

Ascension Island as a mid-Atlantic developmental habitat for juvenile hawksbill turtles

SAM B. WEBER^{1,2*}, NICOLA WEBER^{1,2*}, BRENDAN J. GODLEY², TARA PELEMBE³, STEDSON STROUD¹, NATASHA WILLIAMS¹ AND ANNETTE C. BRODERICK²

¹Ascension Island Government Conservation Department, Georgetown, Ascension Island, ASCN 1ZZ, British Overseas Territory,

²Centre for Ecology and Conservation, College of Life & Environmental Sciences, University of Exeter, Cornwall Campus, Penryn TR10 9FE, UK, ³Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 1JY, UK

*These authors made equal contributions to the manuscript.

Ascension Island in the South Atlantic Ocean is renowned for its globally-important nesting population of green turtles (Chelonia mydas) that has been the subject of long-term research. By comparison, very little is known about the apparently small population of hawksbill turtles (Eretmochelys imbricata) that have been recorded in its waters, thousands of kilometres from known nesting beaches. Here, we collate 10 years of in-water tagging data, opportunistic public sighting records and underwater observations to provide a baseline for future research, and present preliminary data on habitat use derived from two individuals fitted with GPS transmitters. Although public sightings were inevitably biased towards popular recreation areas, the resulting distribution suggests that hawksbill turtles occur year round in Ascension Island's waters along the entire 65 km of coastline. Hawksbills were observed feeding on benthic algae and encrusting sponges, and were frequently seen scavenging on fish discards around the Island's pier at night aided by anthropogenic lighting. Between 2003 and 2013, 35 turtles were captured, measured, tagged and then released. Curved carapace lengths ranged from 33.5 to 85 cm (mean = 48.8 cm) indicating that most (if not all) individuals encountered around Ascension are post-pelagic juveniles. Four individuals were recaptured at least once giving a mean minimum residence time of 4.2 yr (range: 2.8–7.3 yr) and a mean growth rate of 2.8 cm yr⁻¹. Turtles fitted with Fastloc™ GPS devices remained at Ascension Island for the duration of the study (>90 days) and occupied restricted home ranges with an average area of 2.5 km² and an average 'core use area' (50% utilization distribution) of 0.05 km². Together, these results suggest that Ascension Island serves as a mid-Atlantic developmental habitat for benthic-feeding, juvenile hawksbill turtles on extended oceanic migrations before recruiting to their adult foraging grounds, likely to be located in Brazil or tropical West Africa.

Keywords: marine turtle, life history, home range, growth rate, South Atlantic

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INTRODUCTION

Marine turtles have complex life histories characterized by long developmental migrations and multiple ontogenetic shifts in diet and habitat use (Musick & Limpus, 1997; Bolten, 2003). Knowledge about the adult life stage is reasonably well-advanced for most species. However, many details of the years spent as juveniles are only recently emerging (e.g. Meylan *et al.*, 2011; Witherington *et al.*, 2012; Putman & Naro-Maciel, 2013; Mansfield *et al.*, 2014). After hatching on tropical and sub-tropical sand beaches, neonates embark on an oceanic dispersal phase that has often been referred to as 'the lost years' due to infrequent sightings (Carr, 1980). This is the least understood life stage, but it appears that post-hatchlings are epipelagic and obtain food and shelter by associating with floating mats of vegetation or other debris

entrained in ocean currents (Witherington *et al.*, 2012; Mansfield *et al.*, 2014). Movements during this time are largely determined by ocean circulation patterns, but young turtles may actively position themselves to ensure transport into favourable areas (Mansfield *et al.*, 2014; Putman *et al.*, 2014).

Once they have attained sufficient size and can effectively regulate their buoyancy, most juvenile green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) turtles leave the oceanic zone and recruit to neritic feeding habitats where they assume a species-specific benthic diet (Bolten, 2003). Although adults and post-pelagic juveniles sometimes occupy the same foraging areas, in many cases the transition to a neritic lifestyle appears to be a multistage process, with individuals passing through one or more intermediate habitats that are geographically distinct from both pelagic nursery and adult foraging habitats (Musick & Limpus, 1997; Meylan *et al.*, 2011). The term 'developmental habitat' has been used to describe these staging areas, which are characterized by a predominance of benthic-feeding

Corresponding author:

S.B. Weber

Email: sam.weber@ascension.gov.ac

juveniles originating from multiple nesting stocks and exhibiting a degree of residency and site fidelity (Meylan *et al.*, 2011). Developmental habitats have been described for at least four species of marine turtle in the Atlantic and Indo-Pacific and may constitute a normal part of the life cycle of most chelonid sea turtles (Meylan *et al.*, 2011).

