Fidelity to foraging sites after long migrations

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18   **Abstract**

19   1. Patterns of animal movement associated with foraging lie at the heart of many ecological

20   studies and often animals face decisions of staying in an environment they know, versus

21   relocating to new sites.

22   2. The lack of knowledge of new foraging sites means there is risk associated with a decision to

23   relocate (e.g. poor foraging) as well as a potential benefit (e.g. improved foraging).

24   3. Using a unique long-term satellite tracking dataset for several sea turtle species, combined

25   with capture-mark-recapture (CMR) data extending over 50 years, we show how, across species,

26   individuals generally maintain tight fidelity to specific foraging sites after extended (up to almost

27   10,000 km) migration to and from distant breeding sites as well as across many decades.

28   4. Migrating individuals often travelled through suitable foraging areas *en route* to their "home"

29   site and so extended their journeys to maintain foraging site fidelity.

30   5. We explore the likely mechanistic underpinnings of this trait, which is also seen in some

31   migrating birds, and suggest that individuals will forgo areas of suitable forage encountered *en*

32   *route* during migration when they have poor knowledge of the long-term suitability of those

33   sites, making relocation to those sites risky.

34   **1 | INTRODUCTION**

35

36   Migration is an integral component of the life history of many animals with a range of examples

37   of birds, mammals, fish, insects, and reptiles that migrate up to many 1000s of km. The oft cited

38   general reason for migration is that the quality of resources, such as food availability, varies

39   through space and time, so that it is best for an animal to visit particular locations at specific

40   times (e.g. Alerstam, Hedenström, & Åkesson, 2003). In some cases the end point of migration is

41   associated with tight fidelity to particular sites. For example, many taxa including birds, sea

42   turtles and some fish migrate to specific breeding sites to which they maintain fidelity across

43   years (Bett & Hinch, 2016; Jensen, FitzSimmons, & Dutton, 2013; Vardanis, Nilsson, Klaassen,

44   Strandberg, & Alerstam, 2016). This fidelity may help ensure that individuals breed in suitable

45   sites. Likewise there may be fidelity to foraging sites with for example, many wading birds

46   breeding in northern Europe travelling 1000s of km to West Africa to forage in winter in

47   particular wetland areas, notably Banc d'Arguin which covers approximately 12,000km^2 in

48   Mauritania (Oudman et al., 2018). In other cases, animals may migrate to even broader regions.

49   For example, seabirds, such as albatrosses and shearwaters, and marine mammals including

50   many seals, may range widely over many tens of thousands of km as part of their migrations

51   (Clay, Phillips, Manica, Jackson, & Brooke, 2017; Dias, Granadeiro, Phillips, Hany, & Paulo,

52   2010; Sztukowski et al., 2018). Given this range of migration patterns, assessing the cost and

53   benefits of migration strategies remains a key question in movement ecology (Hays et al., 2016).

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55   Here we consider an enigmatic, but classic, group of migrators that may reveal some general

56   reasons for why animals migrate and have fidelity to particular sites. Sea turtles are well known

57   to migrate many thousands of km and to have fidelity to breeding sites (e.g. Jensen et al., 2013).

58   There is increasing evidence for fidelity to foraging sites in some species. Almost thirty years

59   ago capture-mark-recapture (CMR) studies in eastern Australia started to suggest that loggerhead

60   turtles (*Caretta caretta*) and green turtles (*Chelonia mydas*), identified with numbered flipper

61   tags, may have strong long-term fidelity to localised foraging sites (Limpus et al., 1992) with

62   further evidence for this trait being provided more recently by satellite tracking (e.g. Broderick,

63   Coyne, Fuller, Glen, & Godley, 2007; Limpus & Limpus, 2001). Yet at the same time, it has

64   become apparent that within the same population, migration distances from breeding to foraging

65   sites may vary from a few 10s of km up to many 1000s of km (e.g. Hays, Mortimer,

66   Ierodiaconou, & Esteban, 2014). Here, using satellite tracking data from multiple species across

67   the Pacific, Atlantic, Indian Ocean, Mediterranean and Caribbean Sea, as well as a 50+ year

68   CMR dataset, we explore the general applicability of foraging site fidelity in sea turtles across a

69   broad range of migration distances and we develop a mechanistic understanding of the processes

70   that may drive the observed patterns of fidelity.

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73   **2 | MATERIALS AND METHODS**

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75   As part of long-term satellite tracking studies in the western Indian Ocean and NE coast of

76   Australia (Esteban, Mortimer, & Hays, 2017; Hays et al., 2014; Limpus & Limpus, 2001;

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77   Shimada, Limpus, et al., 2016), we satellite-tracked adult sea turtles from their breeding sites to

78   their foraging sites (Supporting Information Table S1 which includes details of make and model

79   of tags). In the central Indian Ocean, we equipped nesting green turtles with satellite tags on the

80   island of Diego Garcia within the Chagos Archipelago. Results presented here came from

81   deployment of Fastloc-GPS Argos tags, i.e. tags that relayed Fastloc-GPS data via the Argos

82   network. On the NE coast of Australia, across 22 years, both Fastloc-GPS Argos tags, as well as

83   Argos-only tags (i.e. tags from which Argos locations were obtained, but not Fastloc-GPS

84   locations), were deployed on green, loggerhead, hawksbill (*Eretmochelys imbricata*), and

85   flatback (*Natator depressus*) turtles on the nesting and/or foraging sites. From Fastloc-GPS

86   Argos tags, highly accurate locations are obtained, with locations generally within a few tens of

87   metres of the true position (Hazel, 2009). For tracks obtained with Argos-only tags, we used only

88   high quality locations (location classes 3, 2 and 1), which are generally within a kilometre of the

89   true location (Hoenner, Whiting, Hindell, & McMahon, 2012). We used the SDLfilter package in

90   R (R Core Team, 2019) to improve the overall accuracy of tracking data by removing temporal

91   and spatial duplicates, and suspect locations which are biologically unrealistic for each species

92   based on the travel speed and turning angle (Shimada, Jones, Limpus, Groom, & Hamann, 2016;

93   Shimada, Jones, Limpus, & Hamann, 2012).

94

95   For each track, we identified foraging sites based on the changes in speed of travel, as is done

96   routinely (Schofield et al., 2010). First, we visually identified the track segment during which a

97   turtle was clearly migrating between the foraging and breeding site, and calculated a 2-day

98   average of the migration speed at each location. Each turtle was considered to have arrived at its

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99   foraging site once the speed was below the minimum migration speed of each track. In cases

100   when turtles were originally tracked from the foraging site, they returned to the same foraging

101   sites, or in cases where tags were attached to nesting turtles, locations continued to be obtained

102   on the foraging site for >1 months until tags failed, confirming the end point of migration has

103   been identified. Similarly, a turtle was considered to have left the foraging site, on its migration

104   to breed, once the 2-day averaged speed exceeded its minimum migration speed.

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106   To quantify the extent of foraging site fidelity, we calculated the midpoint of the foraging site

107   location for dates separated by migration to breed. The mid-point of the foraging site location

108   was determined as either: (1) the mean location obtained on the foraging site, using either

109   Fastloc-GPS or Argos locations; (2) if tracking data were lacking, the mean capture location of

110   an individual. So, for some individuals we compared tracking data across dates separated by a

111   migration to breed. For example, from a single satellite tag deployment an individual was tracked

112   from its foraging site to its breeding site and back; or an individual was equipped with a satellite

113   tag while breeding in different years. In other cases, we tracked an individual from its breeding

114   site and compared the post-breeding foraging site with a previous capture location.

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116   To visually identify the home-range for turtles equipped with Fastloc-GPS tags, foraging site

117   home range was plotted as the 95% volume contour of a utilisation distribution (UD). We used a

118   movement-based kernel density estimator based on a biased random bridge (Benhamou, 2011) to

119   estimate a UD from each Fastloc GPS track. The spatial resolution was 50 m and the other

120   parameters required for UD estimation were adopted from Benhamou (2011) and Shimada et al.

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121   (2016). The R package adehabitatHR (Calenge, 2006) was used to estimate a UD and delineate

122   the 95% volume contour. We only completed this analysis with Fastloc-GPS locations, because

123   their high accuracy allows reliable estimates of overall space use to be determined (Thomson et

124   al., 2017).

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126   To assess the temporal scale of fidelity to foraging sites we examined 2001 re-sightings of turtles

127   marked with flipper tags while breeding and then re-sighted at foraging sites. The data source is

128   the Queensland Turtle Conservation Project (QTCP) database, which contains almost half a

129   million capture records from 172,661 tagged turtles, gathered across 50+ years along the NE

130   coast of Australia and neighboring countries (Queensland Environmental Protection Agency,

131   2018). Foraging site locations of flipper tagged turtles were used to document the known

132   foraging sites for each species and, in this way, we examined if turtles equipped with satellite

133   tags travelled through foraging areas used by conspecifics.

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135   In addition to the unpublished satellite tracks, we also examined the QTCP database and the

136   literature for similar datasets where adult sea turtles were recorded at their foraging sites and

137   later, either satellite-tracked from their breeding sites or recorded successively at their breeding

138   and foraging sites. We examined literature cited by the highly-cited seminal study (Broderick et

139   al., 2007), and by the subsequent 282 publications which cited the Broderick study (Google

140   Scholar - 24 July 2019). Once relevant literature were identified, we further examined the

141   references cited within. In doing so we assessed the generality, across species, of whether

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142 individuals show fidelity to previously used foraging sites. Tracks in the literature with suspect

143 premature transmitter failures were not included in this review (e.g. Luschi et al., 2013).

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146 **3 | RESULTS**

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148 We satellite-tracked a total of 27 individuals whose previously used foraging locations were

149 known (Supporting Information Table S1), one turtle in the Indian Ocean and 26 in NE Australia

150 (Supporting Information Figure S1). Individuals spanned multiple species: n = 13 green turtles, n

151 = 11 loggerhead turtles, n = 1 hawksbill turtle and n = 2 flatback turtles. In all cases we obtained

152 evidence that individuals returned to foraging sites they had used previously. For example, where

153 individuals were satellite-tracked before and after a breeding season, locations obtained at the

154 foraging sites before and after breeding were intermingled showing individuals were using

155 broadly the same area. Before and after migrations to breed, the mean distance between the mid-

156 point of the locations on the foraging site was only 7 km (n = 27, range = <1 - 25 km). This tight

157 fidelity was maintained across long migrations, with the mean distance travelled between the

158 breeding site and the foraging sites being 508 km (range = 14 - 4810 km). So tight fidelity to

159 foraging sites was always observed.

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161 Individuals from all four species often travelled through areas used by their conspecifics, and

162 returned to their home foraging site. We showcase some selected examples in Figure 1 to

163 highlight how foraging site fidelity was maintained after very long distance breeding migrations

164 and also over many years.

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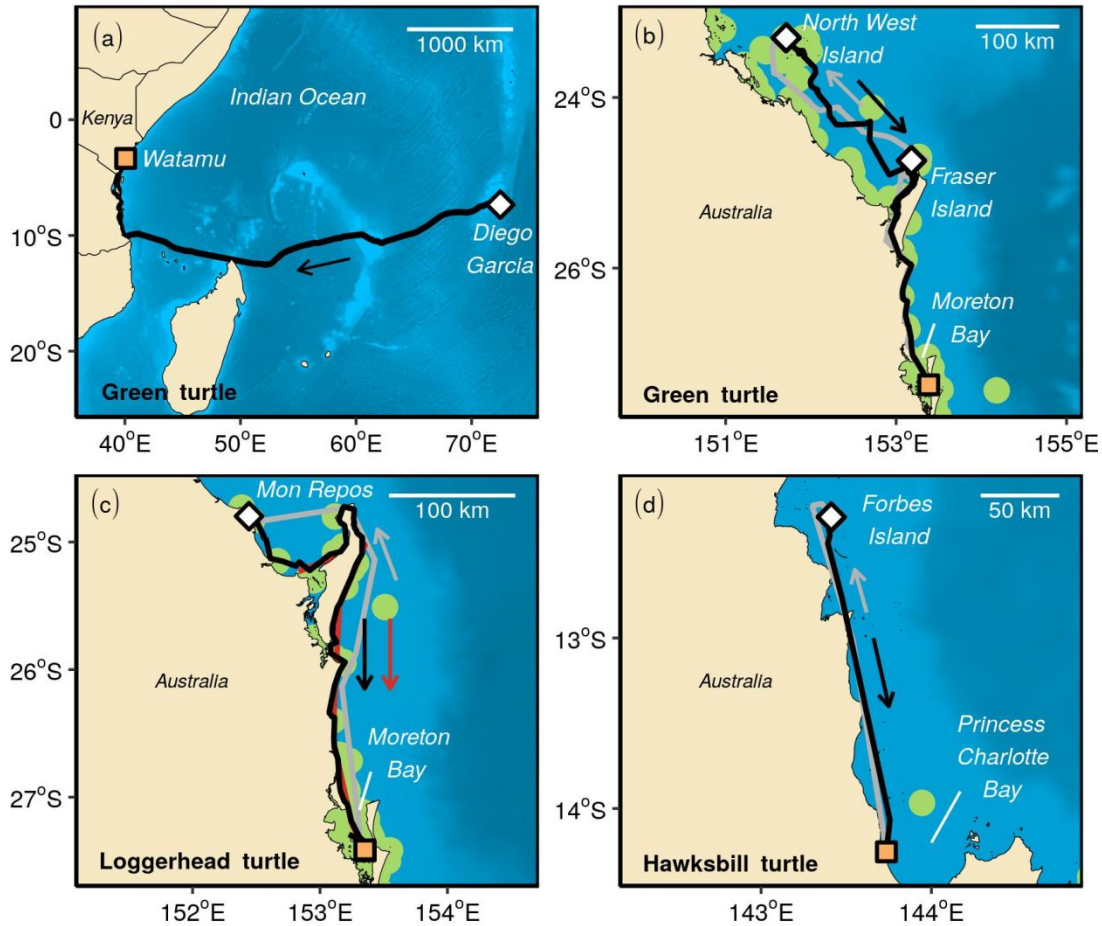
167 **FIGURE 1** Examples of satellite tracks of turtles that, after breeding, returned to previously used

168 foraging sites (orange square = flipper tagging location on foraging site; white diamond =

169 nesting site; black line = 1st migration route, red line = 2nd migration route, grey line =

170 migration route to breeding site; green circle = known foraging sites inferred from flipper tag

171 recapture of each species). (a) Post-nesting migration of a green turtle (KE0633) equipped with a

172 Fastloc-GPS satellite tag on the island of Diego Garcia in 2015 and tracked to its foraging site

173 off the coast of Watamu, Kenya, a site where it was captured 12 years prior and flipper tagged.

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174   (b) A green turtle (QA11747) captured and released with a satellite tag at the foraging site in

175   Moreton Bay, 57 days before the breeding migration in 2010. It was then tracked during

176   breeding migration to its nesting site on Fraser Island and North West Island and back to its

177   foraging site in Moreton Bay. (c) A loggerhead turtle (T14914) satellite-tracked twice in

178   different years. In 1996/1997 it was tracked from the foraging site in Moreton Bay to the Mon

179   Repos nesting beach, and back to its foraging site in Moreton Bay. It was again equipped with a

180   satellite tag on the Mon Repos nesting beach in 2010 and tracked back to its foraging site in

181   Moreton Bay until transmissions ceased in 2013. (d) A hawksbill turtle (QA40538) captured on

182   the foraging site in Princess Charlotte Bay before the breeding migration in 2014. It was satellite-

183   tracked to its nesting site on Forbes Island, and back to its foraging site.

