fertl & Newman, 2017), turtles (Epibiont Research Cooperative, 2007; Ten *et al.*, 2019) or sea snakes (Yamato *et al.*, 1996).

Occasionally goose barnacles are recorded from fish. The Plymouth Marine Fauna (MBA, 1957) cites a grey triggerfish (*Balistes capriscus*) from Devon which hosted *L. anatifera*, *L. hillii* and the striped goose barnacle *Conchoderma virgatum*. Since then, *L. anatifera* has been recorded from within the mouth of a sunfish (*Mola mola*) near the Azores (Barreiros & Teves, 2005) and *C. virgatum* has been found on a sunfish from Ireland (Cooper *et al.*, 1982), and attached to a grey triggerfish from Portugal (Ramos *et al.*, 2010). An Atlantic tripletail (*Lobotes surinamensis*) in the Adriatic Sea has been found hosting both *L. hillii* and *C. virgatum* (Dulčić *et al.*, 2015). In southern oceans goose barnacles sometimes attach to seals and penguins (Reisinger & Bester, 2010; Fertl & Newman, 2017).

In his review of turtle records from European Atlantic waters Brongersma (1972) cites five loggerhead and two Kemp’s ridley turtles with unidentified goose barnacles attached from British, French, Dutch and Norwegian waters. One of the loggerhead turtles, from Jersey in 1950, was so laden with clusters of goose barnacles that the turtle floated upside down. A

leatherback from Brittany in 1932 hosted two *C. virgatum* and one from Norway in 1956 had a few *Conchoderma* sp. on its upper and lower shell.

Studies of turtles in the Mediterranean indicate the occurrence of five goose barnacle species on loggerheads (*L. anatifera*, *L. anserifera*, *L. hillii*, *L. pectinata* and *C. virgatum*) with *L. hillii* present on more than half of stranded turtles on the eastern coast of Spain (Casale *et al.*, 2012; Domenèch *et al.*, 2015). Similarly, *L. anatifera* and *C. virgatum* have been found on loggerheads from the Canaries (Loza, 2011) and *L. anatifera* on Kemp's ridley turtles stranded on the coasts of Portugal and north-west Spain (Covelo *et al.*, 2016).

There are few previous published records of identified goose barnacles from turtles around the U.K. or Ireland. An adult loggerhead, which stranded in Skye, Scotland in December 1923, harboured a number of *L. hillii* attached to the underside of the carapace and one *C. virgatum* attached to the basal plate of one of the *L. hillii* (Ritchie 1924a,b). The striped goose barnacle, *C. virgatum*, has also been recorded from a leatherback in Irish waters (O'Connor & Bowmer, 1985). The 'TURTLE' database also has a record of a loggerhead (Reg. No. T1970/04), which stranded in Cornwall in November 1970, and had three *L. anatifera* on its underside.

The enigmatic nature of goose barnacles has generated some unusual myths (Lappo *et al.*, 2019). The occurrence of branches washed ashore, festooned with goose barnacles, led to the belief that they grew on trees and such trees were illustrated in medieval herbals. In addition, it was believed, in medieval times, that barnacle geese (*Branta leucopsis*), which vaguely resemble goose barnacles and mysteriously arrived on the shores of western Europe each winter, were actually spawned directly from the barnacles on these trees. This mythology is reflected in the species names *Lepas anatifera* and *L. anserifera* which translate as bearer of ducks and of geese respectively.

Turtles as hosts to balanomorph acorn barnacles

Among the balanomorph barnacles the superfamily Coronuloidea includes around 30 species worldwide which are mostly obligate epibionts on whales or turtles, but are also sometimes found on manatees, sea snakes, crocodilians, crabs and horse-shoe crabs (Young, 1991; Epibiont Research Cooperative, 2007; Hayashi, 2012, 2013).

Only three species of coronuloid barnacles are cited by Southward (2008) from turtles in British or Irish waters. In 1923 nearly 60 *C. caretta* were found on the aforementioned loggerhead from Skye, which also hosted two species of goose barnacle (Ritchie, 1924a,b). In July 1993 around 15 juvenile *Chelonibia testudinaria* were reported from a leatherback stranded in Gwynned, North Wales (Rees & Walker, 1993). *Chelonibia* barnacles are usually large and distinctly dome-shaped, up to 6 cm in basal diameter, and cement

themselves to their host (Monroe & Limpus, 1979; Zardus, 2021). Both these species are widely recorded on turtles in the Mediterranean Sea and the Atlantic and Pacific Oceans (Hayashi, 2013).