In this study, we report on a previously uncharacterized developmental habitat for hawksbill turtles in the central Atlantic Ocean. The hawksbill turtle has a circumglobal distribution in tropical waters of the Atlantic, Indian and Pacific Oceans but has undergone dramatic reductions in population size across its range due to overharvesting for meat, shells and eggs (Mortimer & Donnelly, 2008). In the Atlantic, significant nesting populations (>1000 nests yr^{-1}) now only occur in the Caribbean (Mexico, Barbados, the Bahamas and Cuba) and Brazil (Mortimer & Donnelly, 2008). Particle drift models and genetic studies suggest that neonates and juveniles originating from these western Atlantic rookeries frequently undertake extensive trans-Atlantic migrations before being transported back to neritic feeding grounds in the Americas (Proietti *et al.*, 2014; Putman *et al.*, 2014). Numerous juvenile-dominated developmental habitats for hawksbill turtles have now been described in the Caribbean and their ecology has been well studied (Diez & van Dam, 2002; Blumenthal *et al.*, 2009a; Meylan *et al.*, 2011; Scales *et al.*, 2011; Berube *et al.*, 2012; Hart *et al.*, 2012, 2013; Wood *et al.*, 2013). By comparison, relatively little is known about immature stages elsewhere in the Atlantic. Although several hawksbill developmental habitats have been identified in Brazil and tropical West Africa, most studies have focused on determining the natal origins of these feeding aggregations rather than on establishing ecological profiles (Monzón-Argüello *et al.*, 2010, 2011; Vilaça *et al.*, 2013; Proietti *et al.*, 2014; Putman *et al.*, 2014; but see Proietti *et al.*, 2012).

Lying close to the Mid-Atlantic Ridge, the tiny British Overseas Territory of Ascension Island is renowned for its globally-important nesting population of green turtles that migrate more than 2000 km from feeding grounds along the Brazilian coastal shelf (Broderick *et al.*, 2006; Figure 1). However, the Island also supports a small population of juvenile hawksbill turtles about which very little is known. Recent work suggests that 85% of hawksbills observed in Ascension

Island's waters originate from nesting populations in north-eastern Brazil, with the remainder linked to smaller rookeries in West Africa (e.g. São Tomé and Príncipe) and potentially even the Indian Ocean (Putman *et al.*, 2014). With the exception of this study, however, published information relating to hawksbills at Ascension Island amounts to a handful of brief anecdotes, with no detailed accounts of their ecology (Ashmole & Ashmole, 2000). Here, we summarize available information on the spatio-temporal distribution, residence times, growth rates and diets of hawksbill turtles at Ascension Island obtained through 10 years of public sightings records, opportunistic in-water tagging and diver observations. In addition, we present preliminary assessments of habitat use and home range size derived from two animals fitted with FastLoc™ GPS tags. It is hoped that these data serve as a baseline for future studies on this little known hawksbill turtle feeding aggregation.

MATERIALS AND METHODS

Public sighting records

Public sightings schemes are increasingly being used to rapidly gather large volumes of data on the spatial and temporal distribution of wildlife (e.g. Witt *et al.*, 2012). Although such approaches are frequently limited by a lack of correction for survey effort, by drawing on a large body of volunteer observers they allow species distributions to be mapped more efficiently than would be feasible for professional scientists alone. This type of participatory 'citizen science' can also be an effective means of building public engagement in biodiversity research and conservation (Silvertown, 2009). In 2003, the Ascension Island Government Conservation Department (AIGCD) launched a scheme whereby divers, hikers and other members of the public were encouraged to report sightings of hawksbill turtles made around the Island. Reporting was managed through a standard form that was made available at the Department's visitor centre, along with annotated photographs offering guidance on how to distinguish between the two species of marine turtles found in Ascension Island's coastal waters (green and hawksbill). Since juvenile green turtles are rare visitors to Ascension Island's waters (with only a single verified report), we are confident that the majority of observers were able to distinguish between the two species based on size alone. Indeed, correct identifications were confirmed in photographs submitted by regular divers and snorkellers from whom the majority of sightings originated. Observers were asked to record a range of basic information relating to their sighting including the date, location, depth (for divers) and the number of turtles seen. Locations could be reported as a GPS coordinate, marked on a map or given as a geographical description which was then assigned the nearest coordinate from a standard gazetteer. To minimize duplication, sightings reported from the same date and location were treated as a single record.