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187   Tracking with Argos-linked Fastloc GPS tags allowed detailed foraging site home ranges used

188   across different years to be assessed and further highlighted overlap between home ranges used

189   across different years (Figure 2; Supporting Information Figure S2). For example, a loggerhead

190   turtle (T93038) was tracked during post-nesting migration in 2010 and 2012, and following each

191   migration had foraging home range centred on a coastal bay (Moreton Bay) 310 km distant from

192   the nesting beach (Mon Repos), with the home range spanning around 20 km (Figure 2a;

193   Supporting Information Figure S1v). Additionally, this turtle had been captured in 1997 within

194   its 2012 home range (Figure 2a). During these 15.5 years, it migrated to breed at least 7 times, as

195   evidenced from recapture records at the nesting beaches (Supporting Information Table S1).

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196   Another example is a flatback turtle (T20452) whose post-nesting migration was tracked twice

197   with a four-year gap in-between. In each case, the foraging home range was located to the

198   northwest of Shoalwater Bay, 270 km distant from the nesting beach (Curtis Island), with the

199   home range spanning 76 km across (Figure 2b; Supporting Information Figure S1z).

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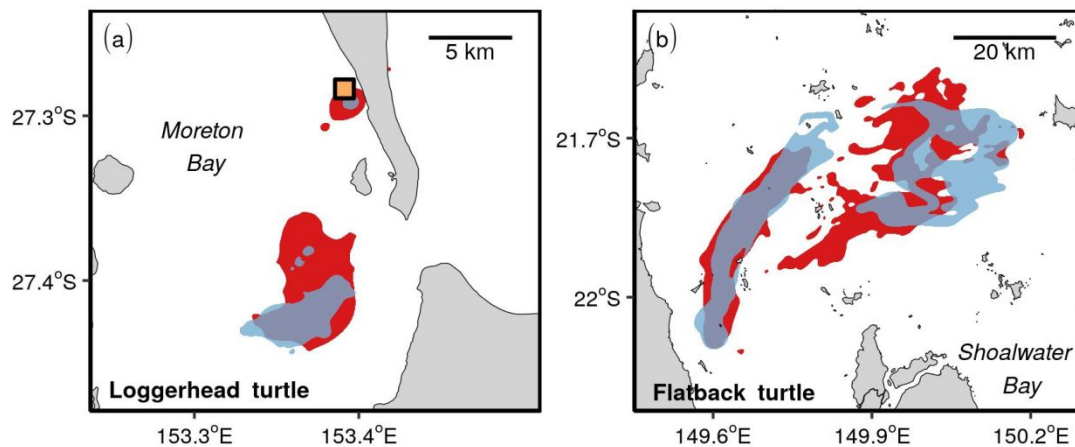
202   **FIGURE 2** Detailed patterns of space use by sea turtles who were satellite-tracked from their

203   nesting sites to their foraging sites in different years. In these examples, home ranges (95%

204   utilisation distributions - polygons) were determined from Fastloc GPS locations obtained during

205   two separate tracking occasions; 1st time = light blue, 2nd time = red. (a) A loggerhead turtle

206   (T93038) originally captured and tagged with a numbered flipper tag in 1997 (orange square)

207   and then tracked on its post-breeding foraging site for 104 days (1208 Fastloc-GPS locations

208   obtained) in 2010, and then again for 280 days (653 Fastloc-GPS locations obtained) in 2012

209   after another post-breeding migration. (b) A flatback turtle (T20452) tracked on its foraging site

210   for 544 days (1314 Fastloc-GPS locations obtained) in 2010 and then again for 39 days (212

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211   Fastloc-GPS locations obtained) in 2014 following two separate post-nesting migrations. These

212   examples show how the foraging areas used across multiple years were very similar.

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216   From the QTCP database, we obtained CMR records of 175 flipper-tagged turtles, who were

217   recorded at foraging sites up to 51 times, spanning up to 29 years, with breeding records of up to

218   6 separate breeding seasons between foraging area captures (Supporting Information Table S2).

219   These records comprised 134 green turtles (111 female, 23 male), 39 loggerhead turtles (32

220   female, 7 male), and 2 female flatback turtles. In all cases individuals returned to foraging areas

221   they had used previously. In only one case was a shift in foraging site identified. This female

222   adult loggerhead (T1276) was first flipper-tagged at its nesting beach in Mon Repos in 1989 and

223   recaptured on the foraging site of Moreton Bay in 1992. It was recorded again at the Mon Repos

224   nesting beach in 1994 and 1999 and released with a satellite tag on both occasions. Following

225   each post-breeding migration, it repeatedly settled in Hervey Bay, approximately 270 km north

226   of its previously known foraging site in Moreton Bay. The two post-nesting tracks largely

227   overlapped until transmissions ceased in 71 and 64 days respectively after the turtle had arrived

228   at the foraging site (Supporting Information Figure S3; Table S1). From the individuals listed

229   above, 28 green and 11 loggerhead turtles were originally captured as immature at foraging sites

230   in NE Australia, maintained fidelity to the respective sites throughout years of growth to

231   maturity, and continued to do so after reaching maturity and subsequent breeding migrations

232   (Supporting Information Table S2). One unique example is a loggerhead turtle (T93076) with its

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233 capture history spanning 40 years. It was originally tagged as a hatchling leaving its natal beach,

234 Mon Repos, in February 1975, recaptured as an immature female foraging and growing up on the

235 eastern banks of Moreton Bay in 1997, 1998, 2000 and 2001. At 29 years of age, it returned to its

236 natal beach during the December 2004 - January 2005 summer to breed for the first time

237 (confirmed by gonad examination), and laid 2 clutches of eggs. In April 2005 it was recaptured

238 again foraging on the eastern Banks of Moreton Bay. It returned at 39 years of age to its natal

239 beach, Mon Repos, for its second breeding season in the 2014-2015 summer during which it laid

240 3 clutches of eggs. In September 2015 it was recaptured again foraging on the eastern banks of

241 Moreton Bay, exactly the same site as it was originally captured at 18 years ago as an immature

242 turtle. This turtle is displaying fidelity to both a chosen nesting beach, which was also its natal

243 beach and to the foraging site it chose as an immature turtle and in which it grew to maturity.

244

245 From the literature we compiled 76 previously published satellite tracks of 43 individuals (some

246 were equipped with satellite tags more than once), where the post-breeding migrations were

247 documented for individuals whose foraging areas had been previously known. These examples

248 comprised 11 female loggerhead, 1 female hawksbill and 7 female kemp's ridley turtles in the

249 Caribbean (Hart, Sartain, & Fujisaki, 2015; Hawkes et al., 2012; Shaver & Rubio, 2008; Tucker,

250 MacDonald, & Seminoff, 2014); 3 female green and 11 loggerhead turtles (5 female, 6 male) in

251 the Mediterranean (Broderick et al., 2007; Casale, Freggi, Cinà, & Rocco, 2013; Mingozzi,

252 Mencacci, Cerritelli, Giunchi, & Luschi, 2016; Schofield et al., 2010); 5 female loggerhead

253 turtles in Brazil (Marcovaldi et al., 2010); 5 female loggerhead turtles in NE Australia (Limpus

254 & Limpus, 2001). In addition we considered 3 green turtles (1 female, 2 male) equipped with

255   diving loggers while at their foraging sites in Hawaii, who were tracked to the breeding site, as

256   evidenced from the logged dive data, and subsequently relocated at foraging sites and the dive

257   loggers removed (Rice & Balazs, 2008). So new and existing data all combined, a total of 243

258   individuals of five species, whose previous foraging areas were known, were satellite-tracked

259   and/or flipper-tagged across the Pacific, Atlantic, Indian Ocean, Mediterranean and Caribbean

260   Sea (Figure 3). In all cases, after breeding individuals returned to foraging areas they had used

261   previously.

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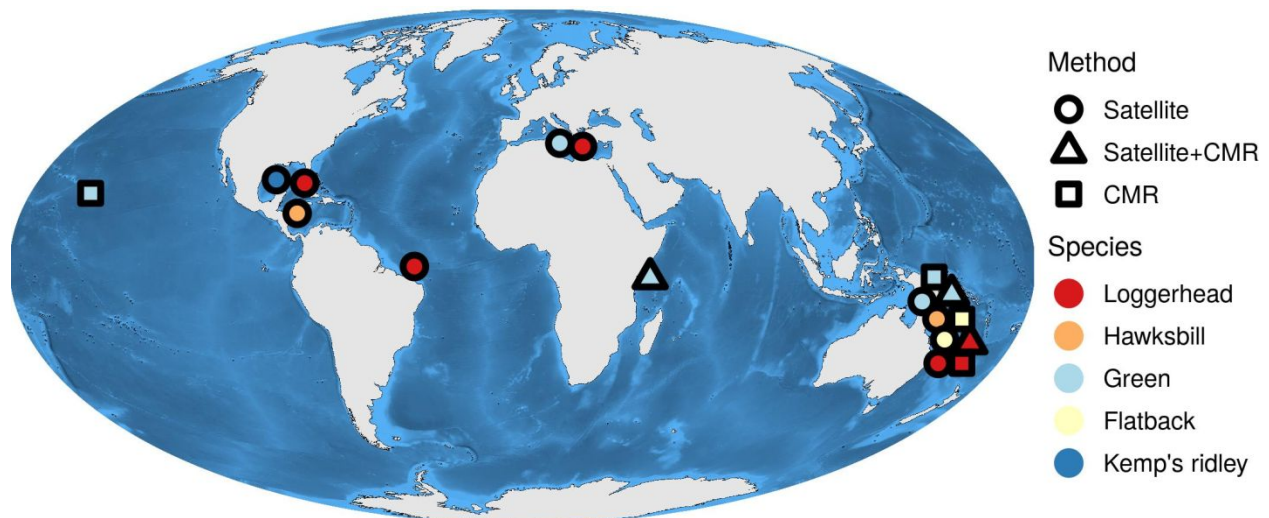
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265   **FIGURE 3** Locations around the world where adult breeding sea turtles, whose previous

266   foraging areas were known, have been equipped with electronic or flipper tags to record their

267   foraging sites after post-breeding migrations. In all cases individuals returned to foraging areas

268   they had used previously. Foraging sites were identified by entirely satellite telemetry, a

269 combination of satellite telemetry and capture-mark-recapture (CMR), or solely CMR. Species

270 are colour-coded. See text for details.

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4 | DISCUSSION

274 Key conclusions from our study are that fidelity to specific localised foraging sites following

275 migrations to breed, seems to be a common trait across several species of sea turtle; this fidelity

276 can occur after very long migrations, with some individuals travelling up to 10,000 km to-and-

277 from their breeding sites; this fidelity occurs over long-periods of up to at least 29 years; and

278 individuals often travel through areas used by conspecifics *en route* to their foraging site.

279 Foraging site fidelity after long journeys, and foregoing potential foraging sites *en route*, has also

280 been observed in other taxa such as birds and seals (Aharon-Rotman, Buchanan, Clark, Klaassen,

281 & Buttemer, 2016; Bonadonna, Lea, Dehorter, & Guinet, 2001), suggesting that the trait might

282 be driven by common selective pressures acting across taxa.

283

284 A mechanistic understanding for why taxa may show tight fidelity to localised foraging sites

285 following migration versus having a more nomadic existence, may be centred on the patterns and

286 predictability of prey resources and the risks involved in relocating to new sites. At one extreme,

287 the tight foraging site fidelity that we reported contrasts with some other marine taxa that may

288 show regional fidelity to certain broad foraging sites, but still travel extensively while foraging in

289 a nomadic way of life (Teitelbaum & Mueller, 2019). For example, some sea birds, marine

290 mammals and pelagic turtles (e.g. the leatherback, *Dermochelys coriacea*) can travel extensively

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291   outside the breeding season, foraging across broad expanses of ocean basins (Hays, Hobson,

292   Metcalfe, Righton, & Sims, 2006; James, Ottensmeyer, & Myers, 2005; McIntyre, Bester,

293   Bornemann, Tosh, & de Bruyn, 2017). In these cases, the lack of tight fidelity is presumably

294   related to the nature of their prey as well as environmental conditions, with animals wandering

295   over large areas in a semi-predictable manner to search for patchily distributed prey while also

296   being constrained by an environmental niche such as their temperature tolerances (McIntyre et

297   al., 2017; Sousa, Queiroz, Mucientes, Humphries, & Sims, 2016; Sztukowski et al., 2018;

298   Teitelbaum & Mueller, 2019). Compared to these oceanic foragers, for animals not feeding in

299   pelagic open-ocean sites, such as sea turtles foraging on the seabed in coastal areas or wading

300   birds feeding in shallow wetlands, forage quality may be more predictable. Certainly the sea

301   turtle species with demonstrated foraging site fidelity are largely benthic foragers. For example,

302   green turtles are largely herbivorous feeding on seagrasses and macroalgae, hawksbill turtles

303   tend to feed on sponges or algae in reef habitats and loggerhead turtles consume a range of

304   benthic invertebrates such as bivalve molluscs (Bjorndal, 1997). For all these benthic prey taxa,

305   there may often be relatively stable levels of abundance in particular areas, such as the

306   occurrence of sponges on particular coral reefs or seagrasses in particular seagrass meadows

307   (Diaz & Rützler, 2001; Duarte & Chiscano, 1999), contrasting to the more ephemeral, localised

308   abundance of pelagic prey resources such as plankton and fish. So, for benthic foragers, foraging

309   areas may have long-term suitability. However, the particular foraging site of some sea turtles

310   and other taxa, such as wading birds, cannot alone explain why individuals transit through areas

311   with suitable forage encountered *en route* which will incur some costs.

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313   Migrating an extra distance will first impose a metabolic cost of travelling further, for example

314   the cost of swimming for a sea turtle or flying for a bird. Second is the opportunity cost of

315   missed time spent foraging since individuals will be away from their foraging sites for longer.

316   Both of these costs may be appreciable. For example, for sea turtles the oxygen consumption has

317   been measured directly for individuals swimming in respirometry chambers, with metabolic rates

318   while swimming being up to 3-4x the resting metabolic rate (Prange, 1976). Similarly, using data

319   from acceleration loggers, Enstipp et al. (2016) estimated that the metabolic rate of migrating

320   green turtles was 3x the resting metabolic rate, equating to 2327 kJ day^{-1}. The estimated energy

321   content of a single green turtle egg has been estimated at 279.5 kJ (Hays & Scott, 2013) and the

322   mean clutch size measured at 113 eggs (Miller, 1997). So the estimated energy expenditure

323   during 13.6 days of migration, equates to the energy content of about one clutch. This model

324   does not account for opportunistic energy intake during migration that may happen in the same

325   way that turtles feed on gelatinous prey in their home foraging areas (Arthur, O'Neil, Limpus,

326   Abernathy, & Marshall, 2007). Nonetheless, this simple calculation suggests that migrating long

327   distances involves a considerable amount of energy, which may reduce reproductive output.

