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Twenty years of turtle tracks: marine turtle nesting activity at remote locations in the Pilbara, Western Australia

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Abstract. Little is known about the biology and ecology of marine turtles in the Pilbara region of Western Australia and most potential habitat is unconfirmed and, therefore, undescribed. Understanding basic biological parameters at a regional level is critically important for effective long-term management. We used the 'track census' methodology to identify reproductive habitat and assess species-specific abundance of adult flatback (*Natator depressus*), green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles at 154 locations in the Pilbara region of Western Australia.

Between 1992 and 2012, potential nesting habitat was assessed via either ground or aerial 'snapshot' (single visit) or 'census' (more than one night) surveys and additional information obtained using the Expert Elicitation Method. Species-specific abundance (tracks night^{-1} $\pm$ s.d.) was varied; green turtles were most abundant, nesting at fewer locations ($n = 47$) but in greater numbers (1200.5 $\pm$ 62.0) than flatback or hawksbill turtles and primarily (93%) at island locations. Flatback turtle nests were more widely distributed ($n = 77$) than those of green or hawksbill turtles, yet abundance (877.4 $\pm$ 29.5) was lower than that of green and greater than that of hawksbill turtles. Activity was primarily (76%) island-based and activity on the mainland coastline was concentrated close to Mundabullangana and Cemetery Beach. Hawksbill turtle abundance (314.1 $\pm$ 17.1) was lowest and the least widespread ($n = 43$), concentrated primarily in the Onslow and Dampier subregions with no activity recorded in the Port Hedland subregion or on the mainland coastline.

The findings provide information with which the Federal government can meaningfully assess the status and distribution of *EPBC Act*–listed species where habitat overlaps with areas zoned for development. We highlight the urgent need for the Federal Government to regulate the process by which we accumulate data to support data quality and provide meaningful information to enhance efficacy in state and Federal management of species of concern.

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Introduction

Little is known about the biology and ecology of marine turtles in the Pilbara region of Western Australia. Much of the area is considered remote and access to known or potential marine turtle nesting habitat limited. Recently, some larger rookeries have been described (Limpus 2009; Whiting *et al*. 2009; Pendoley *et al.* 2014).

All six species of marine turtle found in Australian waters are considered to be of conservation concern (IUCN 2010). The predominant species nesting in the Pilbara region – green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and endemic flatback (*Natator depressus*) turtles – are listed as 'Vulnerable' under both national (*Environmental Protection of Biodiversity and Conservation (EPBC) Act 1999*) and State (*Wildlife Conservation Act 1950*) legislation and 'may become endangered' if current threats are not curtailed.

The Western Australian (WA) Management Unit (MU) is one of four genetically delineated marine turtle MUs for flatback turtles (Dutton *et al*. 2002; Wallace *et al*. 2010) and encompasses the entire Pilbara region. The largest rookeries are at Cape Dommett (Whiting *et al*. 2009), Barrow Island and Mundabullangana (Pendoley *et al.* 2014).

The North-West Shelf MU is one of seven genetically delineated green turtle MUs in Australia and extends from the Muiron Islands in the south to the Lacepede Islands in the north (Dethmers *et al*. 2006). Within the MU, nesting populations potentially comprising tens of thousands of females are known, yet have not recently been reported (Prince 1994; or see Limpus 2009 for review).

The WA hawksbill turtle population comprises a single genetic stock. Primary rookeries are located in the Dampier archipelago and Montebello Islands (Broderick *et al.* 1994; Limpus 2009; Vargas *et al*. 2016) with additional low-level nesting throughout the North-West Shelf, which collectively could be substantial. Generally monitored since the mid-1980s (Prince 2000), the rookery at Rosemary Island in the Dampier archipelago is the largest in the Indian Ocean and one of the largest remaining hawksbill populations worldwide (Limpus 2009).

British colonisation of the Pilbara coast, previously inhabited by indigenous peoples, began in the early 1860s (Commonwealth of Australia 2008). Significant historical impacts on turtles in the Pilbara include atomic testing in the Montebello Islands in the 1950s (Kendrick 2003) and commercial harvesting for export and trade between the 1930s and the 1970s (DEC 2007).

Today, the region is important for the petroleum industry, with Australia's two largest ports (by tonnage) located at Dampier and Port Hedland (Ports Australia 2013). In association with this development, the human population in the Pilbara has grown, increasing, for example, by 59% between 2001 and 2011 (Australian Bureau of Statistics 2011). Contemporary threats to marine turtles result therefore directly and indirectly from expansion of the petroleum industry, specifically oil and gas exploration and associated infrastructure, along the Pilbara coastline.

Potential impacts include artificial light emissions from off- and onshore lighting and gas flares (Kamrowski *et al*. 2012, 2014; Pendoley and Kamrowski 2015), direct loss of habitat due to dredging (benthic) and construction (nesting beaches, mangroves), accidental spillage of petroleum products and physical disturbance from rapidly increasing human presence in the region (DEC 2007) and increased vessel activity. Commercial fisheries, seismic surveys and sand extraction are also noted (DEC 2007).

Interactions between industrial development and reproductive habitat can negatively affect distribution (Carstensen *et al*. 2006; Harewood and Horrocks 2008) and abundance (Ng and Leung 2003; Madsen *et al*. 2006; Stewart *et al*. 2007; Thompson *et al*. 2010) of terrestrial and marine species during different phases of their life cycle (Whittock *et al.* 2014). Understanding basic biological parameters such as spatial distribution and habitat use at a regional level is critically important for effective management (e.g. Witt *et al*. 2009) and ongoing protection (Hamann *et al.* 2010). In Australia, the *EPBC Act 1999* considers marine turtles as Matters of National Environmental Significance. To manage interactions with development, proposed projects with potential to impact Matters of National Environmental Significance are required to submit an Environmental Impact Assessment to Federal Government, providing information describing the current status of potentially affected populations and the potential risk to populations utilising the affected habitat should the project be approved. Consequently, much available data have been accumulated in multiple, discrete surveys run by private entities within the resources sector to meet *EPBC Act 1999* requirements and are therefore privately held. Publicly available information on the location and significance of marine turtle nesting habitat in the region is sparse, spatially, temporally and methodologically inconsistent and subject to ownership and sharing limitations.