Tag and release

In parallel with the public sightings scheme, a number of recreational divers also participated in an in-water tagging programme aimed at gathering information on hawksbill turtle

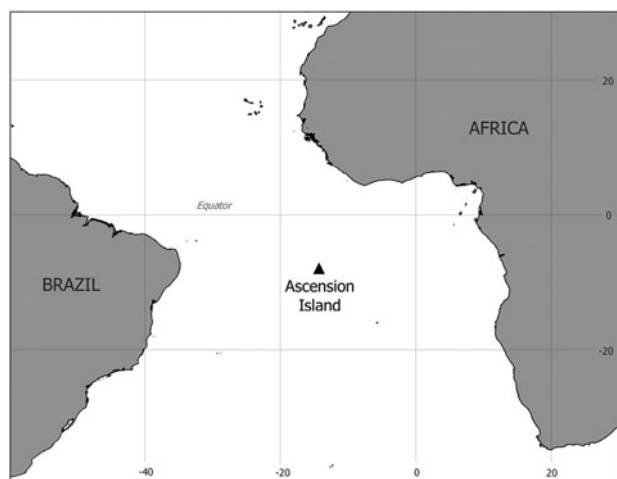


Fig. 1. Geographical location of Ascension Island.

residence times and growth rates. Turtles were captured opportunistically by divers using SCUBA equipment and brought to the shore where they were transferred to AIGCD staff. Once ashore, curved carapace length (CCL) and curved carapace width (CCW) of each turtle were measured to the nearest 0.5 cm using a flexible tape. We defined CCL as the distance between the anterior point of the nuchal scute and the posterior tip of the supracaudals measured along the midline (i.e. notch-to-tip), and CCW as width at the widest point. Turtles were checked for existing tags and, where absent, were fitted with an Inconel metal flipper tag on the trailing edge of each fore flipper and a unique Passive Integrated Transponder (PIT Tag) implanted subcutaneously into the dorsal surface of the neck. Tissue biopsies were also taken for a population genetic study that is reported elsewhere (Putman *et al.*, 2014). Turtles were then released as close as possible to the original capture location. For those turtles that were captured more than once, we calculated displacement as the minimum straight line coastal distance (i.e. avoiding land) between first and last capture locations using QGIS v.2.0.1. We calculated annual growth rate as the CCL size increment (in cm) divided by the number of days since first capture, multiplied by 365.

Satellite telemetry and home range analysis

To supplement the in-water tagging programme, in September 2013 two juvenile hawksbill turtles were also fitted with Wildlife Computers SPLASH₁₀ Argos-linked GPS tags allowing their movements and habitat use to be examined in greater detail. Turtles were captured by volunteer divers and taken to the shore where FastlocTM GPS tags were affixed to the carapace using Power-FastTM marine epoxy. Attachment sites were cleared of epibionts (algae and barnacles), lightly sanded and degreased with acetone prior to tag application. Although efforts were made to return tagged turtles to the exact point of capture, an inaccurate position given by divers resulted in one turtle being released approximately 4 km from its capture location. Following its release, this turtle embarked upon a period of coastal travel lasting approximately seven days before occupying a new territory where it remained until tag transmissions ceased 80 days later. Positions recorded during the period of directional travel were therefore excluded from subsequent home range analyses. GPS data were collated and downloaded using SEATURTLE.ORG's Satellite Tracking and Analysis Tool (Coyne & Godley, 2005) and decoded using Wildlife Computers' proprietary DAP Processor software. Argos positions were not used for home range analysis as the spatial resolution has been shown to be inadequate for inferring fine-scale movements of sea turtles (Weber *et al.*, 2013).