328   Added to this metabolic cost of swimming will be the reduction of time at foraging sites. For

329   example, if a green turtle returns to breed every 3 years, spends 8 days mating and 12 days

330   preparing the first clutch of eggs at the breeding area (i.e. 20 days), and lays 6 clutches at 12 day

331   intervals (i.e. 60 days) (Esteban et al., 2017; Miller, 1997), then in the absence of any migration,

332   individuals would be at the foraging site for (365 x 3) - (20 + 60) = 1015 days. Migrating, for

333   example, 4000 km from the foraging area to the breeding area (i.e. a round trip of 8000 km) at a

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334   speed of 50 km per day, would necessitate 80 days of travel each way, reducing the time spent on

335   at foraging sites by 15.8% to 855 days.

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337   Given these extra costs (both energy expended and reduced foraging time) of migrating long

338   distances, there are presumably important counterbalancing selective pressures underpinning the

339   long distance migrations we observed. Intriguingly those migrations involved travelling through

340   sites used by conspecifics, thus with potential suitable forage. A key benefit of foraging site

341   fidelity is that individuals will have a previous knowledge of that area and know that they can

342   survive in that area for long periods. This benefit presumably outweighs an imperfect knowledge

343   of sites encountered *en route* that may have suitable food but whose long-term quality is

344   unknown. Furthermore for these sites encountered *en route*, migrators will likely have an

345   incomplete knowledge of seasonal changes in conditions, the extent of competition with

346   conspecifics and the threat from predators, all factors that may impact an area's suitability

347   (Heithaus et al., 2007). Hence there is a risk for an individual to relocate to a new site

348   encountered during migration. In these situations, selective pressure across many sea turtle

349   species seems to have favored an individual returning to the area which had served it well

350   allowing it to survive and attain sufficient body condition to enable successful breeding. In

351   support of these ideas, when comparing migrating wading birds that end their migration early

352   compared to those that forgo foraging areas *en route* and travel further, individuals migrating

353   further have been shown to have lower levels of stress biomarkers and higher feeding rates

354   (Aharon-Rotman et al., 2016).

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356   While there are clearly substantial benefits for sea turtles and other taxa to travel long distances

357   to previously used localised foraging sites, occasionally the foraging conditions will degrade, for

358   example due to environmental perturbations such as heatwaves (Arias-Ortiz et al., 2018). In

359   these situations, relocation to a new foraging site, even if the knowledge of that new site is

360   imperfect, may be a better decision rather than remaining in place and risking reduced breeding

361   rates or possibly dying. One example that fits to this theory is the loggerhead turtle that appears

362   to have moved its foraging site temporarily from Hervey Bay to Moreton Bay, sites

363   approximately 270 km, when two floods and a tropical cyclone caused a loss of >1000 km^2 of

364   benthic habitat in Hervey Bay followed by an elevated number of stranded sea turtles (green,

365   loggerhead, flatback) and dugongs (Preen & Marsh, 1995; Preen, Lee Long, & Coles, 1995;

366   Supporting Information Figure S5). However, notwithstanding this particular case, the decision

367   to "move or face death" was very rare in both our study and others. Rather than relocating, a

368   turtle may usually simply endure temporary degradation of its foraging site aided by its low

369   ectothermic metabolic rate which ensure long fasting endurance and slow use of stored fat

370   reserves (Hays, Broderick, Glen, & Godley, 2002). The same strategy of fasting is less likely for

371   endotherms as their higher metabolic rate means they have much shorter fasting endurance than

372   an equivalent sized ectotherm and indeed, breakdowns in fidelity to foraging sites has been noted

373   in marine mammals and birds (Dias et al., 2010; Knox, Baylis, & Arnould, 2018). While

374   foraging site fidelity in sea turtles will limit the flexibility of individuals to colonise new areas,

375   the dispersal of the young from a single genetic stock to multiple widely scattered foraging areas,

376   for example driven by variable ocean currents (Hays, Fossette, Katselidis, Mariani, & Schofield,

377   2010) has the potential to ensure that populations can respond to spatially and temporally

378 changing availability of food resources and survival probabilities, for example driven by climate

379 change.

380

381 In conclusion, we show here that tight fidelity to foraging sites occurs after long (sometimes

382 >1000 km) breeding migrations for a range of sea turtle species that feed in coastal areas. This is

383 presumably linked to imprinting on an area where the individual has a substantial knowledge and

384 survived for a long period, versus moving to risky alternate sites where an individual's

385 knowledge is much less complete.

386

387

388 **5 | ETHICS**

389 This research was conducted following all applicable guidelines for the care and use of animals

390 approved by the Ethics Committee of the Queensland Department of Environment and Science

391 (DES), James Cook University, Swansea University and Deakin University.

392

400 funded by DES, Gladstone Port Corporation, Sea World, Healthy Waterways, and Bundaberg

401 Brewed Drinks.

402

403 **CONFLICT OF INTEREST**

404 The authors declare no conflicts of interest.

405

406 **AUTHOR CONTRIBUTIONS**

407 G.C.H. conceived the study with T.S. T.S. and G.C.H. analysed the data and wrote the paper

408 with input from all authors building on life history concepts previously developed by C.L. from

409 extensive flipper tag recovery data. C.L., M.H. & I.B. led the data collection in NE Australia

410 with T.S. and R.G. G.C.H. and NE conducted the Indian Ocean fieldwork.

411

412

413 **DATA ACCESSIBILITY**

414 Tracking data are archived on www.movebank.org. Request for data should be addressed to

415 t.shimada@aims.gov.au.

416

417

418 **REFERENCES**

Aharon-Rotman, Y., Buchanan, K. L., Clark, N. J., Klaassen, M., & Buttemer, W. A. (2016). Why fly the
extra mile? Using stress biomarkers to assess wintering habitat quality in migratory shorebirds.
Oecologia, *182*(2), 385–395. doi: 10.1007/s00442-016-3679-1

Alerstam, T., Hedenström, A., & Åkesson, S. (2003). Long-distance migration: evolution and

21

determinants. *Oikos*, *103*(2), 247–260. doi: 10.1034/j.1600-0706.2003.12559.x

Arias-Ortiz, A., Serrano, O., Masqué, P., Lavery, P. S., Mueller, U., Kendrick, G. A., … Duarte, C. M. (2018). A marine heatwave drives massive losses from the world's largest seagrass carbon stocks. *Nature Climate Change*, *8*(4), 338. doi: 10.1038/s41558-018-0096-y

Arthur, K. E., O'Neil, J. M., Limpus, C. J., Abernathy, K., & Marshall, G. (2007). Using animal-borne imaging to assess green turtle (*Chelonia mydas*) foraging ecology in Moreton Bay, Australia. *Marine Technology Society Journal*, *41*(4), 9–13. doi: 10.4031/002533207787441953

Benhamou, S. (2011). Dynamic approach to space and habitat use based on biased random bridges. *PLoS ONE*, *6*(1), e14592–e14592. doi: 10.1371/journal.pone.0014592

Bett, N. N., & Hinch, S. G. (2016). Olfactory navigation during spawning migrations: a review and introduction of the Hierarchical Navigation Hypothesis. *Biological Reviews*, *91*(3), 728–759. doi: 10.1111/brv.12191

Bjorndal, K. A. (1997). Foraging ecology and nutrition of sea turtles. In P. L. Lutz & J. A. Musick (Eds.), *The biology of sea turtles*: *Vol. I* (pp. 199–231). doi: 10.1201/9780203737088

Bonadonna, F., Lea, M.-A., Dehorter, O., & Guinet, C. (2001). Foraging ground fidelity and route-choice tactics of a marine predator: the Antarctic fur seal *Arctocephalus gazella*. *Marine Ecology Progress Series*, *223*, 287–297. doi: 10.3354/meps223287

Broderick, A. C., Coyne, M. S., Fuller, W. J., Glen, F., & Godley, B. J. (2007). Fidelity and over-wintering of sea turtles. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1617), 1533–1539. doi: 10.1098/rspb.2007.0211

Calenge, C. (2006). The package "adehabitat" for the R software: A tool for the analysis of space and habitat use by animals. *Ecological Modelling*, *197*(3–4), 516–519. doi: 10.1016/j.ecolmodel.2006.03.017

Casale, P., Freggi, D., Cinà, A., & Rocco, M. (2013). Spatio-temporal distribution and migration of adult male loggerhead sea turtles (*Caretta caretta*) in the Mediterranean Sea: further evidence of the

importance of neritic habitats off North Africa. *Marine Biology*, *160*(3), 703–718. doi: 10.1007/s00227-012-2125-0

Clay, T. A., Phillips, R. A., Manica, A., Jackson, H. A., & Brooke, M. de L. (2017). Escaping the oligotrophic gyre? The year-round movements, foraging behaviour and habitat preferences of Murphy's petrels. *Marine Ecology Progress Series*, *579*, 139–155. doi: 10.3354/meps12244

Dias, M. P., Granadeiro, J. P., Phillips, R. A., Hany, A., & Paulo, C. (2010). Breaking the routine: individual Cory's shearwaters shift winter destinations between hemispheres and across ocean basins. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1713), 1786–1793. doi: 10.1098/rspb.2010.2114

Diaz, M. C., & Rützler, K. (2001). Sponges: An essential component of Caribbean coral reefs. *Bulletin of Marine Science*, *69*(2), 535–549.

Duarte, C. M., & Chiscano, C. L. (1999). Seagrass biomass and production: a reassessment. *Aquatic Botany*, *65*(1), 159–174. doi: 10.1016/S0304-3770(99)00038-8

Enstipp, M. R., Ballorain, K., Ciccione, S., Narazaki, T., Sato, K., & Georges, J.-Y. (2016). Energy expenditure of adult green turtles (*Chelonia mydas*) at their foraging grounds and during simulated oceanic migration. *Functional Ecology*, *30*(11), 1810–1825. doi: 10.1111/1365-2435.12667

Esteban, N., Mortimer, J. A., & Hays, G. C. (2017). How numbers of nesting sea turtles can be overestimated by nearly a factor of two. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1849). doi: 10.1098/rspb.2016.2581

Hart, K. M., Sartain, A. R., & Fujisaki, I. (2015). Bahamas connection: residence areas selected by breeding female loggerheads tagged in Dry Tortugas National Park, USA. *Animal Biotelemetry*, *3*(1). doi: 10.1186/s40317-014-0019-2

Hawkes, L. A., Tomás, J., Revuelta, O., León, Y. M., Blumenthal, J. M., Broderick, A. C., … Godley, B. J. (2012). Migratory patterns in hawksbill turtles described by satellite tracking. *Marine Ecology*

23

Progress Series, *461*, 223–232. doi: 10.3354/meps09778

Hays, G. C., Broderick, A. C., Glen, F., & Godley, B. J. (2002). Change in body mass associated with long-term fasting in a marine reptile: the case of green turtles (*Chelonia mydas*) at Ascension Island. *Canadian Journal of Zoology*, *80*(7), 1299–1302. doi: 10.1139/z02-110

Hays, G. C., Ferreira, L. C., Sequeira, A. M. M., Meekan, M. G., Duarte, C. M., Bailey, H., … Thums, M. (2016). Key questions in marine megafauna movement ecology. *Trends in Ecology & Evolution*, *31*(6), 463–475. doi: 10.1016/j.tree.2016.02.015

Hays, G. C., Fossette, S., Katselidis, K. A., Mariani, P., & Schofield, G. (2010). Ontogenetic development of migration: Lagrangian drift trajectories suggest a new paradigm for sea turtles. *Journal of the Royal Society Interface*, *7*(50), 1319–1327. doi: 10.1098/rsif.2010.0009

Hays, G. C., Hobson, V. J., Metcalfe, J. D., Righton, D., & Sims, D. W. (2006). Flexible foraging movements of leatherback turtles across the north Atlantic Ocean. *Ecology*, *87*(10), 2647–2656. doi: 10.1890/0012-9658(2006)87[2647:FFMOLT]2.0.CO;2

Hays, G. C., Mortimer, J. A., Ierodiaconou, D., & Esteban, N. (2014). Use of long-distance migration patterns of an endangered species to inform conservation planning for the world's largest marine protected area. *Conservation Biology*, *28*(6), 1636–1644. doi: 10.1111/cobi.12325

Hays, G. C., & Scott, R. (2013). Global patterns for upper ceilings on migration distance in sea turtles and comparisons with fish, birds and mammals. *Functional Ecology*, *27*(3), 748–756. doi: 10.1111/1365-2435.12073

Hazel, J. (2009). Evaluation of fast-acquisition GPS in stationary tests and fine-scale tracking of green turtles. *Journal of Experimental Marine Biology and Ecology*, *374*(1), 58–68. doi: 10.1016/j.jembe.2009.04.009

Heithaus, M. R., Frid, A., Wirsing, A. J., Dill, L. M., Fourqurean, J. W., Burkholder, D., … BejderO, L. (2007). State-dependent risk-taking by green sea turtles mediates top-down effects of tiger shark intimidation in a marine ecosystem. *Journal of Animal Ecology*, *76*(5), 837–844. doi:

10.1111/j.1365-2656.2007.01260.x

Hoenner, X., Whiting, S. D., Hindell, M. A., & McMahon, C. R. (2012). Enhancing the use of argos satellite data for home range and long distance migration studies of marine animals. *PloS One*, *7*(7), e40713–e40713. doi: 10.1371/journal.pone.0040713

James, M. C., Ottensmeyer, C. A., & Myers, R. A. (2005). Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. *Ecology Letters*, *8*(2), 195–201. doi: 10.1111/j.1461-0248.2004.00710.x

Jensen, M. P., FitzSimmons, N. N., & Dutton, P. H. (2013). Molecular genetics of sea turtles. In J. Wyneken, K. J. Lohmann, & J. A. Musick (Eds.), *The biology of sea turtles*: *Vol. III* (1st ed., pp. 135–161). Boca Raton, FL: CRC Press.

Knox, T. C., Baylis, A. M. M., & Arnould, J. P. Y. (2018). Foraging site fidelity in male Australian fur seals. *Marine Biology*, *165*(7), 108. doi: 10.1007/s00227-018-3368-1

Limpus, C. J., & Limpus, D. J. (2001). The loggerhead turtle, *Caretta caretta*, in Queensland: breeding migrations and fidelity to a warm temperate feeding area. *Chelonian Conservation and Biology*, *4*(1), 142–153.

Limpus, C. J., Miller, J. D., Parmenter, C. J., Reimer, D., Mclachlan, N., & Webb, R. (1992). Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles to and from eastern Australian rookeries. *Wildlife Research*, *19*(3), 347–358. doi: 10.1071/WR9920347

Luschi, P., Mencacci, R., Vallini, C., Ligas, A., Lambardi, P., & Benvenuti, S. (2013). Long-term tracking of adult loggerhead turtles (*Caretta caretta*) in the Mediterranean Sea. *Journal of Herpetology*, *47*(2), 227–231. doi: 10.1670/11-173

Marcovaldi, M. Â., Lopez, G. G., Soares, L. S., Lima, E., Thomé, J. C. A., & Almeida, A. P. (2010). Satellite-tracking of female loggerhead turtles highlights fidelity behavior in northeastern Brazil. *Endangered Species Research*, *12*(3), 263–272. doi: 10.3354/esr00308

McIntyre, T., Bester, M. N., Bornemann, H., Tosh, C. A., & de Bruyn, P. J. N. (2017). Slow to change?

