Investigating hawksbill turtle migratory paths and foraging grounds as strongholds or targets driving critical population declines

Madden Hof, Chris

Madden Hof, C. (2023). Investigating hawksbill turtle migratory paths and foraging grounds as strongholds or targets driving critical population declines [University of the Sunshine Coast, Queensland].
https://doi.org/10.25907/00794
Document Type: Thesis

Investigating hawksbill turtle migratory paths and foraging grounds as strongholds or targets driving critical population declines

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Bachelor of Science

Graduate Diploma in Environmental Management

A thesis submitted for the degree of Doctor of Philosophy at

The University of the Sunshine Coast in 2023

School of Science, Technology and Engineering

Marine and Terrestrial Megafauna Cluster

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Abstract

Once abundant across most tropical regions of the world, only approximately 4,800 adult female hawksbill turtles (*Eretmochelys imbricata*) are thought to remain in the Pacific Ocean, a reduction of more than 75% when compared to historic levels (Mortimer and Donnelly, 2008). With an estimated 9 million hawksbills harvested over a 150 year period for the tortoiseshell trade (Miller *et al.,* 2019) and a continued overexploitation of turtles to the present day (Ingram *et al.,* 2022; Wallace *et al.,* 2010), there is concern these critically endangered turtles will face imminent localised population collapse or extinctions, if not already extirpated (Pilcher *et al.,* 2021; Senko *et al.,* 2022). Yet, hawksbill turtles are the least studied marine turtle in the world (Limpus, 2009), and information regarding their genetic structure and composition, migratory pathways, and foraging grounds is lacking for most populations, leading to a lack of effective policy and conservation management efforts.

In the western Pacific Ocean region, the north-east Queensland (neQld) genetic stock was once considered one of the world's largest hawksbill turtle populations. However, this population is continuing to decline and likely to be extirpated within the decade, despite the highest level of national and marine park protection afforded to the neQld index nesting site (Bell *et al.,* 2020). Conversely, Papua New Guinea (PNG) hawksbill turtles remain unprotected and are also reported to be in decline and assessed as overexploited (Kinch 2020a; Wangunu *et al.,* 2004). While there is some evidence of breeding population connectivity between these two neighbouring countries, whether hawksbill migratory paths and foraging grounds are strongholds, or targeted sources driving critical population declines remains poorly understood. Prior to this thesis, no studies had identified the migration routes or foraging home ranges for these populations. The overarching aim of this thesis is to use data to inform policy and to identify mitigation management that is required to recover the neQld and PNG hawksbill populations. The conservation status, threats and legislative provisions of hawksbill turtles in the western Pacific Ocean region were assessed (Chapter 2, 3), leading to the population trend and trajectory of the once world's largest neQld stock to be evaluated. The population continues to decline (58% over the past 28 years) and is likely to be extirpated as early as 2032 (Bell *et al.,* 2020; Chapter 4). Using satellite tracking and genetic analysis, the migratory paths and foraging grounds of the neQld stock and the likely threats continuing to prevent population recovery were also quantified (Madden Hof *et al.,* 2023a; Chapter 5). No satellite tracked turtle left the Australian continental shelf, and their

migratory pathways and home range occurrence dominated western Queensland. As a result of this study, several policy and management recommendations were provided including reducing overharvesting , mitigating fisheries interactions (through both bycatch reduction and ghost net management), and increasing or expanding protected area management. A first in PNG, the migratory paths and foraging grounds of the Conflict Group of Islands nesting population in PNG were also identified, whereby approximately 90% of the satellite tracked turtles travelled to the NE coast of Queensland to forage. Using genetics, we also defined two new management units for PNG in Milne Bay and Kavieng, thereby raising the importance of managing these populations as separate regional management units from the neQld stock and others in the western Pacific Ocean region (Madden Hof *et al.,* 2023b; Chapter 6).

Given the importance of northern Queensland as a multi-stock hawksbill turtle foraging 'sink', further policy protection and management mitigation is urgently needed to reverse the declining trajectory of the neQld stock and PNG population, and to ensure Queensland waters remain a stronghold for these and other western Pacific Ocean hawksbill populations (e.g. Solomon Islands and Vanuatu). This new research highlighted the need for urgent and prioritised action to assess and manage many western Pacific Ocean hawksbill populations, resulting in the development (and endorsement) of a Convention of Migratory Species Single Species Action Plan (Chapter 7). This thesis provides new insight into hawksbill ecology and movement, and has identified critical policy and management interventions required to effectively secure hawksbill turtle populations in NE Australia and PNG before their populations are likely to become extinct.

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, financial support and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my higher degree by research candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

I acknowledge that an electronic copy of my thesis must be lodged with the University Library and, subject to the policy and procedures of The University of the Sunshine Coast, the thesis be made available for research and study in accordance with the Copyright Act 1968 unless a period of embargo has been approved by the Dean of Graduate Research.

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Publications included in this thesis

Bell, I. P., Meager, J. J., Eguchi, T., Dobbs, K. A., Miller, J. D., & Madden Hof, C. A. (2020). Twenty-eight years of decline: Nesting population demographics and trajectory of the north-east Queensland endangered hawksbill turtle (*Eretmochelys imbricata*). Biological Conservation, 241, 108376. https://doi.org/10.1016/j.biocon.2019.108376

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Contributions by others to the thesis

To support the analysis and interpretation of research data, significant and substantial inputs were made by Dr Justin Meager (in Bell *et al.,* 2020; Madden Hof *et al.,* 2023a), Caitlin Smith (in Madden Hof *et al.,* 2023a), Dr Michael Jensen (in Madden Hof *et al.,* 2023b). Dr Kimberley Riskas significantly assisted in drafting components in Madden Hof *et al.,* 2022.

Statement of parts of the thesis submitted to qualify for the award of another degree

No works submitted towards another degree have been included in this thesis.

Research Involving Human or Animal Subjects

All work carried out during this thesis was conducted under the University of the Sunshine Coast Ethics approval, AN/S/17/54. A letter copy of this ethics approval is included in Appendix One. Where work was conducted in conjunction with the Queensland Government, all work was carried out under its Queensland Department of Agriculture Animal Ethics approval, SA 2015/11/526.

Acknowledgements

I wish to thank Dr Ian Bell and Dr Michael Jensen for mentoring and guiding me in turtle world over the past 6-10 years, for your honesty and never ending advice, and for being my sounding board and friend. Thank you to Dr Jeff Kinch for believing in me and for all your assistance in navigating working in Papua New Guinea. To Hayley Versace, and Ange Amon, without you and your respective organisations the PNG paper wouldn't have otherwise existed, so I truly thank you both. To Dr Nancy Fitzsimmons, thank you for your superb laboratory coaching and for persisting with the constant laboratory stop start during COVID19. To my primary supervisor and colleague, Associate Professor Kathy Townsend, thank you for your ongoing support and friendship, and helping me see through my beyond busy schedule to fit a PhD amongst working full time, raising children, and the adversities life throws at you during this almost 6 year journey. To Dr Ben Gilby, thank you for persisting with my many GIS questions, and to Dr Graeme Hays, thank you for your satellite tracking assistance – to you both, I thank you for being my co-pilot supervisors throughout this journey. To the many, many colleagues and friends that have answered my multitude of questions, and in particular, Dr Justin Meager and Caitlin Smith for your assistance in the statistical and geographic information system analysis, I am eternally grateful.

Financial support

This research was supported by an Australian Government Research Training Program Scholarship. As is a joint project, most of the funding for this project was sourced from the World Wide Fund for Nature (Australia and the Coral Triangle Programme), its donors, sponsors and corporate partners including philanthropic support from the Isaac Davidson Foundation. Chapter 2 was supported in-kind by the Department of Environment and Science (Queensland Government) and Wildlife Computers (through satellite tracker donations). Chapters 3 and 4 were in part financially supported by Dr David Schoeman and Dr Kylie Scales (University of the Sunshine Coast) and my remaining PhD budget allocation (for satellite trackers), with substantial in-kind support from the Conflict Island Conservation Initiative (for travel and logistics in PNG). Refer to acknowledgments within the published articles and manuscripts for more detail.

Keywords

Hawksbill turtle, western pacific, population abundance, migration, threat exposure, genetic stock, satellite tracking, foraging, policy, recommendations

Australian and New Zealand Standard Research Classifications (ANZSRC)

ANZSRC code: 050211 Wildlife and Habitat Management, 060207, Population Ecology and 060411 Population, Ecological and Evolutionary Genetics, 060205 Marine and Estuarine Ecology (incl. Marine Ichthyology)

Fields of Research (FoR) Classification

ANZSRC code: 0602, Population Ecology and 0604 Population, Ecological and Evolutionary Genetics

Dedications

First and foremost I wish to thank my two amazing children, Coen Madden Hof and Amaya Madden Hof. Without their patience and understanding over the past 6 years I would not have submitted this PhD. I dedicate this PhD to them, and especially to my daughter, in the hope that she has seen and experienced that no matter how many balls you have in the air, what you put your mind to, as a strong, resilient, independent woman, you can achieve the greatest of accolades. I thank all my friends and family for believing in me and providing me with the encouragement when I needed it most. I also dedicate my thesis to my sister and close friend Debbie Thompson who has ridden this journey with me, the ups, downs and everything in between. We women are strong.

<u>List of Figures:</u>

(tagging cohort). Grey text indicates over-parameterised models (e.g. singularities or boundary-value estimates).

[(a)] where '*n to u*' denotes the transition from nester to unobservable state, *'u to n'* the reverse transition and *'f'* a parameter that was fixed.
[(b)] where '*ns'* is the number of elapsed days in a nesting season (arbitrary coded as since October 1 for each year) and β denotes a coefficient.
[(c)] a polynomial spline function (B-spline basis)

Figure 4.3 Autoregressive GAM modelled number of clutches laid per night by *E. imbricata* (log transformed) as a function of nesting year (the long-term trend) and the number of days that had elapsed since the start of each nesting season (the seasonal effect, coded as days since October 1).

Figure 4.4 Average number of clutches laid per night (Std.clutches) for a standard period in each year. The solid black line is the fit of a GAM (± 95% confidence intervals), weighted by sampling effort.

Figure 4.5 Parameters in the final CMR model (±95% confidence intervals): (a) capture probability averaged for each nesting season, (b) probability of residence as a function of secondary sample (fortnightly from November 15), (c) probability of arrival as a function of secondary sample and (d) number of nesters in each nesting season, where the blue trend line represents a GAM (grey region: 95% CIs, weighted by 1/SE). Nesting seasons with no data (2000-2001, 2002-2003, 2011-2012 to 2014-2015) or limited sampling effort (1991-1992 and 2015-2016) were excluded from (a) and (d).

Figure 4.6 Projected trends based on the results of the current analyses (± 95% CI) for (a) average clutches per night for the standard census period between January 15 and February 15 (GAM weighted by sampling effort), (b) clutches per night over the whole period (back transformed from a lognormal autoregressive GAM (see Figure 4.3) and (c) MSORD estimates of number of nesters (trend modelled by a GAM). In fig (b) the small circles represent observed clutches per night and the dark larger circles the average clutches per night for each season. In fig (a), an average of 1 clutch per year is predicted by 2032-2032 (95% CI from 2020-2021 to >2080). In fig (b) an average of < 1 clutch per year is predicted by 2037-2038 (95% CI from 2024-2025 to >2080). In fig (c) less than one nester per year is predicted by 2036-2037 (95% CI from 2026-2027 to 2058-2059). Data from the 2017-2018 nesting season are in red, in fig (c) the red circle represents the number of tagged females and the red triangle represents the number of tagged females divided by an estimate of p.

Figure 4.7 The distribution of nester sizes (CCL, cm) from the 1990-1991 to the 2017-2018 nesting seasons. The first nesting season is used as a reference to compare subsequent nesting seasons. Kernel density estimators were used to smooth the length-frequency histograms, and *p* values represent the significance of permutation tests.

Figure 5.1 Location of Milman Island, in north east Australia. **A)** the 13 satellite tracks; **B)** 95% UD home range east vs west.

Figure 5.2 neQld stock life history. **A)** important (green) and critical (red) nesting sites; **B)** migration corridor (red dots where >5 migratory tracks overlap); **C)** key foraging ground locations (shown as X); **D)** post-hatchling cumulative exposure as modelled by CONNIE 3 (red shading where greatest likelihood of modelled dispersal) (Credit: CSIRO).

Figure 5.3 Likely first "lost-year" distribution within predicted [count] of likely encounters per exclusive economic zones (EEZ). Coloured dots refer to points within Australian State and Territory coastal waters (black), Australian Commonwealth Waters (green), all others (blue).

Figure 5.4 Reported hawksbill and unspecified turtle bycatch per unit effort (BPUE) for hawksbill and hawksbill including unspecified turtles for all fisheries. **A)** all state and Commonwealth TSP; **B)** ETBF; **C)** NPF

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Figure 5.6 Heatmap of potential ghost net tracks in northern Queensland based on daily particle releases and net length found along the Queensland coastline. Black box denotes most 'at-risk' turtle-net encounter area (from Wilcox *et al.,* 2013), overlaid with hawksbill post nesting home range (black polygons). Ghost net data provided by Wilcox *et al.* 2013.

Figure 5.7 Combined multi-species (terrestrial animals including foxes/dingoes, pigs, goannas/monitors, crocodiles, cats, scrub fowl and traditional human harvest) predators on key nesting beaches. Low = 0, Medium = 1, High =2, Very High = 3

Figure 5.8 Marine reserve (IUCN category I and II) and Indigenous Protected Area overlaid with hawksbill post nesting home range (black polygons). IPA = Indigenous Protected Area; DAWE = Department of Environment, Agriculture and Water (Commonwealth Government of Australia); GBRMPA = Great Barrier Reef Marine Park Authority (Commonwealth Government of Australia); DES = Department of Environment and Science (Queensland Government).

Figure 6.1 Locations of hawksbill turtle genetic sampling in **A)** Kavieng, New Ireland Province and with the addition of satellite tagging, in **B)** the Conflict Group of Islands, Milne Bay Province. **C)** Sampling locations and haplotype frequencies (shown as pie graphs) across Asia-Pacific.

Figure 6.2 Satellite tagging locations of hawksbill turtles. Migratory routes and foraging ground end points (shown as circle). Foraging ground clusters (Type I,II,III) shown in colour as per legend. See Table S6.4 for tag and turtle details.

Figure 6.3 Type I and Type II home ranges. Type III not shown. Red circles denote 50% UD, blue circles 95%UD.

Figure 7.1 RMUs in the South-East Asia region. (Adapted from Wallace et al 2010a).

Supplementary Material Figures

Figure S4.1 Number of clutches laid per nesting year and secondary sample (fortnights from November 15 to April 20 of each year). The grey shaded area represents the overall average (GAM).

Figure S4.2 Proportion of new recruit hawksbill turtles nesting at Milman Island 1990-2006, where the size of the points is proportional to the total number of turtles that were examined (from 6 turtles in 1997-1998 to 110 turtles in 1995-1996).

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Table 5.1 Threat assessment (shown in bold). Recovery Plan for Marine Turtles in Australia 2017–2027 (Commonwealth of Australia, 2017) assessment shown [in *italics* and brackets].

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Table 6.1 Matrix of population differentiation showing pairwise FST values below the diagonal and exact test results above the diagonal. Pairwise FST values represent the genetic differentiation between populations, with values ranging from 0 (no differentiation) to 1 (complete differentiation). The significance level (p-value) is indicated P ≤ 0.01 (**), P-value ≤ 0.05 (*), or non-significant (P-value) > 0.05 (n.s.) For the exact test results indicate the actual p-values with standard deviation (±).

Table 6.2 Home range analysis using minimum convex polygons (MCP) for ten hawkbill turtles during their foraging period.

Supplementary Material Tables

Table S2.1 Other relevant international legal instruments, organisations and consortia

Table S4.1 Surveys dates and sample sizes for Milman Island nesting turtle census, and the models that the data were used in: Std.: standard period model; GAM; MSORD and CCL (nester size distribution). Refer to the methods for more details. [1] included in the MSORD model but annual estimates were excluded because of low sample size.

Table S5.1 Tracked-turtle summary [CCL, curved carapace length; P, primary; ISR, interseason recapture]

Table S5.2 Threat exposure assessment and spatial datasets. Identified hawksbill turtle threat categories in northeast Australia are: (1) fisheries by-catch and net entanglement (2) exotic and native egg predation, (3) unsustainable take, (4) habitat loss and degradation, (5) marine pollution (6) climate change (projected long-term beach erosion; skewed sand temperature sex determination of hatchling).

Table S5.3 Hawksbill (HB), unspecified (Un-s) and all turtle species (All turtle) bycatch in Queensland and Commonwealth (C'wealth) fisheries, a) absolute and average over all available years, NA = no data reported or available, b) HB, Un-S and adjusted hawksbill interactions per fishery, c) absolute and average HB and adjusted hawksbill interactions over common reporting period (2012-2019) with HB and adjusted hawksbill range provided in shaded box, percentage in red text, d) turtle interaction rates from the QLD Fishery Observer Program in the ECIF (2006-2012) and potential hawksbill interactions, e) BPUE in the ETBF pre and post introduction of electronic monitoring, and f) Extrapolated BPUE, hawksbill turtle and adjusted hawksbill interactions based upon increase in BPUE observed in the ETBF fishery once independent monitoring was introduced.

Table S5.4 Quantified presence (+) versus absent (x) predation by F/D = fox/dingo; P = pig; G/M = goanna/monitor; Cr = crocodile; C = cat; SF = scrub fowl; H = human (traditional harvest) and non-peak clutch loss to predation by P, G, SF and H extrapolated to 14, 30 and 60 survey days at neQld stock key nesting sites.

Table S5.5 neQld stock harvest history review

Table S6.1 Sample information for all genetics samples collected in the study. Shaded haplotypes boxes show samples removed from analysis.

Table S6.2 Haplotype frequencies for Asia-Pacific hawksbill turtle management units. Haplotype designations indicate previous and new EilP names and GenBank references for the sequences. References (in order as shown) are: [#] Nishizawa et al. 2016; ^Vargas *et al.,* 2016; * Wahidah et al. 2009;[▲]LaCasella et al. 2022; [♠]This study)

Table S6.3 Summary of the 16 hawksbill turtles satellite tagged during 2017-2018 and 2018-2019 nesting seasons at the Conflict Group. P = Primary, first time tagged, WSR = within season recapture, CCL = curved carapace length (max length, cm), CCW = curved carapace width, L = laid, X = no lay.

Table S6.4 The table summarizes sample sizes, and haplotype counts , nucleotide and haplotype diversities, for samples collected from different hawksbill (*Eretmochelys imbricata*) Management Units using approximately 770 base pairs of the mitochondrial DNA control region. haplotype diversity (Hd) and Nucleotide diversity (π) were calculated to assess genetic diversity, and the number of unique haplotypes found in each location was determined.

Table S6.5 Summary of Argos satellite-tracking data, including migratory movements for 15 turtles tagged in 2017-2018. * = calculations pertaining only to turtles tracked to arrival at foraging ground (n = 10).

Table S7.1 Overview of Relevant National Legislation by Country. *Note, where information is missing, Range States did not respond to information requests or was not publicly available.*

List of Abbreviations used in the thesis

ACAMS	Association of Certified Anti-Money Laundering Specialists
ASEAN	Association of Southeast Asian Nations
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COP	Conference of the Parties
CTI-CFF	Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security
CTOC	Program on Countering Transnational Organized Crime
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
IAC	Inter-American Convention for the Protection and Conservation of Sea Turtles
ICCWC	International Consortium on Combating Wildlife Crime
IOSEA MOU/IOSEA Marine Turtle MOU	Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia
IPLCs	Indigenous Peoples and Local Communities
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unreported and Unregulated (IUU) fisheries
London Declaration (IWT)	London Conference on the Illegal Wildlife Trade (October 2018)
MOU ASEAN Sea Turtle Conservation and Protection	Memorandum of Understanding on ASEAN Sea Turtle Conservation and Protection
MUs	distinct populations/management units (or genetic stocks)
neQld	North-east Queensland

NPOA	National Plan of Action
PNG	Papua New Guinea
PSMA	Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
RFMOs	Regional Fisheries Management Organizations (relevant for this SSAP: • CCSBT: Commission for the Conservation of Southern Bluefin Tuna • IOTC: Indian Ocean Tuna Commission • NPFC: North Pacific Fisheries Commission • SIOFA: Contracting Parties of Southern Indian Ocean Fisheries Agreement (SIOFA) • SPRFMO: South Pacific Fisheries Management Organisation • WCPFC: Western and Central Pacific Ocean Commission)
RMUs	Regional Management Units
RPOA	Regional Plan of Action
SPREP	Secretariat for the Pacific Regional Environment Programme
SSAP	Single Species Action Plan
SSME Regional Action Plan	Sulu Sulawesi Marine Ecoregion Regional Action Plan
UNCLOS	United Nations Convention on the Law of the Sea
UNODC	United Nations Office on Drugs and Crime
WiTIS database	TRAFFIC Wildlife Trade Information System
WWF	World-Wide Fund for Nature

Chapter 1: General Introduction

The hawksbill turtle, *Eretmochelys imbricata*, is circum-globally distributed in sub-tropical marine systems, with many populations known to be declining steeply (Mortimer & Donnelly, 2008; Pilcher *et al.,* 2021; Senko *et al.,* 2022). Hawksbill turtles are considered “Critically Endangered” internationally under the IUCN Red List, but disparately listed nationally. For example, the conservation status listing for hawksbills is “Vulnerable” under Australian legislation, but not listed or protected in PNG at all (IUCN Red List 2022; EPBC Act 1999). This disparity is of great concern because hawksbill turtles are among the most poorly studied marine turtle species (Limpus, 2008), so effective conservation action requires significant new knowledge.

Within the Indian and Western Pacific Ocean region, Australia has the largest remaining hawksbill turtle breeding populations. The north-east Queensland (neQld) stock is recognised as one of the largest nesting populations for the hawksbill turtles in the world (Meylan and Donnelly, 1999), but this stock was expected to decline by > 90% by 2020 if the trend at that time continued unchanged (Limpus, 2008). Previous studies have shown that the neQld stock nest and forage in Australia and neighbouring countries (e.g. Papua New Guinea, PNG (Limpus, 2009) and vice versa. However, very few foraging grounds have been reported and only a small number of key hawksbill turtle nesting beaches have been identified, with limited population trend or genetic data published or available. In PNG, very few studies have been conducted and are generally limited to the Milne Bay Province (Kinch, 2003a,b; Wangunu *et al.,* 2004) and without knowledge of haplotype diversity or composition, hawksbill populations of PNG are thought to be in severe decline. Hawksbill turtles across the greater western Pacific Ocean region are also thought to be facing imminent population collapse in some localities, if not already extirpated (Pilcher *et al.,* 2021).

At a regional scale, the unsustainable use and demand for trade in hawksbill turtles, parts and products remains one of the greatest drivers of regional population declines and is clearly identified as one of the major threats to regional hawksbill population recovery (CITES Secretariat, 2019; Kinch & Burgess, 2009; Ingram *et al.,* 2022; Lam *et al.,* 2011; Wallace *et al.,* 2010; Senko *et al.,* 2022). While many contemporary threats (such as by-catch in commercial fisheries) are being addressed, the take and trade of hawksbills for their eggs, meat and scutes continues to the present time, and in most western Pacific countries including some regions of Australia, remains unabated (CITES Secretariat, 2019; Commonwealth of Australia, 2017; Hamilton *et al.,* 2015; Kinch, 2006; Miller *et al.,* 2019; Picher *et al.,* 2021; Senko *et al.,* 2022).

At least 86,020lb (or around 39,000kg/39 ton) of tortoiseshell was exported from north Queensland at the time of commercial tortoiseshell trade (18th century - 1930s). Applying a conversion factor of 2lb (0.907185kg) of tortoiseshell per large turtle (Limpus & Miller, 2008), approximately 43,010 adult-sized hawksbills were taken from the northern GBR and Torres Strait. Other publications suggest this is equivalent to an annual harvest in excess of 1,000 hawksbills (Limpus & Miller, 2008; Limpus, 2009). The industry effectively ceased during the 1940s and became illegal with the protection of hawksbill turtles in Queensland in 1968 (Limpus, 2009).

Unpermitted take remained illegal in Queensland until the *Native Title Act 1994* (section 211) came into effect, allowing Aboriginal and Torres Strait Islander (ATSI) people with legitimate Native Title rights to hunt hawksbills in Australia for personal, domestic, communal, and non-commercial purposes. ATSI's hunted hawksbills for centuries for tortoiseshell, meat and eggs (Limpus, 2009); today take is generally managed through customary lore. However, changes in technology and the disruption of Indigenous culture are a growing challenge to the intensity of take (MACC Taskforce, 2005), although take for all of Queensland remains unquantified. An unquantified number of marine turtle eggs are collected from rookeries throughout Cape York Queensland and the Torres Strait, of which there is a noted preference for hawksbill eggs.

The take of hawksbills and their eggs by indigenous communities within other western Pacific countries, such as PNG also occurs. Hawksbill turtles are not considered a protected species in PNG where the level of take is likely to be substantially high (Kinch & Burgess, 2009). This take is likely to have negative consequences for the neQld stock. Compliance intervention into egg poaching by PNG nationals in the Torres Strait (in contravention to the provisions of the Torres Strait-PNG Treaty), also remain unresolved (The Cairns Post, 2017). Understanding the social, cultural, and economic drivers behind 'take' is fundamental in improving the co-existence between humans and hawksbills, and where loss of a population is likely, exploring other non-consumptive uses (Liles *et al.,* 2015; Mancini *et al.,* 2011).

With PNG and Australia rated in the top three countries for legal take of marine turtles globally (Humber *et al.,* 2014), and with these continued records of illegal, unreported, and unregulated take and trade, we need to determine where hawksbill turtles are being targeted and whether their foraging grounds and nesting sites are locations of unsustainable take or areas that may act as stronghold of population sustainability. There is also an urgent need to develop a deeper understanding of all other threats these populations face for future management and protection.

Whilst considered more extensive than previously supposed (Daley *et al.,* 2008), the Queensland commercial marine turtle fisheries have now ceased (in line with CITES Appendix I listing, 1977), however by-catch in active pelagic and demersal fisheries continues (Commonwealth of Australia, 2017). Although there have been considerable modifications to fishery gear and bait types to reduce bycatch, it has been shown that interactions with hawksbills and other marine turtles remain underreported. For example, new catch monitoring and reporting requirements on the Australian Eastern Tuna & Billfish Fishery has drastically increased logbook reports from 16 marine turtles (all species) caught in 2013, to 198 turtles in 2017, despite a comparable level of fishing activity between the years (AFMA, 2018). Similar significant underreporting or inconsistent identification is suspected within Queensland commercial fisheries (refer Chapter 3). Discarded fishing gear or “ghost nets” also present a serious threat. Wilcox *et al.,* (2014) estimated between 4,866 and 14,600 marine turtles (all species) were caught in 8690 ghost nets sampled between 2005-2012. Although inconsistent identification was acknowledged, 32.6% of turtles caught were thought to be hawksbills (Wilcox *et al.,* 2014). Incorrect identification, under-reporting, weak regulations, and lack of compliance are assumed to be more pronounced in western Pacific commercial fisheries, therefore the extent to which by-catch remains a significant threat for the neQld stock and PNG populations is unknown and warrants further investigation.

Depredation of hawksbill eggs and hatchlings by feral animals, such as pigs and dogs, and native predators, such as goannas and crocodiles remain relatively unquantified, yet are likely to hinder stock recovery (Commonwealth of Australia, 2017). A rapid assessment conducted by Torres Strait Regional Authority revealed multiple Torres Strait islands with regionally significant hawksbills nesting were threatened by goanna or pig predation, but this predation was variable and considered low (Torres Strait Regional Authority, 2017). Limited predation assessments have been conducted at other hawksbill nesting sites across the western Pacific Ocean region.

Similarly, limited climate change impact assessments have been conducted at most nesting beaches across this region. There is an increasing understanding that marine turtle populations will face severe negative impacts from climate change with predicted global warming and sea level rise (Hawkes *et al.,* 2007; Poloczanska *et al.,* 2009). Negative impacts of climate change are already being observed at marine turtle nesting beaches of north Queensland (Jensen *et al.,* 2018), highlighting that while intervention is already required, abatement of all other threats should be a management priority. The Australian Bureau of Meteorology Climate Change Trend Map (Australian Government Bureau of Meteorology, 2018) shows temperatures within the region of the neQld stock and PNG populations increasing at 0.10-0.15°C/decade over the past 55 years. Hawksbill turtle foraging populations throughout the GBR are already skewed to a higher female ratio (approximately 3 females:1 male; Limpus, 2009; Bell *et al.,* 2012). A rise in regional incubation temperatures will likely cause additional female sex ratio skewing for hatchlings and increase the risk of reduced hatchling production during periods when nest temperatures exceed 32°C (Dobbs *et al.,* 2010). Acknowledging that hawksbills nest year-round, and while unlikely, if hawksbills were able to rapidly adapt to rising temperatures by altering their peak nesting period to cooler months, sex ratio output may skew towards an increase in male production.

Although recovering nesting hawksbill populations have been reported in the Solomon Islands after protected areas had been declared and imposed at both nesting (Hamilton *et al.,* 2015) and foraging grounds (Bell & Jensen*,* 2018), population declines in PNG and the neQld index site continues. For the neQld stock, this is irrespective of its high level of protection within national parks and the Great Barrier Reef World Heritage Area. Before recovery management intervention or appropriate mitigation is proposed for the neQld stock and PNG, the identification of foraging grounds and associated threats, and the genetic relatedness to neighbouring western Pacific Ocean hawksbill populations needs to be uncovered.

Marine turtles exemplify the challenges associated with monitoring, assessing, and managing migratory megafaunal taxa across multiple scales (Wallace *et al.,* Accepted). Hawksbill turtles make complex movements between habitats at different life-history stages spanning Exclusive Economic Zones of multiple nations, between local, state, national and regional jurisdictional boundaries with differing or multi-layered governance and legislative regimes (Hay & Scott, 2013). But they often show strong fidelity to their foraging grounds (Bell, 2012). Given their known habitat preferences and presence throughout western Pacific, we need to determine whether hawksbill turtle populations originating from neQld and PNG are being targeted along their migration paths and at their foraging grounds causing population decline. We also need to determine whether the PNG populations are part of the same cohort or genetically distinct (i.e. own genetic stock) in order to effectively manage these populations as either discrete management units or as one. This is important, especially in declining populations, to be able to manage and maintain genetic viability and aid recovery.

Satellite tracking is widely used and considered an ideal method to study migration, movement and habitat use of hawksbill turtles (Godley *et al.,* 2008). Due to costs and technology limitations, this method generally constrains studies to small sample sizes of adult female hawksbill turtles, and these are often designed to map inter-nesting and breeding-foraging ground migrations. Used as an additional tool to infer regional migration and distribution, molecular DNA sampling is being used as a more time-efficient and cost-effective tracking tool to determine the geographical origin of individuals (Jensen *et al.,* 2013) and connectivity of populations (see Vargus *et al.,* 2016). At the time of instigating this thesis, only four satellite transmitters had been deployed on hawksbill turtles from neQld (three of which were deployed by Madden Hof in 2016) and none in PNG, and there was no publicly available data on haplotype assignment or composition from or for PNG hawksbills. Moreover, very little was known about the movements of post-hatchlings or juveniles prior to recruitment to a foraging ground from this geographic region. Migration paths and nursery or developmental foraging grounds (the ‘lost years’) of hawksbill neonates are generally also unknown. Significant empirical knowledge is required to be able to quantify the neQld stock’s predicted > 90% loss, and PNG’s expected severe population decline (Limpus, 2008; Wangunu et al., 2004).

An urgent regional and international response is required to reduce mortalities, arrest demand, and increase the resilience of the remaining neQld and PNG hawksbill turtle populations to encourage the population recovery of western Pacific’s last strongholds. Given the historical population size and importance of these populations in the western Pacific Ocean (Picher *et al.,* 2021), the aim of this thesis was to quantify the population status, distribution and migratory movements of hawksbill turtle populations within NE Australia and PNG, and to indicate whether hawksbill turtle migratory paths and foraging grounds are the strongholds or targeted ‘source’ driving current critical population declines.

In this thesis, my main focus was to use empirical science to inform the policy and mitigation management required to recover neQld and PNG hawksbill populations.

Specifically, the objectives of this thesis was to:

- Identify and describe the migration paths and foraging grounds of hawksbill turtles originating from major nesting sites in neQld and PNG;
- Identify major threats impacting hawksbill turtle foraging grounds and studied nesting sites; and
- Provide recommendations for policy and conservation management outcomes to protect hawksbill turtle populations in neQld and PNG and encourage their recovery.

In the following Chapters of this thesis, I:

- Undertake a literature review to assess hawksbill populations conservation status and connectivity within the western Pacific Ocean region (Chapter 2)
- Undertake a policy review of hawksbill turtles in the South-east Asia and the adjacent Western Pacific (Chapter 3).
- Assess the neQld nesting population demographics and trajectory (Chapter 4).
- Identify policy and mitigation management required to recover the likely extirpated neQld stock using satellite tracking, threat assessment and spatial exposure data (Chapter 5).
- Assess the genetic structure and migration patterns of PNG hawksbill turtles to uncover regional connectivity and inform conservation strategies (Chapter 6).
- Develop a Single Species Action Plan for the hawksbill turtle in South-east Asia and the adjacent Western Pacific to underpin priority policy and management efforts required (Chapter 7).
- Discuss policy and conservation management needs and implications to recover neQld and PNG hawksbill populations (Chapter 8).

Chapter 2: Assessment of the conservation status of the hawksbill turtles in the western Pacific Ocean region

This chapter includes a co-authored report that has been published by the Convention of Migratory Species Secretariat.

Madden Hof, C.A., Riskas, K.A., Jensen, M.P., Hamilton, R.J., Pilcher, N.J, Gaos, A.R., Hamann, M. (2022). Assessment of the conservation status of the hawksbill turtle in the western Pacific Ocean region. 51 Pages. CMS Technical Series No. 45. [Website: https://www.cms.int/en/publication/assessment-conservation-status-hawksbill-turtle-western-pacific-ocean-region]

Preface

Although there are a number of regional agreements and national plans relevant to the long-term conservation and management of marine turtles and their habitats in the region, few are specific to hawksbill turtles in the western Pacific Ocean region – a species and region that has been identified as severely lacking in scientific uncertainty and gaps in knowledge, and classified as one of the most endangered regional management units (grouped based on population and threat risk) (Wallace *et al.,* 2010; Wallace *et al.,* 2011). The scientific data that exists are scattered, highlighting the need to summarise this data for use in designing and implementing effective policy and management action plans.

This chapter presents a synopsis of the current state of knowledge for hawksbill turtles in the western Pacific Ocean region, including biological and ecological knowledge of nesting and foraging populations, legislative provisions, and detailed recommendations and proposals for addressing identified deficiencies. Aimed at an international audience, it has in-depth information for each of the countries within the Pacific Ocean region known to sustain hawksbill populations. This information was collated and synthesised from scientific papers, grey literature and reports to inform the remaining chapters of this thesis. It complements the Signatory States' Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA Marine Turtle MOU; a non-binding framework under the Convention of Migratory Species, CMS) commissioned marine turtle region-wide species assessments (e.g. Hamann *et al.,* 2022) and was published as such to support the CMS's development of a Single Species Action Plan (13.70c). The assessment report as published by CMS is presented in this thesis chapter.

Note: references relating to Madden Hof et al., 2023a,b have been updated in this Chapter from the CMS 2022 publication for thesis reference alignment. In addition, minor editorial changes were also made.

Abstract

The western Pacific Ocean region is home to six out of seven marine turtle species. There are several regional agreements and action plans relevant to the long-term conservation and management of marine turtles and their habitats in the region, including a newly revised Regional Marine Turtle Action Plan 2021-2025 (that came into effect in 2022) developed by the Secretariat of the Pacific Regional Environment Programme (SPREP). SPREP is a regional organisation established and mandated by the governments and administrations of the Pacific to promote cooperation and provide assistance in order to protect and manage the environment and its natural resources. The SREP is non-binding and supported by 21 Pacific Island member countries and territories, but unlike the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA Marine Turtle MOU). The IOSEA Marine Turtle MOU, with its associated Conservation and Management Plan (CMP), is a non-binding framework under the Convention on the Conservation of Migratory Species of Wild Animals (Convention on Migratory Species, CMS). Through the MOU, States of the Indian Ocean, and South-East Asia (IOSEA) region work together to conserve and replenish depleted marine turtle populations for which they share responsibility. The IOSEA Marine Turtle MOU took effect in September 2001 and as of March 2022 has 35 Signatory States. Supported by an Advisory Committee (AC) of eminent scientists, and complemented by the efforts of numerous citizens' groups, nongovernmental, and intergovernmental organisations, Signatory States are working towards the implementation of a comprehensive Conservation and Management Plan (CMP). The CMP is an integral part of the MOU. There is some overlap in

western Pacific Ocean country membership between the SPREP and IOSEA Marine Turtle MOU, and considerable overlap in the geographic distribution and habitat use of the region's shared marine turtle populations.

Aware of the importance of compiling and making available up-to-date information on the status of marine turtle species, particularly in order to identify and address gaps in basic knowledge and necessary conservation actions, the IOSEA Signatory States commissioned a series of region-wide marine turtle species assessments. Following assessments for leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) turtles (Hamann *et al.,* 2006 and Hamann *et al.,* 2013, respectively), the Signatory States Advisory Committee determined the need for a comprehensive assessment of the hawksbill turtle (*Eretmochelys imbricata*). The assessment was completed in March 2022 and reflects the current state of knowledge on the species, albeit geographically limited to the IOSEA region (Hamann *et al.,* 2022).

Parallel to the development of IOSEA's hawksbill assessment, the Convention on Migratory Species (CMS) adopted the development of Single Species Action Plan (SSAP) to specifically address the use and trade of hawksbill turtles in South-East Asia and the adjacent western Pacific Ocean region (Decision 13.70c). IOSEA Signatory States agreed to cooperate with CMS to jointly develop the draft SSAP (refer Work Programme 2020-2024, Action 63). However, much of the western Pacific is outside of IOSEA's geographic scope.