In order to minimize spatial autocorrelation in home range analyses we calculated mean daily locations for each turtle using the Vector Analysis Tools in QGIS v.2.0.1 (Hart *et al.*, 2012). Home ranges were then estimated from daily mean coordinates using minimum convex polygon (MCP) and fixed kernel density (FKD) estimators implemented in the adehabitatHR package for R v.2.15.3 (Calenge, 2006). The MCP method calculates the smallest polygon enclosing the recorded positions of an animal (Burt, 1943). This approach has been used extensively for marine turtle home range analysis (e.g. Van Dam & Diez, 1998; Seminoff *et al.*, 2002; Scales *et al.*, 2011; Berube *et al.*, 2012), but is limited

by its inability to reveal fine-scale patterns of habitat use within an area of residence. In contrast, the FKD estimator is a probabilistic, non-parametric method which calculates the smallest area in which an animal has a given probability of being located, and can therefore be used to identify areas with different intensities of activity (Worton, 1989; Seminoff *et al.*, 2002; Hart *et al.*, 2012). To facilitate comparisons with previous studies we report the total area used by each animal (i.e. 'residence areas') as the 100% MCP and define 'core use areas' within these as the 50% UD from FKD analysis (Seminoff *et al.*, 2002; Scales *et al.*, 2011; Hart *et al.*, 2012; Carrión-Cortez *et al.*, 2013). We used the least-squares cross-validation (LSCV) method to select the most appropriate smoothing parameter (h) for the FKD analysis (Worton, 1989), and set the coastline as a physical barrier that animals were unable cross in order to correct for potential boundary biases in the estimation process (Benhamou & Cornelis, 2010). To facilitate comparisons with previous studies we fit models with and without the boundary constraint. Mean water depths within residence areas and core use areas were extracted from a bathymetric raster layer generated by B-spline interpolation of point depths digitized from Admiralty charts using SAGA GIS v.2.0.8.

RESULTS

Between 2003 and 2013 a total of 221 hawksbill turtle sightings were reported to AIGCD by members of the public. Although these reports were inevitably biased towards popular diving, swimming and hiking areas, particularly in the north and north-west of the Island, sightings data suggest an island-wide distribution in inshore waters (Figure 2A). Sightings occurred in all months and, with the exception of a peak in February, were broadly consistent throughout the year (Figure 2B). This peak coincided with visits of a particularly active pair of volunteers and is almost certainly an artefact (see Figure 2B). In cases where bathymetry was reported by divers ($N = 45$), average water depth at which sightings occurred was 13.8 m with a maximum depth of 34 m. Several divers also recorded feeding behaviour. One observer reported seeing a hawksbill grazing on 'weed' growing on a rocky reef, and there were multiple reports of turtles feeding on a locally-abundant encrusting sponge that is thought to be a *Ulosa* species (Dr C. Goodwin, National Museums Northern Ireland, personal communication). Casual observations of turtles feeding over complex bottom types can be misleading. However, these anecdotal reports are broadly consistent with the expected foraging ecology of neritic hawksbills (Meylan, 1988). More unusually, groups of 2–6 juvenile hawksbills were also frequently observed foraging at night around the Island's pier aided by waterfront spotlighting. Night dives carried out in this area confirmed that turtles were scavenging the carcasses of large pelagic fish (predominantly tuna species) discarded by fishermen.

In addition to public sightings, a total of 35 hawksbill turtles were captured and tagged between 2003 and 2013. The notch-to-tip curved carapace lengths of captured turtles ranged from 33.5 to 85 cm, with an average of 48.8 ± 2.0 cm (Figure 3). Four tagged turtles were subsequently recaptured at least once and one was recaptured on three occasions. The average time between tagging and final recapture was 1536 ± 382 days during which turtles grew at an