25

Individual fidelity to three-dimensional foraging habitats in southern elephant seals, *Mirounga leonina*. *Animal Behaviour*, *127*, 91–99. doi: 10.1016/j.anbehav.2017.03.006

Miller, J. D. (1997). Reproduction in sea turtles. In P. L. Lutz & J. A. Musick (Eds.), *The biology of sea turtles*: *Vol. I* (pp. 51–81). Florida: CRC Press.

Mingozzi, T., Mencacci, R., Cerritelli, G., Giunchi, D., & Luschi, P. (2016). Living between widely separated areas: Long-term monitoring of Mediterranean loggerhead turtles sheds light on cryptic aspects of females spatial ecology. *Journal of Experimental Marine Biology and Ecology*, *485*, 8–17. doi: 10.1016/j.jembe.2016.08.007

Oudman, T., Piersma, T., Ahmedou Salem, M. V., Feis, M. E., Dekinga, A., Holthuijsen, S., … Bijleveld, A. I. (2018). Resource landscapes explain contrasting patterns of aggregation and site fidelity by red knots at two wintering sites. *Movement Ecology*, *6*(1), 24. doi: 10.1186/s40462-018-0142-4

Prange, H. D. (1976). Energetics of swimming of a sea turtle. *Journal of Experimental Biology*, *64*(1), 1–12.

Preen, A., & Marsh, H. (1995). Response of dugongs to large-scale loss of seagrass from Hervey Bay, Queensland Australia. *Wildlife Research*, *22*(4), 507–519. doi: 10.1071/WR9950507

Preen, A. R., Lee Long, W. J., & Coles, R. G. (1995). Flood and cyclone related loss, and partial recovery, of more than 1000 km^2 of seagrass in Hervey Bay, Queensland, Australia. *Aquatic Botany*, *52*(1), 3–17. doi: 10.1016/0304-3770(95)00491-H

Queensland Environmental Protection Agency. (2018). *Queensland Turtle Conservation Project database*.

R Core Team. (2019). R: a language and environment for statistical computing (Version v. 3.5.3). Retrieved from https://www.r-project.org

Rice, M. R., & Balazs, G. H. (2008). Diving behavior of the Hawaiian green turtle (*Chelonia mydas*) during oceanic migrations. *Journal of Experimental Marine Biology and Ecology*, *356*(1–2), 121–127. doi: 10.1016/j.jembe.2007.12.010

Schofield, G., Hobson, V. J., Fossette, S., Lilley, M. K. S., Katselidis, K. A., & Hays, G. C. (2010). Fidelity to foraging sites, consistency of migration routes and habitat modulation of home range by sea turtles. *Diversity and Distributions*, *16*(5), 840–853. doi: 10.1111/j.1472-4642.2010.00694.x

Shaver, D. J., & Rubio, C. (2008). Post-nesting movement of wild and head-started Kemp's ridley sea turtles *Lepidochelys kempii* in the Gulf of Mexico. *Endangered Species Research*, *4*(1–2), 43–55. doi: 10.3354/esr00061

Shimada, T., Jones, R., Limpus, C., Groom, R., & Hamann, M. (2016). Long-term and seasonal patterns of sea turtle home ranges in warm coastal foraging habitats: Implications for conservation. *Marine Ecology Progress Series*, *562*, 163–179. doi: 10.3354/meps11972

Shimada, T., Jones, R., Limpus, C., & Hamann, M. (2012). Improving data retention and home range estimates by data-driven screening. *Marine Ecology Progress Series*, *457*, 171–180. doi: 10.3354/meps09747

Shimada, T., Limpus, C., Jones, R., Hazel, J., Groom, R., & Hamann, M. (2016). Sea turtles return home after intentional displacement from coastal foraging areas. *Marine Biology*, *163*(1), 8. doi: 10.1007/s00227-015-2771-0

Sousa, L. L., Queiroz, N., Mucientes, G., Humphries, N. E., & Sims, D. W. (2016). Environmental influence on the seasonal movements of satellite-tracked ocean sunfish *Mola mola* in the north-east Atlantic. *Animal Biotelemetry*, *4*(7). doi: 10.1186/s40317-016-0099-2

Sztukowski, L. A., Cotton, P. A., Weimerskirch, H., Thompson, D. R., Torres, L. G., Sagar, P. M., … Votier, S. C. (2018). Sex differences in individual foraging site fidelity of Campbell albatross. *Marine Ecology Progress Series*, *601*, 227–238. doi: 10.3354/meps12684

Teitelbaum, C. S., & Mueller, T. (2019). Beyond migration: causes and consequences of nomadic animal movements. *Trends in Ecology & Evolution*. doi: 10.1016/j.tree.2019.02.005

Thomson, J. A., Börger, L., Christianen, M. J. A., Esteban, N., Laloë, J.-O., & Hays, G. C. (2017).

27

Implications of location accuracy and data volume for home range estimation and fine-scale movement analysis: comparing Argos and Fastloc-GPS tracking data. *Marine Biology*, *164*(10), 204. doi: 10.1007/s00227-017-3225-7

Tucker, A. D., MacDonald, B. D., & Seminoff, J. A. (2014). Foraging site fidelity and stable isotope values of loggerhead turtles tracked in the Gulf of Mexico and northwest Caribbean. *Marine Ecology Progress Series*, *502*, 267–279. doi: 10.3354/meps10655

Vardanis, Y., Nilsson, J.-Å., Klaassen, R. H. G., Strandberg, R., & Alerstam, T. (2016). Consistency in long-distance bird migration: contrasting patterns in time and space for two raptors. *Animal Behaviour*, *113*, 177–187. doi: 10.1016/j.anbehav.2015.12.014

(a) Indian Ocean — Kenya, Watamu, Diego Garcia. Scale 1000 km. Green turtle.

(b) Australia — North West Island, Fraser Island, Moreton Bay. Scale 100 km. Green turtle.

(c) Australia — Mon Repos, Moreton Bay. Scale 100 km. Loggerhead turtle.

(d) Australia — Forbes Island, Princess Charlotte Bay. Scale 50 km. Hawksbill turtle.
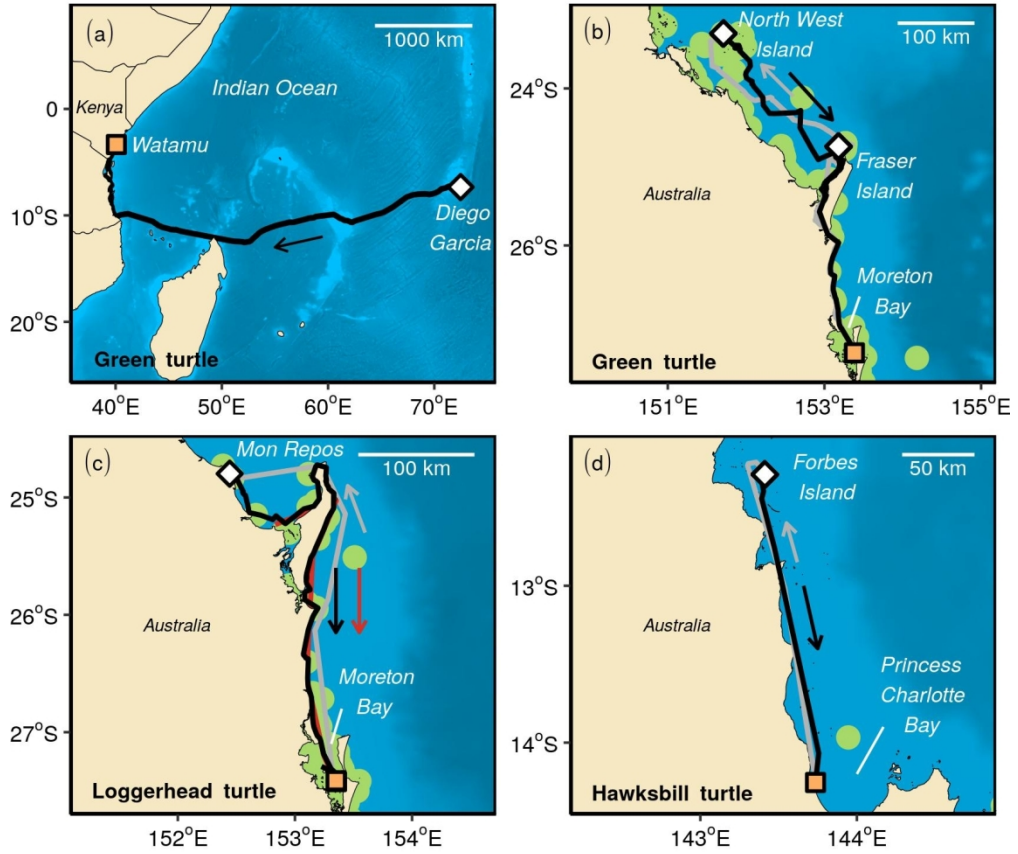
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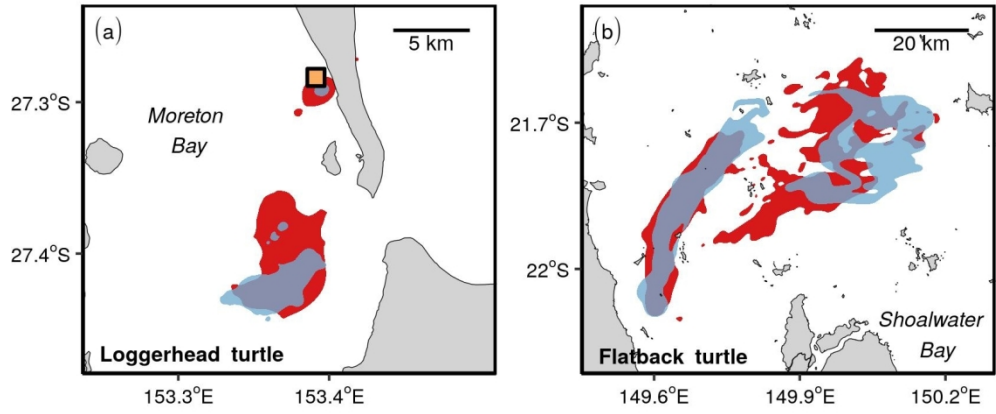
143x63mm (300 x 300 DPI)
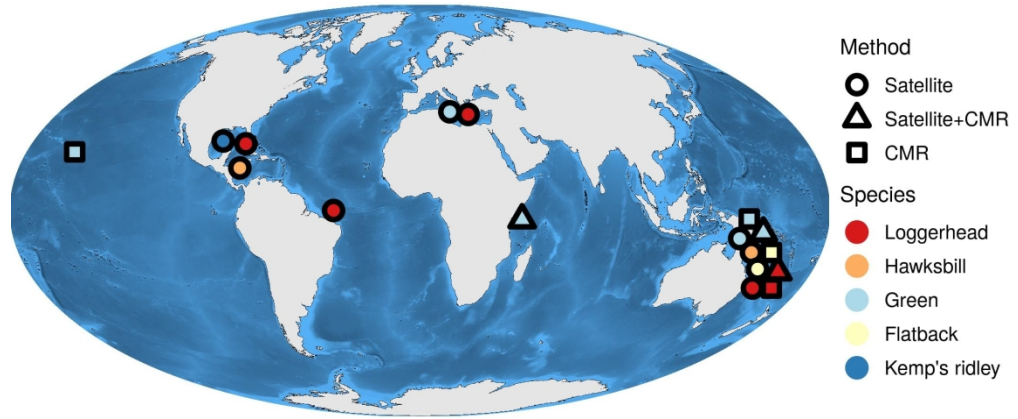
179x74mm (300 x 300 DPI)

Supporting Information

Fidelity to foraging sites after long migrations

Takahiro Shimada, Colin Limpus, Mark Hamman, Ian Bell, Nicole Esteban, Rachel Groom, Graeme C. Hays