Terms of reference

To inform the SSAP's full geographic scope, the CMS Secretariat engaged a team of experts to review the status of hawksbill turtles in the western Pacific Ocean region, led by the World Wide Fund for Nature (WWF) and the University of the Sunshine Coast. This information will also support Pacific countries and territories to implement objectives in the updated Regional Marine Species Action Plans 2022-2026 (SPREP, 2022), specifically the Marine Turtle Action Plan.

This document presents a synopsis of the current state of knowledge for hawksbill turtles in the western Pacific Ocean region, including biological and ecological knowledge of nesting and foraging populations, legislative provisions, and detailed recommendations and proposals for addressing identified deficiencies. We collated and synthesised information from scientific and grey literature, reports from the Turtle Research and Monitoring Database System (TREDS) hosted by the SPREP (noting, there are several unquantified hawksbill records in TREDS and caution should be taken when interpreting the results presented in this assessment; TREDS, 2022), the new online marine turtle breeding and migration atlas "TurtleNet" (2021) developed by Queensland's Department of Environment and Science (DES) in collaboration with the CMS, and turtle experts within the western Pacific Ocean region. The format follows the IOSEA hawksbill turtle assessment (Hamann *et al.,* 2022) for consistency and ease of reference, and complements that report. The assessments for IOSEA member countries that fall within the boundaries of the western Pacific Ocean (e.g. Australia, Philippines) are not repeated herein. In this document, we review the remaining 22 countries and territories that, for the purposes of this review, make up the western Pacific Ocean region (including IOSEA non-members), namely: American Samoa, Commonwealth of the Northern Mariana Islands, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Nauru, New Caledonia, New Zealand, Niue, Palau, Papua New Guinea, Republic of the Marshall Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna (Figure 2.1).

In compiling our assessment of hawksbill turtles in the western Pacific Ocean region, we used the genetic stocks approach as per the loggerhead (Hamann *et al.,* 2013) and hawksbill (Hamann *et al.,* 2022) IOSEA assessments, and as identified by FitzSimmons and Limpus (2014) and Vargas *et al.,* (2015). Where no genetic stock is assigned, we include a summary of published information and reports for countries for which biological data are available.

Introduction

The hawksbill turtle (*Eretmochelys imbricata* (Linnaeus, 1766)) occurs in tropical and sub-tropical regions across the globe. Hawksbill turtles have significant ecological, economic, and cultural value and play an important role in coral reef health, culture, and tourism (Brander *et al.,* 2021). Hawksbill turtles are listed globally as "Critically Endangered" (IUCN Red List, 2022), as some populations around the world are at very high risk of extinction due to continued pressures resulting from combinations of past and continued human activities. Faced with multiple, cumulative threats, and despite international protection, the major contributing factors preventing recovery and/ or driving hawksbill turtle populations to lower levels in the western Pacific Ocean region likely include over- exploitation from unsustainable legal and illegal take, including to supply the tortoiseshell trade, fisheries bycatch, ghost nets, coastal development, and climate change (Mortimer and Donnelly, 2008; Wallace *et al.,* 2010; Lam *et al.,* 2012; Humber *et al.,* 2014; SPREP, 2022). Many dedicated organisations, individuals, communities, and governments have achieved conservation gains, but much more work is to be done to prevent further declines.

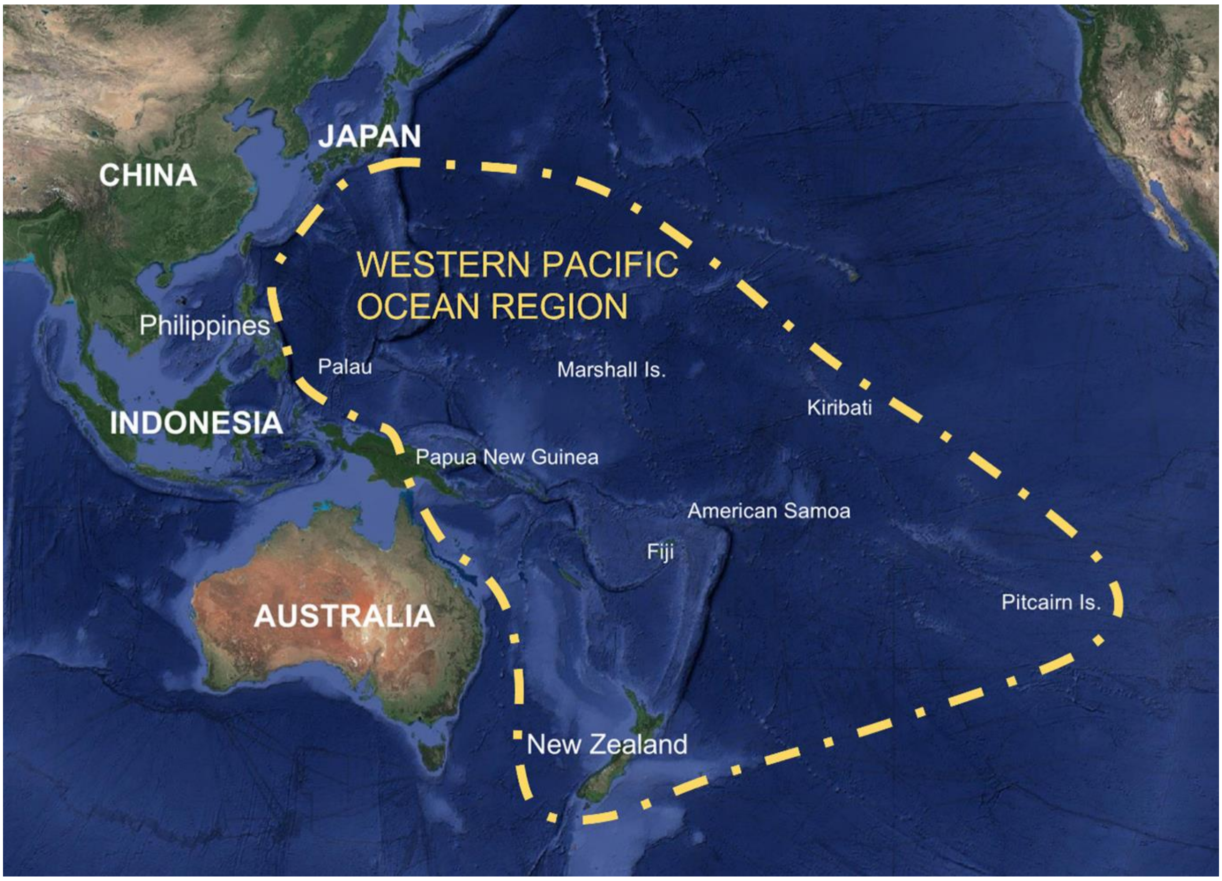

Figure 2.1. Indicative boundary of western Pacific Ocean region used in this assessment. For a list of countries included within this boundary, see Table 2.3 (highlighted countries).

Given the wide variety of threats and management measures in place across the hawksbills ecological range, efforts to determine conservation status at the global level (e.g., IUCN Red List framework) have proven challenging and occasionally provoked debate within the scientific community (Godfrey and Godley, 2008; Campbell, 2012). The most comprehensive assessment estimated the Pacific Ocean hawksbill populations to be at least 75% lower than historical levels, and in the Pacific Ocean basin, an estimated 4,800 nesting females remained in 2008 (Mortimer and Donnelly, 2008). While this number does not include male turtles nor the multiple cohorts of non- breeding turtles in the population, the trend in number of nesting females is a useful way of monitoring population status as female turtles emerge on beaches to lay eggs, whereupon they can be counted. It is also the basis upon which the IUCN Marine Turtle Specialist Group based the 2008 global status assessment for hawksbill turtles. This assessment reported hawksbill populations in many countries were depleted and/or declining (e.g., most of Micronesia, Papua New Guinea, Fiji, Guam, American Samoa, and Palau, among others). A more recent peer-reviewed assessment revealed that the number of hawksbill nests laid within the Arnavons Community Marine Park in Solomon Islands was increasing (Hamilton *et al.,* 2015), but examples of such success are limited. Within its remit, SPREP is currently (2023) undertaking an extinction risk assessment which may further inform decision makers of trends in annual nesting patterns for hawksbill populations in this region, but in the absence of recent quantified nesting census figures across most of the region, and a lack of data on the stability of foraging area populations, the 2008 declining trends for hawksbill populations across the entire western Pacific Ocean region is of significant concern.

As with other long-lived, widely distributed species, it is often difficult to determine the hawksbills conservation status at the scales required for management (Meylan and Donnelly, 1999; Mortimer and Donnelly, 2008; Wallace *et al.,* 2011; FitzSimmons & Limpus, 2014). Hawksbill turtle nesting is widespread and, in some areas, considered abundant within the western Pacific Ocean region (e.g., Arnavon Islands, Solomon Islands). There are numerous hawksbill populations nesting in discrete locations that often display distinct life cycle characteristics (FitzSimmons and Limpus, 2014; Gaos *et al.,* 2012). Confounding our ability to quantify and evaluate populations, hawksbill turtles are migratory and individuals from different nesting populations may overlap in their use of foraging areas (Vargas *et al.,* 2015; Bell & Jensen, 2018), adding to the complexity of understanding the dynamics of each population.

Genetic research techniques can be used to identify distinct hawksbill populations, which may then be grouped into stocks or management units (MUs). Delineating these groups below the species level allows for a more detailed, location-specific assessment of threats and implementation of conservation strategies. Unfortunately, genetic studies to identify appropriate management units across the western Pacific Ocean region are considerably lacking. In the western Pacific Ocean region, only three MUs have been identified (refer below), but the geographical boundaries of each MU remain unresolved due to limited sampling (in large because of a deficiency of nest monitoring programs that can collect samples from nesting females). To specifically address the knowledge gaps in the genetic structure of hawksbill turtle rookeries throughout the region, the Indo-Pacific Hawksbill Genetic Working Group (IPHGWG) was established in 2018. The working group aims to identify sampling gaps, coordinate genetic sampling, share unpublished datasets, and collaborate on data analyses and publication. Supported by WWF, these efforts connect researchers and help fund data collection and analysis to identify the genetic population structure of hawksbills in the Asia-Pacific region, through the ShellBank project (www.shellbankproject.org.au).

Similarly, the Asia-Pacific Marine Turtle Genetic Working Group was established in 2020 (supported by a multi-organization steering committee) to connect researchers across the region and to provide capacity building and training in marine turtle genetics (for all species).

The knowledge gaps in hawksbill genetic structure also affect the designation of regional management units (RMUs) across this region (Wallace *et al.,* 2010). RMUs group populations into regional constructs, largely based upon the sharing of foraging areas and are assessed in terms of population risk level (population size, recent trend, long-term trend, rookery vulnerability and genetic diversity) and existing threats (fisheries bycatch, take, coastal development, pollution and pathogens, and climate change). This assessment lists information by RMU and management units (when known), noting however, that these RMUs are currently under review on a global scale (IUCN Marine Turtle Specialist Group). Countries and territories are either categorised under their currently assigned RMU designation, or under the heading of 'Other'.

To date, four broad RMUs for hawksbill turtles have been described for the western Pacific region: 1. Southwest Pacific, 2. West Central Pacific, 3. West Pacific/Southeast Asia, and 4. South Central Pacific (Figure 2.2). Of the four RMUs for hawksbill turtles in the western Pacific Ocean, three appear in this report. The West Pacific/Southeast Asia RMU is included in Hamann *et al.,* (2022) and is not repeated here. For the Southwest Pacific RMU, two out of the three management units identified (North Queensland, Northeast Arnhem Land) are included in Hamann *et al.,* (2022) and therefore not included here, while the third– the Solomon Islands management unit - is reviewed in this document.

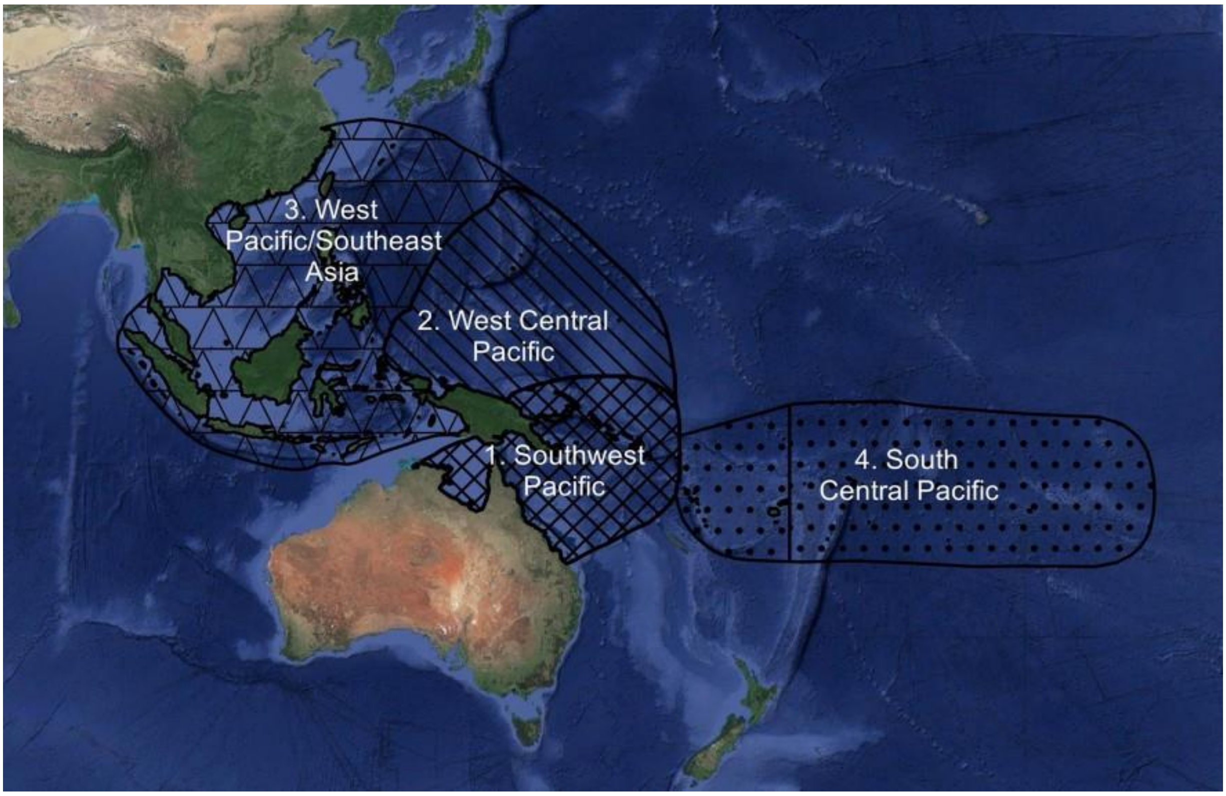

Figure 2.2. Hawksbill turtle Regional Management Units in the Western Pacific Ocean. Adapted from Wallace *et al.,* 2010.

Hawksbill turtle synthesis

In 1996 and again in 2008, the species was assessed at the global level as Critically Endangered by the IUCN Species Survival Commission. Meylan and Donnelly (1999) and Mortimer and Donnelly (2008) provide the supporting information for the 1996 and 2008 assessments, respectively.

Population identification

Three out of the four western Pacific Ocean region hawksbill RMUs are solely in the Pacific Ocean, while one encompasses the waters of the eastern Indian Ocean, South-East Asia, and the western tropical Pacific (Wallace *et al.,* 2010) (Figure 2.2). All except the Southwest Pacific RMU are considered putative due to a lack of data demonstrating connectivity through genetics or distribution. The Southwest Pacific RMU has been assessed for distinct populations/management units, of which it has three: the North Queensland management unit (based on sampling at Milman Island in Queensland, Australia), the Northeast Arnhem Land MU (in Northern Territory, Australia distinguished from the first by a shift in nesting timing), and the Solomon Islands MU (based on sampling at the Arnavon Islands, Solomon Islands) (FitzSimmons and Limpus, 2014; Vargas *et al.,* 2015; LaCasella *et al.,* 2021). The majority of hawksbill RMUs in the western Pacific have not yet been assessed for genetic population structure, although efforts to collect and analyse samples to do so are underway in several countries. Through the work of the IPHGWG, the genetic sampling of the western Pacific now includes data from several rookeries in Vanuatu, American Samoa, Fiji, and Papua New Guinea (Table 2.1). While these data are currently unpublished, they are expected to become publicly available in the foreseeable future.

Nesting

Hawksbill turtles have been recorded nesting in at least 16 countries in the western Pacific Ocean region (including six nations in the West Pacific/Southeast Asia RMU; see Hamann *et al.,* 2022). Many of these are not Signatory States to the IOSEA Marine Turtle MOU as they lie outside the IOSEA region, seven are Parties to the CMS, and all are members of SPREP. There are no recent records to indicate if hawksbills nest in the Commonwealth of the Northern Mariana Islands (CNMI), Cook Islands, Guam, Kiribati, Nauru, New Caledonia, New Zealand, Niue, Tokelau, Tonga, Tuvalu, or Wallis and Futuna. A summary of known hawksbill annual nester abundance is provided in Table 2.2 (adapted from Pilcher, 2021).

Foraging

Data from tag recoveries, satellite telemetry, fisheries bycatch, in-water surveys, and anecdotal reports indicate that foraging hawksbill turtles occur, and in some cases migrate between almost every country in the western Pacific Ocean region. Population and biological studies on foraging hawksbills are limited overall, although some studies have been conducted in Australia, American Samoa, Fiji, Guam, Papua New Guinea, Solomon Islands, and Vanuatu.

Areas within the western Pacific region of known importance for hawksbill turtles

Important nesting sites

There are a number of identified nesting sites within the western Pacific Ocean region, some of which are monitored by local communities, NGOs, and government agencies (Figure 2.3). However, there are many knowledge gaps regarding distribution and abundance (Table 2.1).

Table 2.1. Outputs from the Wallace *et al.,* (2010) RMU designations, management units based on genetic stock designations by FitzSimmons and Limpus (2014) and Vargas *et al.,* (2015), and current sampling/analysis status identified under the IPHGWG. *Denotes inclusion in Hamann *et al.,* (2022).

Regional Management Unit	Western Pacific countries with documented hawksbill turtle nesting	Management Units based on genetic stocks determined by FitzSimmons and Limpus (2014) and Vargas *et al.*, (2015)	Current sampling/analysis status (based on IPHGWG)
Southwest Pacific Ocean (including Australia [Northern Territory and Queensland], Papua New Guinea and Solomon Islands)	Australia (Northern Territory and Queensland), Papua New Guinea and Solomon Islands	North Queensland MU*, Northeast Arnhem Land MU*, and Solomon Islands MU have been assessed	Analysis for genetic-population structure is underway for Torres Strait (Australia) and Conflict Islands and New Ireland (Papua New Guinea). Additional genetic sample collection and analysis is underway across Papua New Guinea (nesting, foraging, bycatch) and Australia (confiscated stockpiles).
West Central Pacific Ocean (including waters surrounding Micronesia, FSM, Palau, the Marshall Islands, Guam, Kiribati, and Commonwealth of Northern Mariana Islands)	Palau Marshall Islands CNMI	Not defined	Efforts to collect samples from countries within this RMU are needed.
South Central Pacific Ocean (including Vanuatu up to the Eastern Solomon Islands, across the Pacific to include Tonga, Samoa, American Samoa, and French Polynesia [equator to 25 South])	Samoa, Vanuatu, American Samoa, Fiji, French Polynesia, Tonga	Not defined	Genetic sample collection and analysis is underway for Vanuatu (nesting), American Samoa, Tonga (nesting, I-ging, bycatch), and Fiji (nesting, foraging, bycatch).
West Pacific/Southeast Asia*	Thailand, Malaysia, Indonesia, Philippines, Viet Nam, plus Singapore (not an IOSEA MOU signatory state)	Sulu Sea (Malaysia) MU, Gulf of Thailand (Kho Kram) (possible MU) and western Peninsular Malaysia MU have been assessed. Rookeries in Indonesia, Singapore, Viet Nam, and Philippines have not been assessed for genetic population structure.	Genetic sample collection and analysis is underway for Thailand (nesting), Philippines (nesting, stranded, confiscated stockpiles), and Indonesia (nesting).

Table 2.2. Summary of the estimated number of female hawksbill turtles breeding per year. Adapted from Pilcher (2021).

Country	RMU	Estimate	Bin category (adapted by Seminoff *et al.*, 2015)
American Samoa	SC	<10-15	11-50
Fiji	SC	20-30	11-50
French Polynesia	SC	n/a	n/a
Samoa	SC	<5-15	1-10
Guam	WC	5-10*	1-10
FSM	WC	10-20	11-50
PNG	SW	<500	101-500
Marshall Islands	WC	n/a	n/a
Palau	WC	20-50	11-50
Solomon Islands	SW	200-300	101-500
Vanuatu	SC	300	101-500

Index nesting beaches

An index beach is one at which monitoring is sufficiently robust and consistent through time and from which population trends may be used to infer trends at other, less frequently surveyed, locations (refer also to the definition provided in Hamann *et al.,* 2022, p.12). There are only two recognised index nesting beaches for hawksbill turtles in the western Pacific Ocean region (as geographically defined by this assessment): Namena Lala Island in Fiji and the Arnavon Community Marine Park (ACMP) in the Solomon Islands. While a small number of countries have nesting beach monitoring programmes for hawksbill turtles, these have not been running long enough or with a consistent level of effort needed to gather robust long- term monitoring data and establish these areas as index nesting beaches (Pilcher, 2021). Monitoring efforts are hampered by the difficulty of accessing remote islands and atolls, and providing staff and essential equipment for the duration of monitoring periods. It is possible that some hawksbill turtle nesting sites have not yet been detected in the western Pacific, particularly for the many archipelagic nations in the region, or that nesting reports have not been documented or shared. There are no trends in hawksbill nesting abundance (nests and females) available for any western Pacific countries, except for the Solomon Islands (Hamilton *et al.,* 2015).

Important non-nesting sites

<u>Migration</u>

Hawksbill turtles in the western Pacific Ocean are known to travel up to ~1,500 km between nesting and foraging sites, and this is potentially a reflection of the vast distances between landmasses. Limited tag recoveries of hawksbill turtles from foraging sites in north-eastern Australia have been recorded nesting in Vanuatu, Solomon Islands, Papua New Guinea, and various sites in the Great Barrier Reef (Miller *et al.,* 1998). Linkages of similar distances are demonstrated between American Samoa and the Cook Islands (Tagarino *et al.,* 2008), the Conflict Islands (Papua New Guinea) and northern Queensland (CICI, 2018; Madden Hof *et al.,* 2023a,b), Arnavons (Solomon Islands) and Queensland (Hamilton *et al.,* 2015; Hamilton *et al.,* 2021), and Tinian (CNMI) and Pohnpei (Federated States of Micronesia; Gaos *et al.,* 2020). Genetics and tag returns have also shown links between hawksbills foraging on the nGBR and nesting beaches in the wider Bismarck–Solomon Sea region (Bell and Jensen, 2018).

Important foraging and refuge sites

Migratory connectivity for hawksbill turtles in the western Pacific Ocean is poorly understood. However, satellite telemetry and tag recoveries have revealed the Coral Sea as a key foraging area for hawksbill turtles in the western Pacific (Limpus, 2008; Pilcher, 2021).

Hawksbills have been reported foraging throughout the Coral Sea after post-nesting migrations from the Conflict Islands in Papua New Guinea (CICI, 2018; Madden Hof *et al.,* in prep), the Arnavons in Solomon Islands (Hamilton *et al.,* 2015; Hamilton *et al.,* 2021), and Vanuatu (Jim *et al.,* 2022; Miller *et al.,* 1998). There is no known officially designated index foraging site for hawksbill turtles in the western Pacific Ocean region. Although not included in this review, genetic studies from the Great Barrier Reef (Howick Group) in north-eastern Australia show it may be a major foraging site for the Solomon Islands MU (Bell & Jensen, 2018). Some other western Pacific hawksbill populations' migratory routes to the Queensland coast of Australia are becoming more apparent, where other major foraging sites are likely to be identified along north-eastern Australia.

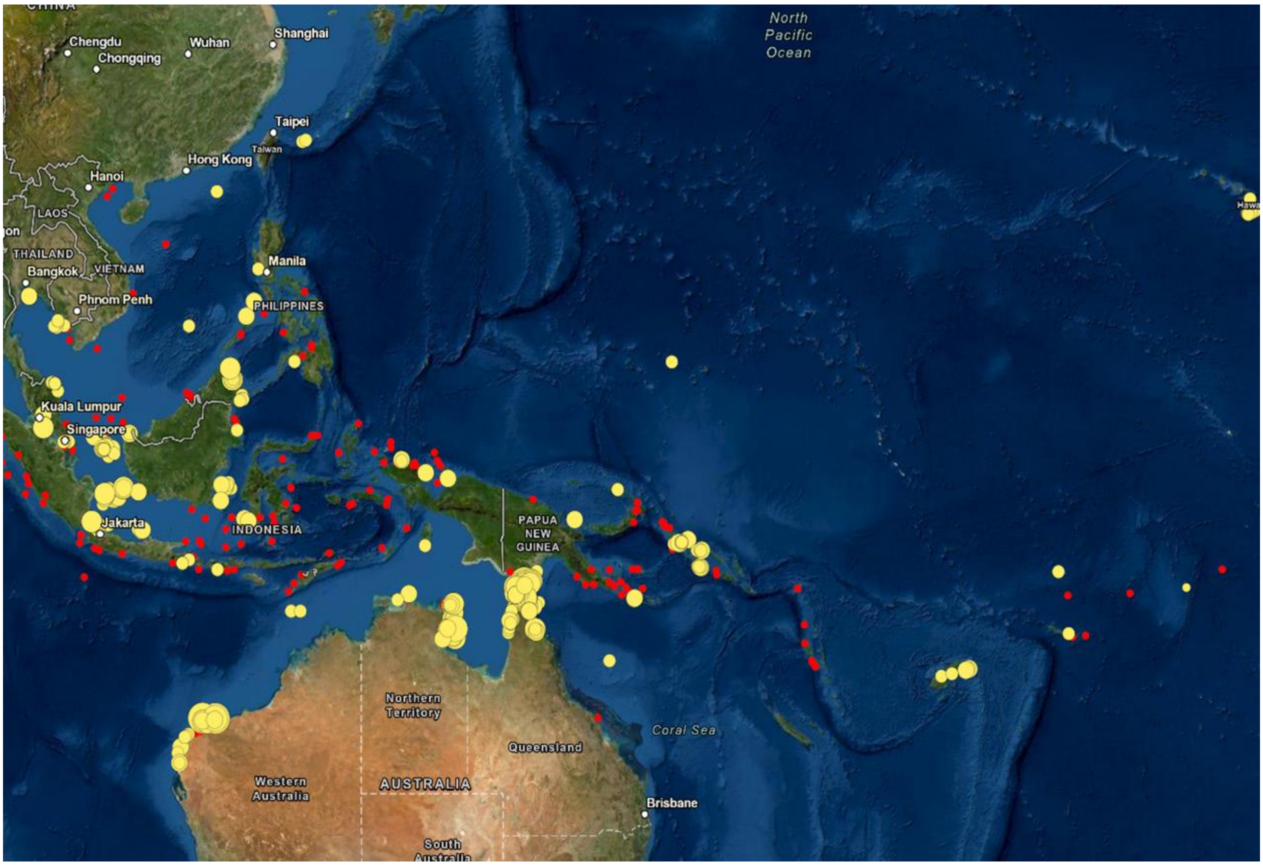

Figure 2.3. Map of known (yellow dots) and unquantified (red dots) hawksbill turtle nesting areas in the broader Asia- Pacific region. Yellow dot sizes reflect the relative nesting abundance. Red dots denote beaches where unquantified nesting has been recorded. (TurtleNet, Accessed 20 April, 2022: https://apps. Information.qld.gov.au/TurtleDistribution)

Gaps in the biological information

Population structure

The vast majority of western Pacific Ocean countries lack information on hawksbill population structure (i.e. age class distribution, sex ratios and/or genetic composition). The Solomon Islands is the only country in this assessment where hawksbill populations have been genetically assigned to management units. Genetic research is underway in American Samoa, Guam, CNMI, Fiji, Papua New Guinea, Tonga, and Vanuatu. Many western Pacific Ocean countries are archipelagic nations consisting of numerous islands and atolls separated by vast distances. Following genetic research, these countries may be found to host one or more MUs, indicating they warrant independent management approaches. In addition to genetic structure, other population variables, such as the proportion of sex ratios at different life stages, growth rates, and survivorship remain unknown. Given the hawksbills current global status of Critically Endangered (Mortimer and Donnelly, 2008), and future plans to review the status are likely to evaluate the species at the subpopulation level, such research is vital to provide future status assessments and guide conservation activities.

Life history attributes

A. Nesting populations

There are substantial gaps in our knowledge of life history attributes for most hawksbill turtle nesting sites in the western Pacific Ocean region. Specific gaps vary among locations, as described in each of the country sections of this report. Data on life history attributes are necessary for the development of accurate population models used in designing and implementing effective management plans. Life history parameters should ideally be collected from at least one rookery for each management unit. Where management units have not yet been defined, efforts to do so through genetic research and consistent nesting beach monitoring should be prioritised. Common gaps in life history attributes are attributable to missing or limited data on the following, as identified by Hamann *et al.,* (2022):

- Sampling for genetic mtDNA profiles
- Annual census figures at representative nesting beaches to quantify the number of females nesting per season, or the number of clutches laid per season, or the number of tracks (nesting attempts) made per season
- Quantified mortality estimates from anthropogenic and non-anthropogenic sources across all life history stages
- Quantified key demographic parameters including:
    - the average number of clutches laid per female per year/nesting season

    - the average number of years between breeding/nesting seasons for individual turtles
    - the rate of female and male recruitment into the breeding population
    - survivorship of adult females
    - incubation success and hatchling recruitment
- Temperature profiles for incubation, hatchling, and operational sex ratios
- Information on habitat use during migration and inter-nesting periods

B. Non-reproductive populations

There are also substantial gaps in our knowledge of hawksbill turtle foraging areas, habitat use (oceanic and coastal), diet, growth, age, survivorship, levels of direct harvest, and threats. Although satellite tracking and foraging area studies have been undertaken in a small number of countries (i.e. Australia, American Samoa, Fiji, Guam, Papua New Guinea, Solomon Islands, and Vanuatu), these have generally been extremely limited in sample sizes, and few published data on migration and home range exist for the majority of nations in the western Pacific Ocean.

C. Oceanic post-hatchling populations

There is no knowledge of the distribution or abundance of hawksbill turtle hatchlings in the western Pacific Ocean, nor the threats associated with this life history phase. Larger post-hatchling hawksbill turtles are at risk of interacting with pelagic longline and purse seine fisheries operating in EEZs and oceanic areas, as well as ingestion of plastic and entanglement in marine debris, as documented in other regions or oceanic basins (refer Hamann *et al.,* 2022). Further research is needed to identify distribution, abundance, and threats concerning hawksbill post-hatchlings.

Key pressures on hawksbill turtles of the western Pacific region

The tortoiseshell trade – a summary

The historical global trade and its impact on hawksbill turtle populations has been well summarised by Milliken and Tokunaga (1987), Groombridge and Luxmoore (1989), Meylan and Donnelly (1999), NMFS and USFWS (1998), and Mortimer and Donnelly (2008). While it is recognised that the international and domestic commercial trade of hawksbill turtles and/or their eggs dates back to the 9th century, demand for hawksbill turtle shell (scutes) to make tortoiseshell products rapidly expanded in the 17th century. Historically, between 1950 and 1992, trade networks concentrated in Southeast Asia harvested approximately 1.3 million turtles (Mortimer and Donnelly, 2008). Trade figures were recalculated by Miller *et al.,* (2019) with a possible 9 million turtles re-estimated to be harvested over a 150 year period (1844-1992). The trade was only managed internationally through the global Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) trade bans starting in 1977, with all trade reservations lifted by 1992. The consequence of this historical trade is that many hawksbill turtle populations are at, or recovering from, low baselines. Yet, recent research indicates there is still an active, underground illegal trade network concentrated in Southeast Asia creating a renewed demand for turtles and turtle products (Gomez and Krishnasamy, 2019). Miller *et al.,* (2019) also noted the trade's likely overlap and links to illegal fishing and small-scale fisheries (see also Riskas *et al.,* 2018; Vuto *et al.,* 2019). Indeed, foreign turtle poachers have been reported encroaching on the national waters of the Coral Triangle and western Pacific countries (IOSEA, 2014; Lam *et al.,* 2012; Gomez and Krishnasamy, 2019).

The tortoiseshell trade continues to be an issue In multiple western Pacific Ocean countries. Recently in the Solomon Islands, Vuto *et al.,* (2019) reported the local sale of hawksbill shell in three of the 10 communities surveyed, with evidence of sales to local carvers and other buyers in Honiara that were presumed to be exporting shell out of the country. In their study, hawksbill turtle products were far more likely to be illegally sold (32%) than green turtle products (12%) because of the domestic and international market for tortoiseshell. In the past, the export of tortoiseshell from the Solomon Islands was among the ten highest globally (Groombridge and Luxmoore, 1989). In Papua New Guinea, Kinch and Burgess (2009) noted that the trade in hawksbill turtles was ongoing in coastal towns, mainly in the form of tortoiseshell items for domestic buyers, and potentially targeting international tourists. Also in Papua New Guinea, Opu (2018) found that turtle harvest was concentrated in Manus, Milne Bay, and Western Provinces. Media reports and anecdotal reports from government stakeholders suggest the tortoiseshell trade is still active in Palau despite a 2018 ban (Reklani, 2021). Recently in Australia, as part of a *ShellBank – Surrender Your Shell* project, several tortoiseshell products donated from Australians were either bought and/or genetically assessed to have originated from hawksbill populations harvested from within the southwest Pacific (Madden Hof *et al.,* 2022a). While attempts to estimate current trade and the resultant mortalities of hawksbills are limited due to a lack of data, the reports (quantified and unquantified) of illegal trade in hawksbill shells occurring in multiple western Pacific Ocean countries warrant further study and action. These estimates may then also be able to be used in models to assess the extinction risk of hawksbills in the Pacific.

Bycatch in legal fisheries

Incidental capture (bycatch) in legal fisheries is globally recognised as a significant threat to marine turtle populations (Alverson *et al.,* 1994; Lewison *et al.,* 2004; Bourjea *et al.,* 2008; Wallace *et al.,* 2011). Broadly, the three major gear types shown to have the highest impact on marine turtles are gillnets, bottom trawls, and longlines. In the western Pacific Ocean region, commercial fisheries are dominated by longline and purse seine fisheries for tuna and tuna-like species. Monitoring of these fisheries in high seas areas is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC), a regional fisheries management organization (RFMO). Peatman *et al.,* (2018a) estimated that hawksbill turtles accounted for 16% of turtle bycatch in purse seine fisheries in the WCPFC area from 2003 to 2017, with a mean of 36 hawksbills per year (range 15-75). Hawksbill bycatch is recorded in longline fisheries, with a mean of 1,126 individuals (range 534-1,598) caught per year in WCPFC longline fleets (Peatman *et al.,* 2018b). Yet, because not all bycatch incidences result in mortalities, and observer coverage is not sufficiently uniform nor normally distributed across the fishery (Peatman *et al.,* 2018b), these figures should be used as indicative of the magnitude of the threat, not the precise quantities. Furthermore, discards of turtles are rarely recorded in log books, the main method of assessing catch of target and nontarget species in the Western Pacific longline fisheries (Brown *et al.,* 2021). Yet, observer data from Fiji’s national longline fleet indicate that hawksbill bycatch has slightly decreased since 2017 (see Fiji’s annual report to the WCPFC scientific committee, July 2021). Similarly, Peatman *et al.,* (2018a) report that hawksbill turtle bycatch by longline fisheries in the WCPFC area occurs at lower rates compared to other species (accounting for 4.9% of all interactions), likely due to their utilization of shallow and nearshore foraging habitats (e.g. coral reefs). Nevertheless, given the multiple threats facing hawksbills in the western Pacific, the interaction of hawksbills with pelagic longline fisheries underscores the need for further investigation into pelagic habitat utilization during other life history stages, such as migration.

In 2018, the WCPFC updated the 2008 Conservation and Management Measures (CMM) to reduce the impact of tuna fisheries on marine turtles by requiring fleets to implement additional gear changes, operational controls, mandatory reporting of interactions, and other measures. Other regional bodies, such as the Pacific Islands Fisheries Forum Agency (FFA) and the Secretariat of the Pacific Community (SPC), are leading ongoing efforts to improve the transparency of fisheries activities, including electronic monitoring (EM) to detect and quantify bycatch. In their analysis of EM trials in RMI, FSM, and Palau, Brown *et al.,* (2021) reported that "discards of tuna, billfish and turtles were almost never reported in logbooks, though EM and human observers did observe discards for these taxa". Observer coverage is very high in purse seine fleets (mandated target is 100% since 2010), but rarely meets the target of 5% in the longline fleets (MRAG Asia Pacific, 2021).

Small-scale fisheries largely operate in nearshore or coastal waters using a variety of gears, including set and drift nets, trawls, seines, longlines, traps, and others (Lewison, 2013). Recent research has shown that small-scale fisheries can have high levels of turtle bycatch that directly cause population declines (Lewison and Crowder, 2007; Peckham *et al.,* 2007; Alfaro-Shigueto *et al.,* 2011; Liles *et al.,* 2017). In the western Pacific Ocean region, small-scale fisheries are widespread, often operating in remote areas and at levels that have not been quantified. Because hawksbill turtles inhabit coral reef habitats and shallow coastal waters, they are highly vulnerable to bycatch and mortality in small-scale fisheries in almost every country in the western Pacific Ocean region. There are only two published examples of small-scale fishery assessments in the western Pacific, one in Malaysia which estimated 988 hawksbill turtles were taken in small-scale fisheries in a single year (extracted from data in Pilcher *et al.,* (2009)) and the other in the Solomon Islands, which estimated small-scale fisheries harvest approximately 10,000 turtles per year (of which almost 1/3 were hawksbill turtles; (Vuto *et al.,* 2019)). Although a commissioned study by the CITES Secretariat (2022) surmised that bycatch and active targeting of marine turtles in small-scale fisheries is unlikely to contribute to the international trade of hawksbills, Vuto *et al.,* (2019) provides evidence to the contrary from the Solomon Islands. Vuto *et al.,* (2019) reported that hawksbill turtle products are far more likely to be sold illegally than green turtle products, and that the shells of 87.5% of hawksbill turtles harvested were sold to local buyers, who then on- sold to Asian buyers in Honiara. With growing evidence of the role of small-scale fisheries in facilitating the turtle trade (IOSEA, 2014), an understanding of hawksbill interactions with small-scale fisheries across a much larger region is urgently needed.