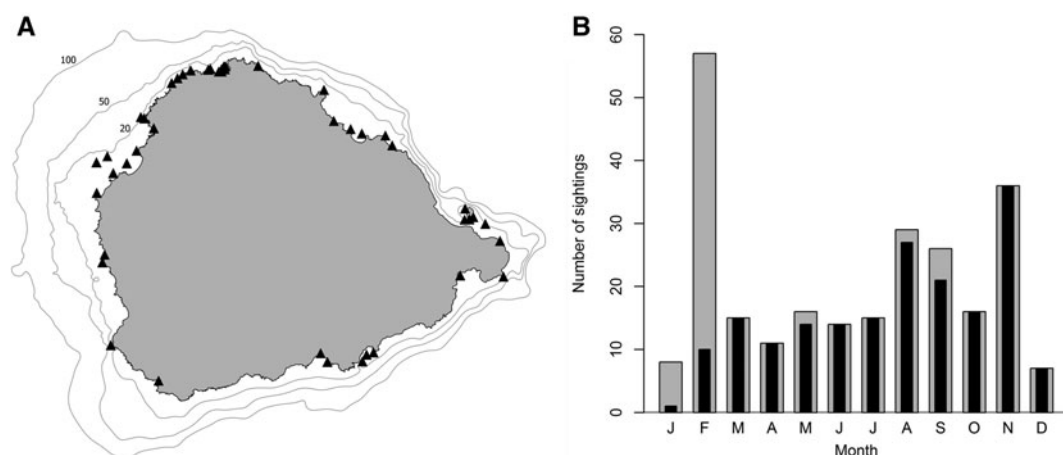


Fig. 2. Spatio-temporal distribution of hawksbill turtle sightings at Ascension Island between 2003 and 2013: (A) shows the geographical locations of public sightings reported to the Ascension Island Government Conservation Department (isobaths in metres); (B) shows sightings pooled by month. Grey bars were drawn using the entire dataset while black bars exclude sightings reported by one particularly active pair of volunteers.

average rate of 2.84 cm yr^{-1} CCL (Table 1). Despite long residence times, individuals were generally recaptured close to the site where they were first encountered, with an average displacement of $940 \pm 372 \text{ m}$ (Table 1). Data from turtles fitted with Fastloc GPS devices also indicated extended residence times and a high level of site fidelity (Figure 4). GPS-tagged individuals were deliberately selected to be at the upper range of sizes found at Ascension Island in the hope of capturing their onward migrations (CCLs of 56.5 and 71 cm). However, both turtles remained in Ascension's waters for the duration of the study (>90 days) during which time they occupied restricted home ranges (100% minimum convex polygons) with an average area of 2.55 km^2 (Figure 4). Core use areas (50% utilization distributions) of both turtles were less than 10 hectares (Figure 4). Fixing the coastline as a physical barrier in FGD analyses had no effect on the estimated core use area for turtle A, but marginally reduced the estimated area for turtle B from 0.6 hectares to 0.5 hectares. Mean water depth within residence areas was $13.5 \pm 0.21 \text{ m}$ (range = 0–45 m) and $3.3 \pm 0.13 \text{ m}$ (range = 0–13.7 m) for turtles A and B,

respectively (Figure 4), and within core use areas was $8.8 \pm 0.26 \text{ m}$ (range = 3.8–19.6 m) and $3.2 \pm 0.14 \text{ m}$ (range = 2–4.8 m).

DISCUSSION

There is growing evidence to suggest that a separate, immature-dominated, neritic developmental stage is a normal part of the life cycle of most chelonid sea turtles (see Meylan *et al.*, 2011 for a recent review). Developmental habitats occupied during this time can be characterized by: (1) the exclusive or near-exclusive presence of post-pelagic, benthic-feeding juvenile animals; (2) a non-transient population exhibiting a high degree of site fidelity; and (3) a mixed-stock composition comprising individuals from multiple nesting grounds (Meylan *et al.*, 2011). Although somewhat limited at present, the available behavioural, morphological and population genetic data for the hawksbill turtle feeding aggregation at Ascension Island are consistent with this definition (this study; Putman *et al.*, 2014).

Hawksbill turtles recruit to Ascension Island's coastal waters at a minimum curved carapace length of approximately 33 cm and there are few individuals larger than 80 cm (Figure 3). Given that the minimum reported size of adult