There are several previous records of "*Stomatolepas elegans*" from leatherback turtles in British or Irish waters: in England from The Lizard, Cornwall, in July 1971 (Brongersma, 1972); in Scotland from Crail, Fife, in November 1967 and from Luce Bay, Kirkcudbrightshire, in September 1975 (Smaldon & Lyster, 1976); and in Ireland, from Cork in July 1971, from Malin Head in July 1973, and off Ventry, Kerry, in July 1976 (O'Riordan & Holmes, 1978). Barnacle specimens from The Lizard, Cornwall, were included in the type description of *S. dermochelys* Monroe & Limpus, 1979, and it now seems probable that all the "*S. elegans*" records cited above from leatherbacks in the U.K. and Ireland should also be referred to *S. dermochelys* as suggested by Hayashi (2013). Specimens cited above from Crail and Luce Bay are held in the National Museum of Scotland (Reg Nos. Z.1985.84-85).

In neighbouring waters *S. dermochelys* has been recorded from leatherbacks in Belgium (Haelters & Kerckhof, 1999; Haelters *et al.* 2001) and from the Netherlands (Holthuis, 1969). Live leatherbacks are known to enter Norwegian waters and have even been sighted within the Arctic Circle (Brongersma, 1972). A leatherback caught eight miles west of Skarvoy (60° 30' North) in 1965 hosted *S. dermochelys* (Smaldon & Lyster, 1976) as did one captured near Finnmark (~ 71° North) in 1997 (Carriol & Vader, 2002). The latter probably represents the most northerly record for both the leatherback and its barnacle hitch-hiker. Elsewhere *S. dermochelys* has a cosmopolitan distribution on leatherbacks from the Atlantic and Pacific Oceans and appears to be restricted to this one turtle species (Hayashi, 2013; Zardus, 2021).

Southward (2008) suggested that *Platylepas hexastylus* might occur on turtles around the British Isles but stated that there were no records from British or Irish waters. In fact, there is a record of this barnacle from a leatherback landed at Dingle, south-west Ireland in July 1978 (O'Riordan, 1979). *P. hexastylus* is flat, cone-shaped, up to 14 mm diameter, and clings to its host by partially embedding its base via downward projecting midribs (Monroe & Limpus, 1979; Zullo, 1979; Zardus, 2021). It also has a cosmopolitan distribution on various turtle species from the Mediterranean Sea and the Atlantic and Pacific Oceans (Hayashi, 2013). However, a sibling species, *P. coriacea*, is now known to occur exclusively on leatherbacks and the Dingle record almost certainly refers to this latter species (Zardus, 2021). In contrast, *P. hexastylus* has been recorded from a loggerhead in the Netherlands along with *C. caretta* (Holthuis, 1952). A summary of all the records of British and Irish turtle barnacles cited here and any additional records from the 'TURTLE' database is provided in Table 2.