Illegal use and Illegal, Unreported and Unregulated (IUU) Fishing

Illegal, unreported, and unregulated (IUU) fishing is a pervasive issue for fisheries management in every ocean basin (Agnew *et al.,* 2009). Vessels engaged in IUU fishing are less likely to comply with conservation mandates intended to reduce bycatch and mortality of non-target, vulnerable species, including marine turtles (MRAG, 2005). Riskas *et al.,* (2018) found that IUU fishing (both foreign and domestic, commercial and artisanal) poses a threat to marine turtle populations in the IOSEA region, and that in certain regions IUU fishing is associated with poor fisheries management and wildlife trafficking. Similarly, Lam *et al.,* (2012) notes the potential involvement of small-scale fishing vessels in the trafficking of hawksbill turtles and products. In the western Pacific Ocean, commercial IUU fishing incidence is estimated to be lower than in many other seafood-sourcing regions globally and has decreased in the Pacific Islands region relative to a 2016 assessment of data from 2010-2015 (MRAG Asia Pacific, 2021). This is attributable to the concerted and ongoing cooperative efforts by Pacific countries and partner organisations (e.g. FFA, SPC, WCPFC) to increase the monitoring, control and surveillance (MCS) of fleets operating in the region.

There is little documented information however, on hawksbill turtle interactions with illegal commercial fisheries in the western Pacific Ocean. Where turtle take is prohibited by law, the take of hawksbills in small-scale fisheries would also be considered illegal and, hence, be considered IUU fishing. From that perspective, the illegal take of hawksbill turtles by coastal fisheries recorded throughout the western Pacific Ocean (i.e. CNMI, Fiji, Guam, Palau, Solomon Islands, and Vanuatu) constitutes IUU fishing. More information regarding take levels and size classes across both commercial and small-scale fisheries is needed to inform risk assessments and mitigation measures.

Human use of turtles and their products

Hawksbill turtles have a high level of cultural significance in many countries across the IOSEA and western Pacific Ocean region and are a traditional food, with both eggs and meat consumed, and shells used in customary practice and in trade.

Hawksbill turtles and their eggs are harvested in every RMU in the western Pacific Ocean, despite laws banning these practices in many countries. Particularly in the west and south central Pacific, data are sparse on legal and illegal turtle and egg harvests, as documentation of these is inconsistent or unrecorded. Monitoring turtle harvest over vast distances among atolls and islands is logistically challenging.

Harvest by humans is of serious concern, particularly for green turtles that have predominantly been used for food (NMFS and USFWS 1998 in Pilcher *et al.,* 2021) and hawksbills also used for trade (Miller *et al.,* 2019). Nonetheless, there is often no clear distinction between species, nor harvest levels. Unless otherwise indicated, the studies mentioned below refer to the take of all marine turtles. Maison *et al.,* (2010) indicate that there have been uncontrolled, long-term harvests of turtle eggs and females in FSM that are likely to have had an impact on current population numbers. In RMI, turtles have historically been a food source and played an important cultural role. Egg collecting and harvest of turtles while they are onshore is prohibited at all times, but current levels of exploitation are unknown (Maison *et al.,* 2010). In Palau, hawksbill turtles are taken to support a tradition of gift exchanges of toluk (tortoiseshell currency) (Pilcher, pers. obs.), despite traditional closures and a current moratorium banning the take of turtles or eggs. While many pieces of toluk are heirloom artefacts, it is unknown what proportion of new pieces are added to the tradition each year. In the Cook Islands, turtles are occasionally killed and eaten at Tongareva, Rakahanga, Manihiki, and Palmerston, and probably at other atolls, but the true level of direct take remains unclear (White, 2012). There are no estimates or reports of adult or egg harvests for Kiribati, Nauru, Niue, the Pitcairn Islands, Tokelau, Tuvalu, or Wallis and Futuna.

In Papua New Guinea, Opu (2018) found that the highest catches of turtles occurred in Manus, Milne Bay, and Western Provinces. Although the report estimates 4,760 turtles (all species) in 2016 and 5,320 turtles (all species) in 2017 were landed in various Papua New Guinea markets over the survey period, these numbers are likely an underestimate of the true degree of turtle harvest in Papua New Guinea, given the limitations of the survey method (37 stakeholders interviewed over 15 maritime provinces) and that many landed turtles were likely used for personal consumption, cash sales, or in the barter trade or in the barter trade, or were not reported. However, it remains unquantified how many were hawksbills.

Vuto *et al.,* (2019) provides a recent update on turtle harvests in the Solomon Islands. Modelled data (based on coastal community location, footprint of fisheries, and existing average catch rates per hectare of reef in localities with both typical and high levels of turtle harvesting) estimated that 9,473 (95% CI: 5,063 to 22,423) turtles were harvested each year with hawksbill turtles accounting for 2,435 turtles (26%) of the estimated total harvest. Over 90% of these turtles were harvested by free divers (The Nature Conservancy unpublished data), and juvenile turtles comprised 1,860 (76%) of hawksbill captures; the remaining were adult- sized hawksbill turtles (equating to 575; >75cm in carapace length, sex unknown, but likely caught near nesting localities). Hawksbill turtle meat was most used for subsistence purposes (82%) and were most likely to be consumed by the family of the fisher that captured the turtles. However, the shells of 88% of hawksbill turtles harvested were sold to local buyers, who frequently on- sold to Asian buyers in Honiara.

In Vanuatu, there is a strong programme of local turtle monitors that aids in protecting turtles and convincing local communities to participate in turtle conservation efforts (Hickey and Petro, 2005). Past estimates suggest turtle harvest may have been in the region of 1,500 turtles per year, although Hickey and Petro (2005) suggest that much of this harvest has since ceased. However, a recent survey found that people still catch some turtles intentionally to eat and sell (Shaw, unpublished data). While Shaw's study site was not representative of the island chain as a whole, it does indicate that turtle captures continue to this day, and that updated estimates of take and trade are needed.

Collaborative efforts to understand the drivers and annual levels of hawksbill turtle harvest and trade are underway. In collaboration with governments, WWF and SPREP are supporting the delivery of a sociocultural survey in Papua New Guinea, Fiji, and Tonga. The project is part of WWF's broader *Cracking the Code for Recovery – Protecting Turtles for Tomorrow Strategy*, which will collect and synthesise data on turtle use, trade, and genetics to advocate for targeted policy action to recover Asia-Pacific hawksbill turtle populations.

Climate change

Countries in the western Pacific are highly vulnerable to the effects of global climate change. A recent study (Patrício *et al.,* 2021) reviewed the impacts of climate change on marine turtles globally and highlighted that even if marine turtles survive as a group, species with restricted distribution ranges and depleted populations are likely to be most vulnerable.

Changes in sex ratios due to higher incubation temperatures are likely to affect the population dynamics of hawksbill turtles. Rising sand temperatures can negatively impact marine turtle population function by producing clutches that are extremely female-biased (i.e. feminizing the population) and by causing excessive mortality of eggs and/or hatchlings. Feminization of turtle populations is already occurring in the Pacific at Australia's largest green turtle rookery (Jensen *et al.,* 2018; Booth *et al.,* 2021). However, of note are the marine turtle populations in the Arabian Gulf, where temperatures have long remained high, but do not seem to produce feminised stocks (Pilcher *et al.,* 2015). Whereas Chatting *et al.,* (2021) future forecast of hawksbill turtle hatchlings sex ratios from rookeries in Qatar predicted female bias in the current and up to the year 2100 populations to be around 75% and >85%, respectively. Hence, the situation is not clear (historically or in the future), and there are likely to be different thermal thresholds for each species and population. In the central west Pacific, Summers *et al.,* (2017) reported reduced hatching success and embryonic death above 34 °C for green turtles in CNMI, and that these impacts, combined with egg poaching, could decrease the abundance of nesting females.

There is a high risk of loss of nesting habitat due to sea level rise, which is projected to reach one metre in the Pacific by 2100 (IPCC, 2019). Most of the volcanic islands in the western Pacific are barely a few metres above sea level (Oppenheimer *et al.,* 2019). However, recent studies have suggested that some atolls and islands are actually growing (Hollingsworth, 2020) and may be less vulnerable than expected to the impacts of sea level rise. Jeh Island, in the Marshall Islands, has increased in size by 13% since the 1940s (Ford *et al.,* 2020). Thus, estimates of nesting habitat loss due to rising seas should be made at scales that can be supplemented with location-specific data, rather than basin-wide estimates (Pilcher, 2021).

Possibly of greater consequence, projected increases in the severity of tropical cyclones and hurricanes (IPCC, 2007) could cause accelerated erosion of nesting beaches and degradation of foraging habitats (coral reefs and seagrass meadows) (Work *et al.,* 2020). Hawksbills are also likely to be impacted by loss of coral reef habitat through bleaching caused by marine heat waves.

Marine debris and plastic pollution

Marine debris, and plastic pollution in particular, has been increasingly recognised as a serious and widespread threat to marine turtle populations globally (Schuyler *et al.,* 2014; Schuyler *et al.,* 2015; Wilcox *et al.,* 2013; Duncan *et al.,* 2019; Duncan *et al.,* 2021), and especially to hawksbill turtles (see Lynch, 2018).

The main threats that plastics pose to turtles are ingestion of plastic fragments and plastic bags, entanglement in abandoned, lost or discarded fishing gear (ALDFG) (also called ghost gear), and contamination of nesting and foraging habitat. Ingestion of plastics can be directly life threatening through intestinal blockage (Kühn and Van Franeker, 2020), as well as through introduction of toxic substances (either accumulated on the plastic surface (Rochman *et al.,* 2013) or from the plastic itself). The population level impacts of plastic ingestion are still unknown. Entanglement in ALDFG can result in damaged limbs and drowning (Stelfox *et al.,* 2016). The mechanisms enabling accumulation of heavy metals and chemical contaminants in turtles have been studied (Kittle *et al.,* 2018; Leusch *et al.,* 2020), but little is known about the effects of plastic pollution on turtle health.

More research on the impacts of marine debris and plastic pollution is needed for the western Pacific region. Hamann *et al.,* (2022) note six key areas requiring investigation: 1) quantification of health impacts across populations and life stages; 2) toxicological impacts on turtle health; 3) the role of debris particles as vectors for heavy metal and chemical contamination (see Clukey *et al.,* 2018); 4) identification of the oceanographic forces that disperse pollution; 5) understanding the social and economic drivers contributing to the creation of pollution; and 6) the barriers and opportunities for improved management of marine debris and plastic pollution (see Vegter *et al.,* 2014; Nelms *et al.,* 2015; Duncan *et al.,* 2017).

Management and protection

Countries in the western Pacific Ocean have adopted a variety of regional international agreements aimed at protecting hawksbill turtles and their habitats, or to mitigate threats that may directly or indirectly affect hawksbills (Table 2.3). On a national scale, hawksbill management and protection vary from country to country. For example, in Papua New Guinea, hawksbill turtles remain unprotected, whereas in Fiji there is currently a total ban on all take, sale, possession and transport. Whilst a marine species legislative review was conducted for Asian countries (Ezekiel, 2018), no comprehensive marine turtle policy and legislative review has been undertaken in the western Pacific Ocean region, yet is urgently required to understand gaps and inconsistencies.

A coordinated regional effort towards the conservation of hawksbill turtles through collaborative efforts, linkages between countries, and the exchange of information at the national, regional, and global levels is needed if hawksbill populations are to recover. Such an effort is constrained by limited resources, both financially and in terms of capacity to implement many management actions in the western Pacific Ocean region. However, SPREP's Regional Marine Turtle Action Plan 2021-2025 (that came into effect in 2022) will help provide direction and support.

Table 2.3. Selection of regional and international Legally and Non-legally Binding Instruments and Relevant Bodies (refer also: CMS/IOSEA/Hawksbill-SSAP/Inf.5).

Asia-Pacific Signatories and Parties	CITES	CBD	CMS	UNCLOS	RFMOs	PSMA	Ramsar Convention	IOSEA Marine Turtle MOU	MOU ASEAN Sea Turtle Conservation and Protection	CTI-CFF	London Declaration (IWT)	SSME Regional Action Plan	SPREP
American Samoa (USA)	✓			✓	✓	✓	✓	✓		✓	✓		✓
Australia	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓
Brunei Darussalam	✓			✓					✓				
Cambodia	✓	✓				✓	✓	✓			✓		
China	✓	✓		✓	✓		✓				✓		✓
Cook Islands		✓	✓	✓	✓	✓	✓						✓
Federated States of Micronesia		✓		✓	✓								✓
Fiji	✓	✓	✓	✓	✓	✓	✓						✓
French Polynesia (France)	✓	✓	✓	✓	✓	✓	✓				✓		✓
Guam (USA)	✓				✓	✓	✓	✓			✓		✓
Hawaii (USA)	✓				✓	✓	✓	✓			✓		
Hong Kong (China)	✓	✓	✓	✓			✓						

Asia-Pacific Signatories and Parties	CITES	CBD	CMS	UNCLOS	RFMOs	PSMA	Ramsar Convention	IOSEA Marine Turtle MOU	MOU ASEAN Sea Turtle Conservation and Protection	CTI-CFF	London Declaration (IWT)	SSME Regional Action Plan	SPREP
Indonesia	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	
Japan	✓	✓		✓	✓	✓	✓				✓		
Kiribati		✓		✓	✓		✓						✓
Lao People's Democratic Republic	✓	✓		✓			✓		✓		✓		
Malaysia	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	
Marshall Islands		✓		✓	✓		✓						✓
Myanmar	✓	✓		✓		✓	✓	✓	✓		✓		
Nauru		✓		✓	✓								✓
New Caledonia (France)	✓	✓	✓	✓	✓	✓	✓				✓		✓
New Zealand	✓	✓	✓	✓	✓	✓	✓				✓		✓
Niue		✓		✓	✓		✓						✓
Northern Marianas (USA)	✓					✓	✓	✓			✓		✓

Asia-Pacific Signatories and Parties	CITES	CBD	CMS	UNCLOS	RFMOs	PSMA	Ramsar Convention	IOSEA Marine Turtle MOU	MOU ASEAN Sea Turtle Conservation and Protection	CTI-CFF	London Declaration (IWT)	SSME Regional Action Plan	SPREP
Palau	✓	✓	✓	✓	✓	✓	✓						✓
Papua New Guinea	✓	✓		✓	✓		✓	✓		✓			✓
Philippines	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Republic of Korea	✓	✓		✓	✓	✓							
Samoa	✓	✓	✓	✓	✓		✓						✓
Singapore	✓	✓		✓					✓		✓		
Solomon Islands	✓	✓		✓	✓					✓			✓
Taiwan (China)				✓	✓								
Thailand	✓	✓		✓		✓	✓	✓	✓		✓		
Timor-Leste		✓		✓						✓			
Tokelau				✓			✓						✓

Asia-Pacific Signatories and Parties	CITES	CBD	CMS	UNCLOS	RFMOs	PSMA	Ramsar Convention	IOSEA Marine Turtle MOU	MOU ASEAN Sea Turtle Conservation and Protection	CTI-CFF	London Declaration (IWT)	SSME Regional Action Plan	SPREP
Tonga	✓	✓		✓	✓	✓							✓
Tuvalu		✓		✓	✓								✓
United States of America	✓				✓	✓	✓	✓			✓		✓
Vanuatu	✓	✓		✓	✓	✓	✓						✓
Viet Nam	✓	✓		✓		✓	✓	✓	✓		✓		
Wallis and Futuna (France)	✓	✓	✓	✓	✓	✓	✓						✓

Blue: Countries within the range of the IOSEA Marine Turtle MOU, and adjacent areas
Orange: Western Pacific countries and territories

Southwest Pacific Ocean

Solomon Island management unit

The nesting hawksbill population in the Solomon Islands MU is considered genetically distinct (Vargas *et al.,* 2015). These samples were only collected from hawksbills nesting in the ACMP. There are unsampled rookeries throughout the Solomon Islands and other countries in close proximity, for example Papua New Guinea, meaning hawksbills from this management unit may occur throughout the western Pacific; however, this remains to be determined.

Ecological range

The ACMP in the western Solomon Islands supports the largest rookery for hawksbill turtles in the oceanic South Pacific (Hamilton *et al.,* 2021; Pilcher, 2021). Hawksbill turtles nest throughout the year in the ACMP, with peak nesting activity occurring from approximately May to July, with a second shorter nesting peak occurring from December to January. In peak periods, the number of nests laid per month are approximately double those laid in quieter nesting periods. During the May to July nesting peak, approximately 3-4 hawksbill turtle clutches are laid within the ACMP each night (Hamilton *et al.,* 2015). In the past 15 years, it is estimated that between 1000-1500 nests have been laid in the ACMP each year, representing 200-300 breeding turtles annually. Initial beach surveys that were conducted in the ACMP from the mid-1970s to 1995 revealed that the island of Kerehikapa accounted for 51–65% of all clutches laid in the ACMP, however by 2000, greater nesting activity was occurring on Sikopo Island (Mortimer, 2002). The increasing nesting activity on Sikopo has coincided with conservation efforts and the chronic erosion of low-profile nesting beaches on Kerehikapa between 1991 and 2020 (Hamilton *et al.,* 2021). The ACMP is an important hawksbill turtle breeding site, with mating hawksbill turtles observed on numerous occasions over the past 30 years at five locations within the ACMP (Hamilton *et al.,* 2021). The genetic characterisation of this management unit is based solely on samples from the ACMP, and the geographical boundaries of the management unit remain unknown, but are likely to extend across the Bismarck-Solomon Sea area, including rookeries in Papua New Guinea (Bell & Jensen, 2018).

Geographic spread of foraging sites and migration

Hawksbill turtles from this management unit forage across the southwest Pacific region. Genetics studies from the Great Barrier Reef (Howick Group) show that the majority of turtles foraging at this nGBR foraging site (83%) originated from the Solomon Island management unit (Bell & Jensen, 2018). Flipper and satellite tagging studies show that many hawksbills that nest at the ACMP make long distance migrations to foraging grounds in Australia, Papua New Guinea and New Caledonia (Vaughan and Spring, 1980; Parmenter, 1983; Mortimer, 2002; Limpus *et al.,* 2008; Hamilton *et al.,* 2015; Bell & Jensen, 2018; Hamilton *et al.,* 2021), while a small proportion of ACMP nesters travelled to nearby foraging grounds in Solomon Islands. Hamilton *et al.,* (2021) satellite tracked 30 female hawksbill turtles that were nesting in the ACMP, and these turtles had a mean migration distance between nesting and foraging grounds of 2028 km ± 222 km, much further than the mean migration distance reported for any other nesting hawksbill turtle population (e.g. Parker *et al.,* 2009; Gaos *et al.,* 2012a; Hart *et al.,* 2019).

Satellite tracking has revealed that many of the turtles that nest in the ACMP follow a common post nesting migratory corridor before dispersing across the Solomon and Coral Sea (Hamilton *et al.,* 2021). Sixteen of the ACMP nesters that were tracked to their foraging grounds by Hamilton *et al.,* (2021) displayed short-term fidelity to specific sites (mean 50% utilisation density (UD) 1.1 km2 ± 0.3 km2), with one individual demonstrating foraging site fidelity over multiple post-nesting migrations. Many of these 16 hawksbills established foraging sites on outer barrier reefs, with several turtles also foraging on inshore reefs close to the Queensland mainland.

Juvenile foraging hawksbill turtles comprise a small portion of total catch in multispecies coral reef fisheries throughout Solomon Islands (i.e. Hamilton *et al.,* 2012; Vuto *et al.,* 2019). Juveniles and some adults have been observed foraging on coral reefs in multiple locations in Solomon Islands including Kolombangara (Argument *et al.,* 2009) and Marovo Lagoon in New Georgia (Green *et al.,* 2006). Howard (2022) reported 105 juveniles were tagged foraging in Kolombangara between 2013-14 (cited in Esbach *et al.,* (2014)), and 12 tagged while foraging in Tetepare between 2004-2008 (cited as unpublished data, Tetepare Descendants Association).

The TREDS database contains over 140 records of foraging hawksbill encounters from Wagina Island (Choiseul Province), Santa Isabel (Arnavons, Kia Village, Sire Bay), and Tetepare Island.

Geographic spread of nesting

Index nesting beaches: Nesting is concentrated in the ACMP, and the islands of Sikopo and Kerehikapa are designated as the index nesting beaches for this management unit.

TurtleNet records approximately 25 localities and the TREDS database contains over 1,200 records of 'nesting' hawksbill encounters, overwhelmingly from the Isabel Province (Kerehikapa Island in the Arnavons), and the Obeani Group in Western Province. A list of historical and current hawksbill nesting sites in the Solomon Islands with an estimated number of nests was recently published in Howard (2022) and can be found in Table 2.4.

Table 2.4. Historical and current hawksbill turtle nesting sites and estimated number of nests (not always taking into account re-nesting) in Solomon Islands (Adapted from Howard, 2022).

Site/Island	Estimated numbers of nests/year	Source
Arnavon Islands	1000-1500 nests	Hamilton *et al.*, (2015)
Shortland Islands	400-500 nests	Vaughan (1981)
	Bagora/Obeani Is.: 50-100 nests Balaka Is.: 50-100 nests	Wilson *et al.*, (2004)
Ramos Islands	50-100 nests (combined with green turtles)	Vaughan (1981); Wilson *et al.*, (2004)
Choiseul Islands	230-450 nests (mostly on Haycock and Wagina Islands)	Vaughan (1981)
Tetepare Island	5 nested between 2005-2007	TDA, unpublished data
Makira	~50-100 nests (combined with green turtles)	Vaughan (1981)
Russell Islands	50-100 nests	Wilson *et al.*, (2004)
Hele Bar islands (Marovo)	50 nests	Wilson *et al.*, (2004)
Santa Cruz	50-200 nests	Wilson *et al.*, (2004)
Kolombangara	Nesting recorded but no data	Esbach *et al.*, (2014)
Ngalo Island	Nesting recorded but no data	Ceccarelli (2018)
Munda/Gizo barrier islands	Nesting recorded but no data	Dr. Alec Hughes, pers comm (2022)

Ontong Java Island	Nesting recorded but no data	Ceccarelli (2018)
Cross Island (Gizo)	Nesting recorded but no data	Vaughan (1981)

Trends in nesting data

Nesting numbers are increasing in the ACMP, with the number of nests laid at the ACMP islands of Big Maleivona, Kerehikapa, Sikopo, and Small Maleivona combined doubling since its establishment in 1995 (Hamilton *et al.,* 2015). No other long-term data are available to assess trends at other nesting sites.

Threats to the population

Quantitative information on the impacts of threats in the Solomon Islands is limited, except in the case of use and trade, along with some data on climate change impacts (i.e. nest inundation from flooding (Howard, 2022)).

Hawksbill turtles and eggs are harvested in the Solomon Islands, mainly for subsistence purposes. Some historically important hawksbill nesting beaches now appear to be functionally extinct. For example, historically >100 hawksbill nests were laid annually at Haycock Island, Wagina, Choiseul (Vaughan, 1981). Yet since the early 1990s, permanent Gilbertese communities have been established on Haycock Island, and any turtles that still return here to nest face a very high probability of being killed for food (John Pita, personal communications). Vuto *et al.,* (2019) more recently calculated that hawksbill turtles comprised 2,435 (26%) of all turtle captures (in an annual country survey) of which 575 (or 24%) were adult-sized (sex unknown) reported to be likely caught near nesting localities (beaches and breeding grounds) despite Solomon Island legislation banning the harvesting of turtle eggs or nesting turtles (Fisheries Management Prohibited Activities Regulations, 2018). Based on all available data, Pilcher (2021) estimated that between 2,500 and 5,000 hawksbill turtles are likely taken each year in the Solomon Islands, although these figures require further investigation.

Despite legislation in 1993 banning the trade of turtle products, the tortoiseshell trade remains active in the Solomon Islands. Vuto *et al.,* (2019) reported the sale of hawksbill shell in three of the

10 communities surveyed, but was only a common practice in one (Wagina). In the Wagina community, Vuto *et al.,* (2019) found that shells of 87.5% of hawksbill turtles harvested were sold to local buyers, who then on-sold to Asian buyers in Honiara. LaCasella *et al.,* (2021) used mtDNA extracted from tortoiseshell products for sale at local markets in Papua New Guinea and Solomon Islands (Honiara) and demonstrated that nine of the 13 tortoiseshell products were from turtles with haplotypes found primarily from the Solomon Islands management unit. In the past, the export of tortoiseshell from the Solomon Islands was ranked among the ten highest globally (NMFS and USFWS, 1998; Miller *et al.,* 2019), peaking at around 4,000 kg of hawksbill shell exported per year in the late 1980s (Limpus and Miller, 2008).

Nesting beach erosion, and compromised or lost hawksbill clutches due to climate change, remain a key and ongoing threat to many hawksbill nesting sites (Foale *et al.,* 2017). Since 1993, sea levels have risen by approximately 8mm per year (more than the global average of 2.8-3.6mm per year), and are expected to continue to rise 4-15cm by 2030 (Anon, 2011).

Similarly, annual maximum air temperatures have increased in Honiara by 0.15°C per decade since 1951 (Howard, 2022). Although hatchling survival in the nest and sex-determination is governed by sand temperature, there is limited nest temperature monitoring on any nesting beach in the Solomon Islands. Where there are known hatcheries (for other species than hawksbills), there is concern hatcheries are not being monitored, as high temperatures potentially feminize the incubating clutches within the hatcheries. Sand temperature monitoring within the nest chamber to gauge the effect of rising global temperatures on embryonic development in the Solomon Islands is needed (Howard, 2022).

While predation of nests by crabs, megapodes, rats, and iguanas (Wilson *et al.,* 2004) remains a problem at some hawksbill nesting beaches in the Solomon Islands, there appears to be no quantitative or qualitative reporting on the impact of other known marine turtle threats, including light pollution, plastic pollution, ghost nets, unsustainable coastal development, boat strikes and fibropapilloma disease within Solomon Island (Howard, 2022).

Summary of threats to the Solomon Islands management unit (MU) of hawksbill turtles

These are provided in Table 2.5.

Table 2.5: Type, quantification and likely location of threat to the Solomon Islands hawksbill turtle management unit (MU)

Type of threat	Known or likely location of impact 1=nesting beach 2=oceanic/high seas 3=coastal foraging areas	Quantified 1=comprehensive documentation across population 2=comprehensive documentation for some of the population 3=non-published evidence only 4=not quantified
Consumption – nesting beach		
Egg collection	1	2
Commercial use of turtles	1,2,3	2
Non-commercial use of turtles	1,2	1
Predation of eggs by non-native fauna	1	3
Predation of eggs by native fauna	1	2
Consumption – foraging turtles		
Commercial use of turtles	2,3	2
Non-commercial use of turtles	2,3	2
Climate change impacts		
Increasing beach temperature	1	4
Beach erosion	1	2,3
Sea level rise	1	4
Coastal development		
Habitat modification (urban)	1	4

Habitat modification (industrial)	1	4
Light horizon disorientation	1	4
Fisheries impacts		
Bycatch – trawl	2,3	4
Bycatch – longline	2	3
Bycatch – gillnet	3	3
Impact to benthic ecology from fisheries	3	4
IUU fishing	2,3	4
Pollution		
Water quality	3	4
Entanglement in discarded fishing gear	2,3	4
Ingestion of marine debris	2,3	4
Noise pollution	3	3
Disease and pathogens	3	4

Management and protection

Under existing Solomon Islands law, only the leatherback turtle (*Dermochelys coriacea*) is fully protected. Hawksbills can be legally harvested for subsistence purposes, excluding eggs and the harvesting of nesting females. Additional protection is afforded under the ACMP, prohibiting egg and turtle harvesting (since 1995). The sale of any hawksbill product (meat, eggs or shell) is banned (Fisheries Management Prohibited Activities Regulations, 2018). International instruments applicable to hawksbill turtles in Solomon Islands are listed in Table 2.3.

Biological data – breeding population

These are provided in Table 2.6.

Table 2.6 Breeding population biological data and values known for the Solomon Island hawksbill turtle MU

Parameter	Value	Reference(s)
Pivotal temperature		
Remigration interval	modal inter-nesting interval of 14 days [range 12–19 days]	McKeown 1977; Hamilton *et al*., 2021 (see SEM data)
Clutches per season	3-6	Mortimer 2002; Hamilton *et al*., 2021 (max 6)
Mean size of nesting adult (CCL)	88 cm (75.5-93) 84.3 cm (82-90) 86.6 cm (78.4-96.5)	McKeown 1977 Leary 1992 Hamilton *et al*., 2021
Age at maturity		

Biological data – foraging population

These are provided in Table 2.7.

Table 2.7 Foraging population biological data and values known for the Solomon Island hawksbill turtle MU

Parameter	Value	Reference(s)
Mean size at recruitment (to inshore foraging) (CCL)	69.9 cm	Bell and Pike 2012
Growth rates (from Howick Group, nGBR)	2.5 cm/yr at 60-70 cm 0.5 cm/yr at 70-80 cm 0.6 cm at 80-90 cm	Bell and Pike 2012
Sex ratio – in foraging populations		

Adults	97% female (A)	Bell and Jensen *et al.*, 2018
pubescent immature	85% female (SA)	Bell and Jensen *et al.*, 2018
large pre-pubescent immature		
small pre-pubescent immature	96% female (J)	Bell and Jensen *et al.*, 2018

Papua New Guinea

Geographic spread of foraging sites

There is a lack of data on foraging sites for hawksbill turtles in Papua New Guinea. Tagged hawksbills have been recovered at Fishermen's Island (Central Province), Tagula Island (Milne Bay Province), and other locations within Milne Bay Province. The TREDS database contains records of foraging hawksbill encounters at Tureture Reef in Western Province, Fishermen's Island in Central Province, Kavieng in New Ireland Province, and on the northern coast of Papua New Guinea.

Geographic spread of nesting

Hawksbill turtle nesting has been recorded in multiple provinces throughout Papua New Guinea, although population densities are unknown. Surveys in the 1970s found hawksbill nesting in the following locations: East Sepik Province at Laboin Island, Musschu Island, Kairuru Island, Wuvulu Island, and Kaniet Island; Manus Province at Pak Island, Los Reyes Islands, Harengan Island, Paluwak Island, Bipi Island, and the Ninigo Group of Islands; New Ireland Province in the Boloma Group of Islands, Emirau and Mussau Islands, and the Tanga Islands; East New Britain at Nuguria; Madang Province on the north and south coasts and at Long Island; and in Western Province along the whole coast. More recently, hawksbill nesting has been reported at numerous islands in the Jormad Passage and Conflict Islands groups in Milne Bay Province (Wangunu *et al.,* 2004). A detailed review of historical records of hawksbill nesting in Papua New Guinea is provided in Kinch (2020a) (in Work *et al.,* 2020).

The TREDS database contains 27 records of nesting hawksbills throughout multiple islands of Milne Bay Province (Panarairai, Lunn, Jomard, and Irai), one hawksbill turtle nesting in Wide Bay of East New Britain Province, and one nesting hawksbill turtle on Suau Island on the south coast of Milne Bay Province.

Trends in nesting data

There are no data on long-term trends in nesting hawksbill turtle populations in Papua New Guinea. Mortimer and Donnelly (2008) suggested that 500 to 1,000 females may nest annually in Papua New Guinea. In Milne Bay Province, the Conflict Island Conservation Initiative have now tagged a total of 130 nesting hawksbill turtles between 2017-2020 (CICI, 2021). Kinch (2020a, in Work *et al.,* 2020) reports several sites where nesting occurs, but surveys have been inconsistent and thus an updated assessment of the nesting populations status and trajectory at a national level is not currently attainable. Based on all available data, Pilcher (2021) suggests that the total nesting population may be less than 500 turtles per year.

Migration and distribution of foraging areas

Nesting and foraging hawksbill turtles from the northern Great Barrier Reef (Australia) are known to migrate to Papua New Guinea and several other nations (Miller *et al.,* 1998; Hamilton *et al.,* 2015). TREDS records indicate that one hawksbill turtle that was flipper tagged in Samoa was later reported as a tag recovery in Papua New Guinea; similarly, three foraging turtles that were tagged in Australia were later reported as tag recoveries in Papua New Guinea (Trevor, 2010). Other tagging data shows that an adult female hawksbill turtle tagged at Kerehikapa in the Arnavon Group of the Solomon Islands in December 1976 was later killed on its foraging grounds at Fisherman’s Island, Central Province, Papua New Guinea in February 1979 (Vaughan and Spring, 1980). Similarly, one nesting hawksbill turtle that was satellite tagged at Kerehikapa in July 2001 migrated to its foraging grounds at Tagula Island in the far south- eastern end of the Milne Bay Province (Hamilton *et al.,* 2015). Many turtles that were satellite tracked in the ACMP made post-nesting migrations through Milne Bay en route to Torres Strait Islands and GBR foraging grounds, with several ACMP nesters also returning to foraging grounds in Milne Bay (Hamilton *et al.,* 2021).

Threats to the population

Papua New Guinea is identified as having the highest legal harvest of marine turtles globally (all species combined) and subsistence harvest of hawksbill turtles for meat, eggs, carapace, and other products is widespread throughout the country (Humber *et al.,* 2014). Coastal communities use turtles and turtle parts for a variety of reasons, including food, bartering, selling for cash, and as part of cultural activities and celebrations (Opu, 2018). Opu (2018) estimated an annual turtle harvest of around 5,000 turtles (all species), with the highest take occurring in Manus Province, Milne Bay Province, and Western Province. It is currently not known what proportion of these are hawksbills. However, given the lack of data and the remoteness of many coastal villages where turtle harvest takes place, accurate figures for annual harvest – and the proportion of hawksbills – may differ among sites. Further research is needed to better understand this specific impact.

Hawksbills are widely targeted for their carapaces to produce tortoiseshell items, such as jewellery and other trinkets, mainly for international tourists (Kinch and Burgess, 2009). Decorative tortoiseshell items (e.g., jewellery, ornaments) are sold in major provincial centres (i.e. Port Moresby), as well as areas popular with tourism (Opu, 2018).

Other threats include bycatch and retention of hawksbills in coastal fisheries, and bycatch in commercial fisheries (Papua New Guinea's tuna fleet in the WCPFC area recorded 506 hawksbills caught as bycatch in 2017; see Annual Report to WCPFC, 2020).

Management and protection

Hawksbill turtles are not protected in Papua New Guinea. Even in Australia, the taking of hawksbill turtles by Papua New Guineans within Australia's EEZ (i.e. the Torres Strait Protected Zone) is allowed under the 1985 Torres Strait Treaty, as long as they are traditional inhabitants of 'Treaty' Villages (Kinch, 2020a in Work *et al.,* 2020). International instruments applicable to hawksbill turtles in Papua New Guinea are listed in Table 2.3.

Biological data on breeding and foraging

The Conflict Islands Conservation Initiative (CICI) initiated a nesting beach monitoring program in 2017, which includes quantification of nesting, flipper and satellite tagging, and the collection of morphometric data from nesting and foraging hawksbills. Scientific publication of 2017-2021 data is expected by the end of 2023. Prior to this, there have been limited quantitative studies on the nesting and foraging hawksbill turtles in Papua New Guinea.

West Central Pacific

Federated States of Micronesia (FSM)

Geographic spread of foraging sites

Hawksbill turtles are known to forage on nearshore reefs of FSM, but there is little documented information on the abundance or location of foraging activities (McCoy, 2020 in Work *et al.,* 2020). The TREDS database contains 12 records of foraging hawksbills encountered at various sites across FSM from 1991 to 2018.

Geographic spread of nesting

Nesting by hawksbill turtles in FSM is believed to be rare. Buden and Edward (2001) indicated that nesting was infrequent in Pohnpei, although they were unable to provide a figure for annual nesting females. A single hawksbill was reported nesting on Losiep and Gielop islands in Ulithi from 2005-2008 (Yap Marine Resources Management Division 2005-2008, in Work *et al.,* 2020). No hawksbill nesting has been reported for Yap (Buden, 2000). In December 2017, hawksbill turtle hatchlings were photographed emerging from a nest at Ant Atoll. Local Chief William “Willie” Hawley Sr. reported that a handful of hawksbill clutches are deposited each year, but limited funding to support patrols of the lagoon and islets of the atoll has prohibited accurate estimates (PIFSC unpublished data). Based on all available data, Pilcher (2021) estimated it is likely that less than 10 to 20 females per year nest at FSM. The TREDS database contains eight records of nesting hawksbills from 1990 to 2009.

Trends in nesting data

There is no information on nesting trends for hawksbill turtles in FSM.

Migration and distribution of foraging areas

No systematic monitoring has been carried out to document the abundance and distribution of hawksbill turtles in FSM waters. A large adult female hawksbill measuring 72.3 cm straight carapace length was captured by staff of the National Oceanic and Atmospheric Administration (NOAA) in the nearshore waters off of Tinian Island, in the Commonwealth of Northern Marianas Islands (CNMI), in July of 2014, and was fitted with a satellite transmitter. In April of the following year (2015), the turtle migrated towards Pohnpei, arriving at Ant Atoll on 01 July 2015, where it continued to transmit locations until April of 2016 (Gaos *et al.,* 2020). Although it is unclear whether the hawksbill nested at either site, given the duration of stay at Ant Atoll, it is likely this area was a foraging / residential area for this turtle. Whatever the case, the migration demonstrates adult hawksbill connectivity between CNMI and Pohnpei.

Threats to the population

Hawksbill turtles in FSM are threatened by illegal harvest of nests, bycatch, and hawksbills are killed for their carapaces (McCoy 2020 in Work *et al.,* 2020). Nest depredation by ghost crabs, monitor lizards, and wild pigs documented for green turtle nests in FSM (see Pilcher, 2021), may potentially affect hawksbill turtle nests where they occur. Given the low numbers of turtles nesting in FSM it is unknown what proportion of turtles are impacted by these threats.