CONTENTS
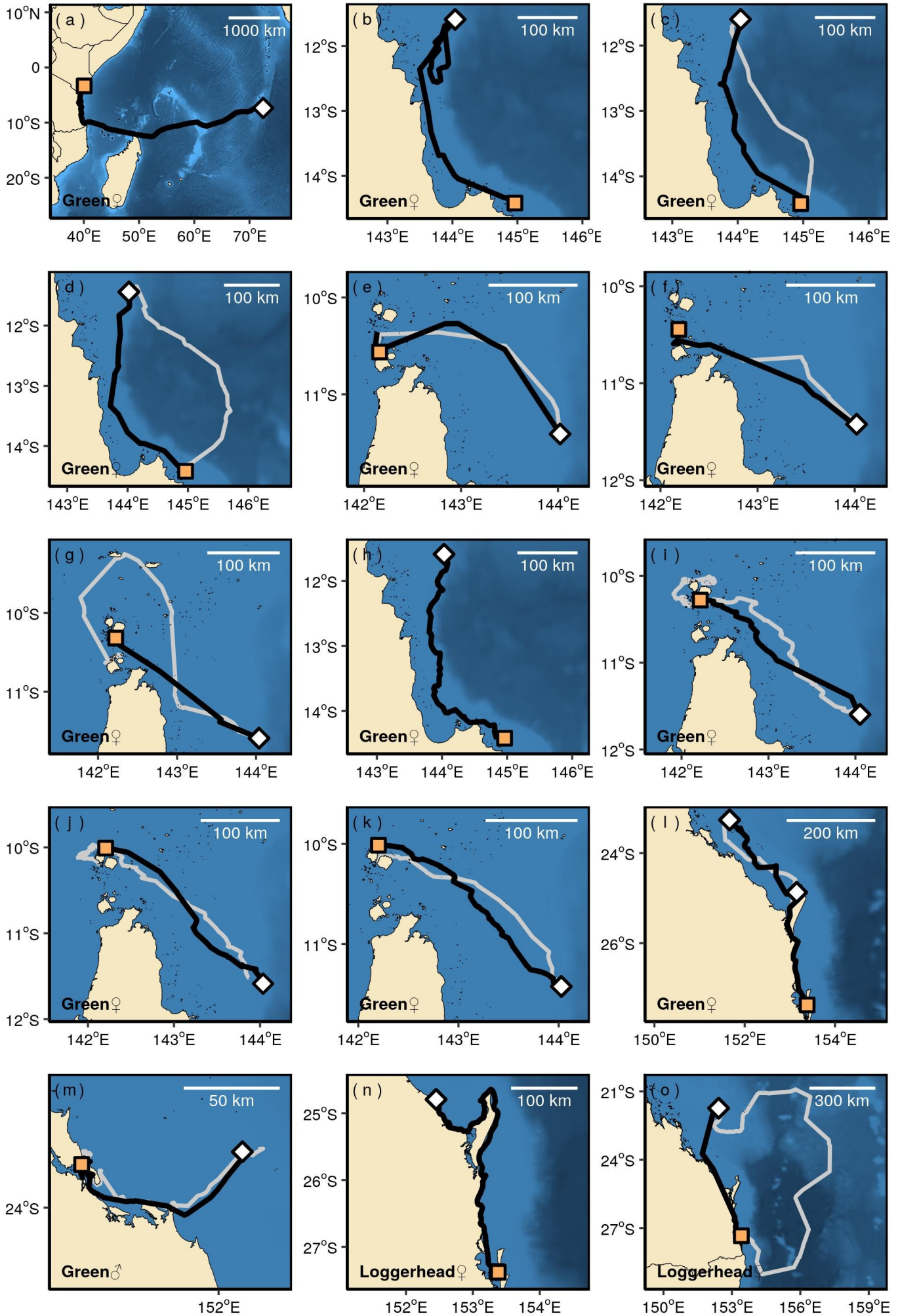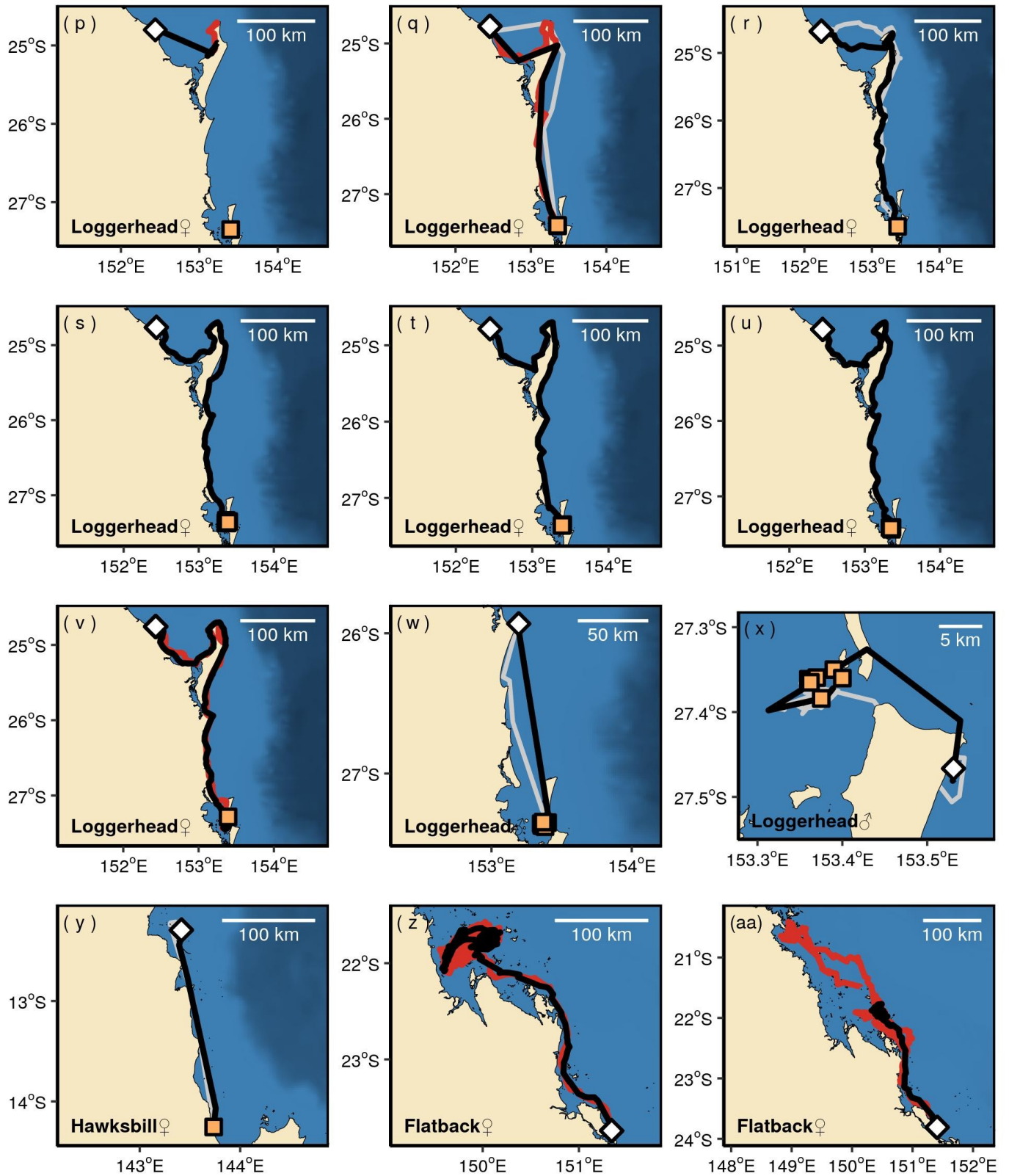
Figure S1 Satellite tracks of 27 turtles showing post-breeding migrations to previously used foraging sites (black line = 1st time, red line = 2nd time). For turtles tracked from the foraging grounds, the migration paths to the breeding grounds are also shown (grey line). The symbols denote the nesting beach (white diamond) and the previous capture on foraging site (orange square). The letter of each panel facilitates cross-reference to the data in Table S1.
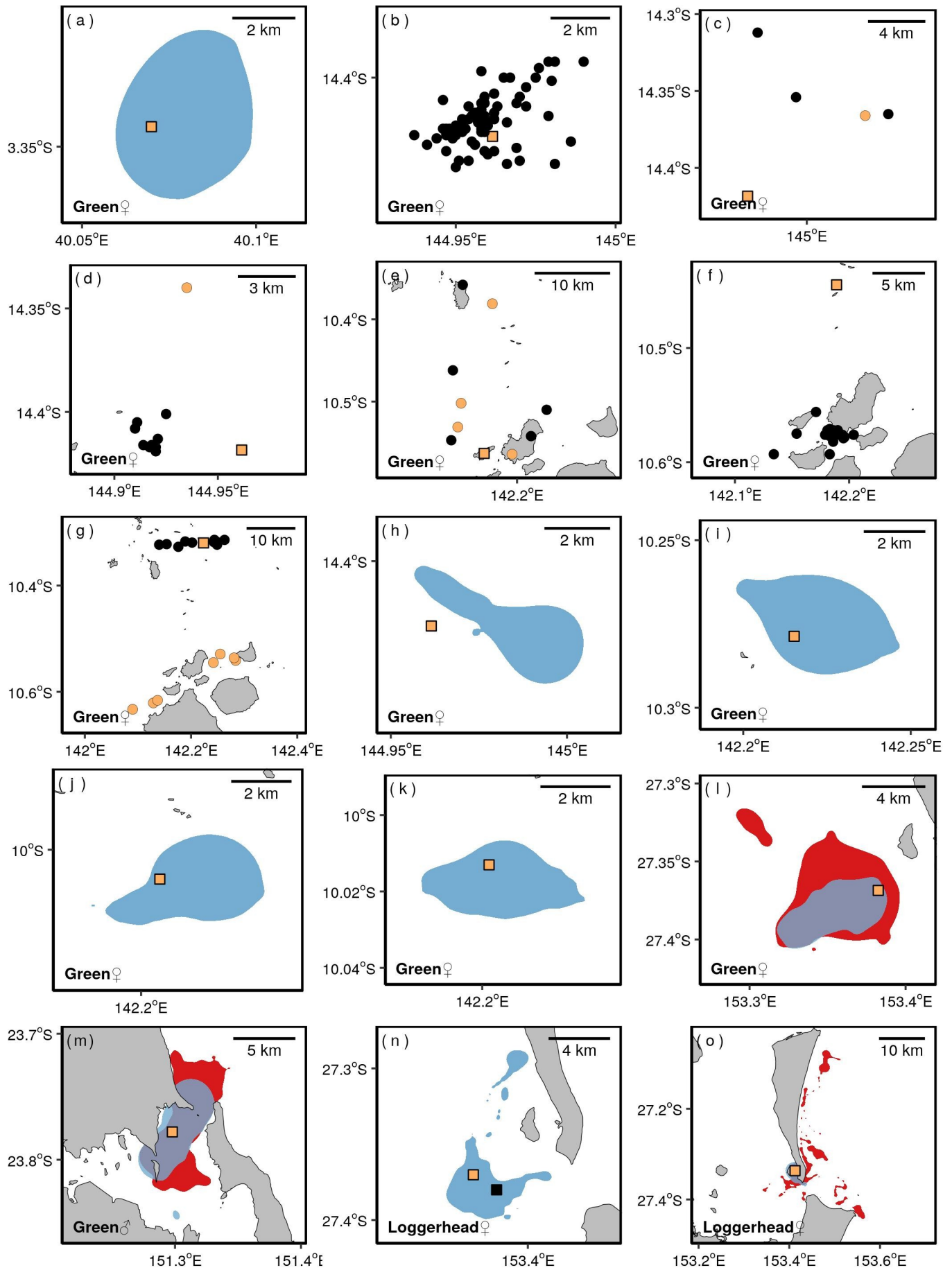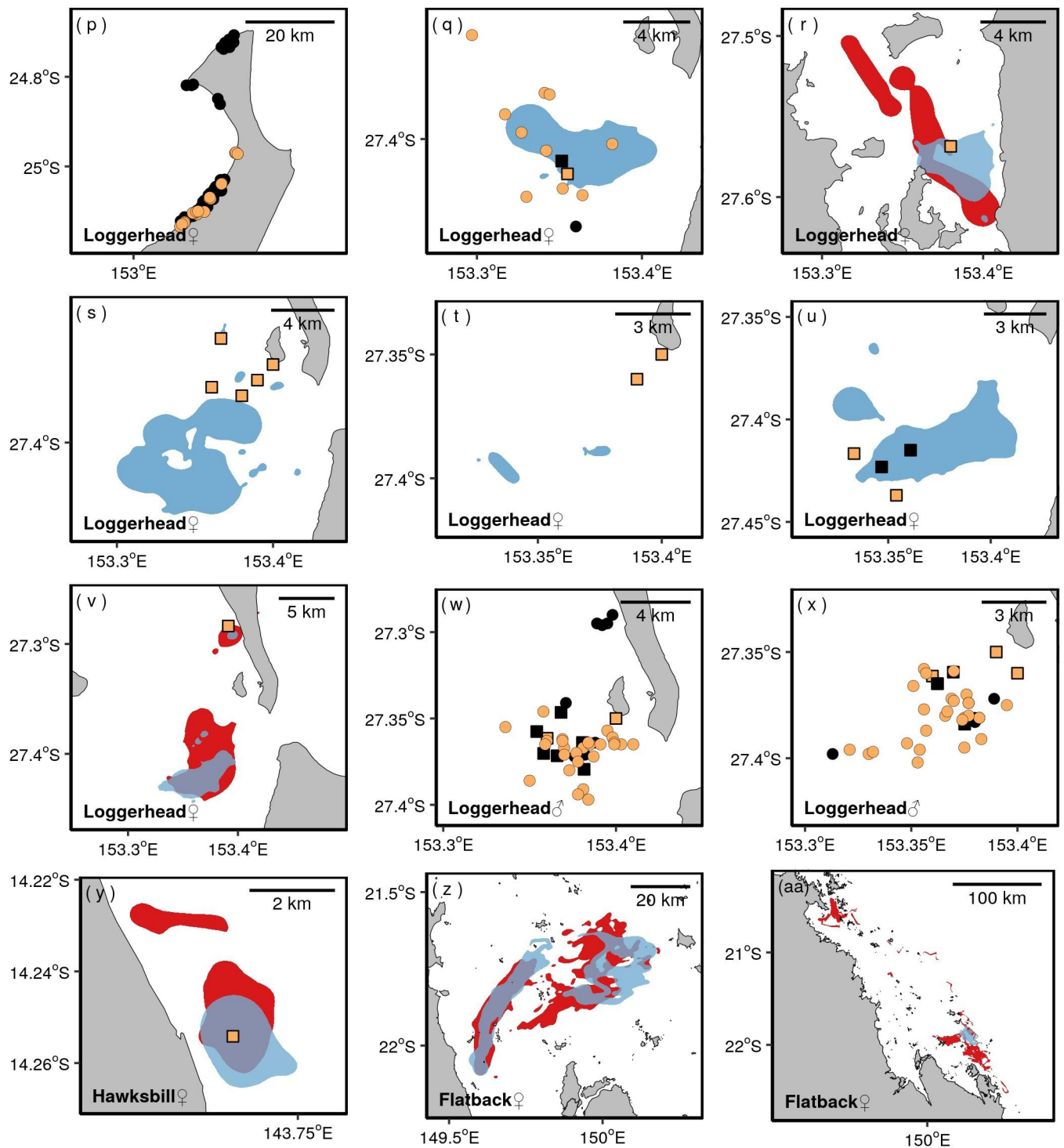
Figure S2 Detailed patterns of space use by 27 sea turtles satellite-tracked to their foraging grounds across years separated by breeding migrations. Home ranges (95% utilisation distributions - polygons) were determined from Fastloc-GPS locations obtained during each tracking occasion; 1st time = light blue, 2nd time = red. For turtles tracked with Argos-only tags, high quality fixes (location classes 3, 2, 1 - circles) show their locations before (yellow) and after (black) a breeding migration. Squares denote capture locations before (yellow) and after (black) a breeding migration. The letter of each panel facilitates cross-reference to the data in Table S1. We compared the midpoint of the space used in different years. See main text Methods for details. In one of the 27 cases (Figure S2aa), during the second tracking occasion this flatback turtle used two distant foraging sites >100km apart. In this case, to calculate the midpoint of the foraging site, we used the first aggregation of foraging locations prior to its departure to the distant foraging site.
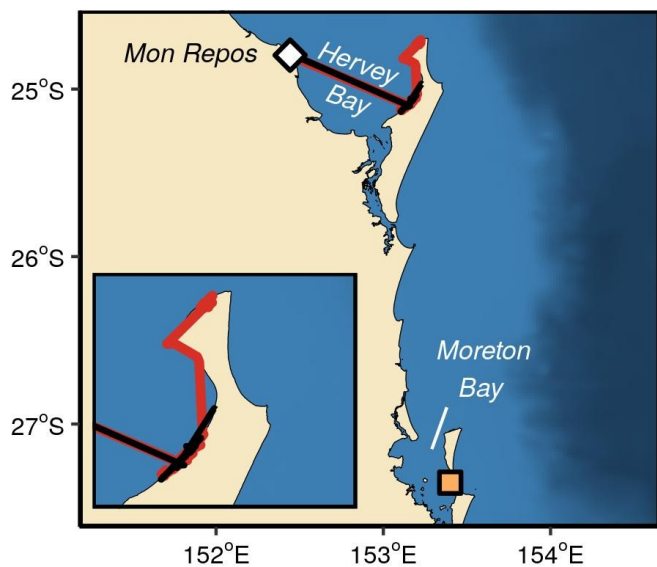
Figure S3 A rare example where a sea turtle shifted its foraging habitats as an adult. This female loggerhead turtle (T1276) was first flipper-tagged at its nesting beach in Mon Repos (white diamond), captured two years later in the Moreton Bay foraging grounds (orange square), and equipped with a satellite tag when it reappeared in Mon Repos to nest 2 and 6 years later (black and red lines respectively). The two separate post-breeding satellite tracks confirmed its residency on the foraging grounds in Hervey Bay, approximately 270 km from the previous capture on the Moreton Bay foraging grounds.