Turtle	Location	Date	Barnacles (some source nomenclature updated)	Source
Loggerhead (1923/02)	Skye, Scotland	Dec. 1923	<i>Lepas hilli</i> , <i>Conchoderma virgatum</i> , <i>Chelonibia caretta</i>	Ritchie, 1924a,b
Kemp's Ridley (T1938/05)	Jersey	Dec. 1938	Goose barnacles on shell	Brongersma, 1972
Loggerhead (T1938/09)	Bognor Regis, Sussex, England	Dec. 1938	Goose barnacles attached	Brongersma, 1972
Loggerhead (T1950/02)	Jersey	Nov. 1950	Goose barnacles (turtle upside-down)	Brongersma, 1972
Leatherback (T1959/03)	Kilbrannan Sound, Firth of Clyde, Scotland	Aug. 1959	Sessile barnacles	Stephen, 1961
Leatherback (T1967/11)	Crail, Fife, Scotland	Nov. 1967	<i>Stomatolepas dermochelys</i>	Smaldon & Lyster, 1976
Loggerhead (T1970/04)	Perranporth, Cornwall, England	Nov. 1970	<i>Lepas anatifera</i> on underside	TURTLE Database
Leatherback (T1971/03)	Cork, Ireland	Jul. 1971	<i>Stomatolepas dermochelys</i>	Brongersma, 1972; Smaldon & Lyster, 1976; O'Riordan & Holmes, 1978
Leatherback (T1971/05)	Enys Head, The Lizard, Cornwall, England	Jul. 1971	<i>Stomatolepas dermochelys</i>	Brongersma, 1972; Smaldon & Lyster, 1976
Leatherback (T1973/04)	Malin Head, Donegal, Ireland	Jul. 1973	<i>Stomatolepas dermochelys</i>	O'Riordan & Holmes, 1978
Leatherback (T1975/05)	Stairhaven, Luce Bay, Kirkcudbrightshire, Scotland	Jul. 1975	<i>Stomatolepas dermochelys</i>	Smaldon & Lyster, 1976
Leatherback (T1976/03)	Ventry, Kerry, Ireland	Jul. 1976	<i>Stomatolepas dermochelys</i>	O'Riordan & Holmes, 1978
Leatherback (T1978/07)	Dingle, Kerry, Ireland	Jul. 1978	<i>Platylepas coriacea</i>	O'Riordan, 1979
Leatherback (T1983/08)	Quilty, Clare, Ireland	Jul. 1983	<i>Conchoderma virgatum</i>	O'Connor & Bowmer, 1985
Unidentified (T1992/56)	Cork, Ireland	1992	Barnacles on carapace & head	
Leatherback (T1993/17)	Lleyn Peninsula, Gwynedd, Wales	Jul. 1993	<i>Chelonibia testudinaria</i>	Rees & Walker, 1993
Leatherback (T1997/03)	St. Anthony Lighthouse, Cornwall, England	Jun. 1997	Back covered in barnacles	TURTLE Database
Loggerhead (T2006/39)	Pembray, Carmarthenshire, Wales	Dec. 2006	<i>Lepas anatifera</i>	Penrose & Gander, 2007
Unidentified (T2008/57)	Wexford, Ireland	Jul. 2008	Barnacles on carapace	TURTLE Database
Loggerhead (T2015/27)	Irvine, North Ayrshire, Scotland	Dec. 2015	<i>Lepas anatifera</i>	Brownlow <i>et al.</i> , 2016; Penrose & Gander, 2016
Loggerhead (T2016/01)	Gwithian Beach, Hayle, Cornwall, England	Jan. 2016	<i>Lepas hillii</i>	Penrose & Gander, 2017
Leatherback (T2016/02)	St. Cyrus, Aberdeenshire, Scotland	Jan. 2016	<i>Stomatolepas dermochelys</i>	Brownlow <i>et al.</i> , 2017; Penrose & Gander, 2017
Leatherback (T2018/04)	Marazion, Cornwall, England	Aug. 2018	<i>Stomatolepas dermochelys</i>	David Fenwick

Table 2. Barnacles reported on marine turtles in the waters around the U.K. and Ireland. TURTLE database numbers are in parenthesis.

Taxonomic confusion in the genus *Stomatolepas*

Among the turtle barnacles, the genus *Stomatolepas* is characterised by bowl- or boat-shaped shells with elaborate sutural ornamentation which helps secure the barnacle within its host's tissue (Epibiont Research Cooperative, 2007; Zardus, 2021). There has been considerable uncertainty regarding the taxonomy within the genus. Five species are listed in the ERC synopsis (2007) but Zardus & Balazs (2007) noted there is confusion with the nomenclature. This was investigated, in part, in a morphological study by Frick *et al.* (2010a) who stated that *Stomatolepas elegans* (Costa, 1838) should be regarded as a valid species and designated a neotype specimen to justify this view. They stated that *S. dermochelys*, erected by Monroe & Limpus (1979), was unnecessary and should be considered as a junior synonym of *S. elegans*. They redescribed *S. praegustator*, a species which surprisingly is often found living within the mouth of leatherbacks or loggerheads. This was the type of the genus *Stomatolepas* Pilsbry 2010 which can be loosely translated as "mouth barnacle" with *praegustator* meaning "before eating". This species was considered commensal by Pilsbry (1910) presuming that it shared some of its host's food, but since then has also been found living externally on the neck of leatherbacks or softer parts of the plastron of loggerheads (Frick *et al.*, 2010a). A new species, *S. pilsbryi*, was also described by Frick *et al.* (2010a) from the skin of leatherbacks off Gabon, Africa. Hence their *S. elegans* is known from leatherbacks, loggerheads, green turtles, and olive ridleys and it appears that *S. elegans* may occur in sympatry on the same leatherback turtle along with *S. praegustator* or with *S. pilsbryi* with all three species known from Atlantic waters.