Management and protection

The harvest of hawksbill turtles is allowed in FSM, with provisions for minimum size limits for hawksbills (27 inches=~68.5 cm curved carapace length (CCL)) and closed seasons (June 1 to August 31 and December 1 to January 31). Harvesting of eggs is not allowed for any species. National jurisdiction covering marine turtles applies only beyond 12 miles in the Exclusive Economic Zone, and thus does not apply in practice to most of the turtle-related activities occurring in FSM. States of Yap, Kosrae, and Pohnpei match national regulations concerning minimum size and closed seasons for hawksbill turtle harvest. In 2014, the Yap State Environmental Protection Agency (EPA) banned the shipment of any seafood – including turtles – from the Yap outer islands to Yap mainland. The ban also restricts turtle catch to one turtle per vessel per week and prohibits catch between March and August, inclusive (cited in Balk, 2016). The municipality of Sapwuahfik, an atoll about 90 miles southwest of Pohnpei Island, banned the hunting of turtles following two incidents of chelonitoxication from hawksbill turtles that caused the deaths of several people on the island (Buden, 1999). Further details on turtle protection in FSM are provided in Hickey (2020) (in Work *et al.,* 2020). International instruments applicable to hawksbill turtles in FSM are listed in Table 2.3.

Biological data on breeding and foraging

There is no biological information on hawksbill turtle breeding and foraging in FSM.

Guam

Geographic spread of foraging sites

Hawksbill turtles have been recorded foraging and residing in the nearshore waters of Guam during NOAA in-water surveys (Martin *et al.,* 2016,2018; Gaos *et al.,* 2020). The coral reefs along north-western Guam (Double Reef) and near the mouth of Apra Harbor may be particularly important for hawksbill turtles as relatively high densities were observed in these areas during these surveys. The TREDS database has 5 records of encounters with non-nesting hawksbills, including mortality in fishing gear and stranded turtles.

Geographic spread of nesting

No hawksbill turtle nesting has been recorded in Guam since 2008, during which four hawksbill nesting attempts were recorded at Dakiki Beach (Grimm and Farley, 2008; Kelly, 2020 in Work *et al.*; 2020). The TREDS database contains 11 records from 1991 to 1995 of hawksbill nesting encounters at Sumay Marina, Cetti Bay, Sella Bay, and Tarague Beach.

Trends in nesting data

There are no consistent records of nesting hawksbill turtles in Guam that would allow for an evaluation of nesting trends, however reports suggest extirpation may have already occurred (Eldredge, 2003, in Work *et al.,* 2020).

Migration and distribution of foraging areas

Aerial turtle surveys found that 15% of turtles in marine habitats of Guam are hawksbills, with mean abundance estimates of 101 to 196 hawksbills found between 2008 and 2012 (Martin *et al.,* 2016).

Between 2013 and 2019, of the 357 non-capture turtle observations in Guam, 258 (72.3%) were identified as green turtles, 19 (5.3%) as hawksbill turtles, and 80 (22.4%) as "unknown" species (but either green or hawksbill turtles) (Gaos *et al.,* 2020).

Preliminary assessment from 14 satellite tagged and tracked hawksbill turtles in nearshore foraging habitats around Guam, Tinian, and Saipan revealed high foraging site fidelity and limited movements (Martin *et al.,* 2018; Gaos *et al.,* 2020). Gaos *et al.,* (2020) described one sub-adult hawksbill (61.7 cm straight carapace length (SCL)) captured in nearshore waters of Tinian (CNMI) in 2013. It was equipped with a satellite tag and subsequently travelled 233 km south to the Achang Reef, on the southern coast of Guam (Figure 2.4) where it remained for over 2 years until the tag ceased transmitting. It is possible this turtle underwent some sort of ontogenetic habitat shift as it was getting closer to maturity, or that it reached maturity at a smaller size than expected and moved to breed (Gaos *et al.,* 2020).

Threats to the population

Hawksbill turtles in Guam are threatened by fisheries bycatch, boat strikes, foraging habitat degradation, and coastal development, as well as human activities, such as intentional take, harvest for the tortoiseshell trade, and plastic pollution. Prior hawksbill nesting in Guam was impacted by predation by monitor lizards, wild pigs, rats, and crabs (Cummings, 2002). The TREDS database contains records of hawksbill turtle strandings at Andersen Air Force Base, Pago Bay, and Jeff's Pirate Cove (Ipan), and one turtle found at Capras with plastic and metal in its intestine.

Figure 2.4. CNMI caught sub-adult hawksbill satellite tracked to Guam (Gaos *et al.,* 2020).

Management and protection

Hawksbill turtles are protected on Guam by the Endangered Species Act (USA) and the Endangered Species Act of Guam. As a US territory, Guam must also uphold its responsibilities under all relevant conservation agreements (e.g. CITES, CMS, CBD). International instruments applicable to hawksbill turtles in Guam are listed in Table 2.3.

Biological data on breeding and foraging

There is no biological data for breeding hawksbill turtles in Guam. Three juvenile foraging hawksbills were tagged and recaptured between 2014 and 2019 on Guam, including two hawksbills that were captured on a total of three occasions (Gaos *et al.,* 2020). The longest period between original capture and most recent capture for one of the hawksbills was 1,119 days, during which the turtle grew 4.4 cm SCL from 52.9 cm on 12 May 2016, to 60.1 cm on 05 June 2019. The turtle also increased 10.0 kg over that time period. Another hawksbill grew 4.6 cm over a period of 307 days, increasing from 42.3 cm SCL on 17 July 2014, to 46.9 cm on 20 May 2015. It increased 8.1 kg during that time. The third hawksbill grew 2.9 cm over 729 days, increasing from 68.2 cm SCL on 19 May 2015, to 71.1 cm SCL on 11 May 2017. The turtle increased 3.9 kg during that time.

The mean core (50% utilization distribution) and overall (95% utilization distribution) home ranges of three juvenile hawksbills equipped with satellite tags in Guam was 0.15 km^2 (sd = 0.17 km^2; range = 0.01−0.34 km^2) and 4.41 km^2, (sd = 7.07 km^2, range = 0.06−12.57 km^2), respectively (Gaos *et al.,* 2020).

Nine hawksbills captured in Guam and CNMI, and equipped with satellite tags incorporating dive computers, revealed that they spent 93.1% of their time in waters <25 m in depth and used an average depth of 15.3 m (Gaos *et al.,* 2020).

Kiribati

Geographic spread of foraging sites

Hawksbills are less abundant than green turtles in Kiribati. During SCUBA surveys conducted in the Phoenix Islands, three and five hawksbill turtles were observed over 11 days in May 2000 and 21 days in June 2002, respectively (Benson *et al.,* 2007). Hawksbill turtles were not observed during a resource assessment conducted at Kanton Island in June 2017. The TREDS database includes three records of foraging juvenile hawksbill turtle encounters at three separate locations: Beru (Gilbert Group) in 2015, Abemama Island in 2010, and Tabiteuea South in 2014.

Geographic spread of nesting

No nesting records of hawksbill turtles in Kiribati are available. The TREDS database does not contain any records of nesting by hawksbills.

Migration and distribution of foraging areas

No tag recapture or genetic data are available to determine the source beaches of the in-water hawksbill population.

Threats to the population

Putative threats to marine turtles in Kiribati include incidental capture in commercial fisheries, habitat degradation, pollution, marine debris, boat strikes, and climate change (Buden, 1999).

Management and protection

Hawksbill turtles are fully protected in the Phoenix Islands Protected Area (PIPA). Kiribati is not a participating party to CITES. International instruments applicable to hawksbill turtles in Kiribati are listed in Table 2.3.

Biological data on breeding and foraging

There is minimal biological data on breeding and foraging hawksbills in Kiribati. There are only two records of hawksbill turtle encounters available in TREDS. The CCL measurements of the two hawksbill records are 30.0 cm and 69.9 cm.

Republic of the Marshall Islands (RMI)

Geographic spread of foraging sites

Hawksbill turtles have been reported at nearshore foraging grounds of at least 17 atolls in the RMI, including Majuro and Kwajalein (Parker, 2020 in Work *et al.,* 2020). However, no information is available on pelagic movements or the migration of adult females or hatchlings from nesting beaches within the RMI. The TREDS database contains three records of foraging hawksbill encounters, all at Likiep Island with two in 1992 and one in 1993.

Geographic spread of nesting

Infrequent nesting by hawksbill turtles is reported to occur in the RMI, but no current data on abundance are available (Pilcher, 2021). Locations of reported nesting are spread across the RMI and not concentrated in a specific location (Figure 2.5). It's estimated that hawksbill turtles accounted for approximately 30% of total turtle nesting on Rongerik and Ailinginae Atolls (L. Tobin in McCoy, 2004). Wotje Atoll has been suggested to possibly be the center of activity for hawksbill turtles (Puleloa and Kilma,1992), and both Wotje and Erikub atolls have recorded hawksbills nesting, but in lower numbers than green turtles. The TREDS database contains one record of a nesting hawksbill at Wotje Atoll in 1992.

Trends in nesting data

Hawksbill turtle nesting is believed to be decreasing in the RMI (see Parker, 2020, in Work *et al.,* 2020).

Migration and distribution of foraging areas

Hawksbill turtles have been reported foraging around at least 17 atolls throughout the RMI (McCoy, 2004; Rudrud, 2008) and have been photographed resting at atolls (Parker, 2020 in Work *et al.,* 2020). No information is available on pelagic movements or the migration of adult females or hatchlings from nesting beaches within the RMI.

Threats to the population

Nesting hawksbill turtles in the RMI are threatened mainly by harvesting eggs and nesting females (McCoy, 2004; Rudrud, 2008). Other anthropogenic threats include sand mining on inhabited islands such as Majuro (Hay and Sablan-Zabedy, 2005), coastal development, light pollution, contamination from nuclear testing, and marine debris. Natural threats to nesting hawksbills include sea level rise due to climate change, beach erosion from extreme weather events, and predation by rats, sand crabs, and seabirds. Threats to foraging and breeding hawksbill turtles include direct harvest, fisheries bycatch in pelagic and nearshore artisanal fisheries, and degradation of foraging and resting coral reef habitats (Parker, 2020 in Work *et al.,* 2020). Commercial longline fisheries operate in the waters of the RMI, with 190 foreign licensed vessels fishing there in 2020. Mandatory bycatch reporting requirements came into effect on 1 January 2020, however data are not yet available and collection may have been impeded by the COVID-19 pandemic.

Management and protection

The harvest of hawksbill turtles is permitted in the RMI, with provisions for minimum size limits (27 inches CCL) and closed seasons from June 1 to August 31 and December 1 to January 31 (Kabua and Edwards, 2010). Egg collecting and harvesting of turtles at nesting beaches is prohibited at all times. The RMI is not a participating party to CITES. International instruments applicable to hawksbill turtles in the RMI are listed in Table 2.3.

Biological data on breeding and foraging

No biological information is available for breeding or foraging hawksbill turtles in RMI.

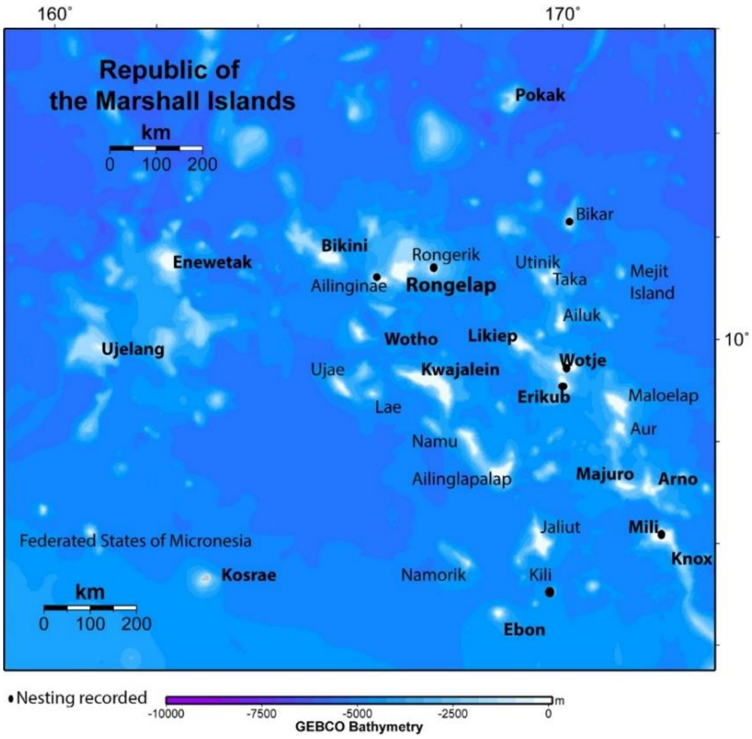

Figure 2.5. Distribution of reported hawksbill turtle nesting in RMI. From Parker, 2020 in Work *et al.,* 2020.

Commonwealth of the Northern Mariana Islands (CNMI)

Geographic spread of foraging sites

Summers *et al.,* (2017) and Gaos *et al.,* (2020) documented predominantly juvenile and subadult sized hawksbills in the waters of the islands of Saipan and Tinian in CNMI. Of note is that numerous small hawksbills were observed along the northwest coast of Tinian, indicating this area may be of particular importance for small hawksbills that have recently recruited to neritic habitats after spending their first years of life in open- ocean pelagic habitats.

Geographic spread of nesting

There is no reported nesting of hawksbill turtles at CNMI (NMFS, 1998; Mortimer and Donnelly, 2008). Summers *et al.,* (2013) and Summers *et al.,* (2017) refer to hawksbill nesting, yet provide no further data.

Migration and distribution of foraging areas

NOAA staff surveyed the nearshore waters of the islands of Saipan and Tinian in CNMI between 2013 and 2019, during which time they captured 11 juvenile and one adult hawksbill and equipped them with satellite tags (Gaos *et al.,* 2020).

One sub-adult hawksbill equipped with a satellite tag after being captured in the nearshore waters of Tinian, subsequently migrated to Guam (see Guam section). An adult hawksbill (72.3 cm SCL) equipped with a satellite tag after being captured in the nearshore waters of Tinian in 2014, subsequently migrated 2,118 km in 74 days to Ant Atoll, adjacent to Pohnpei, in the FSM (Figure 2.6). The turtle remained in the nearshore waters of Ant Atoll for 10 months, at which time the tag ceased transmitting. This individual was possibly making a long- distance migration to a known breeding site on Ant Atoll; however, it is also possible that it was concluding a breeding season near Tinian and returning to Ant Atoll to forage. All other juvenile hawksbills remained on the islands where they were originally captured and tagged.

Threats to the population

Hawksbill turtles in CNMI are primarily threatened by illegal harvest, marine debris entanglement, boat strike, and disease (Parker, 2020 in Work *et al.,* 2020).

Management and protection

All marine turtle species occurring in U.S. territorial waters of the Western Pacific region are protected under the U.S. Endangered Species Act (ESA). International instruments applicable to hawksbill turtles in CNMI are listed in Table 2.3.

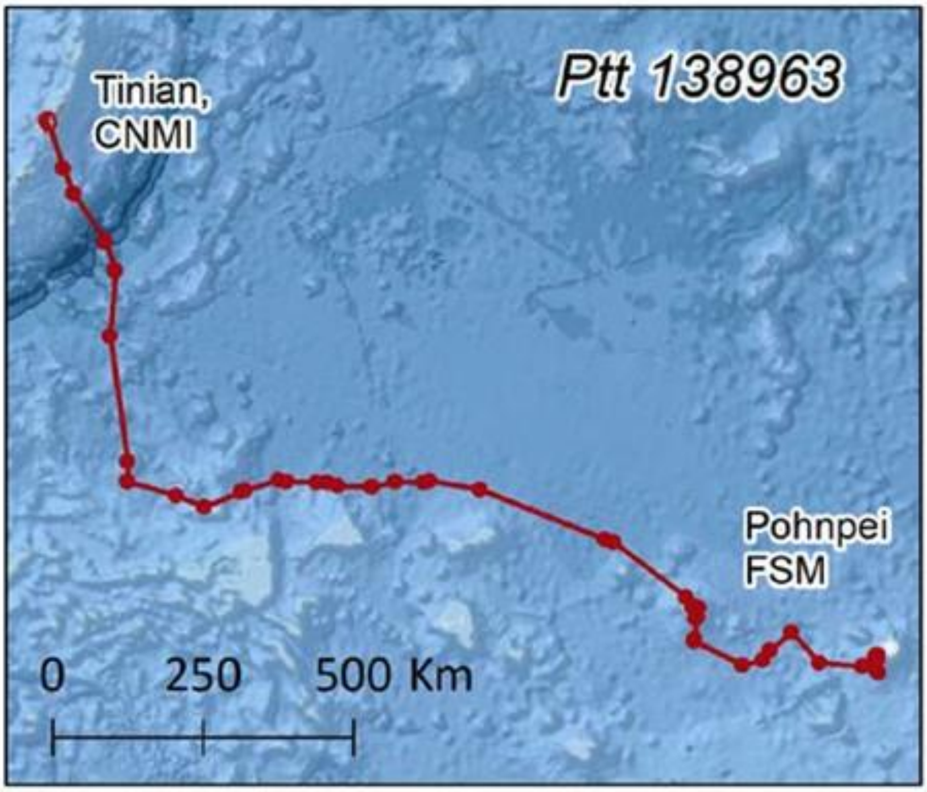

Figure 2.6. Adult hawksbill caught in Tinian, CNMI and satellite tracked to FSM (Gaos *et al.,* 2020).

Biological data on breeding and foraging

There are no biological data for breeding hawksbill turtles in CNMI. Eleven foraging hawksbills were captured and equipped with satellite tags in the nearshore waters of CNMI between 2013 and 2019, including five on Saipan and six on Tinian. The mean core (50% utilization distribution) and overall (95% utilization distribution) home ranges of hawksbills on Saipan were 0.09 km2 (sd = 0.13 km^2; range = 0.01−0.24 km^2) and 0.73 km^2 (sd = 1.08 km^2; range = 0.02−1.97 km^2), respectively, while on Tinian they were 0.37 km^2 (sd = 0.13 km^2; range = 0.28−0.46 km^2) and 2.20 km^2 (sd = 1.36 km^2; range = 1.24−3.16 km^2), respectively (Gaos *et al.,* 2020).

Nine hawksbills captured in Guam and CNMI and equipped with satellite tags incorporating dive computers revealed that they spent 93.1% of their time in waters <25 m in depth and used an average depth of 15.3 m (Gaos *et al.,* 2020).

Palau

Geographic spread of foraging sites

Hawksbill turtles are regularly reported foraging at the seagrass beds, lagoons, and extensive shallow coral reef habitat surrounding the islands of Palau. There has been an apparent steady decline in the population over the past 20 years (Rice, 2020 in Work *et al.,* 2020). The highest concentrations of foraging hawksbills were reported from the Helen's Reef lagoon and the lagoon of Rock Islands (Geermans, 1992). Sub-adult hawksbill turtles have also been observed foraging in the dive areas of Blue Corner and German Channel (Rice, 2000, personal observation). The TREDS database contains 6 records of foraging hawksbill (mostly juvenile) encounters, but some capture and location information is missing.

Geographic spread of nesting

Low level hawksbill turtle nesting is found across Palau, with 5-6 nesting locations reported (Rice, 2020 in Work *et al.,* 2020). Mortimer and Donnelly (2008) and NMFS (1998) reported between 20 and 50 nests per year in Palau. In 2018, approximately 70 hawksbill clutches were reported across 13 beaches on the Rock Islands in Koror State by the Department of Conservation and Law Enforcement (pers comm 25 May 2021). Yalap (2016) also reported that hawksbill turtles nest in small numbers (<10 clutches) on some of the Rock Islands. The TREDS database contains at least 6 records of nesting turtles, but there are other records of "nesting" hawksbills which require clarification and confirmation.

Trends in nesting data

No information is available regarding trends in hawksbill turtle nesting numbers, although these are believed to be declining.

Migration and distribution of foraging areas

There are no data on migration and distribution of hawksbills from foraging areas in Palau.

Threats to the population

Hawksbill turtles in Palau are threatened at nesting sites by illegal human harvesting (eggs and females), predation by wild pigs and monitor lizards, habitat degradation due to tourism development, and increasing frequency of extreme weather events (Eberdong and Klain, 2008; Golbuu *et al.,* 2005). Foraging turtles are threatened by harvesting for the tortoiseshell trade (and/ or cultural toluk trade), entanglement in marine debris, habitat destruction from sand mining and dredging, and water pollution near urbanised areas (Rice, 2020 in Work *et al.,* 2020).

Management and protection

In 2018, Palau enacted a ten-year moratorium on the harvest and sale of hawksbill turtles or their products in response to concerns that populations were declining. Previously, the harvest of hawksbill turtles was permitted in Palau under domestic fishing laws (24 PNCA 1201), with provisions for minimum size limits (27 inches CCL) and closed seasons from June 1 to August 31 and December 1 to January 31 (Secretariat of the Pacific Community and Bureau of Marine Resources Palau, 2007). Taking of eggs or female turtles while onshore is prohibited at all times. Nesting females, eggs, and their habitats are also protected within the Ngerukewid Islands Wildlife Preserve (Guilbeaux, 2002). The Ngeruangel Reserve Management Plan restricts turtle harvesting levels and circumstances under which turtles can be harvested from Ngeruangel Atoll in Kayangel State. At the same time, the implementation of no-fishing and limited public access areas in Koror State offers some protection to turtles in the water, as well as nesting turtles and eggs. However, enforcement of these regulations is weak (Seminoff *et al.,* 2015).

International instruments applicable to hawksbill turtles in Palau are listed in Table 2.3.

Biological data on breeding and foraging

There are no biological data on breeding and foraging for hawksbill turtles in Palau. Despite the number of agencies, NGOs, and community groups working on turtle conservation in the country, monitoring of hawksbill turtles to ascertain key nesting sites, abundance, and other biological data are limited throughout Palau (Rice, 2020 in Work *et al.,* 2020).

South Central Pacific Ocean

American Samoa

Geographic spread of foraging sites

Hawksbill turtles have been reported foraging at Tutuila Island (63 individuals captured between 1995 and 2002) and in small numbers at Rose Atoll (Grant *et al.,* 1997) and Ofu Island (Tagarino *et al.,* 2008). Becker *et al.,* (2019) recorded a relatively high abundance of hawksbills foraging at Tutuila and Tau.

Geographic spread of nesting

Hawksbill turtles nest on the islands of Tutuila, Ofu, and Olosega. A recent survey of Tutuila identified 15 active nesting beaches for hawksbill turtles, with a further 14 described as having high potential for nesting (Tagarino *et al.,* 2008). The TREDS database contains <10 records of hawksbill nesting encounters at multiple locations around Tutuila (Lauli'I Villa, Maloata Village, and Amalau Beach).

Trends in nesting data

NMFS and USFWS (1998) indicated there may be up to 80 nesting females per year in Tutuila and the Manu'a Islands group. However, Mortimer and Donnelly (2008) indicate only 10 to 30 female hawksbill turtles nest per year in American Samoa and Samoa combined. Surveys with local community members in 1991 found that an estimated 50 adult females (green and hawksbills combined) used nesting beaches at Tutuila in 1990-1991 (Tuato'o-Bartley, *et al.,* 1993), indicating that present day populations may have declined dramatically (Utzurrum, 2002). More recently, based on all available data, Pilcher (2021) suggested that <10-15 female hawksbill turtles nest in American Samoa annually. Rapid assessments of three beaches (Mafafa, Toaga, and Airport Beach) over 5-6 weeks in 2017 and 2018 revealed six and seven nests, respectively (Mark MacDonal, pers comm. 13 December 2018). Approximately 10 known nesting beaches are present on Tutuila, but it is uncommon for each site to receive more than one or two nesting females per season and many of these sites may go a season or two with no activity (Mark MacDonal, pers comm. 13 December 2018).

Migration and distribution of foraging areas

Post nesting hawksbill turtles in American Samoa can undertake migrations to other western Pacific countries, including to the neighbouring nation of Samoa, or can remain in local waters. Two hawksbills tracked from American Samoa travelled to the Cook Islands (Tagarino *et al.,* 2008), a straight-line distance of some 1,400 km. Hawksbills satellite tagged at Tutuila and Ofu-Olosega were tracked to the Cook Islands, Samoa, Tonga, and French Polynesia, while others stayed in nearshore waters of Tutuila (Tagarino, 2015). The TREDS database contains over 100 records of foraging hawksbills from numerous locations around Tutuila.

Threats to the population

Turtles have been reported caught in fishing gear, including lines, traps and nets around Tutuila (Utzurrum, 2002). An estimated 14 hawksbill turtles may interact with the American Samoa longline fleet annually (McCracken, 2019). Hawksbill turtles are known to be caught in artisanal fisheries equipment such as gillnets, and small numbers have been found stranded with apparent spear holes in the head (Tagarino *et al.,* 2008, 2015).

Impacts on hawksbill turtles due to climate change include sea level rise, increased air temperatures that may change hatchling sex ratios, increased storm severity, and decreased coral reef habitat quality from bleaching and acidification (Score, 2017). Toxins from non-point source (land-based sources) have been detected in coastal streams in American Samoa at levels known to cause toxicity in aquatic animals (Polidoro *et al.,* 2017). Other threats include entanglement in debris, such as fishing gear (MacDonald, 2016), erosion of nests from storm surges (Peck, 2016), potential predation from feral pigs and rats (Tagarino *et al.,* 2010), and disorientation of hatchlings and adults from light pollution (Tagarino *et al.,* 2008).

The TREDS database contains 6 records of nesting hawksbill encounters, all from Tutuila (Utumea East Village, Lauli'I Village, Maloata Villa, Tula Village, and Amalau Beach) and 69 records of foraging hawksbills, all from multiple locations at Tutuila.

Management and protection

Hawksbill turtles in American Samoa are protected under the U.S. Endangered Species Act (ESA) of 1973. A Sea Turtle Hotline was implemented in 2007 for emergency responses to strandings and other wildlife emergencies (Tagarino *et al.,* 2008). International instruments applicable to hawksbill turtles in American Samoa are listed in Table 2.3.

Biological data on breeding and foraging

There is limited biological data on hawksbill turtle breeding and foraging in American Samoa. Growth rates from mark recapture studies suggest a mean growth rate of 4.5 cm/yr (Grant *et al.,* 1997). Becker *et al.,* (2019) summarized the results of marine turtle observations from towed-diver surveys in the U.S. Pacific Islands. American Samoa had the highest densities of hawksbill turtles within these regions; size class distributions (sample size not reported) are depicted in Figure 2.7.

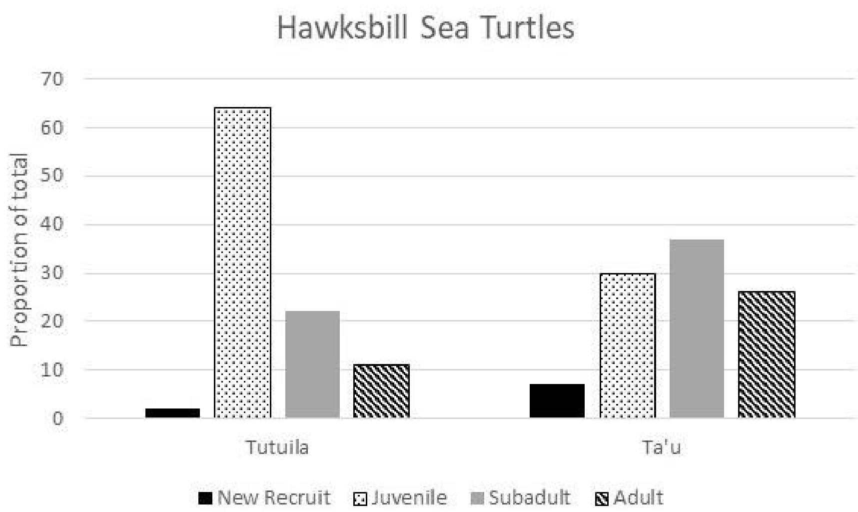

Figure 2.7. Size distributions of hawksbill turtles in waters around islands and atolls of American Samoa (Becker *et al.,* 2019, in Work *et al.,* 2020).

Fiji

Geographic spread of foraging sites

Hawksbill turtles have been recorded on several Fijian coral reefs, including the Great Sea Reef (Laveti, 2010). However, no survey to collect abundance indices has been performed in the last twenty years. Hawksbill turtles reportedly feed on the seagrass beds off the easternmost point of Vanua Levu (Batibasaga *et al.,* 2006). The TREDS database contains over 500 records of hawksbills foraging at coral reef habitats throughout Fiji.

Geographic spread of nesting

Hawksbill turtles are known to nest on several beaches of the islands of Fiji (Figure 2.8). Nesting is diffuse and spread across approximately 27 sites; Namena Lala Island is the only index nesting site for hawksbill turtles in Fiji. Data recorded (and made available) over the last 20 years are summarized in Piovano (2020) (in Work *et al.,* 2020). The TREDS database contains records of hawksbill nesting encounters at Treasure Island, Nukuvadra Island, Kavewa Island, Yadua Island, Bounty Island, and Namena Lala Island. The records span from 1997 to 2015.

Trends in nesting data

Batibasaga *et al.,* (2006) reported a severe decline in the number of nests laid at Namena Lala Island and at Makogai Island. The most recent national estimate of the size of the hawksbill turtle nesting population is 150-200 adult females (Batibasaga *et al.,* 2006). Most recently (during 2015-2019) Prakash *et al.,* (2020) reported Yadu and Yadua Taba recorded 35% of all nesting in Fiji, followed by Katawaqa and Nukuvadra (29%).

There are no long-term data on clutch estimates per female per season for hawksbill turtles in Fiji. It is likely that 20 to 30 females nest annually in Fiji (Pilcher, 2021). Mortimer and Donnelly (2008) suggested that 100 to 200 female hawksbill turtles nest per year in Fiji. However, the most recent nesting assessments are presented from 2015 to 2019; Prakash *et al.,* (2020) report only 147 clutches recorded among 27 nesting sites during the study period. As nesting sites are widely distributed and isolated, the number of nesting turtles at each site is likely to be low, although this is probably underestimated due to the logistics of full-time monitoring.

Migration and distribution of foraging areas

Satellite tracking studies have shown that Fiji is a foraging area for hawksbill turtles nesting in American Samoa (Jayne and Solomona 2007).

Threats to the population

Hawksbill turtles in Fiji are particularly threatened by illegal harvest in coastal waters, and flooding and erosion of nesting beaches.

Management and protection

Hawksbill turtles are protected in Fiji under national law. Despite the expiry of the Fisheries Moratorium on 31 December 2018, Regulation 5 of the Offshore Fisheries Management Regulations 2014 (OFMR) remains in force which imposes a ban on the harvest, sale, possession, and transportation of marine turtles, their eggs, or any part or product of all five species of marine turtles found in Fiji. Provisions of the OFMR apply to "all Fiji Fisheries waters," meaning it applies to all internal, inshore and offshore areas of Fiji. The specific ban under the OFMR applies to the killing, taking, landing, selling or offering or exposing for sale, dealing in, transporting, receiving, or possessing any marine turtle species. However, the Ministry of Fisheries is currently working to update and amend this legislation to allow for permits to be issued to authorise limited cultural harvest by local i-Taukei communities. International instruments applicable to hawksbill turtles in Fiji are listed in Table 2.3.

Biological data on breeding and foraging

A recent literature review (Piovano, 2020 in Work *et al.,* 2020) shows missing key information for nesting and foraging hawksbill turtles in Fiji. Upcoming publications of satellite tracking studies will help identify possible migratory routes and benthic foraging areas, and upcoming publications of data collected under the SPREP BIEM project will likely yield a wealth of data on sizes and species of turtles that are captured and traded.

Prior studies recorded minimum CCL of hawksbill turtles nesting in Fiji as 75 cm (Batibasaga *et al.,* 2006). Calculated from available data, average clutch size and average emergence success were 116 eggs and 98.3%, respectively (Piovano, 2020 in Work *et al.,* 2020). In more recent assessments between 2015-2019, Prakash *et al.,* (2020) reported an average CCL of 81.5cm (n = 4 nesting females), average clutch size of 121 (eggs/clutch; n = 71 nests), average hatching success of 89% (n = 71 nests), and a mean egg incubation period of 56 days (range 49 to 69 days). Based on these assessments, Prakash *et al.,* (2020) reported peak nesting in January.

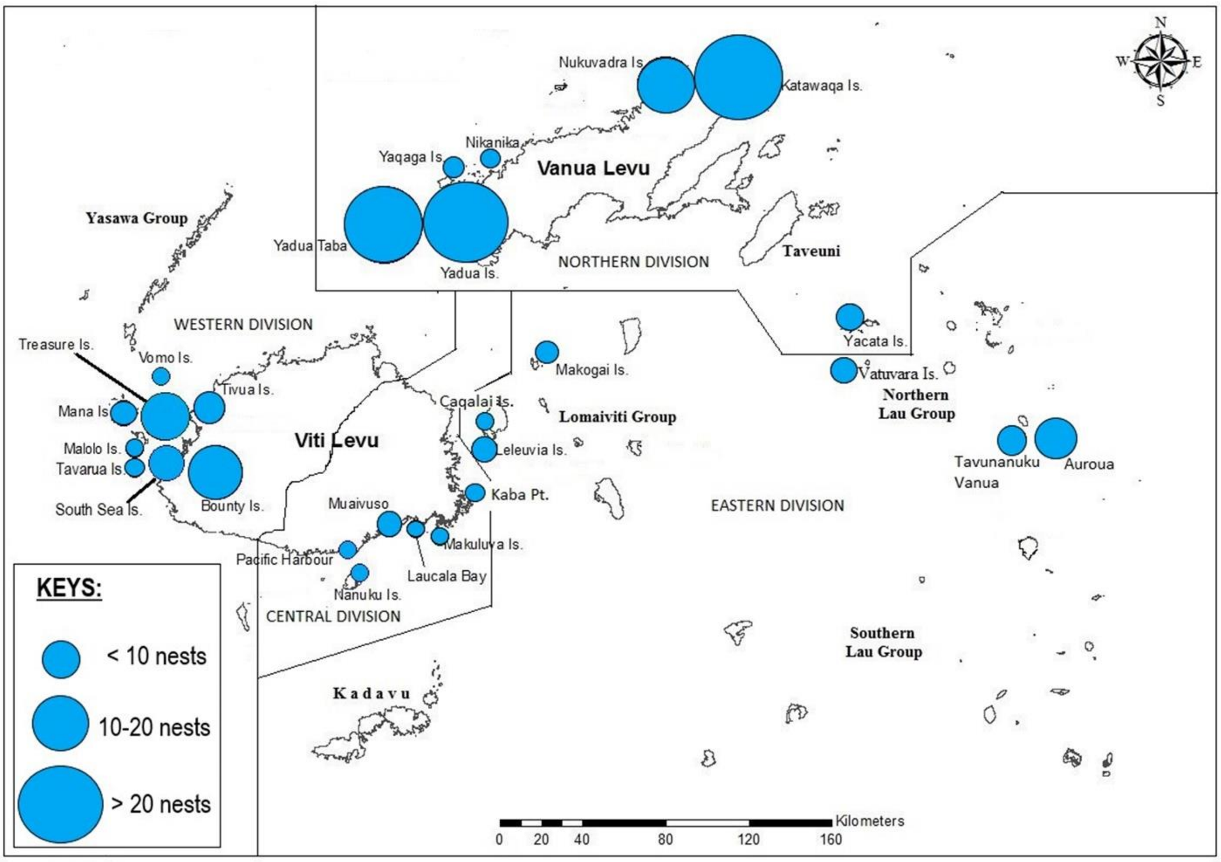

Figure 2.8. Distribution of hawksbill turtle nesting in Fiji. From Prakash *et al.,* (2020), ©2020 British Chelonia Group.

French Polynesia

Geographic spread of foraging sites

Hawksbill turtles are commonly seen foraging and resting throughout French Polynesia (Gaspar, 2020 in Work *et al.,* 2020). An in-water population assessment in 2010-2011 recorded 243 hawksbill turtles at the barrier reefs of six islands: Tetiaroa, Moorea Maiao, Bora Bora, Maupiti, and Tupai (Petit, 2011). The TREDS database contains 46 records of foraging hawksbills at Taha'a, Mataia, Bora Bora, Tiahura Lagoon, and Moorea. The records span from 1993 to 2013.

Geographic spread of nesting

Hawksbill turtles have only been confirmed to nest at one location in French Polynesia: Reao Atoll in Tuamotu archipelago (M. Tatarata, pers. comm, 2020). The TREDS database recorded 28 nesting hawksbill encounters at Taha'a, although these only span from 1995 to 1997.

Trends in nesting data

There are no data on nesting trends for hawksbill turtles in French Polynesia.

Migration and distribution of foraging areas

Limited data are available on the migratory behaviour of hawksbills in French Polynesia. However, two post- nesting female hawksbills equipped with satellite tags on the island of Ofu in American Samoa in 2019 migrated to French Polynesia, a distance of >2,000km (PIFSC unpublished data). The first hawksbill settled in a foraging ground along the eastern coast of Tahiti, while the second settled in a foraging ground in the Palliser Islands.

Threats to the population

There is very limited information available on threats to hawksbill turtles in French Polynesia.

Management and protection

Hawksbill turtles are fully protected in French Polynesia, but laws are difficult to enforce given the distances between islands (Gaspar, 2020 in Work *et al.,* 2020). International instruments applicable to hawksbill turtles in French Polynesia are listed in Table 2.3.

Biological data on breeding and foraging

There is very limited biological data on breeding and foraging of hawksbill turtles in French Polynesia. Mean hawksbill CCL is 61.74 ± 13.74 cm (n = 243), with a minimum size of 30 cm and maximum of 95 cm (Petit, 2011).