Here we present novel information describing species-specific abundance and distribution at 28 locations on the Pilbara mainland coastline and 126 offshore island locations on the North-West Shelf gathered over two decades of nesting habitat surveys. This information is critical for effective management of marine turtle populations, both State and nation-wide, and to the best of our knowledge has not previously been published.

Materials and methods

Survey area

The Pilbara region encompasses coastline between approximately 19.96792°S, 119.14242°E and 21.80769°S, 114.72282°E from the Ashburton River Delta to the southern end of Eighty Mile Beach (Fig. 1). The region is characterised by shallow-water (10–100 m) tropical marine ecosystems (Commonwealth of Australia 2008) and includes inshore coastal and offshore oceanic islands, which may stand in isolation or form chains or archipelagos. Nearshore, mainland waters are characterised by rocky headlands, sandy beach, mangrove and river delta habitat. Inshore coastal islands comprise subtidal and intertidal reefs, sheltered lagoons (DEC 2007), low-energy, low-profile beaches with wide intertidal platforms. Offshore oceanic islands feature high-energy sandy beaches with deep-water approaches. The region exhibits monsoonal climatic patterns and is subject to sporadic and intense storms between December and March (Commonwealth of Australia 2008).

Survey design

Between 1992 and 2012, a series of independent field surveys were carried out on behalf of oil and gas, shipping, ports and mining entities to inform environmental impact assessment and associated environmental management reports. Surveys assessed 154 separate locations considered potentially suitable nesting habitat for adult female marine turtles (Table 1, Fig. 2, Supplementary Material).

During the survey period, both publically available and privately held data were sparse. Where obtainable, existing data were often found to be unreliable and inconsistent, collected by inexperienced personnel and lacking metadata. Consequently, most Pilbara nesting sites were considered to be 'previously unassessed'. Potential nesting habitat was identified from anecdotal reports, academic literature, grey literature, government databases and geo-physical conditions at each location.

Field surveys were carried out in accordance with standardised methods and protocols based on Schroeder and Murphy (1999) and modified for rapid assessment of large geographical areas in limited timeframes.

To quantify species-specific nesting effort per beach, surveys were typically scheduled during the peak reproductive period for each species (Eckert *et al*. 1999; Whiting *et al*. 2007, 2009). In the Pilbara this period is December and January for flatback and green turtles, and October and November for hawksbill turtles (Pendoley 2005). The northern extent of the nesting range for loggerhead turtles (*Caretta caretta*) in Western Australia is the southern boundary of the Pilbara and the southern extent of the nesting range of the Olive Ridley turtle (*Lepidochelys olivacea*) is beyond the Lacapede Islands north of the Pilbara (Limpus 2009). The leatherback turtle (*Dermochelys coriacea*), recorded in Australian waters, is not known to nest at any location (Limpus 2009) and the nesting period of these three species was therefore not considered.

Data acquisition

Species-specific nesting activity at each location (n) was assessed via either 'census' surveys (ground-based: $n = 13$; aerial: $n = 13$;

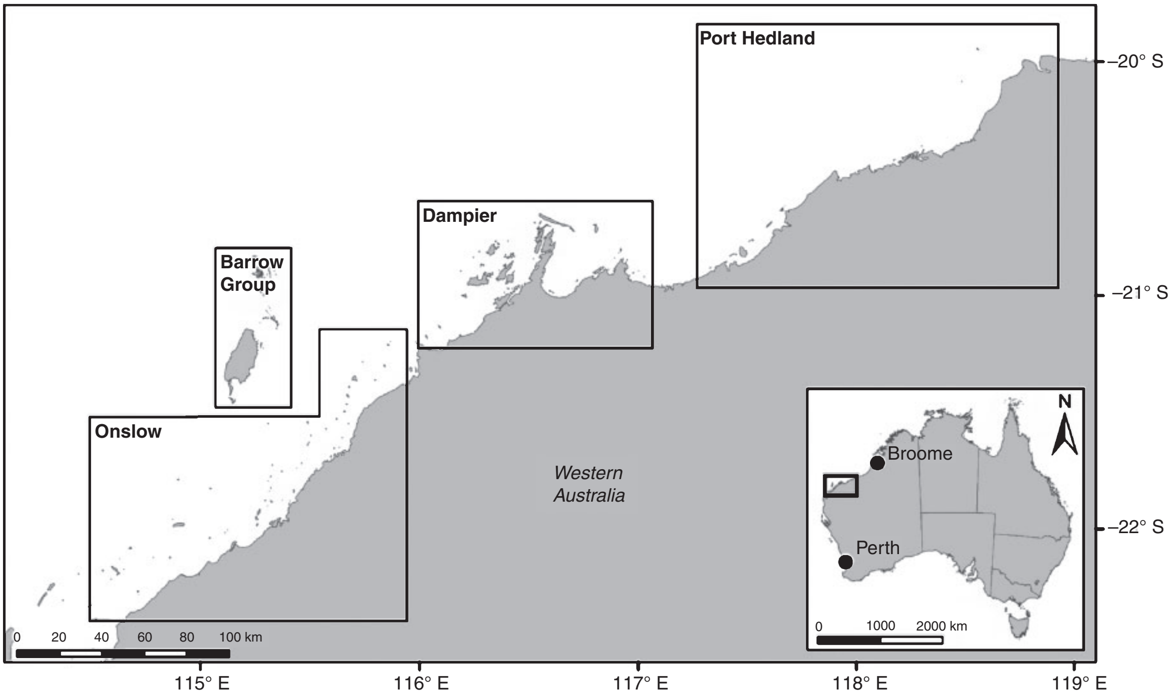

Fig. 1. Subregional groups of surveyed locations ($n = 154$): Barrow group ($n = 21$), Dampier ($n = 56$), Onslow ($n = 53$) and Port Hedland ($n = 24$). See Supplementary Material for surveyed location type, name, duration (days n, seasons n) and species presence in each subregional group.