Two additional *Stomatolepas* species, *S. transversa* and *S. pulchra*, have been described from turtles in Pacific waters (Nilsson-Cantell, 1930; Ren, 1980). *S. transversa* is now also known from the south Atlantic (Young, 1991) and has a characteristic boat-shaped shell (Hayashi, 2012). *S. pulchra* has a similar narrow elliptical shaped shell and Hayashi (2013) argued that *S. pulchra*, should be considered as a junior synonym of *S. transversa*.

The confusion regarding the synonymy of *S. elegans* and *S. dermochelys* persisted in Hayashi (2012), who considered further phylogenetic work is required and, despite a stern rejoinder by Frick (2013), a distinction between *S. elegans* and *S. dermochelys*, mostly based on host preference, continued in Hayashi's checklist of barnacles from turtles and whales (2013). However, a study of epibionts from turtles on the Pacific coast of Mexico by Lazo-Wasem *et al.* (2011) showed a morphological range in *Stomatolepas* specimens which seemed to encompass both *S. elegans* and *S. praegustator*. Subsequently Frick (2013) also hinted that *S. praegustator* could possibly be a junior synonym of *S. elegans* and a genetic analysis by Pinou *et al.* (2013) supported this hypothesis and also suggested that species level complexity for *S. elegans* may be greater than currently recognised. However,

S. praegustator has not yet been formally synonymised with *S. elegans*, nor has the proposed synonymy of *S. elegans* and *S. dermochelys* been confirmed genetically, thus it is evident that further work is required to elucidate the taxonomy of the *S. elegans* species complex. In the meantime, this paper has followed Monroe & Limpus (1979), and aligned with Hayashi (2013), in anticipation that future genetic studies will eventually resolve the confusion within the genus *Stomatolepas* outlined here.

Although up to five *Stomatolepas* species (*S. elegans*, *S. dermochelys*, *S. praegustator*, *S. transversa*, and *S. pilsbryi*) can potentially be regarded as valid, *S. pulchra* still mistakenly appears as an accepted species on the World Register of Marine Species (WoRMS, <https://www.marinespecies.org/>). The WoRMS website also incorrectly synonymises *S. praegustator* with *S. elegans* based on an unjustified supposition of Foster (1978). To add to this confusion, the WoRMS website erroneously includes "*Stomatolepas muricata*" as a member of the genus *Stomatolepas* when this species has always been in a different genus by itself, as *Stephanolepas muricata* Fischer, 1886, which is also listed separately on the WoRMS website.

Other barnacles that might occur on turtles in British or Irish waters

Any turtles migrating, or wandering, around the North Atlantic or from the Mediterranean could potentially carry barnacle hitch-hikers to British or Irish seas. It is evident that three lepadomorph goose barnacle species (*L. anatifera*, *L. hillii* and *C. virgatum*) and four balanomorph turtle barnacle species (*Chelonibia caretta*, *C. testudinaria*, *Stomatolepas dermochelys* and *Platylepas coriacea*) are now known to have occurred on turtles within the waters of the U.K. or Ireland. It is feasible that other lepadomorphs, such as *L. anserifera* and *L. pectinata*, already known from flotsam in British waters, and from turtles in the Mediterranean Sea, may eventually be found on turtles in British Seas. The rabbit-eared goose barnacle, *Conchoderma auritum*, is known in British, or Irish, waters from ships' hulls (MBA, 1957; Evans, 2000; Anon., 2015; King, 2015) and from whales (O'Connor & Fariñas Franco, 2003) but elsewhere it has also occasionally been recorded from turtles (Monroe & Limpus, 1979; Frick, 2015; Majewska *et al.*, 2015).