Samoa

Annual nesting for hawksbill turtles is estimated to be from <10 to 30 female hawksbill turtles per year in Samoa and American Samoa combined (Mortimer and Donnelly, 2008). It is likely that <5 to 15 female hawksbill turtles nest in Samoa annually (Pilcher *et al.,* 2021). The TREDS database recorded 34 "nesting" hawksbill encounters on Upolu Island (Vini Beach, Nuulua Island, Nuutele Island, and Lalomanu). All but two of these records are from the 1993-1994 season.

Tonga

There is no reported nesting of hawksbill turtles in Tonga (NMFS, 1998; Mortimer and Donnelly, 2008). The TREDS database contains 11 records of foraging hawksbill encounters, most caught at Tongatapu Island and two from the Haapai Group (Foa Island and Vavau).

Vanuatu

Geographic spread of foraging sites

Hawksbill turtles have been reported foraging at multiple locations throughout Vanuatu. Hickey (2020) identified foraging habitat (mainly coral reefs) at Southeast Vanua-Lava in the Banks Group, Pakea Island, Reef Island (also known as Rowa), Malekula Island, Uripiv and Uri Islands (Port Stanley and south to Crab Bay), Maskelyne Islands, islands to the north of Efate Island (Lelapa, Kagula, Emao, Nguna, Pele, Emau, and Moso), Aneityum Island, Mystery (Inyueg) Island, and Futuna Island.

Geographic spread of nesting

Hawksbill turtles have been reported nesting at multiple locations throughout Vanuatu, including Banks/ Torres, Malekula, Epi, Green, and Aneityum. Rice *et al.,* (2018) reported that Malekula Island (Bamboo Bay and Wiawi village area) and Moso Island are the most important documented locations for hawksbills in Vanuatu. The TREDS database lists additional hawksbill turtle nesting sites on the islands of Ambrym, Efate, Espiritu Santo, Moso (off north Efate) and Tegua, Torres. The highest numbers of clutches were reported from Moso and Bamboo Bay during the 2006-2007, 2007-2008, 2009-2010, and 2011-2012 nesting seasons. However, these higher figures may be an artifact of greater surveying intensity (Hickey 2020 in Work *et al.,* 2020). More detailed information on hawksbill nesting throughout Vanuatu is summarised in Hickey (2020) (in Work *et al.,* 2020).

Trends in nesting data

Nesting by hawksbill turtles may be declining (Mortimer and Donnelly, 2008), but the lack of long-term monitoring in Vanuatu makes detection of a trend problematic (Hickey, 2020 in Work *et al.,* 2020). During the 2018/2019 nesting season, 170 hawksbills returned to nest at Bamboo Bay (D. Aromalo, pers. comm). Based on all available data, Pilcher (2021) estimated the annual nesting population to be around 300 female hawksbills.

Migration and distribution of foraging areas

Hawksbills nesting in Vanuatu have been documented migrating to overseas foraging grounds, including areas in New Caledonia, Australia, and Samoa (Hickey, 2020 in Work *et al.,* 2020; Jim *et al.,* 2022; Rice *et al.,* 2018). For more information on tagged hawksbill turtles recovered outside Vanuatu, see the TREDS 2015 Report (Siota, 2015). Figure 2.9 shows a summary of migratory tracks of the seven post-nesting hawksbills satellite tagged on Moso Island, central Vanuatu between 2018 and 2020. The most recent data available from the SPREP TREDS database covers 2017-2018. The 2016 data is currently missing. The 2017-2018 TREDS Report (Ward, 2019) indicates that out of the 15,217 tags issued to Vanuatu since 1991, 4,705 tags have been entered into the TREDS database and the hawksbill (n=1,550) is the species with the most records in TREDS for Vanuatu. Genetic samples have been collected from Malekula and are currently being analyzed.

Threats to the population

Despite laws prohibiting turtle take in Vanuatu, harvesting of nesting and foraging hawksbill turtles continues (Rice *et al.,* 2018). Other threats include light pollution, domestic dogs, development of nesting beaches, and bycatch in longline and purse seine fisheries (Hickey, 2020 in Work *et al.,* 2020).

Hawksbill turtle hatchlings are caught and retained for headstarting programs on Efate, and adult hawksbills are occasionally kept in tanks for tourism purposes (Hickey, 2020 in Work *et al.,* 2020). Hatchling mortality is reported to be high in these environments due to poor water quality (ibid.).

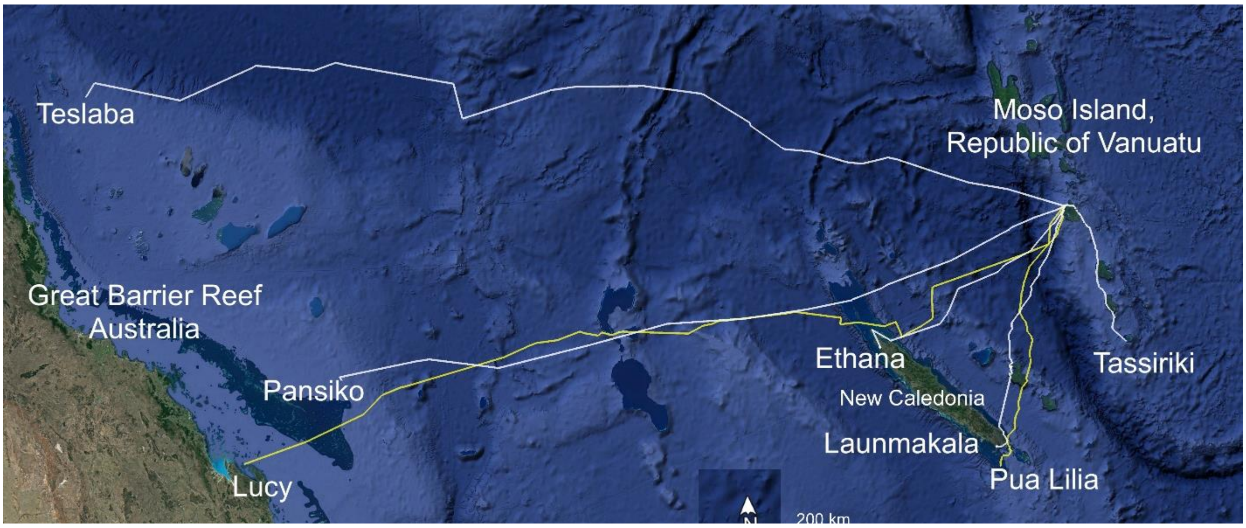

Figure 2.9. Summary of post-nesting migrations of hawksbill turtles from Moso Island, Vanuatu from 2018 to 2020. From Hickey, 2020 in Work *et al.,* 2020.

Management and protection

Take of marine turtles has been prohibited (except for traditional harvests) in Vanuatu since 2005 (Fisheries Act No. 55 of 2005). In 2009, an amendment to the 2005 prohibition was passed, which closed earlier loopholes and prohibited the killing of any marine turtle species. Provisions of the law allow for traditional harvests through application to the Department of Fisheries (Rice *et al.,* 2018). The Vanuatu Fisheries Department has recently begun training community members to monitor fisheries violations at the village level, including for turtle related offenses (Hickey, 2020 in Work *et al.,* 2020). International instruments applicable to hawksbill turtles in Vanuatu are listed in Table 2.3.

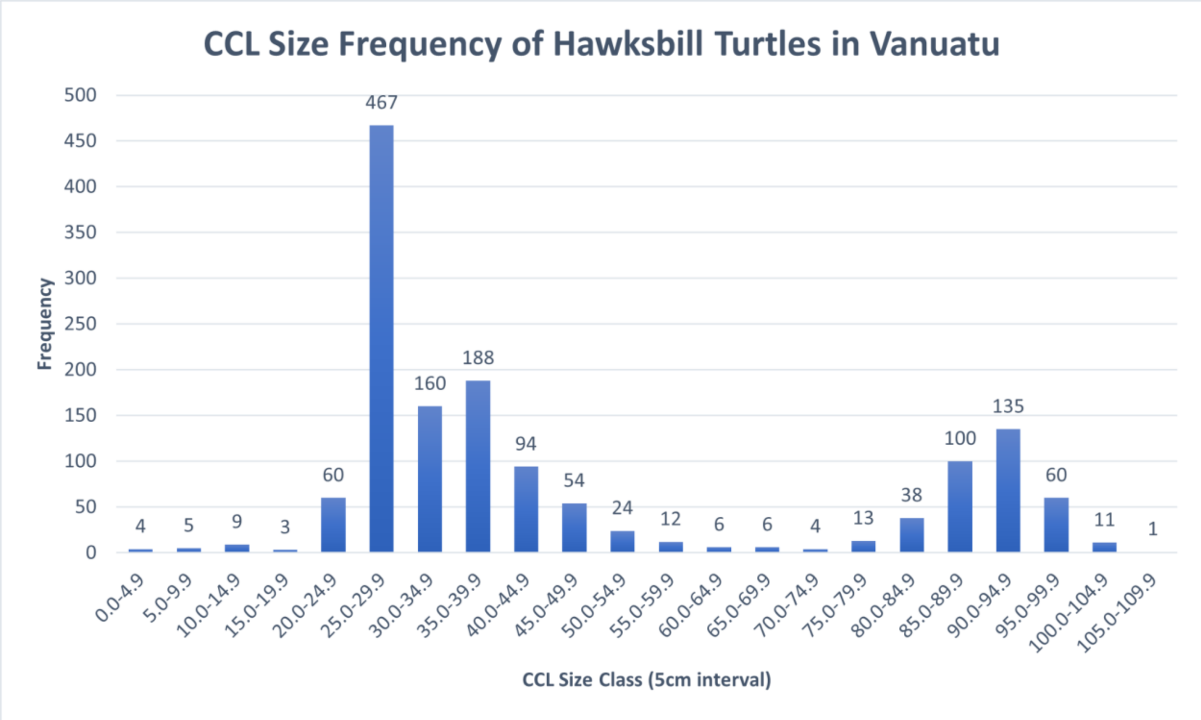

Figure 2.10. Hawksbill CCL size classes from turtles caught in Vanuatu. From the TREDS database (Siota, 2015).

Biological data on breeding and foraging

The TREDS database contains CCL measurement records of 1,454 hawksbill turtles in Vanuatu. The size frequency graph shows 1,086 turtles with a CCL under 64.9 cm, 23 turtles within the range of 65.0-79.9 cm, and 345 adult-sized turtles within the range of 80.0-109.9 cm (Figure 2.10). Siota (2015) reported 1,254 hawksbill turtles with CCL measurements in 2013-2014.

Wallis and Futuna

There are no reports of hawksbill turtle nesting for Wallis and Futuna. Some hawksbill turtles have been reported at the reefs of Futuna Island and flipper tagged as a result of recent monitoring (Work *et al.,* 2020).

Other

Cook Islands

Geographic spread of foraging sites

Hawksbill turtles are known to forage in the waters of the Cook Islands (Ischer, 2019; White, 2012; White, 2013). Foraging hawksbills can be regularly found on coral reefs around Rarotonga and less frequently in its lagoons. White (2012) recorded three juvenile hawksbills at Palmerston Atoll and one adult female seen at Tongareva Atoll in 2010, although only two juveniles have been seen at Tongareva since 2012. Juvenile hawksbill turtles have also been reported at Suwarrow Atoll (White, 2012) and both juvenile and subadult hawksbill turtles in Papua passage (Ischer, 2019). This later study indicates Papua passage may be an important developmental habitat for hawksbill turtles. The TREDS database contains 29 records of foraging juvenile hawksbill encounters from 2004-2010. Four of these were titanium flipper tagged (R series) during 2004-2005.

Geographic spread of nesting

There are no current reports of nesting by hawksbill turtles in the Cook Islands (Ischer, 2019; White, 2012).

Migration and distribution of foraging areas

There are very limited data on migration and distribution of hawksbill turtles from the Cook Islands. Two hawksbills satellite tracked from American Samoa travelled to the Cook Islands (Tagarino *et al.,* 2008), a straight-line distance of some 1,400 km.

Threats to the population

Hawksbill turtles in the Cook Islands are threatened by entanglement in marine debris, plastic ingestion, foraging habitat destruction through dredging and sand mining, water pollution near urbanised areas (e.g. Rarotonga's Muri Lagoon), and climate change impacts, including degraded foraging habitat (e.g. acidification and bleaching of coral reefs) (White, 2020 in Work *et al.,* 2020).

Management and protection

The Marine Resources Act 1989 provides for the protection and management of fishery resources, the definition of which includes marine turtles. It is unknown whether specific regulations exist regarding marine turtle harvest, although Maison *et al.,* (2010) reported that marine turtle eggs were fully protected (Puleloa, 1992). International instruments applicable to hawksbill turtles in the Cook Islands are listed in Table 2.3.

Biological data on breeding and foraging

There are no biological data on breeding and foraging hawksbills in the Cook Islands. A new organisation, 'Te Ara o te Onu', is to work with the tourism industry to collate data on turtle presence, size, and behaviour (White, 2020 in Work *et al.,* 2020).

Nauru

There is no reported nesting of hawksbill turtles in Nauru (NMFS, 1998; Mortimer and Donnelly, 2008). It is not currently possible to determine if nesting occurs. Nauru's coral reef habitats might be foraging habitat to hawksbill turtles, although further investigations are needed.

New Caledonia (France)

Meylan and Donnelly (1999) indicated that few hawksbills were reported to nest in New Caledonia. D'Auzon (2007) reported that the main population (about 200 individuals) was located on the northeast coast, but it was unclear if this referred to in-water or nesting turtles. Recent surveys suggest there is no nesting in New Caledonia (T. Read, pers. comm.). The TREDS database contains three records of foraging hawksbill turtles, one at Sainte Marie Bay in 2011 and two at Anse Vata Beach in 2011 and 2012.

New Zealand

Geographic spread of foraging sites

Almost no local population information exists for this species in New Zealand. However, unpublished diet component analysis shows that hawksbill turtles forage in benthic and pelagic habitats in northern New Zealand, especially around the subtropical Kermadec Islands (Godoy, unpubl. Data).

Geographic spread of nesting

There is no nesting of hawksbill turtles in New Zealand, including the sub-tropical Kermadec Islands.

Migration and distribution of foraging areas

There is very limited information on hawksbill migration in New Zealand. Fifty-three sighting, stranding, and incidental capture (commercial and recreational fishing bycatch) records have been documented from 1949 to 2015 (WCPFC, 2005; Godoy, 2016; Godoy, unpubl. Data). Hawksbill records extend from the Kermadec islands (c. 30o S) south to Palliser Bay, Wellington (c. 41°S), their distribution is mostly concentrated off northeastern North Island, with a significant temporal peak in strandings during winter (July-September) and sightings of free-ranging animals during the warmer summer months (Godoy, unpubl. Data).

Threats to the population

There are very little data on threats to hawksbill turtles in New Zealand. Hawksbill stranding and incidental capture in commercial and recreational fisheries is collected as part of the New Zealand marine turtle sighting and stranding database (private database curated by D Godoy).

Management and protection

Hawksbill turtles are fully protected under the Wildlife Act 1953 and have been assessed as Migrant – Threatened Overseas according to the New Zealand Threat Classification System (NZTCS). International instruments applicable to hawksbill turtles in New Zealand are listed in Table 2.3.

Biological data on breeding and foraging

There is no information on ecology, regional connectivity, or genetic origin of hawksbill turtles in New Zealand. Limited data indicates that hawksbills occurring in New Zealand are juvenile to large sub-adults (μ = 53.2 cm CCL, SD 14.5 cm, range 35.0-90.0 cm, n = 23). Data and samples (including tissue for genetic and isotopic analysis) have been collected since 2007, thus warranting further research initiatives into regional connectivity, migratory corridors, threats, and habitat use.

Niue

There is no reported nesting of hawksbill turtles in Niue (NMFS, 1998; Mortimer and Donnelly, 2008). Hawksbills are reported in marine areas around Niue (Government of Niue, 2001).

Tokelau

Geographic spread of foraging sites

Low numbers of hawksbill turtles have been reported to forage in coastal waters around Tokelau (Balazs, 1983). No further information regarding location or turtle abundance is available.

Geographic spread of nesting

Hawksbill turtles have been recorded nesting at low numbers on Nukunonu Atoll (Balazs, 1983). More recent assessments do not report any hawksbill nesting in Tokelau (Mortimer and Donnelly, 2008; NMFS, 1998).

Trends in nesting data

There are no data on nesting trends for hawksbill turtles in Tokelau, nor is it possible to determine the number of females nesting annually (Pilcher, 2021).

Migration and distribution of foraging areas

There are no data on migration and distribution of hawksbill turtles from foraging areas in Tokelau.

Threats to the population

Hawksbill turtles in Tokelau are threatened by direct harvest of eggs and nesting females, direct take at foraging grounds, fisheries bycatch, predation of nests by crabs and Polynesian rats, and climate change impacts from sea level rise, beach erosion, nest inundation, alteration of sex ratios, and increased frequency of extreme weather events (Ward and Lemalu, 2020 in Work *et al.,* 2020).

Management and protection

There are no national protections for hawksbill turtles in Tokelau. Rules and regulations are determined separately for each atoll and village of Tokelau (Balazs, 1983; Pierce *et al.,* 2012). International instruments applicable to hawksbill turtles in Tokelau are listed in Table 2.3.

Biological data on breeding and foraging

There are no biological data on breeding and foraging for hawksbill turtles in Tokelau.

Tuvalu

There is no reported nesting of hawksbill turtles in Tuvalu. Low numbers of nesting hawksbills (tens of individuals) are recorded in adjacent countries, namely Solomon Islands and Vanuatu. The TREDS database contains records of two foraging hawksbill encounters at Funafuti Island, one of which was a tag return from Tuvalu, although Vanuatu and Solomon Islands are potentially important foraging areas.

Threats to hawksbill turtles in Tuvalu include illegal harvest, habitat degradation, and pollution.

ACKNOWLEDGEMENTS AND CONTRIBUTIONS

We would like to thank Karen Baird and Unity Roebeck from SPREP for providing TREDS data. The authors acknowledge the vast contributions from thousands of turtle biologists and researchers as well as community members, fisher people, government representatives and others who contributed data to the studies we summarise herein, and the wealth of information in their own original publications. We acknowledge that the ownership and intellectual property of that information resides entirely with all the original data owners and providers. We are also grateful to the numerous research teams, NGOs and government agencies who have funded all these research efforts. The layout of this report was made possible thanks to a financial contribution of the Government of the Principality of Monaco under the Migratory Species Champion Programme.

CAMH conceptualised the study. CAMH and KR drafted the text with inputs and review from all co-authors.

Chapter 3: Policy review as background to the development of a Single Species Action Plan for hawksbill turtles in South-east Asia and the adjacent western Pacific.

This chapter includes the policy review that has been published by the Convention of Migratory Species Secretariat.

Convention of Migratory Species (2022). Policy Review as Background to the Development of a Single Species Action Plan for Hawksbill Turtles in South-east Asia and the Adjacent Western Pacific. [Website: https://www.cms.int/en/document/policy-review-background-development-single-species-action-plan-hawksbill-turtles-south]

Preface

Hawksbill turtles have long and geographically complex life histories that often span multiple ocean basins and jurisdictional boundaries (Hays & Scott, 2013). Given the wide variety of threats and management measures in place across the hawksbills ecological range, efforts to mitigate and manage these threats generally prove difficult with sometimes low or resisted uptake. This assessment was undertaken in order to give a non-comprehensive overview of relevant commitments countries have already made to conserve, manage and protect hawksbill turtles in the South-east Asia and western Pacific Ocean regions, and seeks to present a consolidation of actions from existing relevant mandates addressing turtle take and trade. This involved reviewing and consolidating actions or directives from more than 30 detailed plans, policies and international legal instruments, including assessing the role other relevant organisations and consortia contribute (tangibly and show strong links) to hawksbill conservation outcomes.

This policy assessment and review became the background document from which the CMS developed its Single Species Action Plan (Decision 13.70c). A statement by Melanie Virtue, CMS Secretariat, confirms my role as the lead author on this international report (see Appendix Two). The outputs of the policy review, as published by CMS, is presented in this thesis Chapter.

Introduction

CMS Decision 13.70 c) requests the Scientific Council to develop a draft Single Species Action Plan (SSAP) for the conservation of Hawksbill Turtles to address their trade and use in South-East Asia, and the adjacent Western Pacific.

This SSAP is to be developed with support of the Secretariat and in collaboration with the IOSEA Marine Turtle MOU, CITES, Ramsar Convention and relevant non-governmental organizations. It should take into account the 2019 CITES Report on Status, Scope and Trends of the Legal and Illegal International Trade in Marine Turtles, its Conservation Impacts, Management Options and Mitigation Priorities (CITES CoP 18, Inf.18), as well as the Hawksbill Assessment prepared by the Advisory Committee of the IOSEA Marine Turtle MOU (Hamann *et al.,* 2022).

As a first step towards the development of the SSAP, the CMS Secretariat with support from WWF and the University of the Sunshine Coast developed this document, which seeks to give a non-comprehensive overview of relevant commitments countries in the range of the SSAP have already made.

An overview of membership in selected international instruments and relevant bodies for each of the countries and territories in the proposed range of the SSAP is provided in Table 2.2 (Chapter 2). It was followed by a non-comprehensive overview of other relevant international legal instruments, United Nations documents and international organizations and consortia (refer Table S2.1). This section of the document illustrates the many commitments countries have already made that touch on turtle take and trade, and that accordingly, the Hawksbill Turtle SSAP will help to implement in a coherent way with respect to this species.

Review

Table 3.1 seeks to present a consolidation of actions from existing relevant mandates addressing turtle take and trade from all these commitments. For this, they have been grouped into different categories, as follows:

- Improve Legislation, Policy and Enforcement
- Enhance Regional Cooperation
- Furthering Research, Monitoring, Implementation and On-Ground Management

    - Turtle Use and Trade
    - Threats, Population Status and Distribution
    - Implementation and Management
- Awareness, Education, Capacity Building and Resources Required
    - Provide Alternative Livelihoods and Incentives to Change Behaviour

While we have attempted to consolidate text as much as possible to reduce repetition, there remains some overlap in these actions to ensure key wording, meaning and context were not lost.

Priority actions (i.e. those that should be implemented in the short-term) which are already underway and/or are already in part financially supported, have been highlighted.

Table 3.1 served as a starting point for the development of a first draft of the SSAP, which was then consulted with experts and range states in writing and subsequently discussed at a series of meetings in May/June 2022, where countries were offered to adopt the Action Plan.

Table 3.1: Existing Relevant Mandates Addressing Take and Trade in the Region of Interest to support a Draft Single Species Action Plan (SSAP) for the Conservation of the Hawksbill Turtle in South-East Asia, and the Adjacent Western Pacific. Level: I Regional; (N) National; (I) International

No.	Actions	Level	Suggested Partners	Source
Improve Legislation, Policy and Enforcement				
1.	Conduct a thorough review of protective legislation and inconsistencies between countries.	I/R	CMS, IOSEA MOU, SPREP	IOSEA CMP 2009 CITES CoP18 Turtle Decisions 2019 (18.212a) Sulu Sulawesi Marine Turtles Action Plan 2011 Pacific Islands Regional Marine Species Programme 2022-2026 (6.1)
2.	Improve compliance and address weaknesses in the judicial process in countries where turtles are exploited, take is legal and where illegal activities continue	N	National Governments, NGOs	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (27, 29, 91) CITES CoP18 Turtle Decisions 2019 (18.212a) Pacific Islands Regional Marine Species Programme 2022-2026 (6.1)
3.	Consider enacting new laws on marine turtle conservation, remove any inconsistencies within national legislation, and fully implement international commitments including CITES Turtle Decisions.	R/N	National Governments	IOSEA CMP 2009 CITES CoP18 Turtle Decisions 2019 (18.211b) ASEAN MoU 2012 (IV)

No.	Actions	Level	Suggested Partners	Source
				Pacific Islands Regional Marine Species Programme 2022-2026 (4.1, 6.1)
4.	Improve and facilitate training and capacity building of relevant authorities at the national and regional level, including on the implementation and enforcement of national and international regulations that apply to marine turtles, and on identification, monitoring, reporting and wildlife enforcement capability supported by financial or technical assistance	R/N	NGOs, IGOs, Financial Institutions, National Governments	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (27, 48, 91) CITES CoP18 Turtle Decisions 2019 (18.213a) ICCWC tools Pacific Islands Regional Marine Species Programme 2022-2026 (1.1, 8.1, 8.2) (also supported by: IOSEA Hawksbill Assessment 2022)
5.	Complete and implement the CTI (and corresponding National Plans of Action) Sea Turtle Conservation Action Plan with a particular focus on international trade in turtle meat and parts, including surveillance and enforcement	R/N	CTI-CFF, National Governments	CTI-CFF Regional Plan of Action 2012 Pacific Islands Regional Marine Species Programme 2022-2026 (4.5 and C.6)
6.	Complete and implement a region-wide Sea Turtle Conservation Action Plan with a particular focus on incidental bycatch in other fisheries (e.g., longline tuna, purse seine, and small-scale fisheries), including legislative reform and practical modifications of fishing gear	R	CTI-CFF, SPREP, IOSEA MOU, National Governments	IOSEA CMP 2009 CTI-CFF Regional Plan of Action 2012 Pacific Islands Regional Marine Species Programme 2022-2026 (4.1)
7.	Improve monitoring, detection and law enforcement activities related to marine turtles in coastal areas and at transaction points	N/R	National Governments, CTI-CFF, INTERPOL, ASEANAPOL, local community groups	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (91) CITES CoP18 Turtle Decisions 2019 (18.211f) Pacific Islands Regional Marine Species Programme 2022-2026 (6.1, 8.1)

No.	Actions	Level	Suggested Partners	Source
				(also supported by: IOSEA Hawksbill Assessment 2022)
8.	Update, complete and implement conservation action and targeted management plans, which should cover traditional management and regulation addressing conflict over the use of critical habitats (e.g., nesting beaches, feeding grounds) including the findings/recommendations of CITES CoP18/Inf.18 and related Decisions 18.211-18.213	R/N	National Governments, local community groups	CMS Decision 13.70 IOSEA Work Programme 2020-2024 (63) CITES CoP18 Turtle Decisions (18.211 a, b, c) CTI-CFF Regional Plan of Action 2012 Pacific Islands Regional Marine Species Programme 2022-2026 (5.1) (also supported by: IOSEA Hawksbill Assessment 2022)
Enhance Regional Cooperation				
9.	Consult other range states, and work through existing regional agreements, MoUs and action plans to protect habitats in networks that allow for greater safety for marine turtles during their life cycle and in their movements	R/N	National Governments, CMS, IOSEA MOU, IAC	IOSEA CMP 2009 Ramsar Convention Resolution XIII.24 (19) Pacific Islands Regional Marine Species Programme 2022-2026 (8.2)
10.	Strengthen internal, bilateral, and international cooperation in enforcement by collaborating with IGOs and NGOs to ensure the issue of marine turtle trade is on the agenda of CITES I, including the Animals Committee and Standing Committee, the IOSEA MOU, RFMO meetings, and meetings of other relevant organizations	R	National Governments, IGOs, NGOs, INTERPOL, UNTOC, RFMOs	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (58, 59, 60) CITES CoP18 Turtle Decisions (18.210 e, 18.211 d) Pacific Islands Regional Marine Species Programme 2022-2026 (4.5, 8.2)

No.	Actions	Level	Suggested Partners	Source
				(also supported by: IOSEA Hawksbill Assessment 2022)
11.	Review RAMSAR and IOSEA Site Network site management plans, enhance synergies and ensure better coordination with regional initiatives and existing networks	R/N	National Governments, Ramsar, CMS, IOSEA MOU, IAC	IOSEA Work Programme 2020-2024 (89) Ramsar Convention Resolution XIII.24 (22)
12.	Increase intra- and interregional collaboration and exchange of actionable intelligence between source, transit, and destination countries to address the illegal take and trade of wildlife	N/R	National Governments, CITES, ICCWC, INTERPOL, ASEANAPOL, UNODC, RFMOs, CTI-CFF	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (51, 52, 58, 91) CITES CoP18 Turtle Decisions 2019 (18.211h) UNTOC (13) UN Convention Against Corruption (43) PSMA (12-19) London Declaration 2018 (18) Pacific Islands Regional Marine Species Programme 2022-2026 (4.5) (also supported by: IOSEA Hawksbill Assessment 2022)
13.	Cooperate in the conservation and management of living resources in the areas of the high seas and coordinate efforts to identify and address fishing interactions with marine turtles (particularly bycatch).	R	RFMOs and other Regional Fishery Bodies	CITES CoP18 (18.211, l) UNCLOS (197)
Furthering Research, Monitoring, Implementation and On-Ground Management				
	Take, Use and Trade			

No.	Actions	Level	Suggested Partners	Source
14.	In a standardised manner, collect illegal wildlife trade data that can be used for monitoring trade in marine turtles; and submit comprehensive and accurate information on illegal trade in marine turtles in their annual illegal trade reports to the CITES Secretariat	N/R	National Governments, CTI-CFF, NGOs, CITES, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (21) CITES CoP18 Turtle Decisions 2019 (18.211e) Pacific Islands Regional Marine Species Programme 2022-2026 (1.1) (also supported by: IOSEA Hawksbill Assessment 2022)
15.	Ascertain key trade routes, methods, volumes, and trade 'hot-spots' using available technologies	N	CITES, National Governments, NGOs, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (59) CITES CoP18 Turtle Decisions 2019 (18.211i)
16.	Enforce national and international legislation and regulations, as well as other mechanisms that apply to marine turtles take and trade	N	CITES, National Governments, NGOs	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (27) CITES CoP18 Turtle Decisions 2019 (18.211i) (also supported by: IOSEA Hawksbill Assessment 2022)
17.	Research the scale and impact that national and international artisanal, semi-industrial and industrial fisheries, including illegal, unreported, and unregulated fishing, have on marine turtle populations and their linkage to	N	NGOs, National Governments, World Bank, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (1, 6, 7, 24, 85, 87, 88)

No.	Actions	Level	Suggested Partners	Source
	illegal trade including using on-board observer data, fishing community surveys supported by financial and technical assistance			CITES CoP18 Turtle Decisions 2019 (18.213e) Pacific Islands Regional Marine Species Programme 2022-2026(4.4) (also supported by: IOSEA Hawksbill Assessment 2022)
18.	Evaluate social, cultural, and economic value and investigate human dimensions that underpin the use and trade of marine turtles and turtle products	N/R/I	NGOs, National Governments, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (7,20,21,29) Pacific Islands Regional Marine Species Programme 2022-2026 (4.5) (also supported by: IOSEA Hawksbill Assessment 2022)
19.	Where domestic harvest of specimens of marine turtles, including eggs, is legal, ensure any domestic harvest quotas are established based on robust science-based methods and the principles of sustainability, including accounting for existing quota or no-take quotas in other States' that share marine turtle stock(s), taking into account national enforcement capacity	N/R	National Governments, local community groups	IOSEA Work Programme 2020-2024 (29) CITES CoP18 Turtle Decisions 2019 (18.212b)
20.	Continue and/or establish national and regional observer and bycatch mitigation programmes to assess and quantify fishery impact/overlap to turtle populations, stocks and distribution, and prioritise areas, stocks, fisheries for additional management, ensuring this is communicated to relevant authorities	N/R	National Governments	IOSEA Work Programme 2020-2024 (7, 22-25) Sulu Sulawesi Marine Turtles Action Plan 2011 (4.1)
21.	Develop guidelines on incidental capture mitigation mechanisms	I	NGOs, National Governments, IOSEA MOU	Sulu Sulawesi Marine Turtles Action Plan 2011 (4.2) Pacific Islands Regional Marine Species Programme 2022-2026 (4.4)
22.	Increase action to tackle the illicit financial flows associated with wildlife trafficking and related corruption, including the increase of use of financial investigation techniques and public/private collaboration to identify criminals and their networks	N	UNODC	London Declaration 2018 (10)

No.	Actions	Level	Suggested Partners	Source
	Threats, Population Status and Distribution			
23.	Conduct a comprehensive, qualitative threats assessment for HB turtles	I/R/N	NGOs, National Governments, IOSEA MOU, Universities and Research Institutes	CMS Turtle Decisions (13.70) IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (12, 63) Pacific Islands Regional Marine Species Programme 2022-2026 (2.1) (also supported by: IOSEA Hawksbill Assessment 2022)
24.	Address incidental catch in fisheries (e.g., longline tuna, purse seine, and small-scale fisheries), including legislative reform and practical modifications of fishing gear	R	IGOs, National Governments	IOSEA CMP 2009 CTI-CFF Regional Plan of Action 2012 Pacific Islands Regional Marine Species Programme 2022-2026 (4.1) (also supported by: IOSEA Hawksbill Assessment 2022)
25.	Further study HB life history and ecology, population ecology, feeding ecology, long-term population trends, habitat needs, HB influence on foraging habitats, development stages, movement and migrations, and population genetics	I/R/N	National Governments, Universities and Research Institutes, IGOs, NGOs, local community groups	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (12, 43, 63) Pacific Islands Regional Marine Species Programme 2022-2026 (1.1, 1.3, 1.4) (also supported by: IOSEA Hawksbill Assessment 2022)
26.	Compile and analyse satellite tracking and tag recovery data at a regional level to understand regional habitat use patterns, identify hotspots and identify important gaps in protection	I/R/N	NGOs, National Governments, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (12, 43, 63)

No.	Actions	Level	Suggested Partners	Source
				Pacific Islands Regional Marine Species Programme 2022-2026 (1.4)
27.	Collect genetic samples of marine turtles using standardized methods and reliable analysis to determine the species involved and population of origin. Compile and map data to support, for example, research, investigations and prosecutions, and policy decisions nationally and internationally.	N	National Governments, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (1, 44) CITES CoP18 Turtle Decisions 2019 (18.211g) Pacific Islands Regional Marine Species Programme 2022-2026 (1.3) (also supported by: IOSEA Hawksbill Assessment 2022)
28.	Research and establish a baseline for the status and distribution of marine turtles in the different countries/region supported by financial and technical assistance	N	National Governments, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (42, 47, 85, 115) CITES CoP18 Turtle Decisions 2019 (18.213d) Pacific Islands Regional Marine Species Programme 2022-2026 (1) (also supported by: IOSEA Hawksbill Assessment 2022)
29.	Identify and collect standardised data on index nesting and foraging sites and ensure the populations are monitored as precisely as possible, in order to improve our knowledge of the distribution, numbers and state of health of each of the species involved	R/N	National Governments, CMS, IOSEA MOU, IAC, Universities and Research Institutes, local community groups	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (9) Ramsar Convention Resolution XIII.24 (16) Pacific Islands Regional Marine Species Programme 2022-2026 (1.2, 1.4) (also supported by: IOSEA Hawksbill Assessment 2022)

No.	Actions	Level	Suggested Partners	Source
30.	Review existing research methods and monitoring protocols and develop standard guidelines and monitoring systems on genetic identity, population status, migration routes, and other biological and ecological aspects of marine turtles (life history).	I	NGOs, National Governments, IOSEA MOU	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (1, 5) CTI-CFF Regional Plan of Action 2012 Sulu Sulawesi Marine Turtles Action Plan 2011 (5.1) Pacific Islands Regional Marine Species Programme 2022-2026 (3.1) (also supported by: IOSEA Hawksbill Assessment 2022)
	Implementation and Management			
31.	Support fisheries management authorities in implementing turtle mitigation and safe handling practices	N	NGOs, National Governments	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (22, 23) Pacific Islands Regional Marine Species Programme 2022-2026 (4.1)
32.	Improve accountability for the practices undertaken by all vessels and improve the monitoring and control related to CITES-listed marine turtles at landing sites	N	National Governments, FAO (via Port State Measures Agreement), RFMOs	CITES CoP18 Turtle Decisions 2019 (18.211j) Pacific Islands Regional Marine Species Programme 2022-2026 (4.1)
33.	Strengthen the conservation and management of identified index nesting and foraging sites, if possible by designating them as IOSEA Site Network sites and Wetlands of International Importance (Ramsar sites), and strengthen this designation through the promulgation of the appropriate protective measures, in particular through the creation of marine protected areas	R/N	National Governments, IOSEA MOU, IAC	IOSEA Work Programme 2020-2024 (37, 89) Ramsar Convention Resolution XIII.24 (17, 18) Pacific Islands Regional Marine Species Programme 2022-2026 (4.2)

No.	Actions	Level	Suggested Partners	Source
34.	Define and identify habitat critical for turtle stocks at different life history stages with a particular focus on the trans-boundary nature of life-cycle stage requirements, migratory patterns, and related protection strategies and adequately protect it including through marine protected areas	R/N	National Governments, IGOs, CTI-CFF, NGOs, Universities and Research Institutes	IOSEA Work Programme 2020-2024 (30-33) CTI-CFF Regional Plan of Action 2012 (also supported by: IOSEA Hawksbill Assessment 2022)
35.	Formulate economic incentives to reduce threats and mortality as well as implement measures and protocols for the protection and management of marine turtle populations and their habitats	N	National Governments	IOSEA CMP 2009 Sulu Sulawesi Marine Turtles Action Plan 2011 (also supported by: IOSEA Hawksbill Assessment 2022)
36.	Develop and implement management programmes to enhance the protection of nesting habitats and maximize hatchling production and survival	N	National Governments, NGOs	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (9, 15, 87) Sulu Sulawesi Marine Turtles Action Plan 2011 (2) Pacific Islands Regional Marine Species Programme 2022-2026 (1.2) (also supported by: IOSEA Hawksbill Assessment 2022)
37.	Develop guidelines for marine protected area network design for marine turtles	I	National Governments, IGOs, IOSEA MOU, NGOs, Universities and Research Institutes	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (33) Sulu Sulawesi Marine Turtles Action Plan 2011 (6) Pacific Islands Regional Marine Species Programme 2022-2026 (3.1)
Awareness, Education, Capacity Building and Resources Required				

No.	Actions	Level	Suggested Partners	Source
38.	Take further steps to understand and reduce use and domestic trade and to develop awareness campaigns to target online illegal trade.	N	NGOs, National Governments, local community groups	IOSEA Work Programme 2020-2024 (61)
39.	Build community and political awareness on the conservation status of marine turtles and on the importance of promoting the conservation of the species through compliance with CITES at the national level, supported by financial or technical assistance.	N	NGOs, National Governments, local community groups	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (58, 59) CITES CoP18 Turtle Decisions 2019 (18.213b) Pacific Islands Regional Marine Species Programme 2022-2026 (4.5, 8.2)
40.	Work with local communities to reduce poaching; raise awareness of turtle consumers, highlight existing regulations, conservation and possibly health issues involved; engage religious leaders, as appropriate, in awareness campaigns; educate youth and women; enhance transboundary cooperation in education and awareness campaigns	N	NGOs, National Governments, local community groups	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (51, 52) Pacific Islands Regional Marine Species Programme 2022-2026 (3.1, 9.1)
41.	Develop best practices to guide the interaction of humans and marine turtles by raising the awareness of inhabitants of and visitors to coastal zones	R/N	National Governments, CMS, IOSEA MOU, Ramsar	CMS Resolution 11.29 (Rev.COP12), 12.16 Ramsar Convention Resolution XIII.24 (20)
42.	Develop, publish and provide training on information to promote best practices and successes for marine turtle conservation including data collection and monitoring	I/N	NGOs, National Governments, IOSEA MOU	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (15-19, 55, 56) Sulu Sulawesi Marine Turtles Action Plan 2011 (7)
43.	Identify and articulate actual resource needs and raise funds to increase human and material resources, build field-level capacity at national and regional levels, including for enforcement	N/R	SPREP, CTI-CFF, NGOs, National Governments, CITES	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (27)
	Provide Alternative Livelihoods and Incentives to Change Behaviour			

No.	Actions	Level	Suggested Partners	Source
44.	Develop alternative livelihoods, such as ecotourism, transferring skills to former fishermen and poachers, and/or livestock keeping using examples of good practice to ensure genuinely sustainable approaches, which will be beneficial in the long run for both humans and turtle populations	R/N	NGOs, National Governments,	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (53) London Declaration 2018 (13) Pacific Islands Regional Marine Species Programme 2022-2026 (7.1) (also supported by: IOSEA Hawksbill Assessment 2022)
45.	Examine motivations for the legal and illegal harvest and use of marine turtles and their eggs, assess the sustainability of alternative livelihood options for communities which depend on marine turtles, include subsistence users in decision making, and seek financial and technical support to address this item	N	National Governments, NGOs, local community groups	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (20, 28, 29, 87) CITES CoP18 Turtle Decisions 2019 (18.213c) (also supported by: IOSEA Hawksbill Assessment 2022)
46.	Work with local communities, relevant stakeholders and institutions to raise awareness of the importance of conserving marine turtles, their nests and their habitats, and halt poaching and the exploitation of marine turtle products, including through, *inter alia*, fostering alternative sustainable livelihoods, including sustainable eco-tourism	R/N	National Governments, CMS, IOSEA MOU, local community groups	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (50, 51, 52, 53, 54) Ramsar Convention Resolution XIII.24 (21) Pacific Islands Regional Marine Species Programme 2022-2026 (9.1)
47.	Establish direct incentive schemes (employment/payment) to deter illegal poaching	N	NGOs, National Governments	IOSEA CMP 2009
48.	Establish indirect incentives (alternative livelihoods) for turtle users	N	NGOs, National Governments	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (53) (also supported by: IOSEA Hawksbill Assessment 2022)

No.	Actions	Level	Suggested Partners	Source
49.	Use religious edicts to curb turtle consumption	N	NGOs, National Governments	IOSEA CMP 2009 IOSEA Work Programme 2020-2024 (51)

ACKNOWLEDGEMENTS AND CONTRIBUTIONS

We would like to thank the various interns of the CMS Secretariat who assisted in reviewing this assessment.