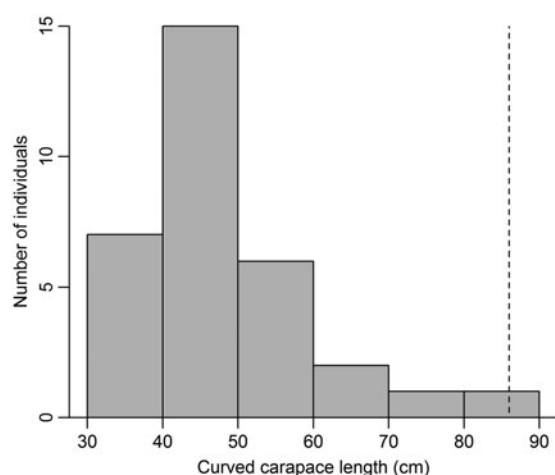


Fig. 3. Size-class distribution of hawksbill turtles captured at Ascension Island between 2003 and 2013. For comparison, the broken line shows the minimum size of adult females nesting at the South Atlantic's largest hawksbill turtle rookery in northern Bahia, Brazil (Marcovaldi *et al.*, 1999).

Table 1. Summary of capture data, biometrics and growth rates for four juvenile hawksbill turtles recaptured at least once during the study.

ID	Capture date	CCL (cm)	Time at large (days)	Growth rate (cm yr^{-1})*	Displacement (m)*
1	22/09/2003	39	–	–	–
	25/07/2006	45	1037	2.11	196
2	07/02/2004	54	–	–	–
	12/06/2004	56.5	126	7.24	0
	24/10/2004	59	260	7.02	325
	10/06/2007	69	1219	4.49	920
3	07/03/2004	48	–	–	–
	03/07/2007	52	1213	1.20	686
4	28/11/2004	38	–	–	–
	26/03/2012	64	2675	3.55	1960

* , since first encounter.

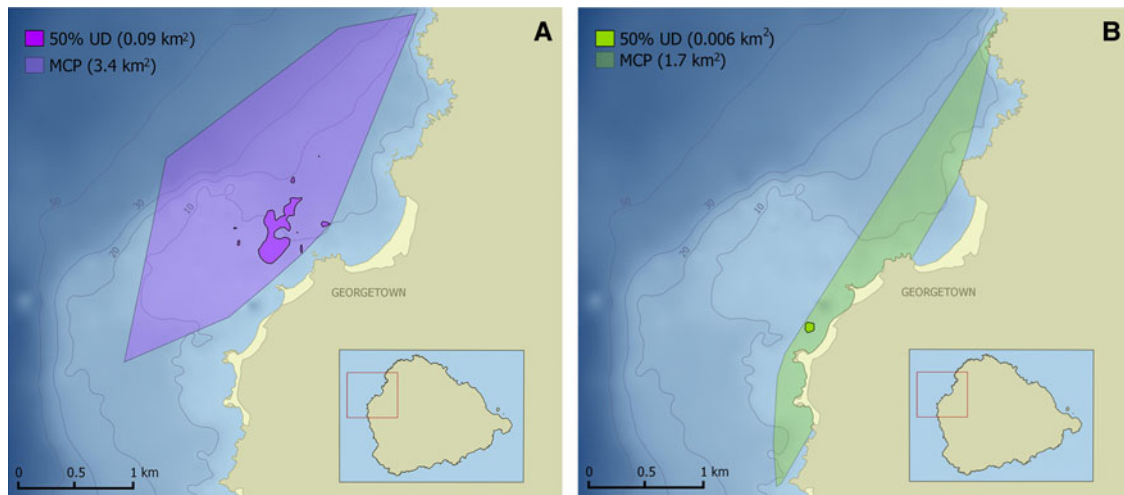


Fig. 4. Habitat use of two juvenile hawksbill turtles fitted with FastLoc™ GPS transmitters. Home ranges are displayed as 100% minimum convex polygons (MCPs) and 'core use areas' are defined as 50% utilization distributions (UDs) from fixed kernel density analysis (i.e. the smallest areas in which turtles have a 50% probability of being located). Curved carapace lengths of turtles A and B were 71 and 56.5 cm, respectively, and tracking durations were 196 days and 90 days.