Green turtle (*Chelonia mydas*)

Loggerhead turtle (*Caretta caretta*)

Flatback turtle (*Natator depressus*)
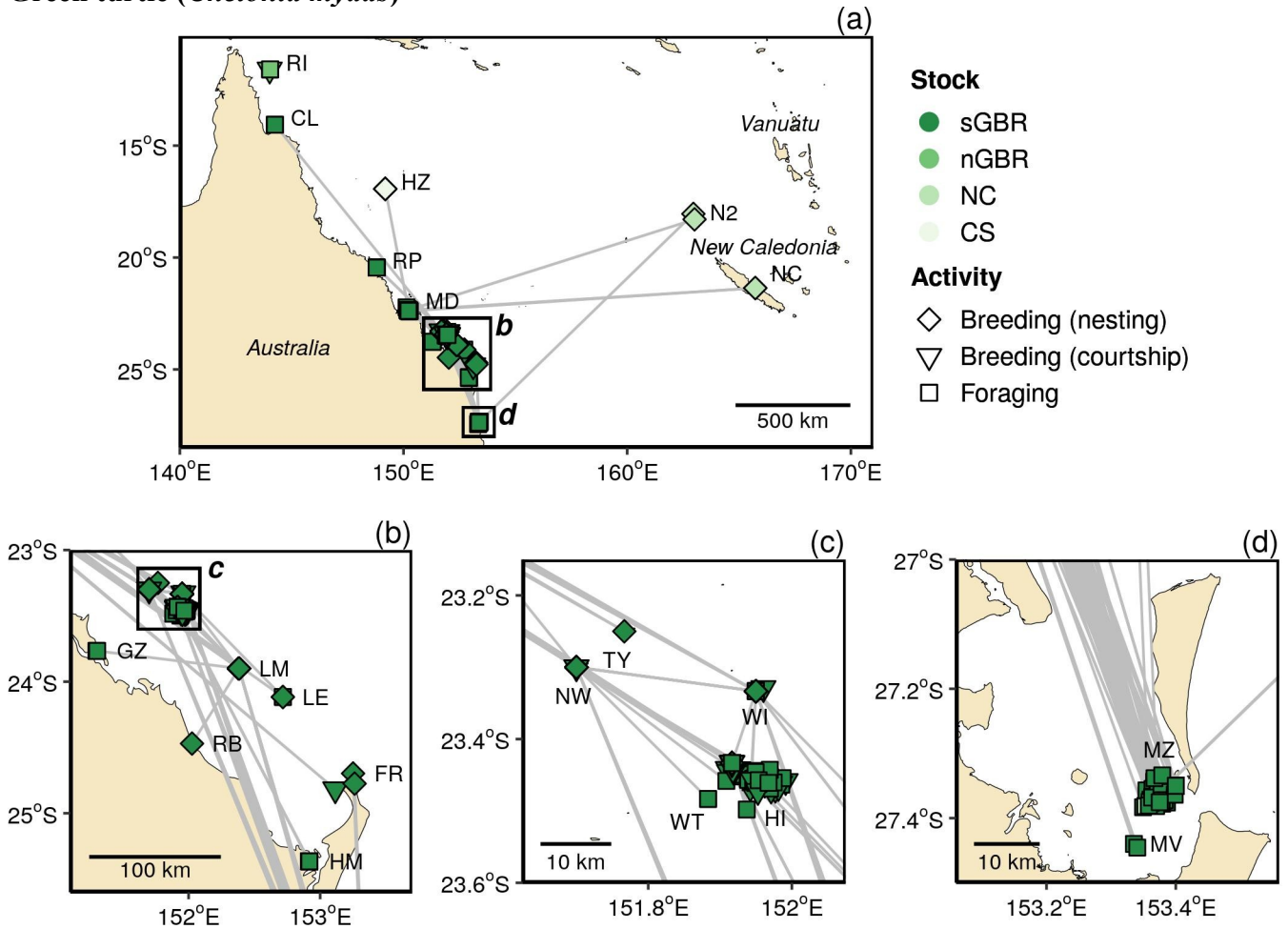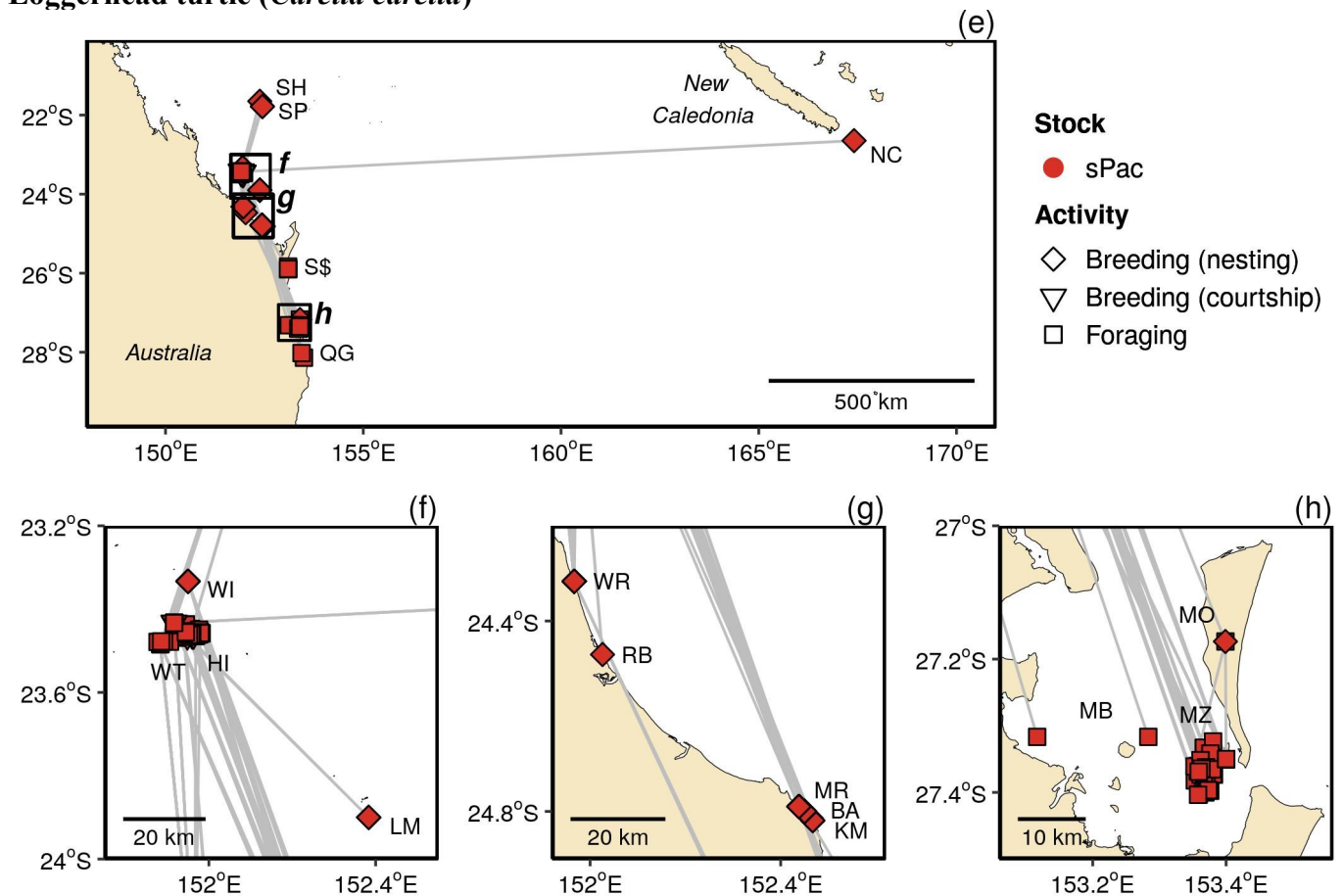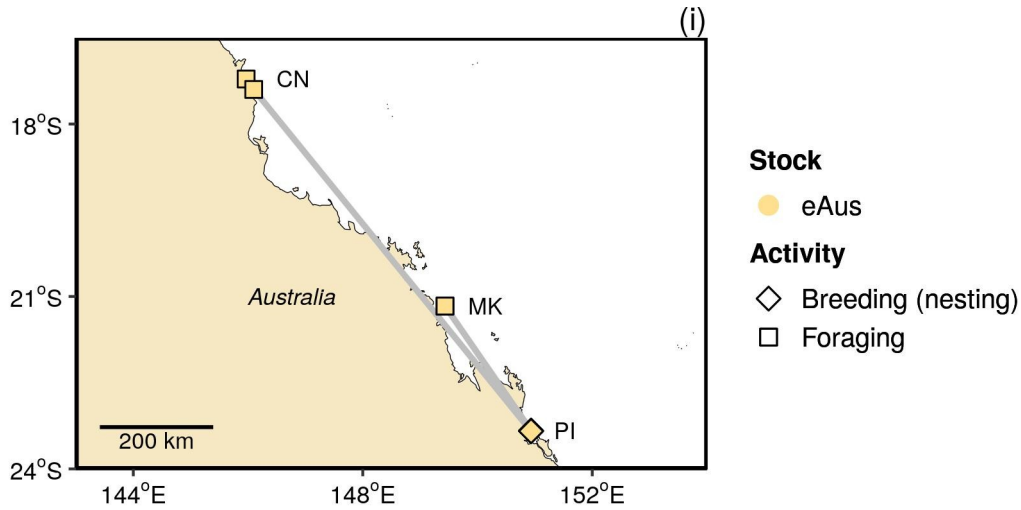
Figure S4 Flipper-tagged turtles (n = 175) showing post-breeding migrations to previously used foraging sites. (a-d) green turtles, (e-h) loggerhead turtles, (i) flatback turtles. Each point is a capture location on the nesting (diamond), courtship (reverse triangle) or foraging site (square). The lines connect at least three capture locations for each turtle from the foraging to the breeding site and back to the foraging site, and so on. *Stock* is a genetically distinct population unit of the respective species (sGBR = southern Great Barrier Reef, nGBR = northern Great Barrier Reef, NC = New Caledonia, CS = Coral Sea, sPac = South Pacific, eAus = eastern Australia).
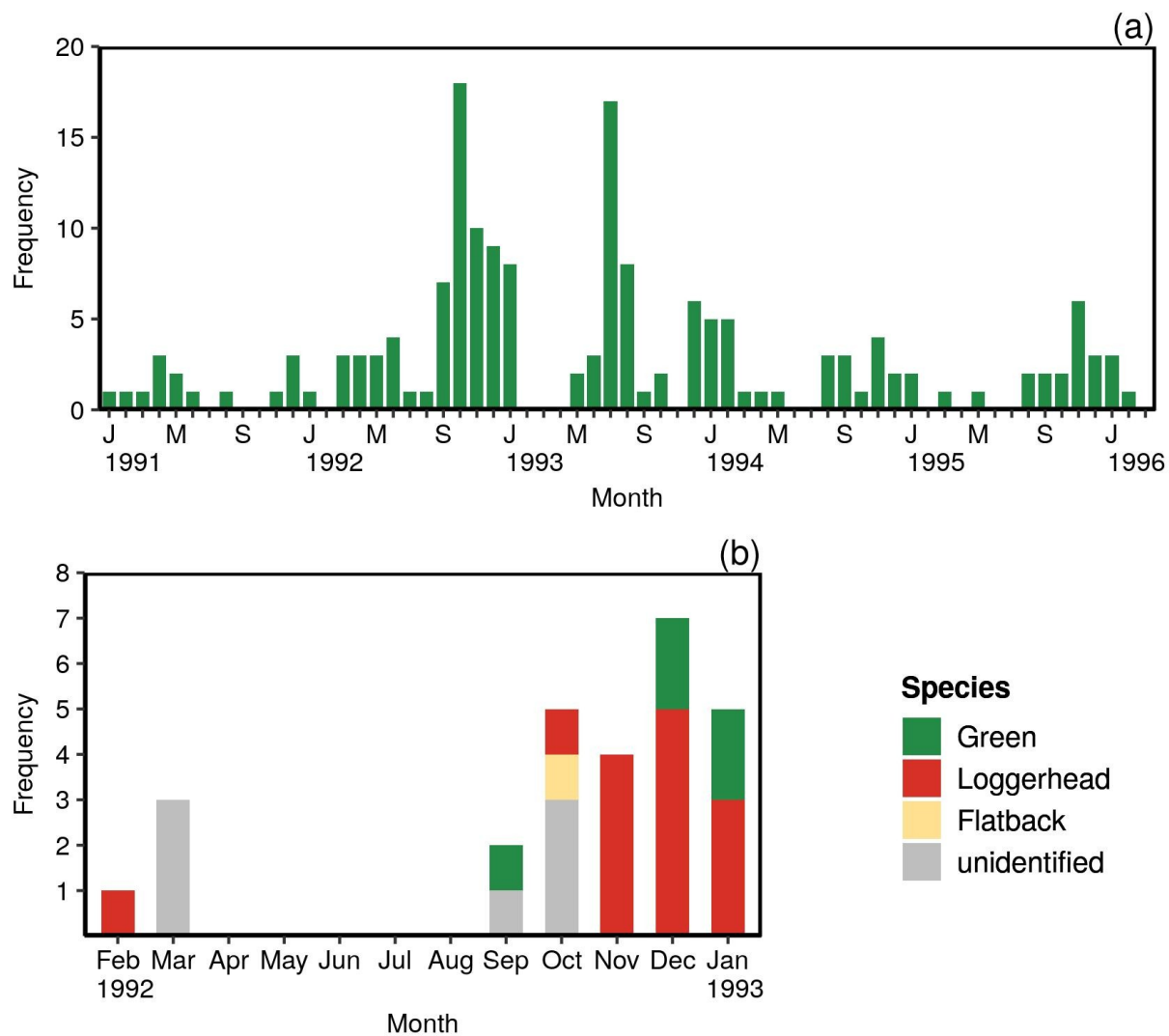
Figure S5 Monthly frequency of stranded sick/dead turtles before and after two floods and a tropical cyclone hit the greater Hervey Bay region in early 1992. (a) Green turtles recorded from the northern Hervey Bay between January 1991 and March 1996 (Queensland Department of Environment and Science, 2018). (b) Multiple sea turtle species recorded in Woongarra Marine Park at the northwest corner of Hervey Bay between February 1992 and January 1993 (modified from Limpus et al. (1993)).