Table 1. Data acquisition method

Locations (n) were assessed by ground census, aerial census, ground and aerial census, and Expert Elicitation method (EEM) in each subregion

Subregion	Ground (n)	Aerial (n)	Ground/Aerial (n)	Snapshot (n)	EEM (n)	Total (n)
Barrow Group	3	0	0	0	18	21
Dampier	2	0	0	7	47	56
Onslow	7	0	0	14	32	53
Port Hedland	1	13	2	3	5	24
Total	13	13	2	24	102	154

both: $n = 2$), comprising multiple visits to a location over consecutive days or, at more remote locations, 'snapshot' surveys (ground-based: $n = 24$) where information was gathered during a single visit (Bell and Pendoley 2012) (Table 1). At Barrow Island, several flatback turtle nesting beaches are monitored at night throughout peak season and data from this program are included.

Data describing species-specific distribution and indicative abundance at 102 additional locations were obtained via the Expert Elicitation Method (Burgman *et al*. 2011). The approach capitalised on the experience of subject matter experts (as per Martin *et al*. 2012) who had previously visited each location to assess marine turtle reproductive activity. Elicitation was conducted by trained and experienced personnel within the structured framework of a State-facilitated workshop. Data were treated using the Delphi technique, widely employed in the process of refining qualitative information to provide a valid, quantative dataset (Martin *et al*. 2012; Mukherjee *et al*. 2015) (Supplementary Material).

Data management/handling

Survey duration (days) was dependent upon available resources, physical conditions (e.g. tide height and beach access) and logistical details (e.g. distance between survey sites), and ranged from one to nine consecutive days, conducted over one to three seasons (Bell and Pendoley 2012). Regardless of duration or technique, surveys recorded all visible marine turtle (downward) tracks (Schroeder and Murphy 1999) and, where possible, assigned them to species (Pritchard and Mortimer 1999).

Spatial distribution was assessed by (1) grouping survey locations ($n = 154$) into four subregions based on geographical proximity as follows: Barrow group ($n = 21$), Dampier ($n = 56$), Onslow ($n = 53$) and Port Hedland ($n = 24$) (Figs 1, 2) and (2) comparing the proportion of all species-specific nesting found at mainland coastline ('mainland') versus island ('island-based') habitat.

Data gathered outside the peak reproductive season for each species were excluded. For surveys of more than one day and/or season, total species-specific track counts from each location were combined and the total averaged over the number of survey days to provide the mean number of overnight tracks (tracks night^{-1}) presented as mean ± standard deviation, range and sample size (n = locations) for each species. Where the Expert Elicitation Method was used to account for potential error inherent in estimation we provide the 'estimated mean' only. To account for variation in data-collection techniques, mean