Other species of balanomorph barnacles are also likely to occur on turtles entering British waters. Leatherbacks, which are the most regular turtle visitors, are known as vectors for *C. testudinaria*, *S. dermochelys* and *P. coriacea*, and these barnacles may be viewed as genuine members of the British barnacle fauna, albeit as summer migrants. However, other barnacle species on leatherbacks may have been overlooked as small barnacles on such big turtles, with mottled colouration, can easily be missed, even on stranded specimens. *Stomatolepas praegustator* which usually inhabits the mouth or gullet of leatherbacks, and other turtles, may also occur but would require

careful examination to find specimens (Pilsbry, 1910; Frick *et al.*, 2010a). The “*S. elegans*” found on the fins and shoulder of the leatherback in the Netherlands by Holthuis (1969) was regarded as referable to *S. praegustator* by Monroe & Limpus (1979) although, as discussed above, the status of this species warrants further study. The mouth of the St. Cyrus leatherback discussed here was examined. It showed the unusual recurved fleshy spines which hold its slippery prey but no barnacles were observed (Fig. 12). *Stomatolepas pilsbryi*, known to date only from leatherbacks off Gabon, may also have been overlooked and could perhaps reach British waters (Frick *et al.*, 2010a). Leatherbacks from Nova Scotia, eastern Canada, which could easily travel onwards to British waters, have been found to host *L. anatifera*, *C. auritum*, *C. virgatum*, *S. dermochelys* and *P. coriacea* (Frick, 2015).

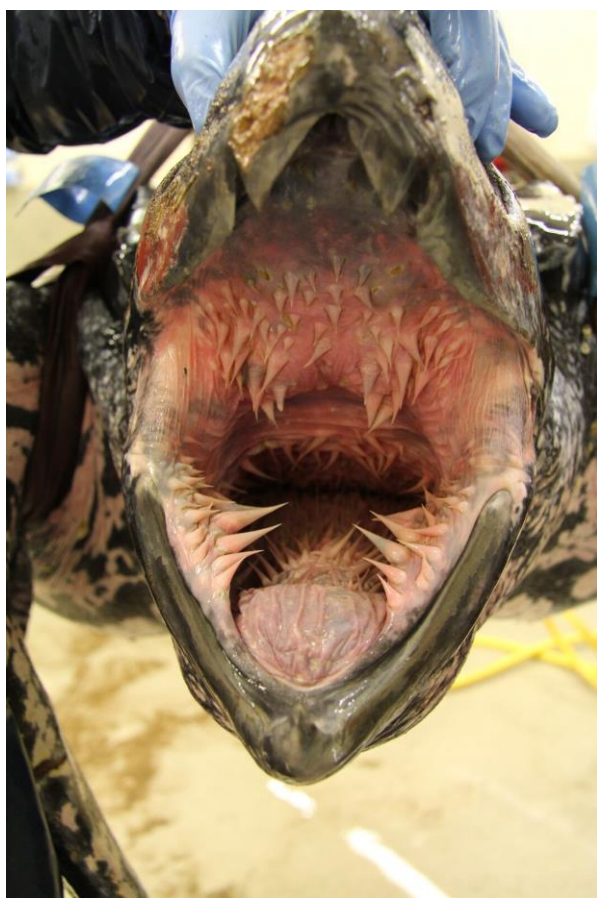


Fig. 12. Mouth of leatherback turtle (*Dermochelys coriacea*) from St. Cyrus, Scotland, January 2016, showing recurved fleshy spines. (Photo: SMASS)