Table S1 Summary of satellite tracking and capture-mark-recapture data. *Stock* is defined as a genetically distinct population unit of the respective species (unk = unknown, nGBR = northern Great Barrier Reef, sGBR = southern Great Barrier Reef, sPac = South Pacific, nQld = north Queensland, eAus = eastern Australia). *Tag* is the types of tracking device (GPS = Fastloc-GPS Argos tag, Argos = Argos-only tag). *Track days* and *no. fixes* are the number of tracking days and location fixes obtained on the foraging grounds before and/or after a breeding migration. *Migration* is the sum distance between consecutive location fixes during migration from breeding sites to foraging sites. *Min. residency* is the number of years between the first and last records on the same foraging sites. *Distance between midpoints* is the distance between the mid-point of the locations on the foraging site before and after a breeding season (but for T97111 see the caption for Figure S2). *Residency estimation method* is either multiple satellite tracks (SAT) or a combination of satellite telemetry and capture-mark-recapture using flipper tags (SAT+CMR). *Breeding seasons* is the number of breeding seasons observed for each turtle between the first and last records on its foraging sites. Letters in the *map* facilitate cross-reference to the maps in Figure S1 and S2.

turtle ID	stock	sex	Argos ID	tag	tracked from (d/m/y)	track days [no. fixes] before migration	after migration	migration (km)	min. residency (yr)	distance between midpoints (km)	residency estimation method	breeding seasons observed (n)	map
Green turtle *(Chelonia mydas)*													
KE0633	unk	F	117570	GPS[1]	10/8/15		143 [319]	4810	12.3	1	SAT+CMR	1	(a)
K40735	nGBR	F	88365	Argos[2]	15/11/08		138 [67]	718	1.9	1	SAT+CMR	1	(b)
K58178	nGBR	F	87898	Argos[2]	9/9/08	1 [1]	13 [3]	281	4.5	5	SAT+CMR	1	(c)
K73295	nGBR	F	87899	Argos[2]	9/9/08	1 [1]	32 [10]	330	3.6	5	SAT+CMR	1	(d)
K73662	nGBR	F	59963	Argos[3]	18/10/05	2 [4]	31 [5]	75	0.4	3	SAT+CMR	1	(e)
K73728	nGBR	F	59965	Argos[3]	5/10/05		69 [25]	197	0.5	15	SAT+CMR	1	(f)
K73740	nGBR	F	59966	Argos[3]	11/10/05	7 [7]	69 [10]	113	0.5	25	SAT+CMR	1	(g)
K74859	nGBR	F	133763	GPS[1]	4/11/16		34 [149]	449	10.7	3	SAT+CMR	2	(h)
K75275	nGBR	F	152622	GPS[1]	14/10/15	8 [215]	119 [617]	232	0.7	12	SAT+CMR	1	(i)
QA20363	nGBR	F	152623	GPS[1]	16/10/15	5 [71]	128 [535]	215	0.7	21	SAT+CMR	1	(j)
QA20370	nGBR	F	95895	GPS[4]	16/10/15	1 [5]	133 [777]	260	0.7	12	SAT+CMR	1	(k)
QA11747	sGBR	F	48861	GPS[4]	15/5/10	58 [225]	62 [98]	577	1	2	SAT+CMR	2	(l)
K93087	sGBR	M	96777	GPS[4]	2/7/10	80 [342]	86 [181]	116	0.7	<1	SAT+CMR	1	(m)
Loggerhead turtle *(Caretta caretta)*													
K22217	sPac	F	95892	GPS[4]	6/1/10		113 [494]	520	11	1	SAT+CMR	3	(n)
QA13932	sPac	F	95892	GPS[1]	10/4/13	177 [1037]	434 [243]	647	2	3	SAT+CMR	1	(o)
T1276	sPac	F	5196	Argos[5]	2/1/94		72 [24]	100	7	8	SAT	3	(p)
			5196	Argos[5]	3/1/99		64 [134]	83	7				
T14914	sPac	F	26040[a]	Argos[6]	18/9/96	37 [10]	1 [1]	303	17.1	2	SAT+CMR	3	(q)
			48847	GPS[4]	13/12/10		1000 [750]	462	17.1				
T23158	sPac	F	48850	GPS[4]	6/9/10	53 [115]	266 [254]	488	1.1	1	SAT+CMR	1	(r)
T29282	sPac	F	88076	GPS[4]	10/12/10		427 [627]	509	16.7	7	SAT+CMR	4	(s)
T54430	sPac	F	48840	GPS[4]	31/12/09		451 [78]	509	19.7	5	SAT+CMR	5	(t)
T81920	sPac	F	48845	GPS[4]	21/12/09		231 [1201]	527	22.4	4	SAT+CMR	3	(u)
T93038	sPac	F	48841	GPS[4]	22/12/09		105 [1208]	488	15.5	14	SAT+CMR	7	(v)
			96778	GPS[4]	20/12/11		281 [653]	502	15.5				
K17100	sPac	M	7222	Argos[6]	30/9/98	42 [26]	38 [8]	151	8	3	SAT+CMR	1	(w)
T53732	sPac	M	7224	Argos[6]	30/9/98	39 [26]	36 [5]	14	27.5	<1	SAT+CMR	1	(x)
Hawksbill turtle (*Eretmochelys imbricata*)													
QA40538	nQld	F	140120	GPS[1]	24/9/14	15 [88]	151 [127]	201	0.7	<1	SAT+CMR	1	(y)
Flatback turtle *(Natator depressus)*													
T20452	eAus	F	96779	GPS[4]	23/12/09		544 [1314]	382	4.1	11	SAT	2	(z)
			134194	GPS[1]	27/11/13		39 [212]	300					
T97111	eAus	F	134195[b]	GPS[1]	26/11/13		35 [345]	230	2.8	12	SAT	1	(aa)
			152720[b]	GPS[1]	4/12/15		257 [1368]	338					

[1]SPLASH10, Wildlife Computers, Seattle, Washington. [4]F4G, Sirtrack, Hawkes Bay, New Zealand.

[2]SPOT-244A, Wildlife Computers, Seattle, Washington. [5]ST3, Telonics, Mesa, Arizona.

[3]KiwiSat1, Sirtrack, Hawkes Bay, New Zealand. [6]ST14, Telonics, Mesa, Arizona.

[a]Limpus & Limpus (2001); [b]Wildermann (2017)

Table S2 Summary of flipper-tagged turtles in SW Pacific, which were recorded on the foraging sites and later successively sighted on the breeding and foraging sites. *Stock* is a genetically distinct population unit of the respective species (sGBR = southern Great Barrier Reef, nGBR = northern Great Barrier Reef, NC = New Caledonia, CS = Coral Sea, sPac = South Pacific, eAus = eastern Australia). See Figure S4 for the site locations. *Min. residency* is the number of years past between the first and last capture records on the same foraging sites. *Spread* is the maximum distance between capture locations on the foraging sites. *No. seasons* is the number of breeding seasons observed for each turtle between the first and last records on its foraging sites. *Min. migration* is the straight line distance between its breeding and foraging sites. Data of a turtle that had been published previously is marked with the relevant citation and presented here with the most updated information as of 27 December 2018 (Queensland Environmental Protection Agency, 2018).

turtle ID	stock	sex		foraging							breeding		
			site	first record		last record		no. capture	min. residency (yr)	spread (km)	site	no. seasons	min. migration (km)
				date (d/m/y)	CCL (cm)	date (d/m/y)	CCL (cm)						
Green turtle (*Chelonia mydas*)													
K1207	sGBR	F	MZ	19/4/97	105.5	22/5/11	106.1	2	14.1	<1	WI	1	468
K7573	sGBR	F	MD	12/7/97	105.0	2/7/05	104.7	2	8	4	LM	1	277
K8514	sGBR	F	MD	13/7/97	110.1	7/7/07	109.5	2	10	9	HI	1	213
K8543	sGBR	F	MD	6/7/97	99.5	26/6/12	99.3	2	15	1	NW	1	186
K8576	sGBR	F	MD	8/7/97	95.4	3/7/04	95.2	2	7	1	LM	1	282
K8630	sGBR	F	MD	9/7/97	95.1	7/7/05	96.2	2	8	1	NW	1	186
K12490	sGBR	F	MZ	19/9/98	102.6	6/11/16	106.6	2	18.1	2	NW	1	482
K17065	sGBR	F	MZ	15/6/98	106.8	22/5/11	109.0	2	12.9	6	HI	2	461
K18511	sGBR	F	HM	14/4/06	100.2	23/9/08	100.8	3	2.4	<1	HI	1	237
K18629	sGBR	F	HM	7/8/07	97.9	4/12/11	97.9	36	4.3	<1	HI	1	237
K22954	sGBR	F	WI	29/12/98	101.7	21/12/00	102.0	2	2	<1	WI	1	<10
K25703	sGBR	F	MZ	7/2/99	109.6	14/4/17	112.8	2	18.2	2	NW	1	481
K25713	sGBR	F	MZ	7/2/99	114.3	4/11/08	114.6	2	9.7	2	NW	1	480
K29972	sGBR	F	HM	23/4/10	103.2	15/2/11	103.1	22	0.8	<1	HI	1	237
K34519	sGBR	F	MZ	15/5/00	106.2	18/5/12	106.3	3	12	2	LM	1	397
K35099	sGBR	F	MV	12/11/01	104.2	15/11/10	105.2	2	9	1	WI	1	477
K36347	sGBR	F	MZ	12/11/01	116.2	25/10/08	115.7	2	7	2	WI	1	470
K36889	sGBR	F	MD	26/7/00	97.7	27/6/12	102.4	2	11.9	<1	WI	1	210
K43396	sGBR	F	MD	6/8/01	104.5	26/6/16	101.2	4	14.9	2	HI	1	214
K49663	sGBR	F	MD	28/6/02	93.1	25/6/08	92.9	2	6	<1	WI	1	203
K55740	sGBR	F	MD	29/6/03	97.2	2/7/12	97.3	2	9	<1	WI	1	211
K56181	sGBR	F	MD	11/7/03	110.4	30/6/06	109.7	2	3	1	WI	1	206
K64707	sGBR	F	MZ	8/4/05	117.8	26/7/15	118.4	3	10.3	2	LM	1	396
K85622	sGBR	F	MZ	19/6/13	111.3	3/9/17	111.0	2	4.2	1	LM	1	397
K87252	sGBR	F	HM	25/4/07	108.9	27/4/11	108.5	16	4	<1	HI	1	237
QA34792	sGBR	F	GZ	1/5/13	101.1	6/11/17	101.3	2	4.5	1	LM	1	111
T4746	sGBR	F	HI	7/5/84	91.5	20/8/97	93.3	3	13.3	4	NW	1	30
T12544[f]	sGBR	F	MD	4/7/87	92.0	29/7/00	96.4	3	13.1	3	HI	1	214
T13634	sGBR	F	LE	14/12/03		2/12/11		2	8	<1	WI	2	117
T13971	sGBR	F	HI	3/4/92	102.5	18/8/99	102.5	3	7.4	5	HI,NW,WI	1	32
T15348	sGBR	F	HI	25/7/85	105.5	1/8/98	106.1	4	13	4	WI	1	14
T16397	sGBR	F	HI	10/11/85	96.0	20/8/99	104.4	7	13.8	5	HI,NW	1	32
T18269	sGBR	F	MD	4/7/87	111.0	22/6/08	110.8	2	21	3	NW	2	188
T18445	sGBR	F	MD	4/7/87	112.0	7/7/90	112.0	2	3	<1	NW	1	188
T21110	sGBR	F	HI	25/3/87		24/8/99	94.0	5	12.4	6	NW	1	33
T21232[f]	sGBR	F	MD	11/7/87	107.5	26/6/16	108.5	5	29	3	TY	1	190
T23103	sGBR	F	MD	6/7/88	104.0	11/7/90	103.0	2	2	<1	LM	1	283
T23481	sGBR	F	RP	22/6/88	115.0	17/8/91	114.2	5	3.2	<1	LM	1	531
T23598	sGBR	F	MZ	23/3/97	108.2	22/4/12	109.1	3	15.1	2	HI	2	459
T23600	sGBR	F	HI	3/4/90	101.0	23/8/99	101.5	2	9.4	7	HI	1	<10
T25882[f]	sGBR	F	MD	10/7/89	101.5	28/6/04	101.2	3	15	1	HI	1	215
T29785[f]	sGBR	F	MD	17/7/87	102.0	3/7/03	102.4	3	16	3	NW	1	188
T31419[f]	sGBR	F	MD	4/7/88	114.0	2/7/03	114.5	2	15	3	NW	1	188
T32203[f]	sGBR	F	MD	16/7/90	97.0	7/7/04	97.8	4	14	9	NW	1	188