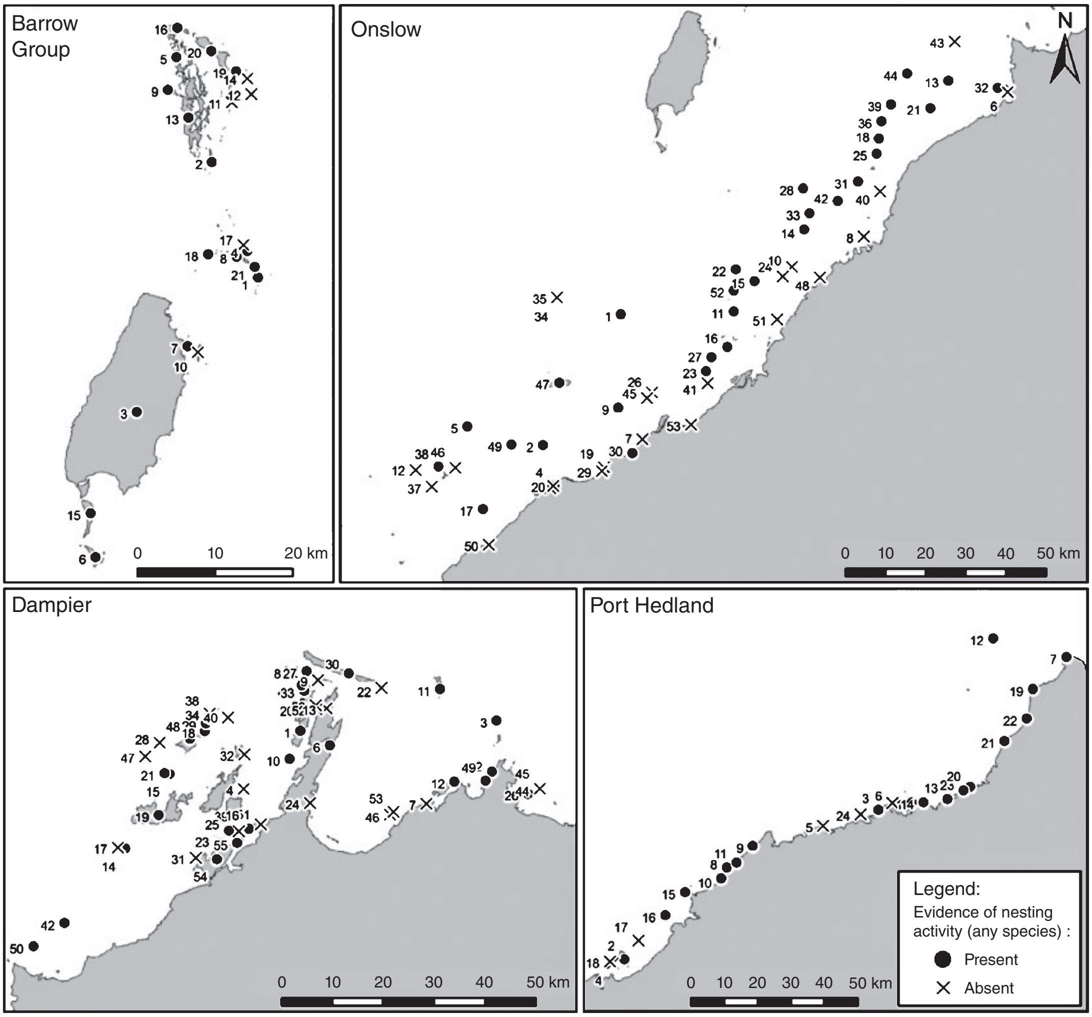

Fig. 2. Survey locations in each subregion, showing presence and absence of marine turtle nesting activity. Black dot, present; grey cross, absent.

abundance (tracks night^{-1}) was assigned to one of five broad categories: 0 (none), 1–10 (low), 11–100 (medium), 100–500 (high) and >500 (very high) tracks night^{-1} for each species, as per Limpus (2009).

Survey location, technique, duration (n) and species-specific presence/absence at all locations are given in the Supplementary Material.

Results

Flatback turtles

Regional flatback nesting activity was recorded at 58% of all surveyed locations ($n = 89$) (Table 2). Most activity (76%) was island-based, distributed across both islands situated closer to shore (<25 km) within the Dampier, Onslow and Port Hedland subregion and on the outer islands of the Barrow Group subregion >50 km from the mainland coastline (Figs 3–6). The Onslow and Dampier subregions had the equal highest regional proportion of flatback nesting among surveyed locations (Table 2). Regional flatback turtle nesting at locations where abundance was quantified was 877.4 ± 29.5 tracks night^{-1} (range = 0.2–221.0, $n = 77$).

Green turtles

Regional green turtle nesting activity was recorded at 36% of all surveyed locations ($n = 55$) (Table 2). Most locations (93%) were islands with activity primarily located on outer islands away from the mainland coastline (Figs 3–6). Activity at surveyed mainland locations was low (7%). Subregional nesting activity was most widespread within the Barrow Group subregion, recorded at 71% of all surveyed locations (Table 3). Regional overnight nesting at locations where abundance was quantified was 1200.5 ± 62.0 tracks night^{-1} (range = 0.1–313.0, $n = 47$).

Hawksbill turtles

Regionally, hawksbill turtle nesting was recorded at 29% of all survey locations ($n = 45$), concentrated within the Onslow subregion (42% of all regional nesting) (Tables 2 and 3). There was no hawksbill nesting in the Port Hedland subregion or at any

Table 2. Activity (*n*, %) per surveyed subregions
Distribution (*n*, %) of regional nesting activity in each subregion: Active, activity recorded; Inactive, no activity recorded

Subregion	*N. depressus*			*C. mydas*			*E. imbricata*		
	Active		Inactive	Active		Inactive	Active		Inactive
	(*n*)	(%)	(*n*)	(*n*)	(%)	(*n*)	(*n*)	(%)	(*n*)
Barrow Group	14	16	7	15	27	6	14	33	7
Dampier	28	31	28	13	24	43	12	28	46
Onslow	28	31	25	23	42	60	19	44	34
Port Hedland	19	21	2	4	7	20	0	0	24
Total	89	100	65	55	100	99	45	100	111