CAMH conceptualised the study and conducted the first analysis. CAMH, the CMS Secretariat and its interns revised the table in 2021 prior to its use as a background document to the development of the Single Species Action Plan.

Chapter 4: Twenty-eight years of decline: nesting population demographics and trajectory of the north-east Queensland endangered hawksbill turtle (Eretmochelys imbricata)

This chapter includes a co-authored manuscript that has been published in Biological Conservation.

Bell, I. P., Meager, J. J., Eguchi, T., Dobbs, K. A., Miller, J. D., & Madden Hof, C. A. (2020). Twenty-eight years of decline: Nesting population demographics and trajectory of the north-east Queensland endangered hawksbill turtle (Eretmochelys imbricata). Biological Conservation, 241, 108376. https://doi.org/10.1016/j.biocon.2019.108376

Abstract

Globally, hawksbill turtles (*Eretmochelys imbricata*) are listed as Critically Endangered, the cause of which is largely attributed to excessive historical take by the tortoiseshell industry. Yet few long-term data analyses describing population trends or survivorship exist. Here we analyse a long-term dataset for a globally significant western Pacific *E. imbricata* nesting population on Milman Island, northern Great Barrier Reef. Three demographic indicators were used: (1) number of egg clutches laid, (2) nester abundance and survival, and (3) the body-size distribution of nesters (curved carapace length, CCL). Models were developed for a time series from the 1990 – 91 to 2016 -17 nesting season that included 21 years of sampling, with predicted trends evaluated against samples from the 2017-18 nesting season. The number of clutches laid and nester abundance rate of decline varied over the study period, but the decline was markedly similar with a 58 and 57% overall reduction, respectively. Annual survival rate was high (0.972, 95% CI = 0.965 to 0.977), but was not estimated separately for all years. Models predicted that the current rate of decline would lead to nesting extirpation by 2036 (95% CI: 2026-2058) and 2032-2037 (95% CI: from 2020 to increasing), for the models of nester abundance and number of eggs laid, respectively; and aligned with the observed values for the test data set (2017-18 season).

The rate of decline of *E. imbricata* nesting at Milman Island highlights the urgency to understand and mitigate risks faced by this endangered population and more broadly across the western Pacific.

Introduction

Centuries of *Eretmochelys imbricata* take by the tortoiseshell (bekko) industry have resulted in the prohibition of international trade (Appendix I Conventional on International Trade in Endangered Species, CITES), and a global listing as 'Critically Endangered'(Mortimer and Donnelly 2008) . Despite the development of regional and international conservation agreements and legislative protection designed to reduce trade, threats to the viability of *E. imbricata* populations in the western Pacific Ocean remain, including: unrestricted legal and illegal take; incidental catch in active fisheries or discarded ghost nets; and, loss or degradation of nesting and foraging habitat (Humber *et al.,* 2014; Kinch & Burgess, 2009; Lam *et al.,* 2011; Mortimer & Donnelly, 2008; Wallace *et al.,* 2011). Although considered major threats to *E. imbricata* populations throughout the region, the level of take and incidental catch remain uncertain in many western Pacific countries (CITES, 2018; Wallace *et al.,* 2011). In spite of Japan withdrawing its reservation to take *E. imbricata* under Appendix I of the Convention on International Trade in Endangered Species (CITES) (Marine Turtle Newsletter 1994), the continued take of *E. imbricata* for food and tortoiseshell is considered the greatest contemporary threat to *E. imbricata* survival (GBR Marine Park Authority, 2014; Wallace *et al.,* 2011). Several aspects of climate change impacts on foraging ground and nesting habitat viability has been elucidated (Montero et al 2018), nesting success and offspring sex ratios for this nesting cohort remains unknown. Confounded by the current lack of comprehensive genetic stock assignment, stock boundaries and 'management unit' delineation (Fitzsimmons & Limpus, 2014; Vargus *et al.,* 2016), it also remains unclear how these threats affect *E. imbricata* populations at a stock level.

Genotypic mixed-stock-analysis, flipper tagging and satellite telemetry have revealed breeding migrations of *E. imbricata* between north-eastern Australian rookeries and south-western Pacific regions including Vanuatu, New Caledonia, Solomon Islands and Papua New Guinea (PNG) (Bell & Jensen, 2018; Fitzsimmons & Limpus, 2014; Hamilton *et al.,* 2015;

Vargus *et al.,* 2016). There are currently two genetically distinct nesting stocks described in this region: 1) Solomon Islands; and, 2) one stock managed as two subpopulations – Arnhem Land, and north-east Queensland, in Australia (Broderick *et al.,* 1994; Vargus *et al.,* 2016).

The south-western Pacific region was highly exploited throughout the nineteenth and twentieth centuries to meet the demand of the tortoiseshell trade (Hamilton *et al.,* 2015; Kinch & Burgess, 2009; Limpus, 2009), which was concentrated in the northern Great Barrier Reef (GBR), where *E. imbricata* were once abundant. However, conservation initiatives undertaken at both nesting (Arnavon Islands in the Solomon Islands) and foraging grounds (Howick Group) has resulted in some recovery of this nesting cohort (Bell & Jensen, 2018; Hamilton *et al.,* 2015). Few other robust estimates of population trends for this region exist. Where data exist, nesting density at many other major rookeries lack sufficient data, are approaching extirpation, or continue to decline (Meylan & Donnelly 1999; Mortimer & Donnelly, 2008).

Australian *E. imbricata* are listed as "Vulnerable" (*Environment Protection and Biodiversity Conservation Act, 1999*) and "Endangered" under Queensland legislation (*Nature Conservation Act, 1992*). *Eretmochelys imbricata* nest in low density on islands in the northern GBR and Torres Strait areas of eastern Australia (Limpus, 1980; Miller *et al.,* 1995). Based on nesting density surveys during the 1980-90s, Milman Island, located in remote far northern GBR, (Figure 4.1) was identified as supporting a high-density *E. imbricata* nesting population. It was selected as Queensland's primary index nesting beach for monitoring long-term variability of the north-east Queensland stock representative of multiple nesting sites over a large spatial area, and what was once considered to be one of the world's largest *E. imbricata* stocks (Limpus 2009; Limpus & Miller 2008; Loop *et al.,* 1995; Meylan & Donnelly, 1999; Miller *et al.,* 1995). The island and surrounding waters have, since 2004, received the highest level of State and Federal zoning protection, classified as National Park "Scientific" and "Preservation" zone[s], within the GBR Marine Park.

Here we provide the first comprehensive analysis of a 28-year dataset (1990 – 91 to 2016 – 17 season) to ascertain the north-east Queensland stock population trend. The potential for substantial fluctuations in nester abundance and life-history traits, such as age-at-maturity and nesting phenology highlights the need for multiple lines of evidence to diagnose trends (Piacenza *et al.,* 2016). We therefore examined changes in demographic parameters of *E. imbricata* at Milman Island using three independent datasets: (1) egg production using nonlinear models (autoregressive generalised additive models, GAM), (2) survival, nester abundance, remigration interval and number of clutches laid per female using multistate open robust design models (MSORD) (Kendall, 2004; Kendall & Nichols, 2002) and (3) the distribution of nester body size. Body-size distribution has been used extensively for exploited populations (Genner *et al.,* 2010; Graham *et al.,* 2005; Hutchings, 2005), as a fitness-related phenotypic trait that can relate directly to population stability (Anderson *et al.,* 2008) and as an early warning signal of population collapse (Carvalho *et al.,* 2018; Clements *et al.,* 2017). Finally, we evaluate the predictive models of nester abundance and egg production against the observed rates for the 2017 – 18 nesting season. Together these approaches provide more robust evidence of nesting turtle population demographics and trajectories, and essential quantitative evidence critical to support future conservation management of the north-east Queensland *E. imbricata* stock before an non-viable population may lead to extirpation.

Methods

Study area and data set

Milman Island (143^{0} 00’ 57”E, 11^{0} 10’ 08” S) is an uninhabited, densely-wooded sand cay located approximately 23 km off mainland Australia, in the far northern section of the GBR Marine Park, Queensland (Figure 4.1). The island is approximately 2.4 km in circumference. An intertidal reef flat (area ~ 560 ha) extends around much of the island, preventing access by nesting turtles at low tide. *Eretmochelys imbricata* nest (or attempt to nest) on beaches around the entire island, typically on a rising tide after sunset (1930-2300 h) (Loop *et al.,* 1995).

Monitoring teams patrolled the beach after sunset whenever turtles had tidal access to nesting sites. Monitors were trained in data collection, utilized minimal disturbance methods and were routinely scrutinized for competency to ensure data collection consistency.

Turtles were double-tagged on the trailing edge of each front flipper using uniquely numbered titanium tags (Limpus, 1992). Nesting, measurement, laparoscopy and tagging data were collected using standard protocols (as described in Dobbs *et al.,* 1999; Limpus & Miller, 2008) and stored in the Queensland Turtle Research Database.

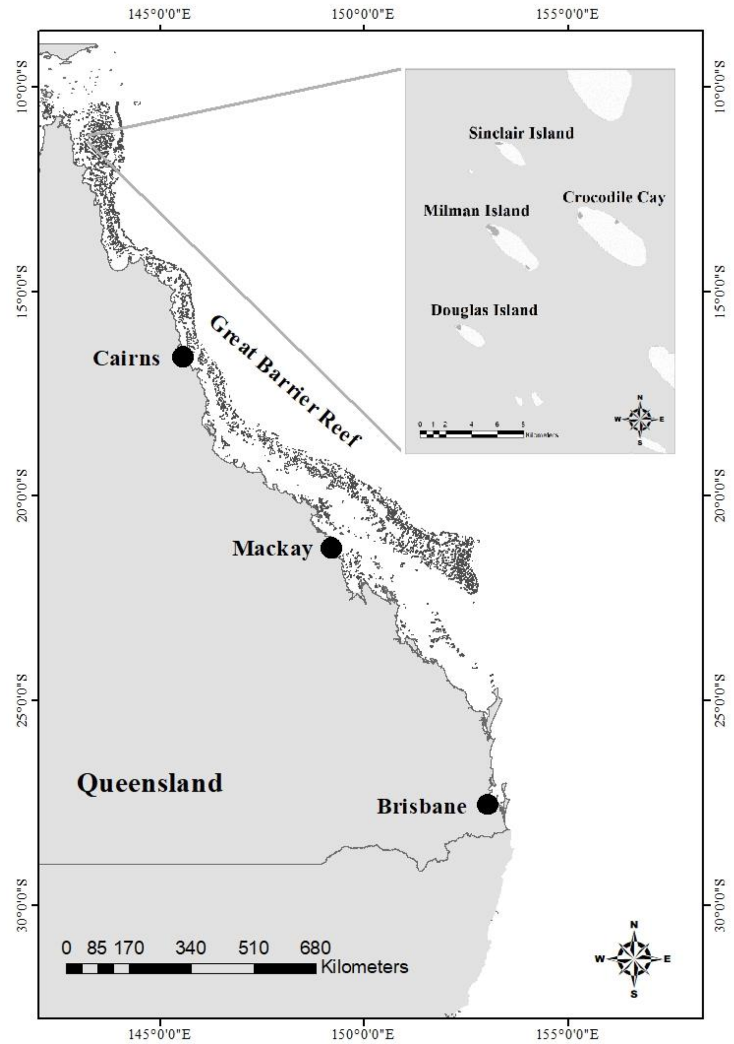

Figure 4.1 Location of Milman Island, in north east Australia.

Eretmochelys imbricata nesting on Milman Island peaks between January and February (Loop et al 1995; Dobbs *et al.,* 1999; Limpus & Miller, 2008). The monitoring period varied among years because of logistical constraints and cyclones (Table S4.1, online supplement). Over the 28-year period from the 1990 to 2017 nesting seasons, no data were collected during 2000, 2002 and from 2011 to 2014 (Table S4.1). For the 22 years where data were collected, the sampling period effort ranged from 12 to 117 nights (average = 43 nights per season), with most surveys being undertaken from January 15 to February 15, in order to cover the peak nesting activity (Figure S4.1). Data were analysed as “nesting season[s]” (Table S4.1) because most nesting occurred as a peak over the tropical wet season (December to March) and thereby spanned two calendar years (Figure S4.1).

Statistical approach

Trends in the number of clutches laid: We modelled the trend in the number of clutches laid using a generalised additive model (GAM) in the ‘mgcv’ package of R (v 1.8-26, Wood & Wood, 2018). This model predicted the number of clutches laid on a given day as a nonlinear function of nesting year (i.e. the long-term trend) and days within a nesting season (i.e. the seasonal effect). The long-term trend was modelled with a penalised thin plate regression spline and the seasonal effect was modelled with a cyclic cubic spline. The model was fit to all monitoring data from 1990-1991 to 2016-2017 (Table 4.1), and the predictive performance of the model was evaluated against the 2017 – 18 data.

Initial modelling indicated adequate fit of lognormal and Tweedie error distributions, and we therefore chose the simpler lognormal form, where the response variable was transformed [log(x+1)]. Finally, because of serial autocorrelation in the residuals with a lag of 1 year (Phi = 0.31), the final model included an autoregressive process of order 1 (‘corAR1’ parameter) and was fitted using the Restricted Maximum Likelihood (REML) approach.

For comparison with earlier studies (Limpus, 2009; Limpus & Miller, 2008), we also used a standardised measure of clutches laid. This represents the nightly average number of clutches laid from January 15 to February 15 (standard period; Dobbs *et al.,* 1999, Limpus & Miller, 2008) (excluding years with $\leq$ 20 nights of sampling, Table 4.1). The long-term trend in clutches laid was modelled with a weighted GAM where the average clutches laid per standard season was the response variable and year was the explanatory variable. The regression was weighted by the inverse of the number of nights sampled because the sampling effort varied between nesting seasons (Table 4.1).

Table 4.1 Comparison of different models for the survival of hawksbill nesters, based on information theoretic weight of evidence (w_1) and the number of estimated parameters. Other parameters (Ψ, pent, φ and *p*) were specified according to Figure 4.2. QAIC: quasi-Akaike information criterion.

Model rank	Hypothesis	Formula (refer to Fig 2)	No. of param.	No. param. Estimated	QAIC	ΔQAIC	w_i
1	Varies between marked cohorts and nesting seasons	S_{tc}	90	53	23408.74	0.00	0.999
2	Varies between nesting seasons	S_t	67	45	23459.96	51.22	<0.001
3	Constant over time	$S\cdot$	40	38*	23460.24	51.50	<0.001
4	Varies between marked cohorts	S_c	65	47	23484.14	75.39	<0.001
5	Linear relationship between survival and nesting season plus varies between marked cohort	$\text{logit}(S) = \beta_0 + \beta_1 t + c$	90	50	28422.04	5013.29	<0.001
6	Quadratic relationship between survival and nesting season plus varies between marked cohorts	$\text{logit}(S) = \beta_0 + \beta_1 t + \beta_1 t^2 + c$	66	49	28422.55	5013.29	<0.001
7	Quadratic relationship between survival and nesting season	$\text{logit}(S) = \beta_0 + \beta_1 t + \beta_1 t^2$	41	39	28483.75	5075.01	<0.001
8	Linear relationship between survival and nesting season	$\text{logit}(S) = \beta_0 + \beta_1 t$	41	39	28483.76	5075.01	<0.001

* model did not estimate *p* in 2015-2016 or in the last secondary sample (12). We therefore did not estimate nester abundance for these samples.

Capture mark-recapture (CMR) models: We used the multistate open robust design model (MSORD), which was developed to deal with several hawksbill-specific nesting behaviours (Kendall & Bjorkland, 2001). These included: (1) not all females migrate to the nesting area every year (breeding omission or skipped breeding), (2) females arrive and leave the nesting area in a staggered manner, and (3) females lay multiple clutches and do not nest every night (i.e. they nest at ~ 14-day intervals) (Loop *et al.,* 1995). The two states in this multistate framework are 'nesters' and 'unobservable', where the latter state represents turtles that have skipped nesting and are therefore unobservable at the rookery. Live encounter histories were compiled and analysed for all nesting females captured between November 15 to April 30 of each nesting season. Encounter histories were pooled into 14-day sampling periods within each nesting season, which reflected the ca. 14-day nesting cycle (or internesting interval) known for the Milman rookery (Loop *et al.,* 1995). The primary sampling occasions consisted of 27 annual austral summer nesting seasons from 1990-1991 to 2016-2017, and secondary sampling occasions consisted of 12 successive sampling periods (each 14 days long). Capture histories were therefore comprised of 324 occasions (i.e. 27 primary x 12 secondary samples), coded as '1' if an individual turtle was caught, '0' if it was not caught, or '.' if no sampling occurred for a given secondary sample. Tag loss was assumed to be minimal because turtles were double tagged. Analyses were conducted using the software MARK (v. 9.0, White & Burnham, 1999) through Rmark (Laake, 2013) in R (v 3.4, R Development Core Team, 2018).

Goodness of fit and tests of assumptions: There are no established procedures for assessing the goodness-of-fit of MSORD models (Kendall, 2004; Pradel *et al.,* 2005). Instead, we tested the underlying CMR assumptions separately for each of the primary periods under the fully-time varying Cormack-Joly-Seber model implemented in the software U-CARE (v 2.3.2, Choquet *et al.,* 2006; Choquet *et al.,* 2009). We then added the X^2 values of each test and the degrees of freedom for each test to calculate the global goodness-of-fit, and to estimate the variance inflation factor ($\hat{c}$), which is a measure of overdispersion, as the quotient between the sum of the X^2 statistics divided by the sum of the degrees of freedom (following García-Cruz *et al.,* 2015).

Model construction: Model parameters included survival probability (*S*), temporary emigration probability (Ψ), entry/arrival probability (*pent*), departure probability (Φ) and capture probability (*p*). The complexity of MSORD models meant that it was not feasible to fit all 12,936 combinations of the parameter specifications that we considered. Instead, we tested different parameter structures one-by-one and retained those that reduced Akaike Information Criterion (AIC) by more than 2 points, or in the case of overdispersion, quasi AIC (QAIC) (Burnham & Anderson, 2002; García-Cruz *et al.,* 2015). This was undertaken for each of the five parameters (Ψ, *pent*, Φ, *p* and *S*); the other four parameters were set to be time-invariant. We then constructed the final model using the parameter specifications with the lowest AIC values. Where an examination of parameter estimates and/or parameter counting indicated that parameters were not adequately identified (e.g. boundary effects or singularities), we proceeded to the second-ranked parameter specification, or if necessary, by choosing a simpler parameter formulation. In all models, capture probability was fixed to zero for years where sampling did not take place (2000-2001, 2002-2003, 2011-2012, 2012-2013, 2013-2014 and 2014-2015).

Each parameter was allowed to vary (a) between nesting years (primary samples), (b) between 14-day sampling periods (secondary samples) and (c) between strata ('nester' or 'unobservable'). More complex formulations were also considered (Figure 4.2). Other terms included in the candidate model set were based on specific biological predictions. Firstly, because hawksbill nesting seasons have a quasi-Gaussian shape (Dobbs *et al.,* 1999; Girondot, 2017; Fig. S1), we used a cubic spline to allow *pent* to peak in the middle of the season.

Secondly, because the probability of an individual leaving the nesting ground is expected to increase as a function of the number of egg clutches laid, we included a linear function between Φ and time since arrival to the island (following García-Cruz *et al.,* 2015). Finally, because of the high energetic demands of reproduction and migration, nesting in consecutive years is very rare (Kendall *et al.,* 2019). We therefore also set the probability of transitioning from the nester to the unobservable (non-breeding) state ($\Psi^{n \text{ to } u}$) to one.

Because analysing long-term trends in *S* was a focus of the study, we tested a number of alternative hypotheses (Table 4.1), including (1) constant *S*, (2) *S* varied over time, (3) *S* varied between turtles tagged in different nesting seasons and (4) *S* varied with marked cohort and time.

We modelled the long-term trend in nester abundance using a GAM, where the response variable was the number of nesters and the explanatory variable was nesting season. The GAM was weighted by the inverse standard error of the nester abundance estimates. Model predictions were then compared to the observed number of nesters in the 2017-2018 nesting season, and the observed number of nesters adjusted by recapture probability (i.e. tagged females/recapture probability). This latter estimation was based on the formula for the derived estimate (Cooch & White, 2017), and used the average recapture probability for years with same sampling effort as 2017-2018 (2001-2002, 2004-2005, 2009-2010 and 2010-2011).

Nester size and recruitment rates

To characterise changes in CCL frequency distribution over time we used the 'sm' library (Bowman & Azzalini, 2018) in R to compare annual kernel density plots with the first nesting season (following García-Cruz *et al.,* 2015). A permutation test was used to compare differences between size distributions (Bowman & Azzalini, 1997). Sample sizes in this analysis ranged from 102 turtles in 1991-1992 to 566 in 1998-1999.

As an indicator of the rate of recruitment into the nesting population, we also analysed available laparoscopy data (1991-1992 to 1997-1998; 1999-2000; 2003-2004 to 2006-2007) to differentiate between turtles breeding for the first time (recruit) and turtles that had nested before (repeat). Data prior to 1999-2000 were taken from Limpus & Miller (2008). The temporal trend in new recruits was analysed by a binomial GAM where the response variable was 'recruit' or 'repeat' nesters and the explanatory variable was nesting season. The significance of the nesting season effect was estimated by a bootstrapped log-likelihood ratio test (LRT).

Survival | **Temporary migration** | **Entry/arrival Departure** | **Departure** | **Capture probability**

$$
\left\{\begin{array}{c}
\boldsymbol{S}\,\cdot \\
S_t \\
S_{tc} \\
S_c \\
S_s \\
S_{t,s} \\
\mathrm{logit}(S) = \beta_0 + \beta_1\, t \\
\mathrm{logit}(S) = \beta_0 + \beta_1\, t + \beta_1\, t^2 \\
\mathrm{logit}(S) = \beta_0 + \beta_1\, t + c \\
\mathrm{logit}(S) = \beta_0 + \beta_1\, t + \beta_1\, t^2 + c
\end{array}\right\}
+
\left\{\begin{array}{c}
\boldsymbol{\Psi^{n\,to\,u} = \Psi^{u\,to\,n}} \\
\Psi^{n\,to\,u} \neq \Psi^{u\,to\,n} \\
\Psi^{n\,to\,u}_{f=1} = \Psi^{u\,to\,n\,(a)} \\
\Psi^{n\,to\,u}_{f=1} \neq \Psi^{u\,to\,n}
\end{array}\right\}
+
\left\{\begin{array}{c}
\mathrm{pent}\,\cdot \\
\mathrm{pent}_t \\
\mathrm{pent}_s \\
\mathrm{pent}_{t,s} \\
\mathrm{mlogit(pent)} = \beta_0 + \beta_1 ns^{(b)} \\
\mathbf{mlogit(pent)} = \mathbf{B_0} + \boldsymbol{f}(\boldsymbol{ns})^{(c)}
\end{array}\right\}
+
\left\{\begin{array}{c}
\Phi\,\cdot \\
\boldsymbol{\Phi_{arrival}} \\
\Phi_c \\
\Phi_t \\
\Phi_s \\
\Phi_{t,s}
\end{array}\right\}
+
\left\{\begin{array}{c}
p\,\cdot \\
p_t \\
p_{t,s} \\
p_{t:s*} \\
p_{s*} \\
p_{effort\,(days)} \\
p_{t,s} \\
p_{s(f=0)} \\
\boldsymbol{P_{t,s(f=0)}}
\end{array}\right\}
$$

Figure 4.2: full set of parameters considered in the multistate open robust design (MSORD) mark-recapture analyses. Inclusion of parameters in the final model was based on information theoretic criteria and parameter identifiability. The notation '·' denotes that a given parameter was held constant, the subscript '*t*' denotes a parameter that was allowed to vary between primary sessions (nesting seasons), the subscript '*s*' denotes parameters that varied between secondary sampling periods (i.e. fortnightly periods within a year) and '*c*' represents turtles tagged in a given year (tagging cohort). Grey text indicates over-parameterised models (e.g. singularities or boundary-value estimates).

[(a)] where '*n to u*' denotes the transition from nester to unobservable state, *'u to n'* the reverse transition and *'f'* a parameter that was fixed.

[(b)] where '*ns'* is the number of elapsed days in a nesting season (arbitrary coded as since October 1 for each year) and β denotes a coefficient.

[I] a polynomial spline function (B-spline basis)

Results

Annual trend in the number of egg clutches laid

The number of clutches laid declined significantly over the study period (autoregressive GAM, nesting seasons: estimated degrees of freedom, edf 3.428, $F = 2.47$, $p < 0.01$; seasonal effect: edf = 4.14, $F = 3.43$, $p < 0.01$; Figure 4.3). The overall adjusted r^2 (0.161) showed considerable variation within and between years, suggesting that factors not included in the analysis affected egg production. Fitted model values were then back transformed and averaged for each year, which indicated that the average number of clutches laid per night declined by 58% from 1990-1991 to the 2016-2017 nesting season. This decline was the steepest from 1990-1991 to 1999-2000 (7.08 clutches·night^{-1} to 4.42 clutches·night^{-1}, or 38%), and from 2010-2011 to when monitoring started again in 2015-2016 (26% decline).

The average number of clutches laid per night in the standard period also declined over the study period (Figure 4.4, edf = 2.90, $F = 3.54$ $p = 0.04$; adjusted $r^2 = 0.43$) and followed the same trend as the autoregressive GAM described above. This model suggested an overall decline of 50% from the 1990-1991 nesting season to the 2016-2017 nesting season.

MSORD model selection

A total of 2,831 individually-tagged female *E. imbricata* were included in this analysis. Overall the variance inflation factor ($\hat{c} = 1.80$) indicated slight but statistically significant overdispersion (Global $X^2 = 315.2$, df = 175, $p < 0.001$). We therefore used QAIC in model selection and adjusted confidence intervals accordingly (Cooch & White, 2017). The Goodness of Fit tests for each of the 19 nesting seasons (i.e. seasons with > 2 secondary samples) indicated the presence of transient turtles (i.e. turtles not observed again within a nesting season after their first capture) within the 1992-1993, 1995-1996, 1996-1997 and 2005-2006 nesting seasons (TEST.3R, p values from 0.01 to 0.03). Capture heterogeneity (‘trap dependence’) was evident in 1995-1996, 1997-1998, 1998-1999 and 1999-2000 (TEST2.CT, p values < 0.01). TEST.3M was also significant for 1992-1993 and 1995-1996, whereas TEST.CL was significant only for the 1997-1998 season.

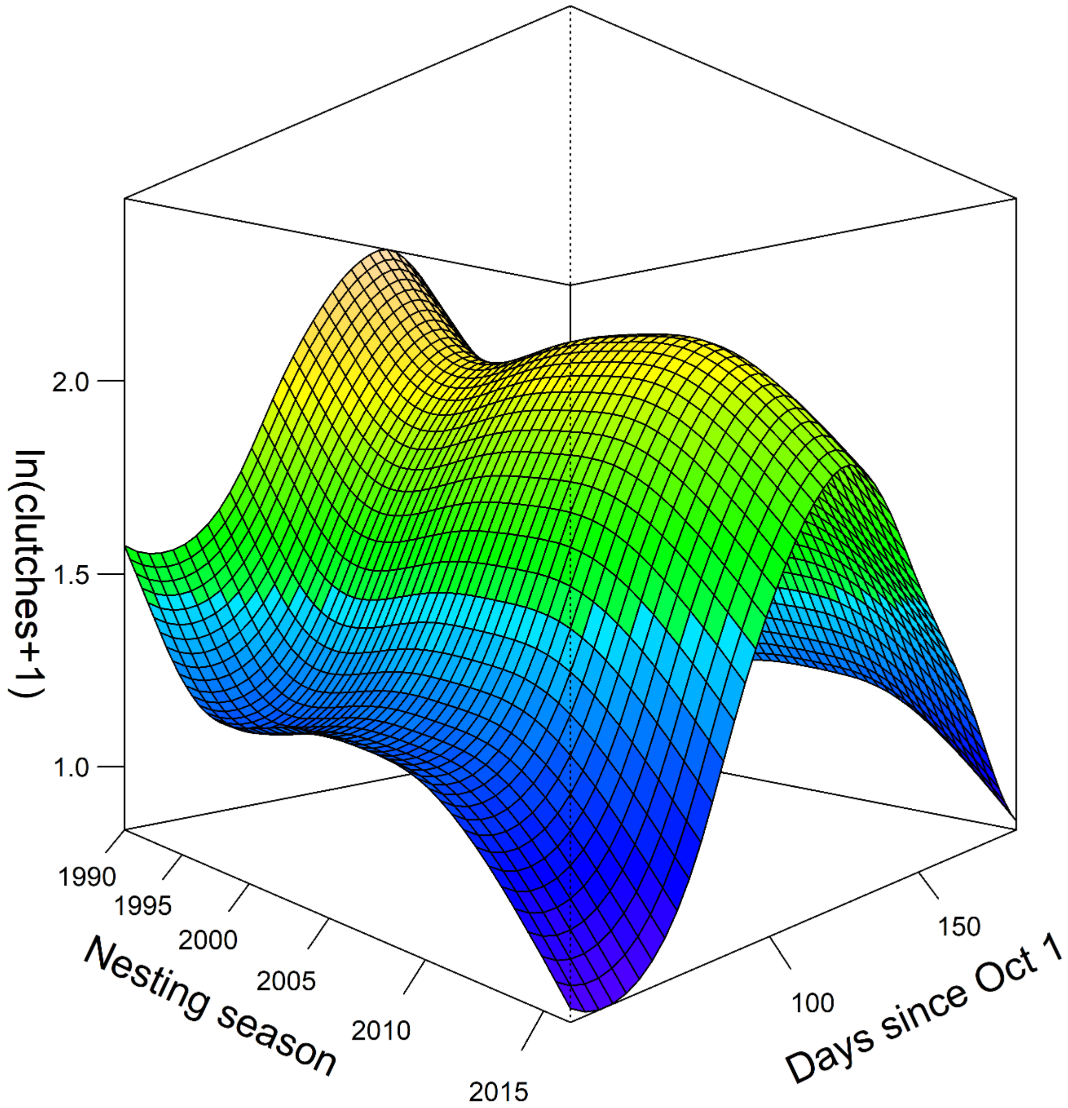

Figure 4.3 Autoregressive GAM modelled number of clutches laid per night by *E. imbricata* (log transformed) as a function of nesting year (the long-term trend) and the number of days that had elapsed since the start of each nesting season (the seasonal effect, coded as days since October 1).

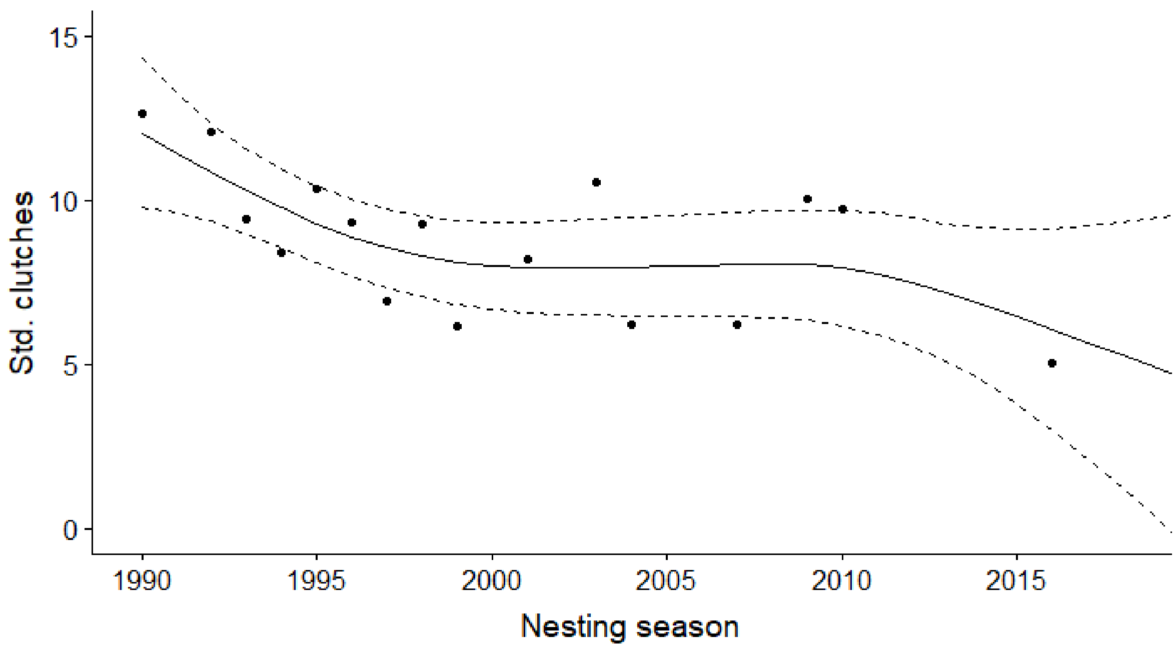

Figure 4.4 Average number of clutches laid per night (Std.clutches) for a standard period in each year. The solid black line is the fit of a GAM (± 95% confidence intervals), weighted by sampling effort.

These results point towards the need to consider appropriate models with the arrival and departure probabilities of turtles within a season. The QAIC values of the fitted MSORD models also suggested that the entry (*pent*) and departure (Φ) varied between secondary samples, as expected for species with staggered arrivals to, and departures from rookeries. However, because secondary samples were not taken from the first and last secondary samples in every year, all parameters were not estimable in the fully time-dependent models (see also Figure S4.1 in supplementary online material). We therefore used the 'time since marking' formulation for Φ and a nonlinear smoother for *pent* (B-spline function of 'days since the start of the nesting season'). These formulations were based on a trade-off of high QAIC rank and parameter estimation 'Time-since-marking' models are often used to account for 'transience' or 'trap dependence' detected by the TEST.3R or TEST2.CT tests (Cooch & White, 2017; Gimenez *et al.,* 2018).

The model with a simple Ψ parameter, where the probability of transitioning from breeder to a non-breeder or non-breeder to breeder was constant had greater weight of evidence (w_i) support than the model that allowed Ψ to vary over time. The model that allowed *p* to vary between nesting seasons had the highest weight of evidence. However, the QAIC rank 2 model that also included a term allowing *p* to vary between secondary samples and between nesting seasons (Figure 4.2) resulted in more reliable estimation of the other parameters. We therefore used this formulation to compare different alternative hypotheses for changes in survival of nesters over the study period.

The model ranked the best by the weight of evidence criteria (Rank 1, Table 4.1) indicated that *E. imbricata* nester survival varied between nesting seasons and between marked cohorts. Turtles marked with tags earlier in the study tended to have lower survival than cohorts tagged later in the study. However, because of nesting seasons with few or no samples, we were not able to estimate survival over time for every marked cohort. Similarly, the model that allowed survival to vary between nesting seasons (Rank 2, Table 4.1) was not able to estimate survival in every season because of seasons with few or no samples. Estimates of survival ranged from 0.96 (0.80-0.99) in 1993-1994 to 0.84 (0.72 to 0.92) in 1998-1999.