Turtles and their epibionts from the Mediterranean Sea are relatively well studied (Fuller *et al.*, 2010; Domenèch *et al.*, 2015; Casale *et al.*, 2018; Ten *et al.*, 2019) and their barnacle fauna may indicate species likely to arrive on British shores as vagrants. Seven balanomorph barnacles are cited by Hayashi (2013) as occurring on turtles from the Mediterranean. Some of these have yet to be found from British or Irish waters: *Chelonibia patula* was recorded from loggerheads in Greece (Kitsos *et al.*, 2003, 2005), and is also found on

crabs and bivalves in the Mediterranean (Bakir *et al.*, 2010; Beşir & Çınar, 2012). However, Cheang *et al.* (2013) have since shown that *C. testudinaria* and *C. patula* are conspecific. Both *Platylepas hexastylus* and *P. coriacea* were recorded from loggerheads in Malta (Gramentz, 1988), though the latter is likely to be a misidentification. *P. hexastylus* has also been found on Aegean loggerheads (Kitsos *et al.*, 2005), and has already reached the Netherlands on a loggerhead (Holthuis, 1952). There is a single old record of *P. decorata* from Corsica from an unknown turtle host (Gray, 1825), this barnacle being known elsewhere from loggerhead, green, and Kemp’s ridley turtles. Small species, such as *Stephanolepas muricata*, which penetrate deep into the skin of turtles, could easily be overlooked (Frick *et al.*, 2011). This species, originally described from Vietnam (Fischer, 1886), was cited as occurring only from Pacific waters and from Florida by Hayashi (2013). In fact it was discovered in the western Mediterranean in 2007, infesting loggerheads (Badillo-Amador, 2007), and since then has also been found on loggerheads in the central Mediterranean (Casale *et al.*, 2012; Karaa *et al.*, 2012).

It is feasible that other balanomorph turtle barnacles from the western North Atlantic may, on rare occasions, appear in British waters. These could include *Cylindrolepas darwiniana* known from loggerheads and hawksbills (Frick & Zardus, 2010) or *Calyptolepas bjordalae* from loggerheads and green turtles (Frick *et al.*, 2010b). Surprisingly this latter genus and species does not appear on the WoRMS website. *Chelonibia manati* is also known from loggerheads, green turtles, and also manatees in the western North Atlantic (Pilsbry, 1916; Wells, 1966) but recent genetic studies (Zardus *et al.*, 2014) have shown *C. manati* and *C. patula* to be host morphotypes which should both be synonymised with *C. testudinaria*.

A further 19 species of non-coronuloid acorn barnacles are cited in the Epibiont Research Cooperative synopsis (2007) as very occasionally occurring on turtles and an additional non-obligate species has since been found on Japanese loggerheads (Hayashi, 2016). Of these non-obligate turtle barnacles, five (*Amphibalanus amphitrite*, *A. eburneus*, *Balanus trigonus*, *Perforatus perforatus* and *Pachylasma giganteum*) have been found on Mediterranean loggerheads (Karaa *et al.*, 2012). Both *A. amphitrite* and *P. perforatus* already occur on shores of southern England (Southward, 2008). The only non-chelonophilic barnacles found from a turtle close to British waters were small specimens of the Australian barnacle *Austrominius modestus*, found on a green turtle washed ashore in the Netherlands in 1952 (Brongersma, 1972). However, this introduced barnacle species was already widespread on the shores of the English Channel at that time and is likely to have infected the turtle on its arrival there. Although these exotic barnacles are more likely to arrive on flotsam or ships’ hulls, some could potentially appear on turtles arriving in British waters. Even gulls (with plastic leg

rings) have now been shown to act as occasional vectors for non-indigenous barnacles to European waters (Tøttrup *et al.*, 2010).

Effects of barnacles on turtles and removal strategies

The epibiont communities on sea turtles are discussed at length by Casale *et al.* (2012), Frick & Pfaller (2013) and Robinson & Pfaller (2022). These communities can include a variety of different organisms and may change their composition with the long-distance migrations of their turtle hosts. Healthy turtles indulge in cleaning associations or self-grooming activities to control epibionts. However, *Lepas* goose barnacles, in particular, are known to grow quite rapidly (Evans, 1958; MacIntyre, 1966; Eckert & Eckert, 1987; Mesaglio *et al.*, 2021). They typically reach up to 15 cm stalk length with a capitulum of 3-4 cm but in extreme examples may achieve a stalk up to 80 cm in length and a capitulum of 7 cm in length (De Wolf, 2008; Jensen, 2010). Hence, heavy infestation by goose barnacles can seriously affect the turtle's ability to swim and forage (Casale *et al.*, 2012), as is highlighted by the examples herein.