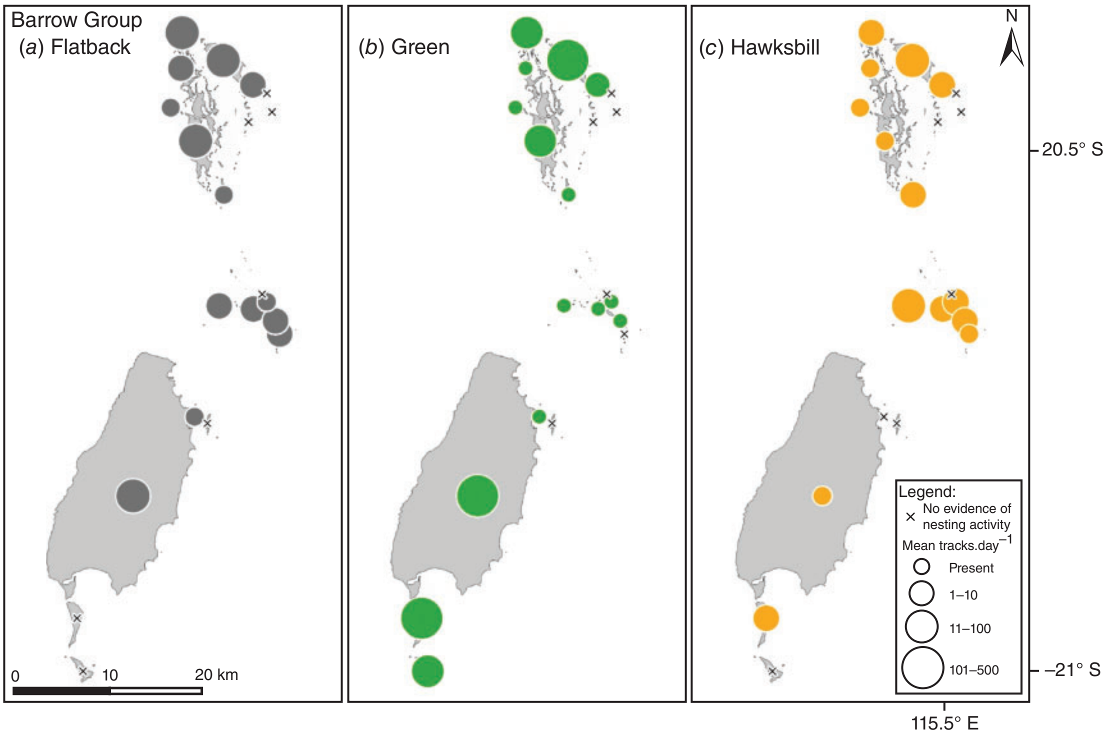

Fig. 3. Abundance (tracks night^{-1}) of (*a*) *N. depressus*, (*b*) *C. mydas* and (*c*) *E. imbricata* in the Barrow Group subregion. Abundance categories (as per Limpus 2009): × (no nesting); 1–10 (low); 11–100 (medium); 101–500 (high); >500 (very high) tracks night^{-1}.

location on the mainland (Figs 3–6). Regional overnight nesting at locations where abundance was quantified was 314.1 ± 17.1 tracks night^{-1} (range = 0.2–114, n = 43).

Regional distribution

Nesting activity by either flatback, green or hawksbill turtles was confirmed at 66% of all surveyed locations (n = 101). Nesting activity by one or more species was widespread at both mainland and island locations and was recorded at more than 50% of all surveyed locations within each subregion (Fig. 2, Table 2). Overall, the proportion of all surveyed island locations utilised for nesting by any species (79%) was greater than for mainland locations (21%). The distribution of nesting activity between surveyed island and mainland locations varied among subregions. The relative proportion of Pilbara nesting activity for each species is described for each subregion below. Sites where no activity was recorded by any species are listed in the Supplementary Material.

Barrow group

The Barrow Group supported 16% of flatback turtle nesting activity, 27% of green turtle nesting activity and 31% of all hawksbill turtle nesting activity documented within the assessed Pilbara region. Mean overnight nesting activity at active locations for all species combined was 29.1 ± 64.0 tracks night^{-1} (range = 0–313, n = 15) and was higher than in the Dampier, Onslow or Port Hedland subregions. Mean species-specific nesting activity at active locations was 17 ± 27 tracks night^{-1} (range = 0–93, n = 14) for flatback turtles, 62 ± 98 tracks night^{-1} (range = 0–313, n = 15) for green turtles, and 6 ± 6

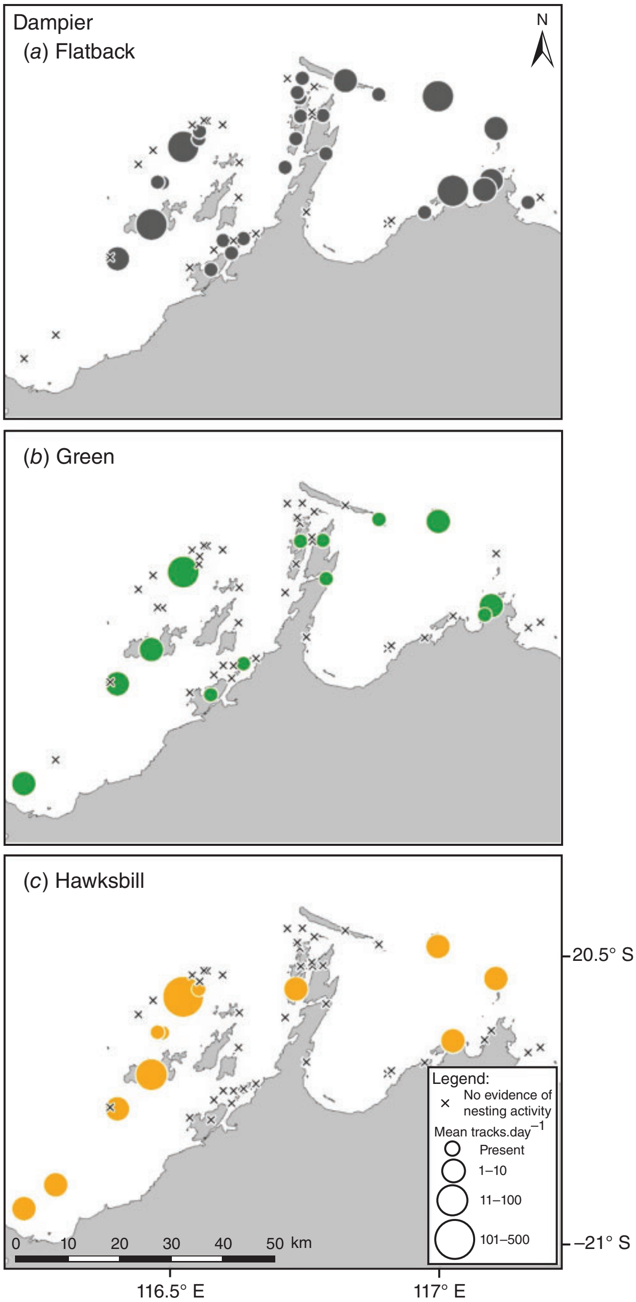

Fig. 4. Abundance (tracks night^{-1}) of (*a*) *N. depressus*, (*b*) *C. mydas* and (*c*) *E. imbricata* in the Dampier subregion. Abundance categories (as per Limpus 2009): × (no nesting), 1–10 (low), 11–100 (medium), 101–500 (high) and >500 (very high) tracks night^{-1}.