The third-ranked model assumed constant survival, which was estimated to be 0.972 (SE= 0.003; 95% CI = 0.965 to 0.977). This model also had the highest estimability for the other parameters (Table 4.1) and was therefore used in the final model, which featured a constant survival parameter, a constant $\Psi^{u\ to\ n}$ ($\Psi^{n\ to\ u}$ = 1), an additive term for *p* (secondary sample + nesting year) (Figure 4.3), a polynomial spline for *pent* and a time-since-arrival term for Φ.

Predictions from the final CMR model

Recapture probabilities ('*p*') were the highest in 1992-1993 (0.69, Figure 4.5), with reliable estimates for 19 nesting seasons (i.e. the 1991-1992 and 2015-2016 seasons were excluded because of low sample size). Recapture probability was not estimable for the first secondary sample (1, Nov 15 – 28) because sampling in the first secondary sample only took place in the 1994-1995 and 1997-1998 nesting seasons (Table S4.1 and Figure S4.1 in online supplement). Recapture probability for the remaining secondary samples ranged from 0.09 in the last secondary sample (12) to 0.55 in secondary sample 6.

The final model structure for *pent* suggested a staggered, nonlinear trend of arrivals at the nesting area, which was consistent with the time-after-arrival function for Φ that suggested individual turtles left the nesting area after all of their clutches were laid (rather than all at once; Figure 4.5). Consequently, the modelled residence probability declined over the secondary samples, consistent with the pattern of staggered arrivals, a peak nesting period (Figure 4.5) and departures once all clutches had been laid.

Overall, the estimated number of nesters declined over the study period with trend for cyclic variation suggesting extrinsic variables influenced nesting migrations (Figure 4.5d). The number of nesters fluctuated from year to year, but an overall decline from a maximum of 437 (423-452) in 1996-1997 to a minimum of 141 (137 to 147) nesting females in the 2016-2017 nesting season was apparent. A GAM fitted to the nester abundances (weighted by 1/SE) indicated a linear decline across the study period, corresponding to an overall decline of 57% from the 1990-1991 to the 2016-2017 nesting season.

The MSORD model estimated that an average of 5.92 (95% CI= 5.69-6.16) clutches were laid by each female per year, based on the recapture histories of 2,831 turtles over the period from November 15 to April 30 for the 21 years with data. However, we caution that annual estimates are likely to be biased because turtles possibly arrived before sampling commenced and departed after sampling finished (*sensu* Cooch & White, 2017).

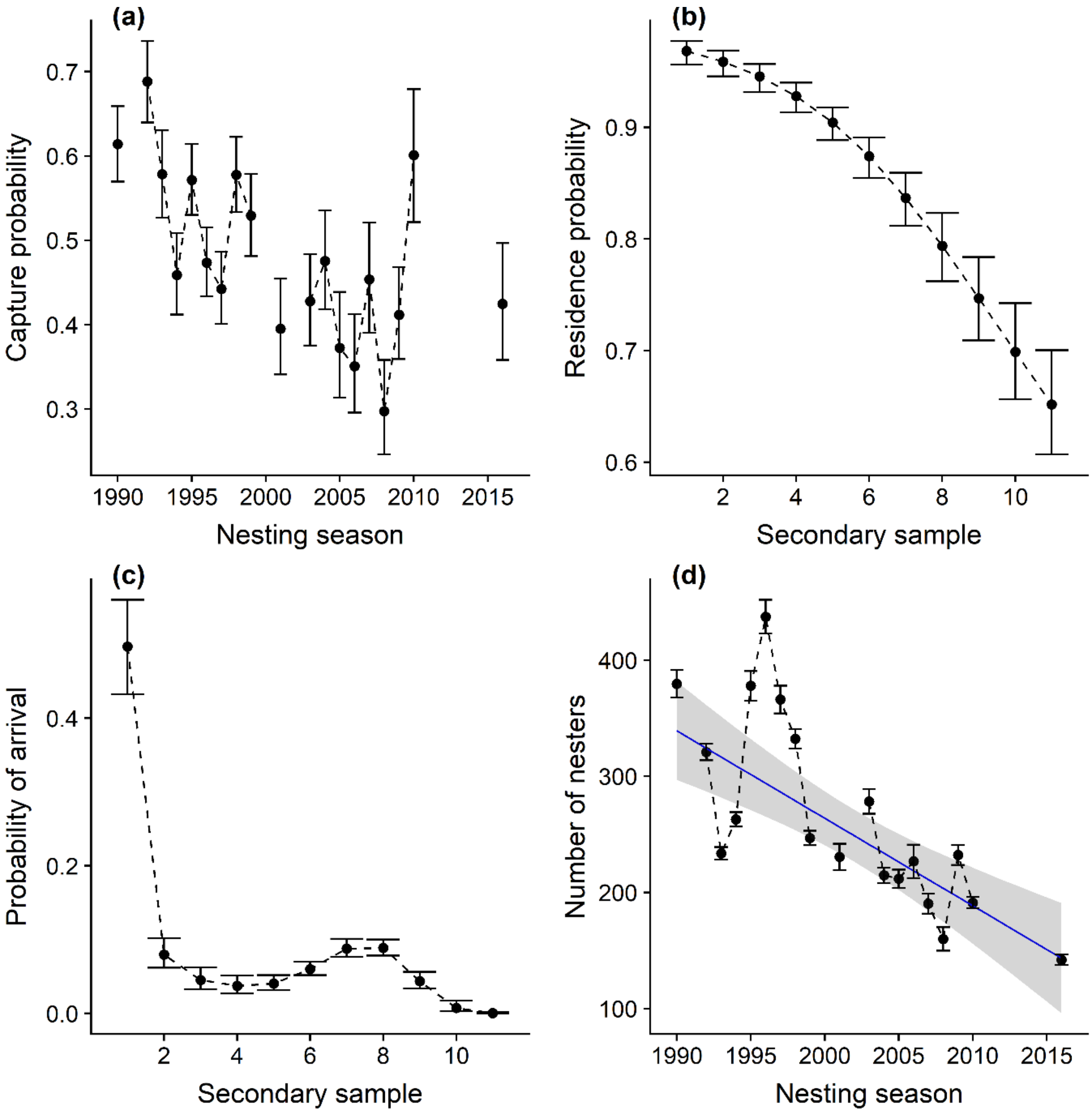

Figure 4.5 Parameters in the final CMR model (±95% confidence intervals): (a) capture probability averaged for each nesting season, (b) probability of residence as a function of secondary sample (fortnightly from November 15), (c) probability of arrival as a function of secondary sample and (d) number of nesters in each nesting season, where the blue trend line represents a GAM (grey region: 95% Cis, weighted by 1/SE). Nesting seasons with no data (2000-2001, 2002-2003, 2011-2012 to 2014-2015) or limited sampling effort (1991-1992 and 2015-2016) were excluded from (a) and (d).

Forecasted nesting and nester abundance trends

Each model was then extrapolated to predict the year when less than one turtle nested per year (MSORD model) or less than one nest was laid per year (standard period and GAM models), assuming that the current rate of decline continues unabated. The forecast also assumed that most nesting occurs over the nesting season from November to April.

The standard-period model for the average nightly clutches laid over the standard period (January 15 to February 15) predicted less than one clutch per year by 2032-2033, with the 95% Cis ranging from as early as 2020-2021 to an increase over the forecast period (2017-2018 to 2080-2081) (Figure 4.6a). However, the predicted average number of clutches laid was close to the observed nightly clutches for the 2017-2018 season (Figure 4.6a).

The more comprehensive GAM model of nightly clutches laid (autoregressive GAM) predicted less than one clutch per year by 2037-2038, but with wide 95% confidence intervals spanning extirpation in 2024-2025 to an increasing number of clutches laid (Figure 4.6b). The predicted average number of clutches laid was within the range of the observed nightly clutches for the 2017-2018 season (Figure 4.6b).

Finally, the GAM fitted to the MSORD nester abundance estimates suggested less than one nester per year by 2036-2037 (95% CI from 2026-2027 to 2058-2059) (Figure 4.6c). The predicted nester abundance for the 2017-2018 nesting season aligned with the observed number of nesters (Figure 4.6c). However, when the observed number of nesters in 2017-2018 was adjusted for recapture probability using an ad-hoc Horvitz Thomson estimator (i.e. estimated number of nesters = number of observed females/average capture probability), more turtles were observed than expected in 2017-2018 (Figure 4.6c).

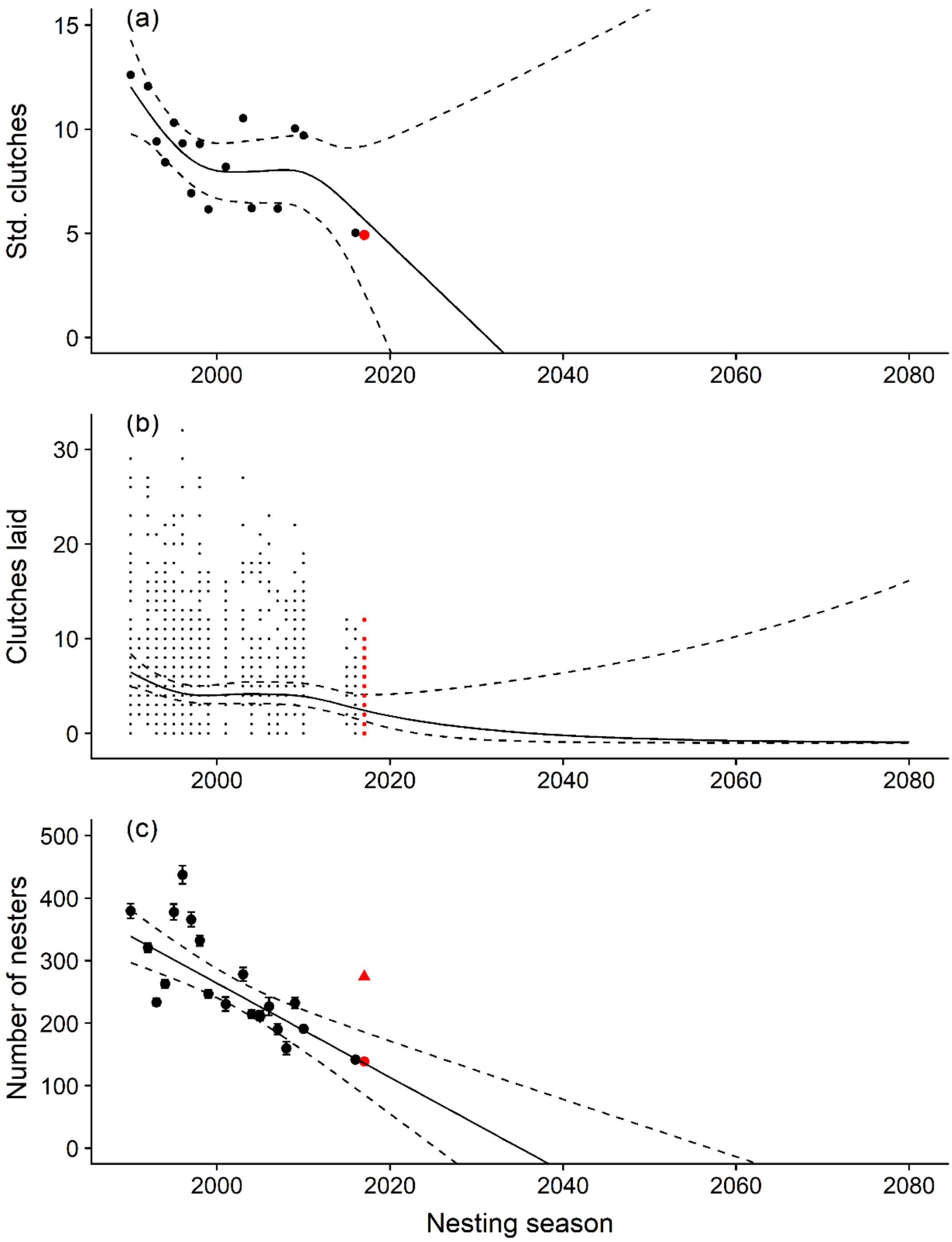

Figure 4.6 Projected trends based on the results of the current analyses (± 95% CI) for (a) average clutches per night for the standard census period between January 15 and February 15 (GAM weighted by sampling effort), (b) clutches per night over the whole period (back transformed from a lognormal autoregressive GAM (see Figure 4.3) and (c) MSORD estimates of number of nesters (trend modelled by a GAM). In fig (b) the small circles represent observed clutches per night and the dark larger circles the average clutches per

night for each season. In fig (a), an average of 1 clutch per year is predicted by 2032-2032 (95% CI from 2020-2021 to >2080). In fig (b) an average of < 1 clutch per year is predicted by 2037-2038 (95% CI from 2024-2025 to >2080). In fig (c) less than one nester per year is predicted by 2036-2037 (95% CI from 2026-2027 to 2058-2059). Data from the 2017-2018 nesting season are in red, in fig (c) the red circle represents the number of tagged females and the red triangle represents the number of tagged females divided by an estimate of *p.*

Nester size (CCL) and recruitment

Significant differences ($p < 0.05$) were found in nester CCL between the first nesting season (1990-1991) and 1992-1993, 1996-1997, 1998-1999, 2008-2009, 2010-2012, 2016-2017 and 2017-2018 (Figure 4.7). In all cases, a leftward shift occurred suggesting that the size of nesters became smaller than 1990-1991. This was particularly pronounced in the latter nesting seasons of the study (>2007-2018), with the exception of 2015-2016 when left skewness was evident but not significant, likely resulting from the relatively small sample size (n=110)

Although the proportion of recruit breeders tended to increase from 1990-1991 to 2006-2007 (S1.2), there was considerable variation among years and the overall effect of nesting season was not significant (LRT: 3.412, p = 0.257, 1,000 bootstrap replicates). Excluding years with less than 20 samples, the highest proportions of recruit breeders occurred in 2003-2004 and 2005-2006 (21-27% recruit breeders) and the lowest in 1991-1992 (10%) and 1994-1995 (12%).

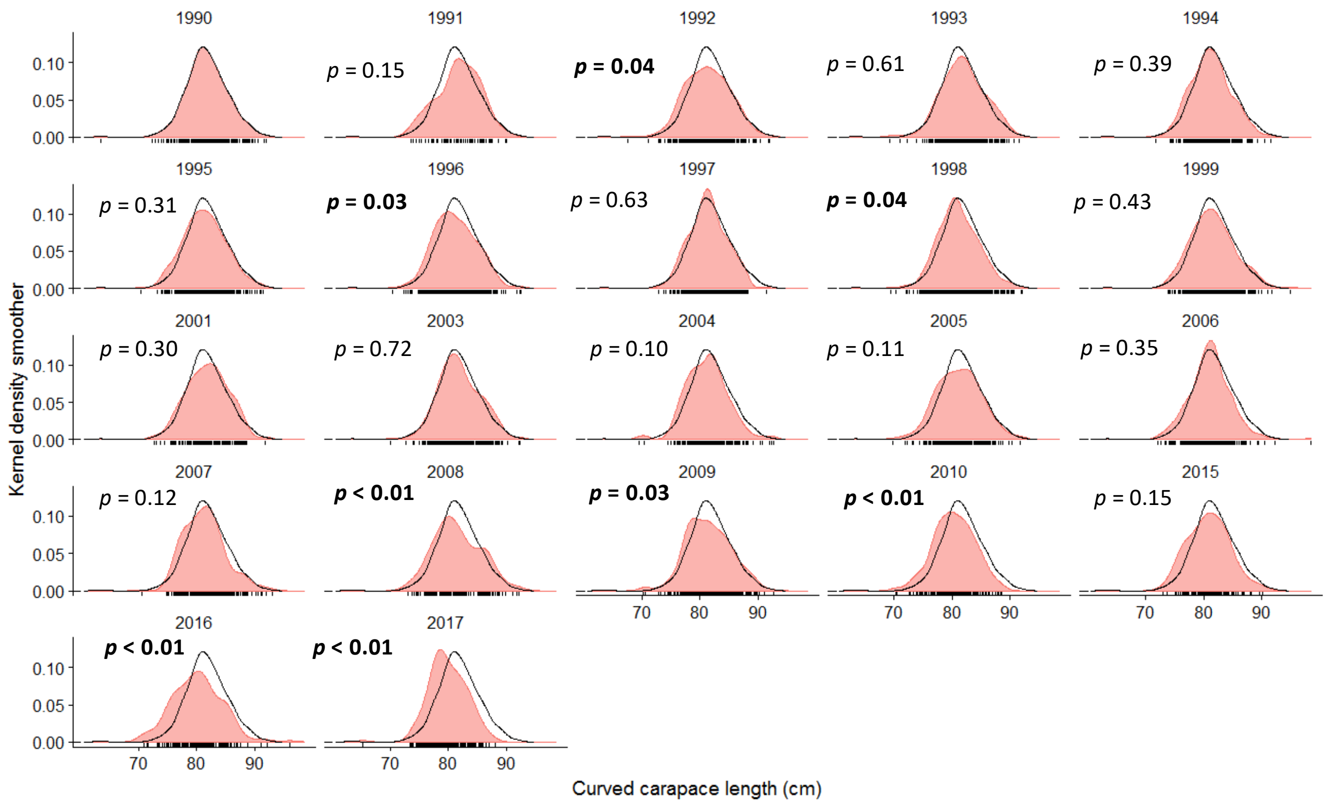

Figure 4.7: the distribution of nester sizes (CCL, cm) from the 1990-1991 to the 2017-2018 nesting seasons. The first nesting season is used as a reference to compare subsequent nesting seasons. Kernel density estimators were used to smooth the length-frequency histograms, and *p* values represent the significance of permutation tests.

Discussion

The number of nesting *E. imbricata* on Milman Island has declined by 57% between the 1990-1991 and 2016-2017 nesting seasons, with a corresponding 58% decline in the number of clutches laid. Should this severe decline continue, our models predict nesting extirpation could occur between the 2032-2033 and 2036-2037 seasons, (with 95% Cis from 2020-2021 to increasing). Assuming this nesting cohort and site is representative of the north-east Queensland stock and the larger south-western Pacific population in general, these results are alarming. Particularly so, as Milman Island receives a comparatively high level of protection within the GBR Marine Park in comparison to other critical nesting sites (Commonwealth of Australia, 2017).

Although this is the longest-term dataset available for *E. imbricata* of any genetic stock within the region, limitations on interpreting population trends must be acknowledged. Because of logistical and resource constraints, not all years were monitored, and the sample period timing was inconsistent in some years. We addressed these issues by using statistical models that accounted for varying sampling effort and by making assumptions that certain parameters, such as the remigration interval and the timing of arrival and departure did no not vary between nesting seasons over the monitoring period. Importantly, we used three different demographic indicators and tested the predictions of our model against the last year of data. All three indicators uncovered a similar pattern of population decline and the predictions agreed with the 2017 – 2018 data.

Overall, estimated annual survival was high (0.972, 95% CI= 0.965 to 0.977) and comparable to those reported for *E. imbricata* populations at Varanus Island off the Pilbara coast (0.947; Prince & Chalpouka, 2012), and Long Island, Antigua rookery, in the Atlantic Caribbean (0.95; Richardson *et al.,* 1989; Kendall *et al.,* 2019). However, we were not able to model survival for all nesting seasons separately, because some years were not sampled or had low sampling effort. A northern GBR foraging *E. imbricata* population with similarly high survivorship rate (0.92) also showed an overall decline of adult females between 1996 and 2008 (Bell, 2012). While only 15% of this foraging population originated from the north-east Queensland nesting stock (Bell & Jensen, 2018), high survival coupled with adult female decline suggests failed hatching success at nesting beaches, and/or low survival through to maturation.

Comparisons of survival models in this study suggested a cohort by time effect (Table 4.1) but we did not have the data to fully parameterise the model. One explanation for this may be differential mortality between stock components, i.e. the abundance of nesters from foraging grounds where turtles are subject to high harvest mortality may have declined faster than for nesters from areas with greater protection. Beyond the GBR, other known (and critical) nesting and foraging habitat lie outside of this protection (Commonwealth of Australia, 2017).

Milman Island is afforded the highest level of marine reserve protection within the GBR (with little to no take of nesting turtles or their eggs), and adult females have been shown to have high survivorship probabilities. During the Austral summer, the island produces both male and female *E. imbricata* offspring with hatchling emergence success >85% (Limpus & Miller, 2008). A rapid and ongoing decline in the number of nesting females is therefore likely to be a result of historical and contemporary tortoiseshell take in unprotected foraging areas within the stock's geographical range, possibly leaving an older cohort of 'protected' adult turtles to survive.

This contemporary exploitation of female turtles is reflected by the observed decline in the average size of nesters, which was more pronounced in the latter decade of sampling. A reduction in average body size is characteristic of an exploited population, and can affect the resilience and capacity of populations to recover (Anderson *et al.,* 2008). The smaller sizes and trend of increased proportion of new breeders prior to 2006 (Figure S4.2) could imply the early stages of population recovery from commercial exploitation. Nevertheless, a substantial increase in recruitment to the nesting population is unlikely given that both nester abundance and the number of clutches laid continued to decline. Other explanations for the reduction in nester body size cannot be ruled out, including maturation at smaller sizes or cohort effects.

Understanding the cause[s] of population decline and the potential for the stock to recover is difficult without supplementary data from foraging grounds, which is required to achieve a more representative description of the demographic composition. Current understanding of the foraging grounds used by Milman Island nesters is imperfect. A limited number of titanium flipper tags (~30) have been recovered from *E. imbricata* throughout the western Pacific region. A turtle tagged while nesting on Milman Island in 1993-1994 was subsequently found dead near Meruake, Indonesia (Miller *et al.,* 1998). Other tags have been recovered in PNG, Western Gulf of Carpentaria, and in northern GBR/Torres Strait (Limpus & Miller, 2008, Limpus *et al.,* 2013). In 2008, a nester tracked with a satellite-linked tag was found to forage in the Torres Strait region (Cturtle.org/tracking). Although limited, these data suggest the stock's geographical range likely extend[ed] to neighbouring countries of Indonesia and PNG. A better understanding of the location and threats within foraging areas and breeding migration routes is essential for identifying and mitigating the cause[s] of decline at the nesting beach). Further defining the nesting distribution of this genetic stock/management unit to confirm Milman Island's suitability or representativeness as an index site for a larger spatial scale nesting cohort is important. Additional studies are required to understand whether historic and continued exploitation have resulted in genetic change (see Allendorf *et al.,* 2008) within the stock's likely geographical range and the consequences for conservation management.

Our estimate of the number of *E. imbricata* clutches laid per year (5.9 yr^{-1}) was much greater than earlier studies on Milman Island (1990-1995, 2.5 yr^{-1}; Loop *et al.,* 1995) and elsewhere (3.8 clutches laid over a similar period in the Solomon Islands; Hamilton *et al.,* 2015). This is likely to be because we derived this parameter from the MSORD model, which accounted for varying probabilities of recapture, arrival and departure over the nesting season (and hence the fact that not all laying events were observed for every turtle). The number of clutches laid per female is likely to be underestimated from census data unless all turtles are observed for all laying events during the nesting season.

The remigration interval of 6.7 years (95% Cis: 6.3-7.1) estimated from our MSORD model was also considerably longer than the 3.4 years earlier reported (Loop *et al.,* 1995). However, our estimate is likely to have been upwardly biased by the assumption that the remigration interval was constant. This assumption was necessary because of missed nesting seasons. Another possible explanation for greater remigration intervals could be escalating coral bleaching events in the northern GBR (AIMS, 2017) that are impacting the quality of the foraging ground, which could in turn affect the breeding condition and the onset of vitellogenesis. As *E. imbricata* play an important role in shaping reef structure and dynamics (Leon & Bjorndal, 2002) and aid in reef recovery, both management and conservation efforts should focus on arresting further declines of the Milman Island subpopulation, and more broadly the north-east Queensland stock across south-west Pacific, at all critical nesting and foraging grounds.

Conclusion

Our results provide the longest running CMR demographic study to record a decline in a nesting *E. imbricata* population within the south-west Pacific or greater Asia-Pacific region. Should the long-term decline in *E. imbricata* nesting on Milman Island continue, it could transition from one of the world's largest nesting *E. imbricata* cohorts to a non-viable nesting level within 100 years of it first being described. Even though *E. imbricata* breeding populations are likely to consist of multiple rookeries within a region rather than a sole rookery (Broderick *et al.,* 1994), effective conservation is difficult to achieve when individual countries afford different levels of protection to nesting beaches, migratory routes and feeding grounds. Urgent conservation effort and tangible management action over multi-geopolitical areas is required to mitigate threats causing the continued decline of the north-east Queensland stock. Until threats to the stock are better spatially quantified and defined, interim moratoriums on turtle take should be considered, while ongoing monitoring of the nesting population on Milman Island will be important to determine the effectiveness of conservation actions.

ACKNOWLEDGEMENTS AND CONTRIBUTIONS

We would like to thank Dr Colin Limpus for his foundational work essential to our understanding of the population at Milman Island. We would like to acknowledge the financial and volunteer support from Earthwatch Institute, Japanese Bekko Association, Reef Joint Field Management Program and World Wide Fund for Nature-Australia. This work would also not have been possible without the support of so many people that gave their energy and time unselfishly in undertaking field work at Milman Island. This work was conducted under the Queensland Department of Agriculture Animal Ethics approval number: SA 2015/11/526.

IB conceptualised the study. All authors participated in the field work. JM led the statistical analysis with support from CAMH and IB. CAMH drafted the manuscript with contributions and review by all authors.

Chapter 5: Delineating spatial use combined with threat assessment to aid critical recovery of northeast Australia's endangered hawksbill turtle, one of western Pacific last strongholds

This chapter includes a co-authored manuscript that has been published in Frontiers in Marine Science.

Madden Hof, C.A., Smith, C., Miller, S., Ashman, K., Townsend, K.A & Meager, J. (2023). Delineating spatial use combined with threat assessment to aid critical recovery of northeast Australia's endangered hawksbill turtle, one of western Pacific last strongholds. Frontiers in Marine Science, 10:1200986. doi: 10.3389/fmars.2023.1200986

Abstract

The current rate of decline in the globally significant western Pacific hawksbill turtle nesting population of Milman Island on the northern Great Barrier Reef (neQLD) suggests that it could be functionally extinct within a decade. Yet a poor understanding of the relative importance and spatial distribution of threats to this population has been a major impediment to recovery actions. For the first time, we assess all threats to the neQLD stock using a combination of a post-hatchling dispersal model, new satellite tracking of post-nesting migrations and a comprehensive review of existing data. We overlay migration routes and foraging areas from satellite tracking data with spatially referenced threat layers to analyse threat exposure. We found all tracked hawksbills remained in Australian waters, with migration to foraging areas in Queensland, including western Cape York to western Torres Strait (n = 8), and eastern Cape York to eastern Torres Strait (n = 5). These results underscore the critical importance of foraging habitats in Queensland (particularly western Queensland) to the Millman Island nesting population. In contrast, the Lagrangian post-hatchling dispersal model predicted a concentration of turtles in the Torres Strait to Gulf of Papua region, with most final positions in Australian waters (63%), followed by Papua New Guinea (31%), Solomon Islands (3%), Indonesia (2%), New Caledonia (1%), Vanuatu (0.49%). Even though 37% of post-hatchling turtles were predicted to recruit to foraging

areas outside of the Australian Exclusive Economic Zone (EEZ), none of the 25 turtles tracked left the Australian EEZ (13 in this study and 12 previously). This suggests that survival to breeding is low for turtles outside of the Australian EEZ, but other explanations are discussed. No single pervasive threat was identified in the threat risk assessment however, fisheries (bycatch/ghost gear) interactions, direct harvesting and climate change were considered to have the potential to impede recovery or result in further declines in the population. Fisheries and harvesting should be the priorities for immediate management actions. The lack of spatial protection in foraging habitats in western Queensland was identified as a major policy gap requiring immediate attention if this population's trajectory is to be reversed and remain one of western Pacific's strongholds.

Introduction

A goal of conservation biology is to identify and assess the magnitude of actual or potential impacts on populations to inform management decisions and to guide recovery actions. Yet for many marine species, threat assessments are often confined to a single impact such as fisheries bycatch (Riskas et al., 2016), artificial lighting (Kamrowski et al., 2012) or climate change (Fuentes et al, 2011), or examine multiple threats but only for a single protected area (see Hays et al., 2019). However, populations of marine wildlife rarely face single threats, nor are populations of marine wildlife likely to be confined to a single protected area. Numerous studies have also shown that the cumulative effect of multiple impacts can be greater than the sum of its parts (e.g. seagrass, Grech et al., 2011; coral reefs, Magris et al., 2018). Spatially explicit risk assessments provide a tangible resource to support place-based management decisions, such as fisheries regulations and marine park zoning, and thereby can help bridge the divide that often exists between research and conservation success.

In the case of highly migratory marine turtles, threat assessments are also often constrained to limited geographical locations (e.g. Fuentes et al., 2020) and/or to habitats defined by post-nesting migrations (e.g. Hart et al, 2018). However, marine turtles characteristically have long and geographically complex life histories that often span multiple ocean basins and jurisdictional boundaries (Hays & Scott, 2013), especially during the long-distance pelagic post-hatchling dispersal and reproductive migrations. Few studies have also assessed the spatial requirements of these different life stages (e.g. Lamont et al., 2015) and the vulnerability of sea turtle species to multiple threats (e.g. Cuevas et al., 2019). Where ontogenetic habitat shifts expose marine turtles to a mosaic of shifting and overlapping threats no peer reviewed studies (that we are aware) have spatially assessed multiple risks to turtle populations at the scale of the population and across life history stages.

Hawksbill turtles (*Eretmochelys imbricata*) are listed as critically endangered globally by the IUCN Red List (Mortimer & Donnelly, 2008). The north-east Queensland (neQld) stock was once considered one of the world's largest hawksbill populations (Limpus & Miller, 2008; Loop et al., 1995; Meylan & Donnelly, 1999) but is now regionally listed as endangered (by the *Nature Conservation Act 1992*, Qld). A recent population assessment of the nesting population at Milman Island reported a continued 58% decline and predicted that it may be functionally extinct as soon as 2032 if the current trajectory continues (Bell et al., 2020). The Milman Island population is presumed to be representative of the greater neQld stock and the larger south-western Pacific population in general (Limpus, 2009; Limpus & Miller, 2008; Loop et al., 1995). Despite these reported and projected losses, threats to the viability of this hawksbill population and greater south-west Pacific hawksbill populations remain unresolved (refer Humber et al., 2014; Kinch & Burgess, 2009; Lam et al., 2011; Mortimer & Donnelly, 2008; Wallace et al., 2011) with unrestricted legal and illegal take reported to persist relatively unabated which continues to threaten these populations (CITES Secretariat, 2019; Humber et al., 2014; Kinch & Burgess, 2009; Lam et al., 2011; Wallace et al., 2011). While many contemporary threats, such as bycatch in active fisheries or predation by exotic and native predators, are being actively managed where known (e.g. Torres Strait Regional Authority, 2017), research suggests historical and contemporary take is likely causing rapid and ongoing declines of nesting females in this stock, although other factors (e.g. plastic pollution, ghost net entanglement, harvesting of juveniles) may be acting on earlier life history stages and/or on foraging populations dispersed across its geographical range (Bell et al., 2020).

Breeding migrations are known to occur among south-western Pacific rookeries and north-east Australian foraging grounds, including from Vanuatu, New Caledonia, Solomon Islands and Papua New Guinea (PNG) (Bell & Jensen, 2018; Fitzsimmons & Limpus, 2014; Hamilton et al., 2015, 2021; Vargas et al., 2016). Other western Pacific hawksbill genetic stocks also forage in Australian waters (Bell & Jensen, 2018; Hamilton et al., 2021; Madden Hof, unpublished data). Historical flipper tag studies suggest that the neQld stock's geographical range likely extends to only the neighbouring countries of southern Indonesia and PNG (Bell et al., 2020). However, this is based on sparse (3/22) historical tag recoveries (Barr et al., 2021), of a beach-washed adult hawksbill in southern Indonesia (in 1994), and two others caught by traditional fishing (one ~ 20 km out from Daru (in 1997) and the other reported from Tube Tube Village (about 20 km southwest from Daru; in 2000) (DES Queensland Turtle Conservation Database), with the latter two likely caught within the bounds of the Torres Strait Treaty. More recently, a hawksbill turtle tracking study revealed all but one (7/8) of the Torres Strait post-nesting females migrate and forage within the Torres Strait with all remaining within Australian waters (Barr et al., 2021). The true extent of critical habitat for the neQld stock is currently lacking, yet is urgently needed to inform critical species recovery actions, including threat mitigation and management if the current population trajectory is to be reversed.

The main legislative protections for the neQld hawksbill population are provided by a marine park network and by their status as a threatened species at state and Commonwealth levels. Milman Island is protected to the highest State and Commonwealth Marine Park levels (classified as a National Park "Scientific" and "Preservation"). In the state of Queensland the status of hawksbill turtles was up listed from "vulnerable" to "endangered" in 2017. At a Commonwealth level, they are listed as "vulnerable" and high-level threat assessment was undertaken for the multispecies *Recovery Plan for Marine Turtles in Australia* in 2017. The priority threats identified were marine debris entanglement, international take (outside of Australia's jurisdiction), terrestrial predation (pig, dog, and goanna), and climate change, although it was recognised that further research was required.

Here we analyse cumulative threats to the neQld hawksbill turtle population across life history stages (nesting, post-hatchling dispersal, migratory routes, and foraging areas) using a spatially explicit risk assessment approach. New spatial layers of habitat suitability are first derived from satellite tracking of post-nesting migrations and a Lagrangian post-hatchling dispersal model. We then overlay available spatial layers of threats to spatially assess risks. Finally we analyse existing spatial protection measures and provide recommendations for actions to halt the decline of this internationally significant population.

Materials and Methods

Study site and life history distribution

Milman Island (143.015833, -11.168889) is located approximately 23 km off the mainland in the remote far northern section of the Great Barrier Reef (GBR), Queensland, Australia (Figure 5.1). While much of the neQld stock nests across the Torres Strait, Milman Island was selected as Queensland's primary index nesting beach for monitoring long-term variability of the neQld stock, and thus acts to represent multiple hawksbill nesting sites over a large spatial area in northern Queensland (Bell et al., 2020). It supports year-round hawksbill turtle nesting, with a peak in Austral summer months.

Hawksbill geographical distribution for each life stage was quantified using multiple methods. For migration and foraging ground distribution, Fastloc-GPS satellite tags were attached directly to 13 sexually mature nesting female individuals, while post-hatchling and "lost year" distribution was identified using ocean current modelling. Hatchling production, males and younger foraging cohorts were not modelled.

Post-nesting tracking and analysis

Thirteen Fastloc-GPS satellite tags (SPLASH10-BF, Wildlife Computers, Seattle, Washington, USA) were attached to four primary (first time flipper tagged) and nine recaptured (previously flipper tagged) nesting hawksbill turtles on Milman Island during the 26 January – 8 February of the 2015-2016 and 2016-2017 nesting seasons (Figure 5.1a; Table S5.1). This work was conducted under the Queensland Department of Agriculture Animal Ethics approval number: SA 2015/ 11/526. Because of the long term saturation tagging nesting monitoring program in place at Milman Island, a mix of primary and recaptured hawksbills were satellite tagged to represent, a) different aged breeders ranging in size (curved carapace length, CCL) from 75.1 to 84.4 cm (mean +/- s.d., 79.22 +/- 3.11 cm)), and b) possible different (historical) migratory paths and foraging grounds over space and time.

After measuring the CCL, applying numbered titanium flipper tags (Limpus, 1992; Limpus & Miller, 2008), satellite tags were attached between the two anterior central scutes (as per Godley et al., 2002). The carapace was cleaned with acetone and lightly sandpapered before attaching the tag using quick-setting two-part epoxy resin (Sika AnchorFix®-3+, Sika Australia Pty Ltd). The epoxy was sanded smooth, and a final coat of anti-fouling paint (Micron66) was applied over the already primed and painted tags. The tethered turtles were released (no longer than 24 hours after capture) when the epoxy had completely cured.

The Argos satellite system (http://www.argos-system.org/) was used to relay the Fastloc-GPS location data and Wildlife Computer Portal to store the received data. GPS satellite tags were fixed with either copper or stainless-steel wet/dry sensors (of which neither yielded better results over the other, pers comm. Kevin Lay, 2018). For four tags, repetition rate was programmed at 15 second intervals, while the other 9 tags with a 30 second nominal repetition rate. The tag battery life was considered similar, as they were all limited to 500 transmissions per day. Preliminary filtering of all tracks was conducted in the Wildlife Computer Portal and exported for further analysis in R (version 4.1.2). High quality locations were included from both Argos-only and Fastloc GPS fixes. For Argos positions, only location classes 3 or 2 were included, which corresponds to an estimated error ≤ 500 m (https://www.argos-system.org/manual/3-location/34_location_classes.htm). For FastLoc GPS positions only locations with more than 3 satellite fixes were included, which corresponds to an estimated 95% of positions within 724 m. Turtle locations were then filtered to remove duplicates. Finally, unrealistic swimming speeds were removed using the 'sdafilter' in the Argosfilter package of R. Briefly, the maximum speed threshold was calculated as the upper 99% quantile from the high-quality FastLoc positions (Shimada et al., 2012).

We then estimated the 95% utilisation distribution (UD) of foraging areas using biased random bridge models, by using the adehabitatHR package of R with parameters from

Shimada (Shimada, 2015). This method accounts for serial autocorrelation between turtle positions (Benhamou, 2011).