Among the coronuloid turtle barnacles, different modes of attachment – cementing, clinging, embedding, boring – result in characteristic modified shell morphologies which make these turtle specialists increasingly difficult for their hosts to remove. The embedded *S. dermochelys* highlighted here are unlikely to be dislodged by grooming activities. However, the embedded chelonophilic barnacles are usually less problematic to the turtles although some of the boring species can cause harm to their hosts. Dense aggregations of acorn barnacles may accumulate on sick or moribund turtles to their detriment (Casale *et al.*, 2012; Zardus, 2021). Such turtles, colloquially known as “Barnacle Bills”, are generally considered to be suffering from debilitated turtle syndrome (Norton *et al.*, 2008; Sloan *et al.* 2014).

Turtles can minimise the settlement of epifauna by sloughing skin (Frick *et al.*, 2011; Frick, 2015) or attending grooming stations where cleaning fish remove epibionts (Sazima *et al.*, 2010). Columbus crabs which often live on turtles may help to remove settling larvae (Davenport, 1994). Groupers have also been observed removing goose barnacles and preying on accompanying pilot fish (Hackradt *et al.*, 2013). Turtles can also remove some barnacles by rubbing on rocks on the sea-bed or in rock crevices (Heithaus *et al.*, 2002; Frick & McFall, 2007). Turtles do eat epibionts, including goose barnacles from floating objects (Brongersma, 1972; van Nierop & den Hartog, 1984), and recent studies with turtle-cams attached to loggerheads in Cape Verde Islands have shown they may graze epibionts from fellow turtles (BBC, 2021).

OTHER EXOTIC FAUNA ACCOMPANYING TURTLES

It is worth noting that migrating leatherbacks bring more than just barnacles to British waters. They are

sometimes accompanied by pilot fish (*Naucrates ductor*) or remora fish (*Echeneis naucrates*). Several records were cited by Brongersma (1972) of both of these fish with leatherbacks in French waters, one record of pilot fish with a leatherback from Dorset and two records of pilot fish with leatherbacks from Norway. Since then pilot fish have been reported from leatherbacks entangled off Wester Skeld, Shetland, in 1973, and off Skerry, Sutherland, in 1989 (Langton, 1996). In Irish waters there have been at least 30 records of pilot fish with leatherbacks, with up to 80 fish accompanying one turtle, and ten records of remoras with leatherbacks (King & Berrow, 2009). The “most northerly” leatherback (cited above) with *S. dermochelys* barnacles and captured above the Arctic circle at Finnmark, Norway, in 1997, also had accompanying pilot fish (Carriol & Vader, 2002).

Columbus crabs (*Planes minutus*) are also known as hitchhikers on marine turtles, especially loggerheads (Davenport, 1994; Dellinger *et al.*, 1997), and have been recovered from a loggerhead stranded in Ireland (Doyle *et al.*, 2013). Two other unusual crustaceans, the copepod *Balaenophilus manatorum*, and the amphipod *Podocerus chelonophilus*, are listed as obligate epibionts of loggerheads in the Mediterranean (Domenèch *et al.*, 2015) and could be found on these turtles in British or Irish waters. Similarly, the turtle leech, *Ozobranchus margo*, is also known from Mediterranean loggerheads (Insacco *et al.*, 2001; Badillo-Amador, 2007; Domenèch *et al.*, 2015) and could be found on turtles that arrive in Scottish waters. This unusual ecto-parasitic leech is 10-15 mm in length with five pairs of external arborescent gills and dozens may attach to turtles, especially around the cloacal region (Davies, 1978; Karaa *et al.*, 2019).

CONCLUDING REMARKS

Although marine turtles such as the leatherback are now known to be regular migrants to British waters, few people get to see them and sightings, strandings or entanglements of these leviathan beasts can be a newsworthy event (BBC, 2014; Barbour, 2014). Associated turtle barnacles are rarely recorded in British waters but their occurrence presents an insight into the fascinating stories behind the evolution and ecology of these enigmatic creatures. Further examination of turtles entering British waters should help shed light on turtle epibionts and perhaps reveal species new to British seas. For the marine taxonomist a rare barnacle brought to British shores on a turtle riding a trans-oceanic current generates a similar level of excitement as a rare bird arriving with unusual trans-oceanic winds.

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