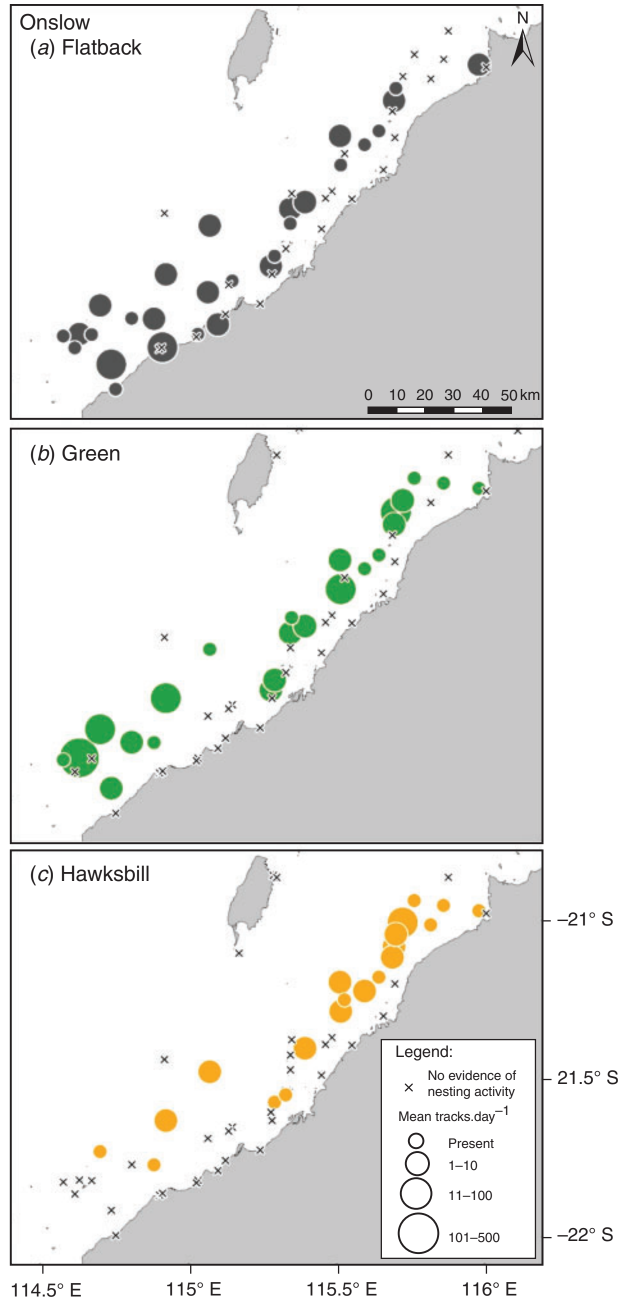

Fig. 5. Tracks.night^{-1} of (*a*) *N. depressus*, (*b*) *C. mydas* and (*c*) *E. imbricata* in the Onslow subregion. Abundance categories (as per Limpus 2009): × (no nesting), 1–10 (low), 11–100 (medium), 101–500 (high) and >500 (very high) tracks night^{-1}.

tracks night^{-1} (range = 0–20, n = 14) for hawksbill turtles. The location with the greatest nesting activity per survey night in the Barrow Group for flatback turtles was at Barrow Island (93 ± 32 tracks night^{-1}, range = 33–96, n = 48), for green turtles was at Middle Island (313 ± 32 tracks night^{-1}, range = 252–347, n = 7), and for hawksbill turtles was at Trimouille Island (estimated mean = 20 tracks night^{-1}) (Fig. 3).

Dampier subregion

Nesting activity within the Dampier subregion comprised 31% of flatback turtle nesting, 24% of green turtle nesting and 27% of all hawksbill turtle nesting in the assessed Pilbara region. Mean overnight nesting activity (tracks night^{-1}) of all species combined was 7 ± 18 tracks night^{-1} (range = 0–114, n = 27). Mean species-specific nesting activity at active locations was