T32315	sGBR	F	MD	8/7/88	115.5	15/7/97	115.5	3	9	3	NW	1	188
T35025	sGBR	F	MZ	1/9/90	109.2	4/2/07	111.7	5	16.4	4	WI	2	469
T35755[f]	sGBR	F	MD	16/7/90	99.4	9/8/01	100.1	3	11.1	8	HI	2	214
T36703	sGBR	F	WI	23/12/01	97.6	26/12/15	97.1	3	14	<1	WI	1	<10
T37192[f]	sGBR	F	MD	16/7/88	99.0	6/7/07	99.6	4	19	6	LM	2	283
T37408	sGBR	F	RP	26/7/88	109.0	18/8/91	107.4	4	3.1	<1	LM	1	531
T37476	sGBR	F	HI	26/3/89	105.0	23/8/99	106.5	3	10.4	7	LM	1	70
T38073	sGBR	F	HI	6/6/89	108.5	22/10/98	109.6	2	9.4	4	HI	1	<10
T39721[f]	sGBR	F	MD	13/7/89	95.0	3/7/06	95.3	4	17	7	HI,WI	2	214
T39733	sGBR	F	MD	12/7/89	111.0	14/7/97	111.3	2	8	6	WI	1	211
T45501	sGBR	F	WI	30/3/90	89.0	18/12/03	101.8	3	13.7	<1	NW	1	26
T45545	sGBR	F	WI	1/4/90	102.0	29/12/00	102.6	3	10.8	<1	LM	1	77
T45593	sGBR	F	HI	10/4/90	103.0	16/8/99	102.9	6	9.4	6	LM	1	70
T45640	sGBR	F	HI	7/4/90		16/8/99	104.7	3	9.4	5	HI	1	<10
T50350[f]	sGBR	F	MD	9/7/90	112.5	3/7/04	112.1	4	14	3	HI	1	215
T50727[f]	sGBR	F	MD	18/7/90	107.8	4/8/00	107.5	4	10.1	6	NW	1	188
T50862[f]	sGBR	F	MD	24/7/90	98.5	29/6/12	98.7	4	21.9	4	WI	1	211
T50898	sGBR	F	MZ	19/8/90	90.5	14/4/17	114.1	5	26.7	4	HI	1	460
T51048	sGBR	F	MZ	20/9/90	88.0	20/10/10	110.1	4	20.1	3	NW	1	480
T51161	sGBR	F	MZ	28/10/90	111.4	13/5/10	114.0	3	19.6	4	NW	1	482
T51205	sGBR	F	MZ	10/11/90	83.0	1/7/18	110.1	5	27.7	4	LM	2	398
T53794	sGBR	F	MZ	31/8/91	87.7	28/5/17	102.4	2	25.8	4	LM,RB	3	398
T53796	sGBR	F	MZ	31/8/91	88.0	25/10/15	106.7	4	24.2	5	HI	1	461
T55135	sGBR	F	MD	8/7/91	97.5	6/7/96	97.9	2	5	4	NW	1	188
T55278[f]	sGBR	F	MD	9/7/91	110.9	7/7/04	111.1	4	13	8	HI	1	214
T55280[f]	sGBR	F	MD	18/7/91	98.7	9/8/01	99.1	2	10.1	8	LM	1	283
T57107[f]	sGBR	F	MD	16/7/91	101.3	3/7/12	101.7	4	21	3	LM	1	283
T57115[f]	sGBR	F	MD	16/7/91	100.6	30/6/04	101.7	2	13	3	NW	1	188
T57117[f]	sGBR	F	MD	16/7/91	107.7	10/7/07	107.4	5	16	3	WI	1	211
T60727	sGBR	F	WI	30/12/98	98.2	26/12/00		2	2	<1	WI	1	<10
T66988	sGBR	F	MZ	6/6/01	106.2	24/5/05	107.0	2	4	<1	NW	1	480
T67510	sGBR	F	MZ	7/11/93	73.4	19/6/13	105.6	4	19.6	5	HI	1	460
T69752	sGBR	F	MD	7/7/97	91.5	29/6/05	91.4	2	8	1	NW	1	187
T71572	sGBR	F	MZ	1/5/93	114.0	25/4/95	113.7	2	2	5	NW	1	481
T77432	sGBR	F	MD	22/7/94	112.2	22/6/08	113.1	3	13.9	2	HI,NW	1	212
T77435[f]	sGBR	F	MD	26/7/94	100.5	2/8/00	100.4	3	6	1	LM	1	277
T77447	sGBR	F	MD	26/7/94	102.0	5/7/10	103.6	2	16	20	LM	2	296
T77449[f]	sGBR	F	MD	30/7/94	106.0	7/7/04	106.5	2	9.9	<1	NW	1	179
T77513[f]	sGBR	F	MD	23/7/94	100.5	3/7/04	101.3	2	10	<1	NW	1	186
T77744[f]	sGBR	F	MD	2/8/94	109.8	31/7/00	109.8	2	6	1	LE	1	318
T77846	sGBR	F	MD	1/8/94	103.3	3/7/05	103.6	2	10.9	1	WI	1	204
T78396	sGBR	F	MD	8/7/95	105.7	27/6/05	106.2	2	10	<1	LM	1	282
T79396	sGBR	F	MZ	13/8/95	105.0	18/9/12	108.1	2	17.1	1	LM	2	395
T82051	sGBR	F	MZ	26/5/96	100.5	30/3/08	111.6	4	11.9	3	LM	1	397
T82466	sGBR	F	MZ	22/10/00	113.3	27/10/07	114.4	2	7	2	FR	1	297
T82542	sGBR	F	MZ	4/10/98	112.7	14/5/12	113.2	2	13.6	1	LM	2	398
T82681	sGBR	F	MZ	4/5/98	107.0	15/11/10	110.0	2	12.5	2	LM	3	396
T83625[f]	sGBR	F	MD	9/7/96	96.7	5/7/06	97.7	3	10	3	LM	1	278
T84474	sGBR	F	MZ	24/9/98	110.5	5/10/15	113.0	4	17	2	WI	1	470
T87153	sGBR	F	HI	30/10/95	102.0	17/10/98	102.6	3	3	5	NW	1	32
T92590	sGBR	F	MV,MZ	29/5/96	93.2	5/10/10		2	14.4	2	HI	1	460
T93006	sGBR	F	MZ	30/3/97	104.5	8/2/07	105.6	3	9.9	4	WI	1	468
T94461[f]	sGBR	F	MD	1/7/96	101.6	3/8/00	101.5	2	4.1	3	NW	1	185
X-38000	sGBR	F	HI	15/4/90	101.0	13/8/97	101.4	2	7.3	6	NW	1	32
X2625[d]	sGBR	F	HI	13/5/76	99.0	23/8/99	101.9	6	23.3	8	HI	1	<10
X9071[d]	sGBR	F	HI	3/6/78		22/10/96	101.7	5	18.4	6	HI	2	<10
X14662	sGBR	F	MZ	23/9/90	117.6	13/5/10	119.1	2	19.6	4	LM	3	398
X15110	sGBR	F	HI	3/11/81	102.5	22/10/98	104.2	5	17	5	LM	1	70
X22178[d]	sGBR	F	HI	18/5/80	106.0	22/10/99	106.4	7	19.4	4	HI	1	<10
X37792	sGBR	F	WT	15/2/85	103.0	12/8/96	103.5	3	11.5	4	NW	1	28
X38371	sGBR	F	HI	12/10/81	89.5	15/10/94	99.1	4	13	5	LM	1	70
K15008	sGBR	M	WI	24/12/97	98.4	26/12/15	98.5	5	18	<1	WI	1	<10
K39096	sGBR	M	WI	26/12/00	95.6	18/12/02	95.4	2	2	<1	NW	1	26

T1083	sGBR	M	HI	5/2/83	80.0	3/8/98	87.3	3	15.5	6	HI	2	<10
T4286	sGBR	M	HI	25/2/84	89.5	26/10/99	96.1	3	15.7	7	HI	1	<10
T4685	sGBR	M	HI	11/5/84	95.0	17/8/99	95.2	4	15.3	7	HI	1	<10
T12111	sGBR	M	HI	7/7/85	100.5	31/7/98	102.8	3	13.1	4	HI	1	<10
T15700	sGBR	M	HI	29/10/94	93.4	25/10/98	93.5	6	4	4	HI	1	<10
T16544	sGBR	M	HI	13/3/87	106.0	21/10/98		5	11.6	4	HI	2	<10
T31049	sGBR	M	HI	23/3/88	86.0	20/8/99	87.7	4	11.4	6	HI	1	<10
T45292	sGBR	M	HI	19/3/90	92.0	25/10/98	93.0	2	8.6	6	HI	1	<10
T45365	sGBR	M	HI	22/3/90	97.5	2/8/98	97.7	3	8.4	6	HI	1	<10
T56258	sGBR	M	HI	1/4/91	105.2	23/10/98	105.0	6	7.6	8	HI	1	<10
T58597	sGBR	M	HI	29/3/92	93.3	22/10/95		3	3.6	<1	HI	1	<10
T60994	sGBR	M	HI	30/3/92	97.7	18/8/97	97.8	2	5.4	6	HI	1	<10
T78307[f]	sGBR	M	MD	12/7/95	92.8	6/7/04	93.9	2	9	1	FR	1	438
T92541	sGBR	M	WI	30/12/95	93.1	29/12/02	92.9	2	7	<1	NW	1	26
X9049	sGBR	M	HI	3/6/78	98.0	16/4/90	100.0	3	11.9	<1	HI	1	<10
X13768	sGBR	M	HI	29/10/78	103.5	21/7/89	103.5	7	10.7	<1	HI	1	<10
X22050	sGBR	M	HI	31/1/80	105.5	19/8/99		10	19.6	7	HI	2	<10
X38260	sGBR	M	HI	27/8/85	95.0	22/8/99	96.0	4	14	5	HI	4	<10
X38458	sGBR	M	HI	13/10/81	92.0	14/8/99	93.5	7	17.8	5	HI	2	<10
X38561	sGBR	M	HI	4/11/81		9/4/90	108.5	2	8.4	<1	HI	1	<10
K24035	nGBR	M	RI	5/8/02	90.5	2/12/05	90.4	3	3.3	<1	RI	1	<10
K25986[g]	NC	F	MZ	13/5/99	102.0	13/3/11	106.1	2	11.8	1	NC	1	1428
K43255[g]	NC	F	MD	1/8/01	88.1	26/6/12	93.1	2	10.9	1	N2	1	1412
T77864[f]	NC	F	MD	4/8/94	98.5	7/8/01	98.9	2	7	3	NC	1	1605
T85488[f]	NC	F	MD	14/7/95	104.0	25/6/12	104.8	3	17	1	NC	1	1610
T43428	CS	F	MD	14/7/89	107.5	6/7/07	107.4	5	18	7	HZ	1	614
X37735	CS	F	CL	11/7/88	108.5	14/6/91	108.5	3	2.9	<1	NW,WI	1	1308

Loggerhead turtle (*Caretta caretta*)

2912[c]	sPac	F	HI	3/11/74		31/3/92		38	17.4	<1	MR	1	159
5330[c]	sPac	F	WT	14/5/75		25/3/92	94.5	4	16.9	<1	BA,KM,MR	6	159
10779[c]	sPac	F	HI,WT	12/5/75	92.5	19/10/95		14	20.5	8	KM,MR	4	163
K25843	sPac	F	MZ	10/5/99	88.9	8/4/05	89.5	3	5.9	4	MR	1	299
K40329	sPac	F	MZ	5/6/02	92.2	22/9/06	94.6	2	4.3	6	MR	1	300
K55341	sPac	F	S$	6/10/06		24/4/10		6	3.6	7	MR	1	138
T732[e]	sPac	F	HI	17/10/82	78.5	2/11/99		32	17.1	7	MR	2	161
T2429[a]	sPac	F	MO,MZ	26/4/92	95.5	10/10/95	96.0	2	3.5	20	MR	1	299
T22667[a]	sPac	F	MZ	10/6/91	101.5	13/8/95	100.7	2	4.2	3	WR	1	365
T22706[a]	sPac	F	MZ	2/9/90	96.2	25/5/04	97.3	7	13.7	6	WR	1	369
T23637[a]	sPac	F	MZ	25/5/91	88.0	29/5/97	88.8	2	6	4	MR	1	298
T38229[e]	sPac	F	HI	16/4/89	77.0	26/10/99	100.5	19	10.5	5	RB	1	115
T41196	sPac	F	MZ	16/9/90	86.3	30/5/06	87.0	3	15.7	4	MR	3	301
T50968	sPac	F	MZ	1/9/90	90.5	15/7/18	91.3	14	27.9	5	MR	2	301
T64304	sPac	F	MZ	9/5/92	90.8	17/9/17	90.2	7	25.4	5	MO	1	21
T85935	sPac	F	QG	5/5/01		12/7/08		2	7.2	14	WI	1	555
T93076	sPac	F	MZ	19/4/97	82.9	13/9/15	89.0	6	18.4	5	MR	2	304
X54[c]	sPac	F	HI,WT	7/11/75	100.5	23/10/85		33	10	7	MR	2	159
X198	sPac	F	HI,WT	13/5/75	92.5	22/8/99	95.4	14	24.3	11	MR	4	161
X2031[c]	sPac	F	HI	12/5/75	101.0	1/11/99		51	24.5	7	HI,SH,SP	2	205
X2061[d]	sPac	F	HI	13/5/75	83.0	23/10/85	86.0	9	10.5	<1	WI	1	12
X2352[c]	sPac	F	HI,WT	6/5/76	92.0	2/4/92	94.2	10	15.9	7	WR	3	98
X2606[c]	sPac	F	HI	10/5/76	87.0	12/5/84		23	8	<1	MR	1	159
X2757[e]	sPac	F	HI	19/5/77	80.0	6/11/96		47	19.5	5	LM	3	70
X2776	sPac	F	HI,WT	23/5/77	90.0	31/7/98	93.7	14	21.2	10	WR	4	98
X2777[c]	sPac	F	WT	23/5/77	89.5	30/8/85	92.0	5	8.3	<1	WR	2	93
X9334[e]	sPac	F	HI	4/11/77		24/10/98	99.1	42	21	5	NC	1	1590
X9342	sPac	F	HI,WT	5/11/77	99.0	26/10/97	101.0	9	20	7	WI	1	18
X9343	sPac	F	HI,WT	5/11/77	82.5	29/10/99	92.3	12	22	7	SF	1	197
X9374[e]	sPac	F	HI	6/2/78	86.0	1/11/95	97.0	27	17.7	4	WR	1	98
X44080	sPac	F	MB	24/9/84		17/3/95		2	10.5	16	WI	3	461
X44635	sPac	F	MZ	31/8/91	93.5	28/2/10	93.1	4	18.5	7	WI	1	473
T708	sPac	M	HI	15/10/82	80.0	12/4/10		24	27.5	5	HI	2	<10
X2034	sPac	M	HI	12/5/75	99.5	19/8/99	101.0	21	24.3	7	HI	1	<10
X2073	sPac	M	HI,WT	13/5/75	94.5	5/1/86	96.0	20	10.7	7	HI	1	<10

X2210	sPac	M	HI	30/10/75	94.0	11/8/98	50	22.8	6	HI	2	<10
X2298	sPac	M	HI	17/12/75		7/11/82	8	6.9	<1	HI	1	<10
X2531	sPac	M	HI	17/2/78	95.5	26/9/85	27	7.6	<1	HI	1	<10
X2615	sPac	M	HI	10/5/76	94.5	18/3/86	21	9.9	<1	HI	1	<10

Flatback turtle (*Natator depressus*)

X35035	eAus	F	MK	31/7/91			2			PI	1+	286
X35172	eAus	F	CN	6/9/83		19/6/89	2	5.8	25	PI	1+	854

[#]This turtle was originally recorded in 1975 as a hatchling at its natal beach in Mon Repos, Queensland, Australia. See main text for details.

[a]Limpus & Limpus (2001); [c]Limpus (1989); [d]Limpus et al. (1992); [e]Limpus & Limpus (2003); [f]Limpus et al. (2005); [g]Read et al. (2014)

References

Limpus, C. J. (1989). Forage area fidelity following breeding migrations in *Caretta caretta*. In S. A. Eckert, K. L. Eckert, & T. H. Richardson (Eds.), *Proceedings of the ninth annual workshop on sea turtle conservation and ecology* (pp. 97–99). Jekyll Island, Georgia: NOAA Technical Memorandum NMFS-SEFC-232.

Limpus, C. J., Deacon, M., & Meech, J. (1993). *Dead turtles on the Woongarra Marine Park and adjacent coast* (pp. 1–15). Brisbane: Queensland Department of Environment and Heritage.

Limpus, C. J., & Limpus, D. J. (2001). The loggerhead turtle, *Caretta caretta*, in Queensland: breeding migrations and fidelity to a warm temperate feeding area. *Chelonian Conservation and Biology, 4*(1), 142–153.

Limpus, C. J., & Limpus, D. J. (2003). Biology of the loggerhead turtle in western south Pacific Ocean foraging areas. In A. B. Bolten & B. E. Witherington (Eds.), *Loggerhead sea turtles* (pp. 93–113). Washington, DC: Smithsonian Books.

Limpus, C. J., Limpus, D. J., Arthur, K. E., & Parmenter, C. J. (2005). Monitoring green turtle population dynamics in Shoalwater Bay: 2000 - 2004. *Great Barrier Reef Marine Park Authority Research Publication, 83*, i–v, 1–51.

Limpus, C. J., Miller, J. D., Parmenter, C. J., Reimer, D., Mclachlan, N., & Webb, R. (1992). Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles to and from eastern Australian rookeries. *Wildlife Research, 19*(3), 347–358. doi: 10.1071/WR9920347

Queensland Department of Environment and Science. (2018). *Marine Wildlife Stranding Database (StrandNet)*.

Queensland Environmental Protection Agency. (2018). *Queensland Turtle Conservation Project database*.

Read, T. C., Wantiez, L., Werry, J. M., Farman, R., Petro, G., & Limpus, C. J. (2014). Migrations of green turtles (*Chelonia mydas*) between nesting and goraging grounds across the Coral Sea. *PloS One, 9*(6), e100083–e100083. doi: 10.1371/journal.pone.0100083

Wildermann, N. (2017). *Flatbacks at sea: understanding ecology in foraging populations* (PhD thesis). James Cook University, Townsville.