females nesting at the largest regional rookery in Bahia, Brazil is 86 cm (Marcovaldi *et al.*, 1999), it is likely that most individuals foraging around Ascension Island are juveniles (although smaller maturation sizes have been reported elsewhere, e.g. Moncada *et al.*, 1999). The size at which hawksbill turtles recruit to benthic developmental habitats appears to vary geographically, ranging from 20–25 cm in the Caribbean (Diez & van Dam, 2002; Blumenthal *et al.*, 2009a; Meylan *et al.*, 2011; Hart *et al.*, 2013; Hawkes *et al.*, 2014) to 30–35 cm in the southern Atlantic and Pacific (this study; Limpus, 1992; Bellini, 1996; Proietti *et al.*, 2012; Carrión-Cortez *et al.*, 2013). This difference may partly reflect variation in the lengths of oceanic developmental migrations. For example, whereas the neritic feeding grounds of Ascension Island and Brazil are thought to lie at the end of long, trans-Atlantic migrations for juvenile hawksbills originating from rookeries in north-eastern Brazil (Proietti *et al.*, 2014; Putman *et al.*, 2014), particle drift models suggest that many neonates and young juveniles originating from Caribbean rookeries are retained within the wider Caribbean region (Blumenthal *et al.*, 2009b) allowing recruitment to adjacent feeding habitats to occur at a relatively smaller size. A second possibility is that neritic juvenile hawksbills in Brazil and Ascension Island have already spent time at an initial developmental habitat elsewhere and are, therefore, larger on average than their Caribbean counterparts (e.g. Wood *et al.*, 2013). Indeed, further studies may reveal as yet un-described hawksbill developmental habitats within the South Atlantic region. For example, juvenile hawksbills are known to occur in the coastal waters of St Helena, 1300 km to the south-east of Ascension Island (Ashmole & Ashmole, 2000), but the population has never been studied and no size-class data exist.

Studies in benthic developmental habitats in the Caribbean and Pacific suggest that post-pelagic, juvenile hawksbills have an adult-type diet, dominated by sponges, tunicates and anthozoans, along with some algae and other animal material (Meylan, 1988; Blumenthal *et al.*, 2009a; Berube *et al.*, 2012; Carrión-Cortez *et al.*, 2013; Hart *et al.*, 2013). Although quantitative data for Ascension Island are lacking, anecdotal

reports from divers broadly conform to this archetype. Hawksbills were observed grazing over rocky reefs with encrusting *Ulosa* sponges and benthic macroalgae apparently featuring in their diets. In addition, we also documented a potentially novel nocturnal feeding behaviour, with groups of 2–6 turtles routinely taking advantage of manmade waterfront illuminations to feed on fish discards around the Island's pier. The use of anthropogenic lighting to continue foraging at night has been documented in various diurnal species (e.g. Dwyer *et al.*, 2013), but we are not aware of any such reports for sea turtles. Scavenging, although once thought to be the predominant feeding mode of hawksbill turtles (Witzell, 1983), is also now considered to be a rare addition to a highly-specialized, largely spongivorous diet (Meylan, 1988). Nocturnal scavenging on protein-rich fish carcasses may yield nutritional and energetic benefits for young turtles, but this habit also creates potential conflicts with fisherman using the pier at night. Indeed, the AIGCD have received a number of anecdotal reports of juvenile hawksbills being inadvertently hooked or ensnared in line in this area. Adjustments to lighting fixtures along with better education on avoiding and responding to the incidental capture of turtles may help to mitigate this threat in future.

Early work on the benthic developmental stage of marine turtles assumed that post-pelagic juveniles were largely itinerant (Carr, 1980). However, subsequent studies have shown that young turtles frequently reside in developmental habitats for periods of several years and occupy well-defined territories (Van Dam & Diez, 1998; Blumenthal *et al.*, 2009a; Scales *et al.*, 2011; Hart *et al.*, 2012, 2013; Carrión-Cortez *et al.*, 2013; Wood *et al.*, 2013). Indeed, tagged juvenile hawksbills recaptured at Ascension Island had residence times ranging from 2 to 7 years and were generally encountered less than 1 km from their original capture location. A high level of site fidelity was also corroborated by GPS tracking of two large individuals which occupied restricted home ranges with an average area of 2.5 km², and had core use areas (in which 50% of daily locations were recorded) of less than 0.1 km² (Figure 4). Relatively few studies have quantified home range size for juvenile hawksbill turtles and estimates vary considerably,

Table 2. Reported home range sizes for juvenile hawksbill turtles in benthic developmental habitats. Abbreviations for estimation methods follow Figure 4.