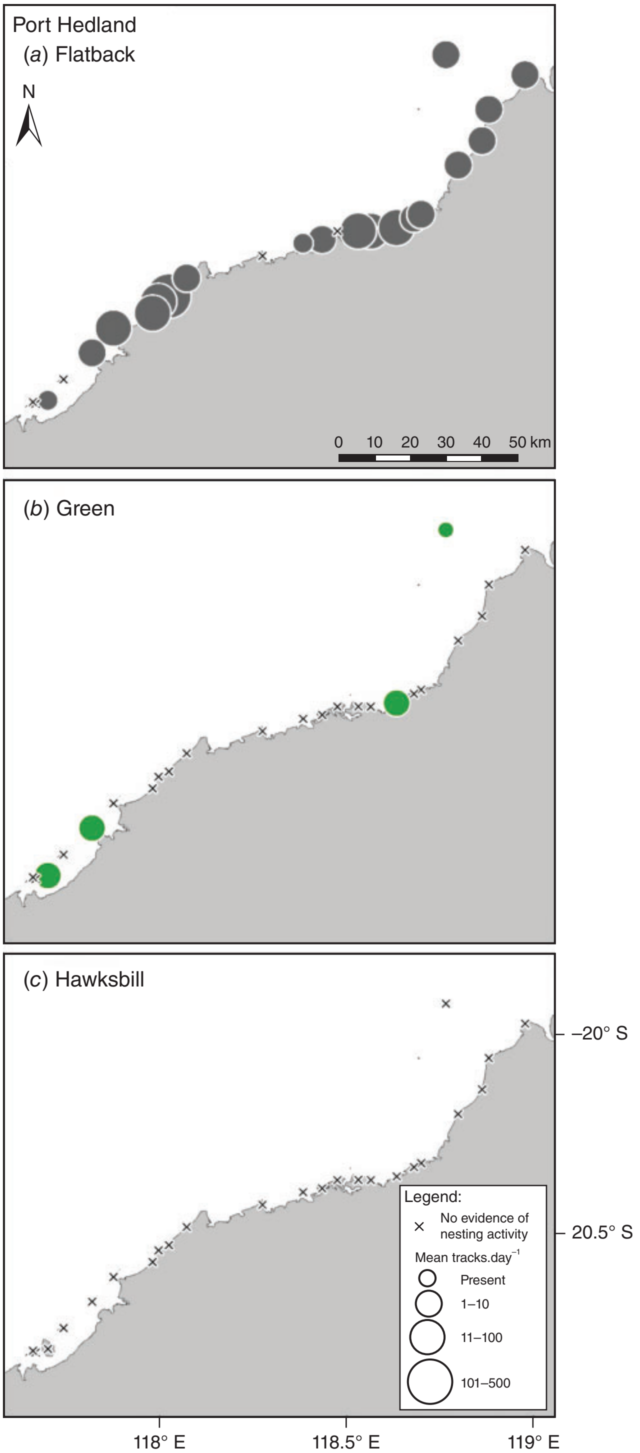

Fig. 6. Tracks night^{-1} of (*a*) *N. depressus*, (*b*) *C. mydas* and (*c*) *E. imbricata* in the Port Hedland subregion. Abundance categories (as per Limpus 2009): × (no nesting), 1–10 (low), 11–100 (medium), 101–500 (high) and >500 (very high) tracks night^{-1}.

6 ± 13 tracks night^{-1} (range = 0–57, $n = 28$) for flatback turtles, 3 ± 8 tracks night^{-1} (range = 0–29, $n = 13$) for green turtles, and 14 ± 32 tracks night^{-1} (range = 0–114, $n = 12$) for hawksbill turtles. The greatest nesting activity for all species in this subregion was at Rosemary Island where estimated mean overnight turtle nesting activity was 57 tracks night^{-1} for flatback turtles, 29 tracks night^{-1} for green turtles, and 29 tracks night^{-1} for hawksbill turtles (Fig. 4).

Table 3. Distribution of nesting activity at island versus mainland locations

Regional distribution (n, %) of nesting activity of *E. imbricata*, *C. mydas* and *N. depressus* at surveyed mainland and island locations

Species	Island		Mainland		Island and Mainland	
	(n)	(%)	(n)	(%)	(n)	(%)
E. imbricata	45	100	0	0	45	29
C. mydas	51	93	4	7	55	36
N. depressus	68	76	21	24	89	58
Total	164		25		189	
Mean		90		10		41

Onslow subregion

The Onslow subregion supported 31% of flatback turtle nesting, 42% of green turtle nesting and 42% of all hawksbill turtle nesting in the assessed Pilbara region. Mean overnight turtle nesting activity at active locations for all species combined was 5 ± 13 tracks night^{-1} (range = 0–103, $n = 36$) and was the lowest of the four subregional groups. Mean species-specific nesting activity at active locations was 3 ± 4 tracks night^{-1} (range = 0–13, $n = 28$) for flatback turtles, 9 ± 22 tracks night^{-1} (range = 0–103, $n = 21$) for green turtles, and 3 ± 4 tracks night^{-1} (range = 0–17, $n = 19$) for hawksbill turtles. The greatest flatback turtle activity was at Locker Island (13 ± 1 tracks night^{-1}, range = 12–13, $n = 2$), greatest green turtle activity was at Serrurier Island (313, $n = 1$) and greatest hawksbill activity was at Sholl Island (estimated mean = 17) (Fig. 5).

Port Hedland subregion

The Port Hedland subregion supported 21% of all flatback turtle nesting, 7% of all green turtle nesting, and 0% of all hawksbill turtle nesting recorded in the Pilbara region. Mean overnight turtle nesting activity of all species combined was 8 ± 17 tracks night^{-1} (range = 0–221, $n = 19$). Activity was largely focussed around Mundabullangana and spatially the subregion was the least utilised by nesting turtles. Mean species-specific nesting activity at active locations was 22 ± 51 tracks night^{-1} (range = 0–317, $n = 19$) for flatback turtles, and 2 ± 2 tracks night^{-1} (range = 0–4, $n = 4$) for green turtles. There was no hawksbill turtle nesting recorded in this region. The greatest flatback turtle activity was at Cowrie Beach, Mundabullangana (221 ± 136 tracks night^{-1}, range = 107–317, $n = 4$) and the greatest green turtle activity was at Depuch Island (estimated mean = 4) (Fig. 6).

Discussion

Meaningful population assessments are based on comparison of past and present abundance across the species' range (IUCN

2004). Data describing either historical or contemporary abundance or distribution of marine turtle populations in the Pilbara region of Western Australia are sparse. The information we present therefore provides an important and novel resource with which to underpin future systematic population assessment for marine turtles within the Pilbara region.

Surveys recorded nesting activity by green, flatback and hawksbill turtles and found the spatial distribution of flatback turtle nesting was more widespread than that of both green and hawksbill turtles. Flatback turtle abundance, however, was lower than that of green turtles but greater than that of hawksbill turtles. Sporadic flatback nesting activity was documented along the length of the mainland coast, with activity concentrated on beaches in the Port Hedland subregion, close to Mundabullangana and Cemetery Beach (Pendoley *et al.* 2014). Substantial island rookeries were recorded at Delambre and Rosemary Islands in the Dampier subregion and Barrow and Trimouille Islands in the Barrow Group.

Track surveys found that the largest flatback rookery within the Pilbara region was at Cowrie Beach, Mundabullangana, and the second largest at Barrow Island. This result is consistent with modelled population abundance estimates which indicate that this population comprises 1861 nesting females year^{-1}. Modelled estimates of the Barrow Island rookery estimate 1512 nesting females year^{-1} (Pendoley *et al.* 2014), which is comparable to both the estimated 1950 nesting females year^{-1} derived from track counts between 1995 and 2005 (Pendoley 2005) and to findings presented here. The population at Cape Dommett, located 1200 km north-east of Mundabullangana within the Kimberley region of Western Australia, comprises an estimated 3250 nesting females year^{-1} (Whiting *et al.* 2009) and is larger than the Mundabullangana rookery, being the largest in Western Australia.