Location	Home range (km ²)	Estimation method	Tracking method	Number of turtles	Duration (days)	Source
Puerto Rico	0.07–0.21	MCP	Acoustic	3	11–16	[1]
Florida Keys	9.2–21.5	50% UD	Acoustic, PTT	3	263–699	[2]
Belize	0.05–4.0	MCP	Acoustic	17	6–25	[3]
Roatán, Honduras	0.15–0.55	MCP	VHF	6	15–60	[4]
Nicoya, Costa Rica	0.15–1.3	95% UD	Acoustic	12	14–30	[5]
Ascension Island	1.7–3.4	MCP	GPS	2	90–196	[6]
	0.006–0.09	50% UD				

Sources: [1] Van Dam & Diez (1998); [2] Hart *et al.* (2012); [3] Scales *et al.* (2011); [4] Berube *et al.* (2012); [5] Carrión-Cortez *et al.* (2013); [6] this study.

ranging from 0.05 km² to more than 20 km² (Table 2). This may in part reflect the wide range of tracking methodologies, study durations and sample sizes used (Table 2). Nevertheless, despite significant intraspecific variation, estimated home range sizes for juvenile hawksbills appear to be substantially lower than those reported for similarly sized green and loggerhead turtles (Renaud & Carpenter, 1994; Seminoff *et al.*, 2002; Godley *et al.*, 2003; Barceló *et al.*, 2013), perhaps reflecting differences in the abundance, density and/or energetic content of prey items exploited by these species.

The onset of maturity is thought to trigger the departure of marine turtles from juvenile developmental habitats (Meylan *et al.*, 2011) meaning that residence times in these areas are likely to be significantly influenced by somatic growth rates. The mean growth rate of 2.8 cm yr⁻¹ for juvenile hawksbills at Ascension Island is close to the species average (see Hawkes *et al.*, 2014 for a recent review), being very similar to rates reported for feeding aggregations in Florida (2.9 cm yr⁻¹; Wood *et al.*, 2013), the Cayman Islands (3 cm yr⁻¹; Blumenthal *et al.*, 2009a) and Mona Island, Puerto Rico (2.6–3.7 cm yr⁻¹; Diez & van Dam, 2002). Significantly lower growth rates have been reported in Australia (Chaloupka & Limpus, 1997), and higher rates reported in the Virgin Islands (Hart *et al.*, 2013; Hawkes *et al.*, 2014) and at Monito Island, Puerto Rico (Diez & van Dam, 2002), with at least part of this variation apparently due to differences in habitat quality (Diez & van Dam, 2002). Based on the growth rates and size-class distribution reported here and a minimum age on arrival of approximately 3–4 years (Putman *et al.*, 2014), the majority of individuals will have departed Ascension Island by the age of 16–17 years.

This study provides the first characterization of a little-known developmental habitat for juvenile hawksbill turtles in the central Atlantic Ocean. More than 85% of hawksbills found in Ascension Island's waters are thought to originate from nesting stocks in the western Atlantic, particularly from north-eastern Brazil, and are thought to be transported to the Island through a combination of entrainment in the south Atlantic gyre and location-dependent orientation behaviour (Putman *et al.*, 2014). At least a proportion of these individuals then remain at Ascension Island, feeding in shallow, benthic habitats and occupying small, coastal home ranges for periods of up to 7 years or more, before completing their trans-Atlantic migrations to adult feeding habitats along the continental coastline of Brazil (Marcovaldi *et al.*, 2012). The size of the resident population is unknown, but is probably limited by the extent of suitable habitat. Benthic-feeding, juvenile hawksbills generally forage at depths shallower than 30 m (this study; Hart *et al.*, 2012;

Carrión-Cortez *et al.*, 2013; Wood *et al.*, 2013), giving an estimated inhabitable area of just 27 km² at Ascension Island. When combined with estimated home range sizes, even allowing for some overlap it seems likely that the population numbers dozens rather than hundreds. Future work should focus on obtaining more quantitative measures of density, distribution and habitat preferences of hawksbill turtles feeding at Ascension Island, as well as elaborating on migratory pathways and links with regional nesting populations and adult foraging aggregations.

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Correspondence should be addressed to:

S.B. Weber
 Ascension Island Government Conservation Department
 Georgetown, Ascension Island, South Atlantic Ocean, ASCN 1ZZ
 email: sam.weber@ascension.gov.ac