Green turtles were the most abundant of the three species, nesting at fewer locations but in greater numbers than both flatback and hawksbill turtles, and were found at island locations only, with few, rare exceptions. The North West Shelf green turtle management unit comprises the largest green turtle population in the Indo-Pacific region (Moritz *et al*. 2002) and one of the largest in the world (Limpus 2009), with significant rookeries located at Barrow Island (Pendoley *et al.* 2014), the Maret Islands (Waayers and Fitzpatrick 2013), the Lacepede Islands and the North-west Cape (Prince 1994). Data from this study suggest that green turtle nesting activity within the Pilbara region may potentially comprise tens of thousands of females annually, which is consistent with previous estimates (Limpus 2009; Pendoley 2005). The Barrow Island rookery alone is considered regionally significant (Prince 1994). Regional activity was concentrated in the Barrow Group with additional, substantial levels of activity in the Onslow subregion. Green turtle nesting activity at mainland sites was low.

Nesting hawksbill turtles were the least abundant overall. Regional nesting was focussed at Rosemary Island in the Dampier subregion. Additional nesting on islands throughout the Dampier and Barrow subregion, notably Ah Chong Island in the Montebellos and Delambre Island in the Dampier Archipelago, may cumulatively represent significant rookeries for this species. Hawksbill nesting activity was found exclusively at surveyed island locations, this distribution providing some level of protection from human development activities on the mainland coastline.

Track census surveys are subject to methodological and climatic limitations (Soto Navarro *et al*. 2012), amplified during large-scale surveys designed to meet constrained development, not extended biological, timeframes. Some variation among surveys was therefore expected and a limited number of minor discrepancies in abundance estimates herein and those reported elsewhere were identified. Surveys of the Ashburton River Delta (flatback turtles) (RPS 2010) and the Barrow Group subregion (hawksbill turtles) (Pendoley 2005) provide examples. In the latter, surveys of nesting hawksbill turtle activity in the Barrow Group estimated 100 nesting females year^{-1} on Barrow Island and a further 1000 nesting females year^{-1} at each of the Lowendal and Montebello Island groups, greatly exceeding estimates from this study.

Environmental factors such as rain, wind, substrate type and condition, tide height and cyclonic conditions influence detection and are particularly relevant to data gathered during 'snapshot' surveys. In the Pilbara, predator activity, e.g. Barrow Island perentie (*Varanus giganteus*) and golden bandicoot (*Isoodon auratus barrowensis*) is high and further reduces visibility of tracks.

Marine turtles do not nest every year and the abundance of nesting female turtles present at the nesting beach in each reproductive season is therefore subject to natural variation (Miller 1997). Nesting females may re-emerge several times on a single night or over multiple, consecutive nights before successful oviposition. Multiple emergences may therefore magnify abundance or, where density is high, reduce observed abundance by obscuring earlier tracks.

Natural variation is further compounded by El Niño or other events that affect the foraging ground resulting in less-than-optimal conditions for acquiring adequate energy reserves for reproductive migration (Solow *et al*. 2002). There is significant annual fluctuation in annual abundance of nesting green turtles, understood to be regulated by the El Niño Southern Oscillation (ENSO) (Limpus and Nicholls 2000; Solow *et al*. 2002).

In the Pilbara region, green turtles nest over ~4–6 months and flatback and hawksbill turtles over 2–3 months and internesting intervals vary among species and locations (Pendoley 1999; Whiting *et al*. 2009; Limpus 2009; Pendoley *et al.* 2014). Data accumulated during surveys limited to less than five days cannot account for inter- or intraseasonal variation and provide an overview of nesting activity only. Greater temporal duration of surveys (i.e. more nights during the peak nesting period and survey repetition over multiple, consecutive seasons) would increase data resolution, capture variation and provide greater confidence in results.

Potential limitations arising from the *ad hoc* nature of these surveys was recognised and limited by consistency in approach, adherence to standardised protocols, retention of data gathered during the peak nesting period only and a clear statement of approach for each method of data acquisition, which should be considered in interpretation of results. The potential limitations of the Expert Elicitation Method are well known (see Burgman 2004 for review) and limited by elicitation of information within a structured framework in the context of a formal environment with trained and experienced personnel (Burgman *et al*. 2011).

Only experts verified by a third-party were selected to avoid bias inherent in self-nomination. Data were handled using the Delphi technique, an iterative and participatory means of gathering and evaluating expert-based knowledge widely accepted as a valid means of addressing complex issues in the field of conservation management (Burgman *et al*. 2011; Martin *et al*. 2012; Mukherjee *et al*. 2015).

Despite these limitations, the track census method is a viable, widely used approach that provides a broad indication of usage across variable spatial areas, be they individual islands or beaches or entire regions. In the absence of publically available and reliable data, this study provides a baseline measure against which more formal and systematic surveys of increased duration and repetition can detect change over time.

Defining the spatial range of preferred nesting habitat for each rookery and identifying periodicity, presence, relative abundance and output during consistent annual survey periods are fundamental for successful conservation management and planning. Population assessment is a Federal requirement for approval of development that overlaps with the habitat of species of concern, yet data acquisition protocols are not stipulated. Variation in the quality of information submitted to Government may undermine effective decision-making. Despite its limitations, use of the track count method is widely considered the most efficient approach as a means for proponents to determine the status of EPBC listed species at the scoping stage of an EIA.

Findings within identify and describe remote marine turtle nesting habitat, describe distribution, provide a broad signal of abundance and highlight the urgent need for Federal Government to regulate the process by which we accumulate information to support increased efficacy in state and national management of EPBC Act listed species.

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