Foraging behaviour was determined from post-nesting tracks using hidden Markov models fitted to continuous time correlated random walk trajectories using the ‘crawl’ and ‘momentuHMM’ packages. Post-nesting migration was defined as directed and sustained movement away from the nesting area (following Barr et al., 2021). Continuous movement trajectories were fit using informative priors for each positional error class and hidden Markov models estimated probable behavioural state using movement step length and turning angles. The optimal number of states for each turtle was determined by comparing the AIC of different models and the most probable behavioural state for each position and turtle was assigned using the Viterbi algorithm (McClintock & Michelot, 2018). Behavioural states were then visualised and checked in qGIS. Individual turtles’ foraging and migration UDs were combined into a post-nesting (inter-nesting, migrating, and foraging) 95% UD for use in threat assessment (see below). Migratory paths were buffered (700 m) to account for positional error before plotting as a likely migratory corridor life history phase.

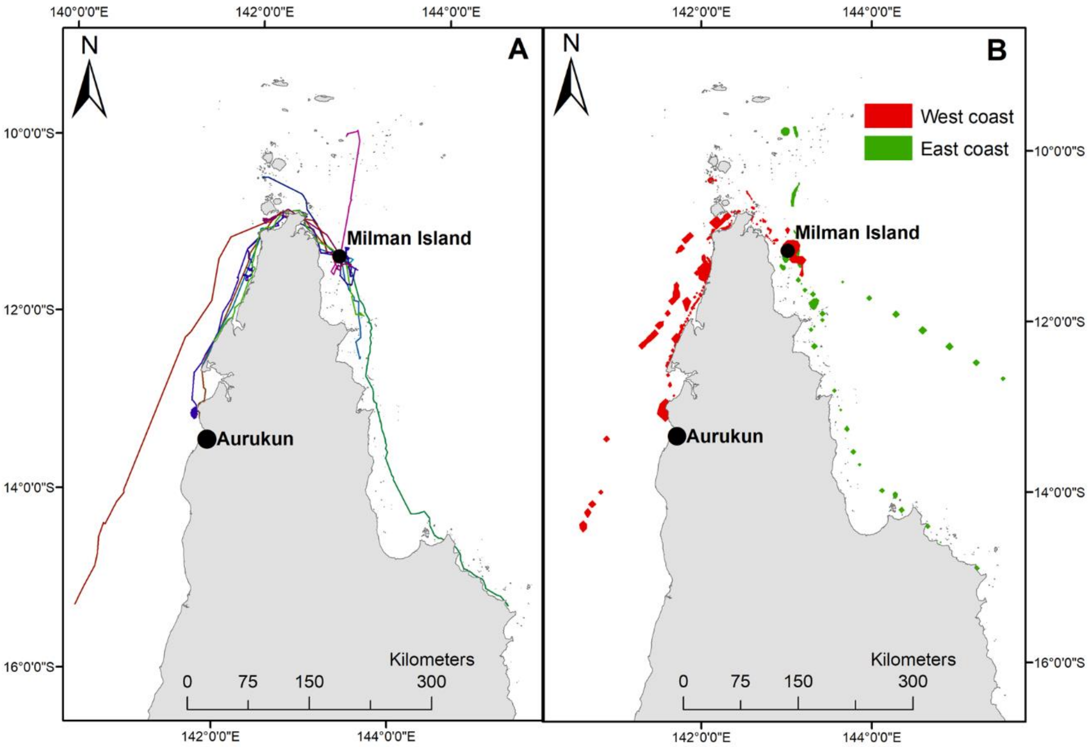

Figure 5.1 Location of Milman Island, in north east Australia. **A)** the 13 satellite tracks; **B)** 95% UD home range east vs west.

Post-hatchling dispersal analysis

Indicative locations of potential post-hatchling distribution were identified using the Connie 3.0 ocean current modelling (CSIRO Connectivity Interface, https://connie.csiro.au/; Run 15/3/21). In refining and as an extension to Hoenner et al., (2016) methodology, parameters of the model included: Milman Island as the 'source' of the particles (hatchlings), ocean current data for Australasia–South-East Asia bioregion at 0.1° x 0.1° blocks, an ocean surface depth of 1–5m (as this is the closest to the surface that the model considers), all years available (2003-2007), and a release period of 120 days from 15 January – 15 February to coincide with the likely peak hatchling emergence period (Dobbs et al., 2010). A two-phase complex behaviour model was chosen based on the (limited) hatchling active swimming and likely migration behaviour studies (Booth et al., 2019; Chung et al., 2009) in that, unlike other species, hawksbill hatchlings only tend to swim in a 'frenzy' for about the first hour, then over 6 or so days float inactively for 15-17 hours/day, dispersed with active swimming for the remaining 7-9 hours/day. In using the two studies, average swimming speeds (tethered and non-tethered) was estimated between 0.14 – 0.28 m/sec. As such, we used a random horizontal propulsion (active swimming) of 0.28m/sec over 6 days for Phase I, followed by a passive distribution (migration) for 114 days (Phase II) to model cumulative exposure (likely post-hatchling home range) and final distribution (likely post-hatchling dispersal). In addition, we recreated the Connie3 final distribution (end point latitude and longitude) dispersal model overlaid with exclusive economic zoning (EEZ) to count the number and proportion of data points intersecting within each EEZ layer as an indicator of post-hatchling distribution between countries in the first few months, which without further knowledge of directional movement and settlement may be at best, indicative of the early "lost years".

Assessing the magnitude of threats to the neQld hawksbill stock

Threats to the neQld hawksbill stock were first identified from the following sources: the *Recovery Plan for Marine Turtles in Australia, 2017* (Commonwealth of Australia, 2017), the Queensland Government's *Marine Turtle Conservation Strategy 2018*, the StrandNET database (Queensland Government marine wildlife stranding program: data from 2009-2014) and the Queensland Government species prioritisation plan (*Back on Track*). For each identified threat, a spatial layer or raw dataset was sourced to represent threats spatially at the finest scales available. Where suitable spatial layers were not available, qualitative assessments were undertaken to investigate the threat posed to the neQld stock.

Risk was assessed using the likelihood-consequence tables from the *Recovery Plan for Marine Turtles in Australia,* based on both quantitative and qualitative data available at the time of this study. The resulting risk matrices are provided in Table 5.1. If threats were considered low, they were evaluated and described but not included in the broader analysis. Only risks rated high to very-high were further evaluated in detail in this study. Area-based protection measures were also assessed.

Table 5.1 Threat assessment (shown in bold). Recovery Plan for Marine Turtles in Australia 2017–2027 (Commonwealth of Australia, 2017) assessment shown [in *italics* and brackets].

Likelihood of occurrence (relevant to neQld stock)	Consequences				
	No long-term effect	Minor	Moderate	Major	Catastrophic
Almost certain			**State fisheries interactions** **Torres Strait Turtle Fishery interactions** **Ghost net interactions**	**Lack of adequate protection** **Indigenous take (domestic and international)** *[International take – outside Australia's jurisdiction]* *[Marine debris – entanglement]*	
Likely		**Terrestrial predation (e.g. Pig, dog, and goanna)** *[Indigenous take (eggs)]* *[International take – within Australia's jurisdiction (shell)]*	**Commonwealth fisheries (excluding Torres Strait Turtle Fishery) interactions** *[Climate change and variability]* *[Terrestrial predation (pig, dog, and goanna)]*	**Climate induced sea level rise**	
Possible	**Sky glow (light pollution)**	**Vessel disturbance** **Chemical contamination** *[Chemical and terrestrial discharge – chronic]* *[Marine debris – ingestion]* *[Fisheries bycatch – domestic (pot, trawl, longline and net)]*	**Climate induced feminisation**		

		[Fisheries bycatch – international (longline, net and trawl)]			
Unlikely	*[Light pollution]* *[Recreational activities]*	**Habitat use (urban activity)** *[Habitat modification – dredging/trawling; infrastructure/coastal development]* *[Vessel disturbance]* *[Chemical and terrestrial discharge – active]*			
Unknown		**Disease** *[Disease and pathogens]* *[Noise interference – active and chronic]*			

A spatial risk assessment was then undertaken for post-nesting turtles in ESRI ArcGIS (version 10.8.1). For the 13 individual turtles with satellite tracking data, the post-nesting 95% UDs (as defined above) were combined into a single polygon spatial layer and divided between east vs west coast Queensland (for some analyses). Where possible, high and very high-risk threats were converted into spatial layers and were individually overlaid with the combined 95% UD layer to quantify threat pressure on migration and foraging grounds for post-nesting neQld stock hawksbill turtles. These layers overlapped the turtle spatial data in time and space. These layers were clipped to the UD polygon to calculate geospatial statistics of the area for each critical threat. For raster datasets, zonal statistics were used.

Climate change impacts on sex ratios

We used WorldClim modelled climate projection temperature data under the Coupled Model Intercomparison Project Phase 6 projection (CMIP6-IPSL-CM6A-LR subset, downloaded from https://www.worldclim.org/data/index.html; Accessed 12/05/2021), to investigate climate change induced feminisation. These data were used as a proxy for sand nest temperatures, as the program uses blended land and sea surface air temperatures. Previous studies have indicated that both sea surface temperature and air temperature are strongly correlated with sand temperature in north-east Australia and the Torres Strait, and are the best proxy indicators of nest sand temperature in this region (Fuentes et al., 2009, 2010). Furthermore, CMIP6 data have been used in recent studies to accurately characterise future sea turtle nesting beach temperatures, needed for conservation management under different climate change scenarios (Butt et al., 2016). Detailed information on the methods and experimental design of CMIP6 data is given in Eyring et al. (2016).

Using a hawksbill turtle pivotal sex determining threshold of 29.2 °C (Dobbs et al., 2010) and the CMIP6 data, mean minimum and maximum nesting beach temperatures (using monthly values averaged over 20-year periods) were calculated for two time periods (2021-2040 and 2061-2080), and examined under two climate scenarios (worst-case SSP585 and conservative SSP370 scenarios). We used CMIP6 data at the spatial resolution of 25 kilometre grids which gave the best coverage of nesting beach locations. At this resolution, each nesting beach fell into a single 25 kilometre grid, enabling the extraction of a single value for mean minimum and maximum temperatures for each nesting beach location in each time period and climate scenario.

Fisheries bycatch and entanglement

For the period 2005-2020, publicly available data of annual fishing effort and hawksbill turtle interactions reported in both Commonwealth and State commercial fisheries was collated from Protected Species Interaction Reports (AFMA, 2021) and fisheries logbooks (AFMA, 2020; Queensland Department of Agriculture and Fisheries, 2021; Queensland Open Data Portal, 2020). As such, all fisheries including Queensland's East Coast Inshore Fishery (ECIF) (gillnet and ringnet only), Gulf of Carpentaria Inshore Fishery (GoCIF) (gillnet and ringnet only), East Coast Otter Trawl Fishery (ECOTF), East Coast and GoC Crab Fishery, Commonwealth's Eastern Tuna and Billfish Fishery (ETBF), the Torres Strait Prawn Fishery (TSPF), and the Northern Prawn Fishery (NPF) were assessed. Due to uncertainty in species identification and/or incomplete reporting (Riskas et al., 2016), data were included for all fisheries to have recorded either a hawksbill or an unidentified (or unspecified) turtle interaction in an area that overlaps with the likely neQld stock distribution. Due to the uncertainty in the fate of released turtles we did not differentiate between turtles reported to have been released alive or dead. Further, because unidentified turtles may include hawksbill turtles as well as other turtle species found within the fishery's area of operation, we calculated the proportion of hawksbill turtles out of the total identified turtles for each fishery and applied that proportion to the unidentified turtles to estimate the potential total number of reported hawksbill interactions (herein referred to as adjusted hawksbill interactions). However, we caution that this is an estimate and the actual proportion of the unidentified turtles that were hawksbills may differ among vessels in a fishery and between fisheries. Bycatch per unit effort (BPUE; caught per day/per shot/per 1000 hooks effort) of hawksbills and the adjusted hawksbill interactions, and all marine turtles combined was calculated for each fishery.

Using QFISH (qfish.qld.gov.au; Accessed 12/04/2021) we calculated days fished (based on 30-minute reporting grid raster cells, categorised into quantiles) within the post-nesting hawksbill UD. Due to varying methods of data collection and validation in the different jurisdictions, data were only standardised to common time periods and reporting metrics (days/hooks etc.), rather than by vessel power, season, or other categories.

Given the marked difference between reported and actual bycatch rates as evidenced in the ETBF and because Australian Government and other studies document underreporting of interactions occurring within Queensland and other Australian fisheries (Commonwealth of Australia, 2018, 2021; Course *et al*., 2020; GBRMPA, 2019), we also calculated two coarse extrapolations using fishery observer and electronic monitoring data, where available. These extrapolations were made to give a generalised comparison of actual versus possible bycatch rates in full acknowledgement that observed interactions and accuracy of BPUE reporting rates could differ among fisheries, and hence we caution against misinterpretation and overuse of our results. To calculate potential monitored BPUE and absolute hawksbills caught for the entire study period (2005-2019), we applied the difference between the BPUE rates for the ETBF prior to independent data validation via electronic monitoring (2012-2015) and post electronic monitoring (2016-2018) to the ECIF and GoCIF. To cross-check these results we also extrapolated the number of observed turtle interactions per fishing day in the ECIF from the Queensland Fishery Observer Program (FOP) from 2006 to 2012 (on the Queensland east coast) to the ECIF and GoCIF effort levels to give an estimate of the total number of marine turtle interactions (all species). We applied the proportion of reported hawksbill turtle interactions in the two fisheries to give an estimate of the extrapolated number of hawksbill turtles.

To assess discarded, abandoned, or lost fishing gear or "ghost net" interaction and risk, we used combined components of Wilcox et al., (2013) estimated areas of concentrated ghost net fishing effort (i.e. the likely number of tracked ghost nets based on final locations of actual observed onshore nets) and the predicted threat to turtles from ghost nets (i.e. the highest probability of a turtle-net encounter), to calculate the likelihood and number of ghost net tracks hawksbills would encounter within their home range.

Harvest and predation

The Torres Strait Turtle Fishery boundary was used as a proxy for likely harvest interaction by calculating the area of fishery overlap with the post-nesting UD. Because legal (primarily) turtle harvests are considered high in Australia and Papua New Guinea (in the top three globally) (Humber et al., 2014; Senko et al., 2022a; Table S5.5), the recreated Connie3 final distribution dispersal model with overlaid exclusive economic zoning was also used to assess the proportion of likely harvest interactions with post hatchling hawksbills per country, acknowledging other threats (e.g. marine pollution) are likely and will compound these interactions.

Traditional harvest of eggs for human consumption and clutch predation by terrestrial animals were considered jointly to account for the cumulative impacts of egg loss

(Department of Environment and Science, 2018). The Atlas of Living Australia predator sightings (https://www.ala.org.au/; Accessed 3 March 2021, refer S3.4 for species), and Torres Strait Regional Authority reported data (2017) were used to create a combined terrestrial animal and traditional harvest spatial layer to examine the distribution of predation at important nesting locations (ranked as low, medium, high and very high). The Torres Strait Regional Authority (2017) predation survey however did not include the most heavily populated western and inner Torres Strait Islands and was only based on varying one-nine day surveys predominantly in November 2016 and February 2017 (months of lowest track counts), so not representative of breeding season (or the highest track count peak (2-5 times higher) of December 2016 and March 2017) (Torres Strait Regional Authority, 2017). Using quantified (non-peak breeding season) clutch predation and total recorded nest percentages, the percentage of clutch loss and likely number of clutches lost to predation at 14 (to standardise survey days), 30 and 60 days (approximate breeding season) was also re-created.

Area-based protection measures

Excluding all other categories, only marine "no-take" reserves (IUCN I and II categories; (Grech et al., 2014) were used from the Marine Collaborative Australian Protected Areas Database (CAPAD 2020) for the protection analysis. Dedicated Indigenous Protected Areas (IPA) were combined with IPA CAPAD 2020 IPA category and included as a separate layer. Areas and percentage of protection in the post-nesting UD was calculated.

Results

Using available data, it was possible to assess and map an indicative sample of the neQld stock across all life history stages (nesting, post-nesting migration and foraging, and post-hatchling dispersal) (Figure 5.2).

Nesting habitat

All known nesting habitat have been mapped previously (Commonwealth of Australia, 2017; Limpus, 2009), however recent aerial surveys (supported by ground-truthed track and nest count data) from the Torres Strait during the 2016-2017 nesting season (Torres Strait Regional Authority, 2017) indicated that a revision of important nesting habitat was needed. Based on this Torres Strait study, Aukane (Au Kein), Sassie, Mimi and Aureed Islands combined accounted for 43.3% of the total hawksbill tracks recorded in the Torres Strait (presented here in Islands in greatest to lowest order of ground-truthed tracks). Along with Milman Island off east Cape York, these sites were elected and plotted as the five critical nesting habitats (as per habitat critical to the survival of a species guidelines; refer Commonwealth Recovery Plan, 2017), with eight other key nesting sites (Bak, Bara, Kebi Kein, Smol Muri, Ullu, Warral, Yauk, Zuizin) (Figure 5.2a).

Post-nesting migrations and identification of foraging areas

Of the thirteen adult females tracked from Milman Island, five migrated to foraging areas on the east coast of Queensland (one within eastern Torres Strait), and eight to the west coast (two within western Torres Strait) (Table S5.1; Figure 5.1). Migration overlapped (>5 tracks) in the waters of north-western west Cape York, from Skardon River to just south of Crab Island and between Seisha and Prince of Wales in Torres Strait, and in north-eastern east Cape York from Albany to Milman Islands (Figure 5.2b). Only two of the thirteen tracked turtles' foraging ground (15.34%) were in a similar locality, adjacent to the township of Aurkun on the western Cape of Queensland, which was also used as a migratory route by one other hawksbill (Table S5.1; Figure 5.1a).

Foraging areas were identified for twelve of the thirteen turtles and ranged from 0.03 km^2 to 4.5 km^2. The final turtle (166711) undertook a post-nesting migration of 700 km before the tag stopped transmitting in the south-east Gulf of Carpentaria, prior to the turtle reaching the foraging ground. The total 95% post-nesting UD of the turtles tracked in this study equated to an area of 4,721 km^2, noting that this is of course an underestimate of the true size of the area used by the nesting population because home range sizes are expected to increase with sample size. Overall, the tracked turtles spent about 75% of their time on the west coast of Queensland and about 25% on the east coast (Figure 5.1b), which represented a total (95% UD) area of 3,525 km^2 and 1,196 km^2 on the west and east coasts, respectively. The likely migratory corridors are shown in Figure 5.2b. Foraging grounds are shown in Figure 5.2c.

Post-hatchling dispersal

Based on 120 days at sea, the cumulative exposure of hatchling dispersion revealed post-hatchling hawksbills are highly likely to be concentrated within and among the Torres Strait, Gulf of Papua, and the Coral Sea, from western Torres Strait to the northeast coast of Shelburne Bay, across the Coral Sea to the coast adjacent to Port Moresby in southwestern PNG (Figure 5.2d). The model predicted post-hatchling hawksbills final distribution is primarily within Australia (62.73%), followed by PNG (31.21%), Solomon Islands (3.28%), Indonesia (1.96%), even as far as Vanuatu (0.49%) and New Caledonia (0.34%) (Figure 5.3; raw numbers in Table S5.2).

Magnitude of threats

The risk assessment using likelihood-consequence tables identified the lack of spatial protection, State and Torres Strait fisheries interactions, ghost net interactions, Indigenous take (domestic and international) and climate-induced sea level rise threats as very high risk, and Commonwealth (excluding Torres Strait) fisheries interactions and climate-induced feminisation threats were reassessed as high risk (Table S5.2). These are presented in more detail below.

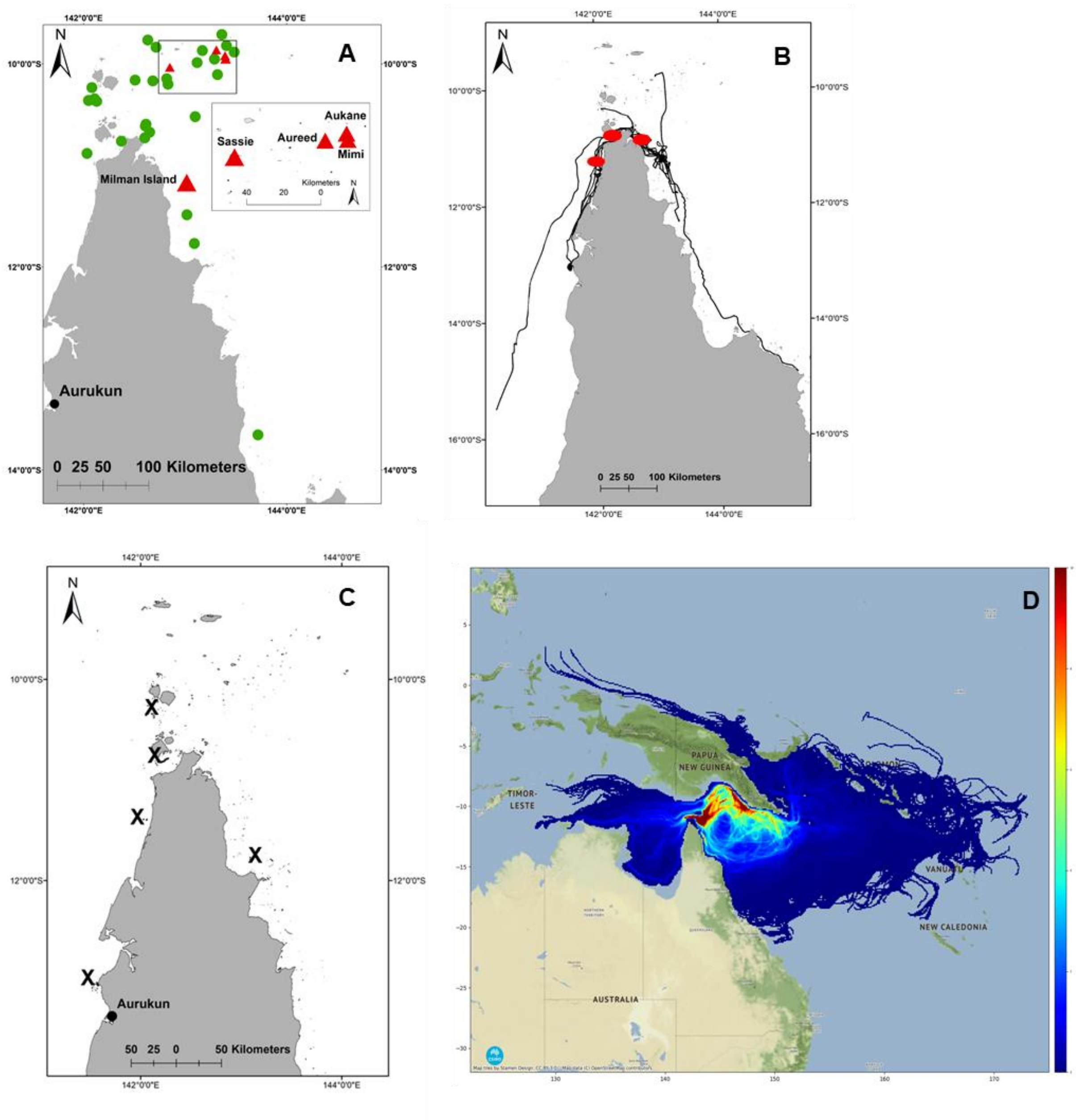

Figure 5.2 neQld stock life history. **A)** important (green) and critical (red) nesting sites; **B)** migration corridor (red dots where >5 migratory tracks overlap); **C)** key foraging ground locations (shown as X); **D)** post-hatchling cumulative exposure as modelled by CONNIE 3 (red shading where greatest likelihood of modelled dispersal) (Credit: CSIRO).

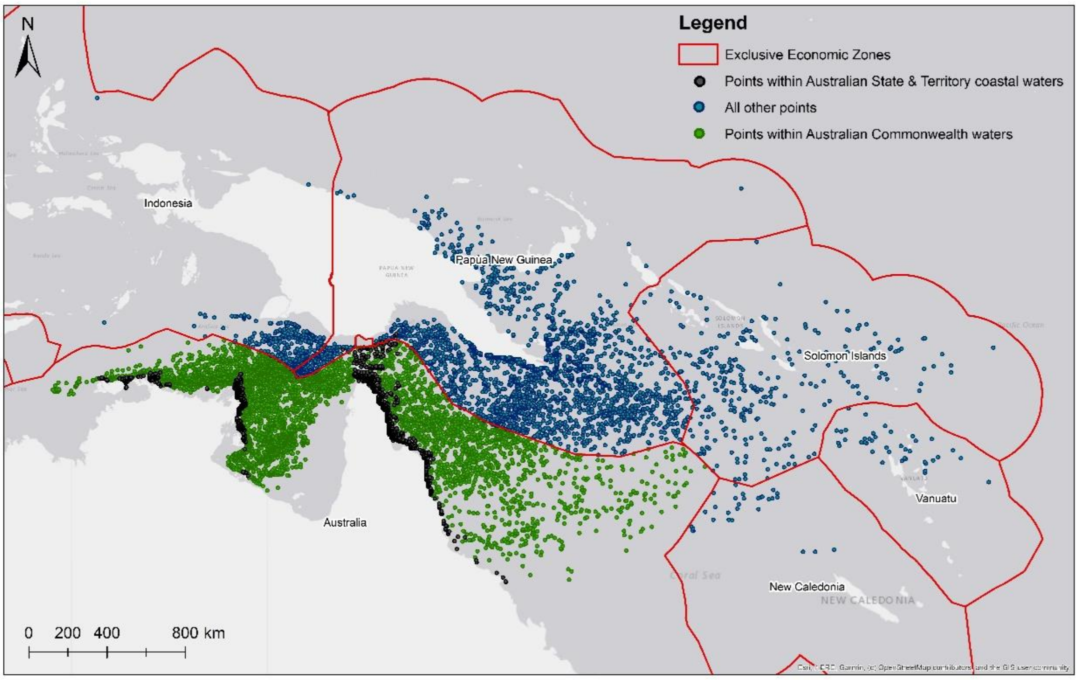

Figure 5.3 Likely first “lost-year” distribution within predicted [count] of likely encounters per exclusive economic zones (EEZ). Coloured dots refer to points within Australian State and Territory coastal waters (black), Australian Commonwealth Waters (green), all others (blue).

Climate change

CMIP6 modelled climate projection temperature data indicated a similar increase in temperature under both emission scenarios (conservative and extreme: Table 5.2). The conservative scenario predicted higher temperatures at nesting beaches for the 2021-2040 period than the extreme scenario, while the extreme scenario predicted higher temperatures for the 2061-2080 period than under the conservative scenario. Modelled maximum temperatures for both periods (2021-2040 and 2061-2080) were above the pivotal thermal threshold (29.2°C) at all investigated hawksbill nesting beaches. Modelled minimum temperatures across all key nesting sites were not greater than 27.1°C (within male production temperatures). However, minimum modelled temperatures under an extreme emissions scenario for period 2061-2080 at four nesting beaches were within 0.2°C and 0.3°C of the pivotal thermal threshold (Aukane: 29.0°C, Zuizin: 28.9°C, Mimi: 29.0°C, Bourke: 29.0°C). The same four nesting beaches modelled maximum temperatures well above upper thermal mortality thresholds (>35.4°C). At these beaches, even under a conservative emissions scenario for this time period, minimum temperatures remain high (28.6°C), although likely still male producing.

Table 5.2 CMIP6 modelled climate projection temperature data of minimum and maximum mean temperatures (°C) for hawksbill turtle nesting areas in northeast Australia for two time periods (2021-2040 and 2061-2080) under conservative and extreme emissions scenarios. See Figure 5.1a for location of nesting beaches. Values shaded indicate temperatures higher than the pivotal threshold for successful incubation of male hatchlings, switching to a female bias (29.2°C). Values in bold indicate the upper thermal limits of mortality (>35°C). Boxed sites (and in red text) are most likely to produce male or more balanced sex ratios across all possible scenarios.

Key nesting site	***2021-2040 Conservative***	***2021-2040 Extreme***	***2061-2080 Conservative***	***2061-2080 Extreme***
Aukane (Au Kein)	min: 27.1 max: 33.9	min: 27.0 max: 33.8	min: 28.6 **max: 35.4**	min: 29.0 **max: 35.8**
Aureed	min: 25.7 max: 32.4	min: 25.6 max: 32.3	min: 27.2 max: 33.9	min: 27.6 max: 34.3
Bet Islet (Bara)	min: 26.6 max: 32.7	min: 26.3 max: 32.6	min: 27.9 max: 34.2	min: 28.2 max: 34.6
Bourke (Bak)	min: 27.1 max: 33.9	min: 27.0 max: 33.8	min: 28.6 **max: 35.4**	min: 29.0 **max: 35.8**
Hawkesbury (Warral)	min: 25.9 max: 31.6	min: 25.9 max: 31.5	min: 27.5 max: 33.1	min: 27.8 max: 33.5
Kabbikane (Kebi Kein)	min: 25.5 max: 32.5	min: 25.4 max: 32.4	min: 27.0 max: 34.0	min: 27.4 max: 34.4
Laoyak (Yauk)	min: 25.7 max: 32.4	min: 25.6 max: 32.3	min: 27.2 max: 33.9	min: 27.6 max: 34.3

Milman Islet	min: 26.4 max: 33.3	min: 26.3 max: 33.2	min: 27.9 max: 34.8	min: 28.3 **max: 35.2**
Mimi	min: 27.1 max: 33.9	min: 27.0 max: 33.8	min: 28.6 **max: 35.4**	min: 29.0 max: 35.8
Saddle (Ullu)	min: 26.6 max: 32.9	min: 28.1 max: 34.4	min: 26.5 max: 32.8	min: 28.4 max: 34.8
Sassie (Long)	min: 26.1 max: 32.4	min: 26.0 max: 32.4	min: 27.6 max: 34.0	min: 27.9 max: 34.3
Zuizin (Halfway)	min: 27.1 max: 33.9	min: 27.0 max: 33.8	min: 28.6 **max: 35.4**	min: 28.9 **max: 35.8**

Fisheries bycatch and entanglement

Where reporting was available (not all years across all fisheries) from 2005-2020, absolute numbers of annual marine turtle interactions (all species) were highest in the ECIF and GoCIF (1,591; 114 average/yr), the ETBF (765; 85 average/yr) and NPF (636; 71 average/year) and the lowest in the East Coast and GoC Crab fishery (9; 1 average/yr) (Table S5.3a). Over this 15-year period, hawksbills were reported as a small component of bycatch in each individual fishery ranging from 0% in ECOTF to 11.1% in the East Coast and GoC crab fisheries. Potential hawksbill interactions (reported hawksbill turtles plus adjusted hawksbill interactions) ranged between 0% in the ECOTF to 13.3% in the TSPF (Table S5.3b). In the period 2012-2019 where all reported fisheries data were available, bycatch of hawksbills and potential hawksbill interactions equated to 2% and 2.8% (38-52 absolute or 5-7 average/year), respectively. For hawksbills alone, bycatch was the highest in the ETBF (18; 2 average/yr) followed by the ECIF & GoCIF (9; 1 average/yr) and NPF (8; 1 average/yr), with the lowest in East Coast Trawl (0/yr) (Table S5.3c). Extrapolated data from the Queensland Fisheries Observer Program indicated that 651 hawksbill turtles may have been caught as bycatch in the ECIF and GoCIF combined during the period 2005-2019 (Table S5.3d).

Turtle BPUE trends differed by fishery (Figure 5.4), with increases in turtle BPUE in the ETBF from 2016 onwards corresponding with the introduction of electronic monitoring, increasing approximately 9-fold from 0.002 turtles per 1000 hooks (or 66 absolute turtles; 16.5 turtles/yr) in the period pre-electronic monitoring (2012-2015) to 0.019 turtles per 1000 hooks (or 454 absolute turtles; 151.3 turtles/yr) in the period with electronic monitoring (2016-2018). Of particular note, the number of dead turtles reported also drastically increased from 8 to 67. For hawksbill and adjusted hawksbill interactions, BPUE increased almost 5-fold between the period pre-electronic monitoring (2012-2015) and with electronic monitoring (2016-2018) (0.00007 to 0.00041 per 1000 hooks) (Table S5.3e). BPUE increases are not reflected in other fisheries, with the ECIF and GoCIF interestingly showing a general negative trend in BPUE throughout the study period (Figure 5.4). If extrapolated using the magnitude of increase in reported hawksbill and adjusted hawksbill interactions BPUE prior to and during electronic monitoring implementation as observed in the ETBF (5.9x increase), BPUE for the ECIF and GoCIF, which does not have independent observation, may be approximately 0.0015 in the 2005-2019 period (versus the 0.0003 reported in 2005-2019) with 150-162 (versus 25-27 reported) hawksbills caught as bycatch (Table S5.3f).

Overall, these results indicate that ETBF and the gillnet and ringnet components of the ECIF and GoCIF, likely pose the greatest risks to hawksbill turtles, followed by the NPF and TSPF. However, given the relatively small effort footprints of the east-coast fisheries (ETBF and ECIF) in relation to the distribution of the neQld hawksbill population, all bycatch cannot be attributed to the neQld hawksbill stock. Further, hawksbills on the east coast of Queensland have mixed foraging populations (e.g. Bell & Jensen, 2018), which means a genetic analysis of bycatch is required to accurately estimate bycatch of neQld hawksbills.

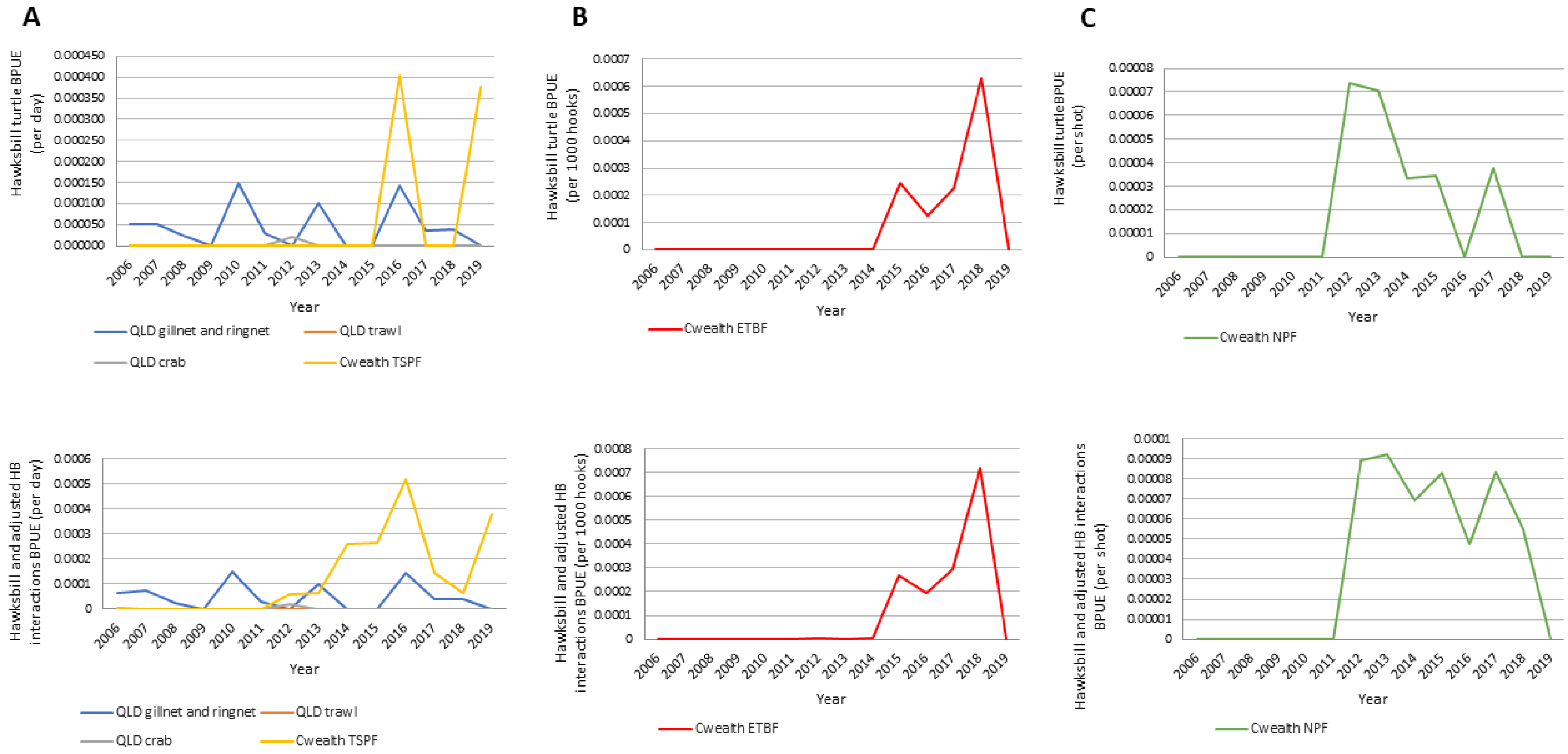

Figure 5.4 Reported hawksbill and unspecified turtle bycatch per unit effort (BPUE) for hawksbill and hawksbill including unspecified turtles for all fisheries. **A)** all state and Commonwealth TSP; **B)** ETBF; **C)** NPF

The total area of the post-nesting UD within the ECIF and GoCIF is 2026 km^2, an underestimate as it excludes reporting cells that we were unable to collect data from due to privacy laws. The total days fished in the post-nesting UD is estimated to be around 4990 days/year over multiple licences. The mean number of days fished in each grid cell equated to 1022 days fished per year (where days fished = days fished by all fishers with a licence in that cell). The greatest (very high) exposure of gillnet and ring net fishing pressure of 1814 days fished/year within post-nesting UD was found off the coastline of Aurukun to the north west of Norman Creek, and off the coast between Mapoon and Nanum of West Cape York (Figure 5.5). Not all data were available for eastern Cape York because there were < 5 licences active in some reporting grids. While most effort in ECIF is from Cairns south, we note that large mesh netting is likely off the coast between Starcke and Cape Melville around the Howick Group of Islands, north to the Claremont Isles and around the inshore areas off the coast of Lockhart, where fishing effort is distributed.

Using StrandNET, for which a cause of death was available, fishery bycatch and entanglement accounted for 63% (29/46) of all hawksbill turtle strandings, with 26/29 occurring at 11° and 12° latitude south blocks (east Cape York) in the vicinity of gillnet and ringnet reporting grids where no data was available. We note that StrandNet mortalities also include entanglement from illegal netting and discarded gear.

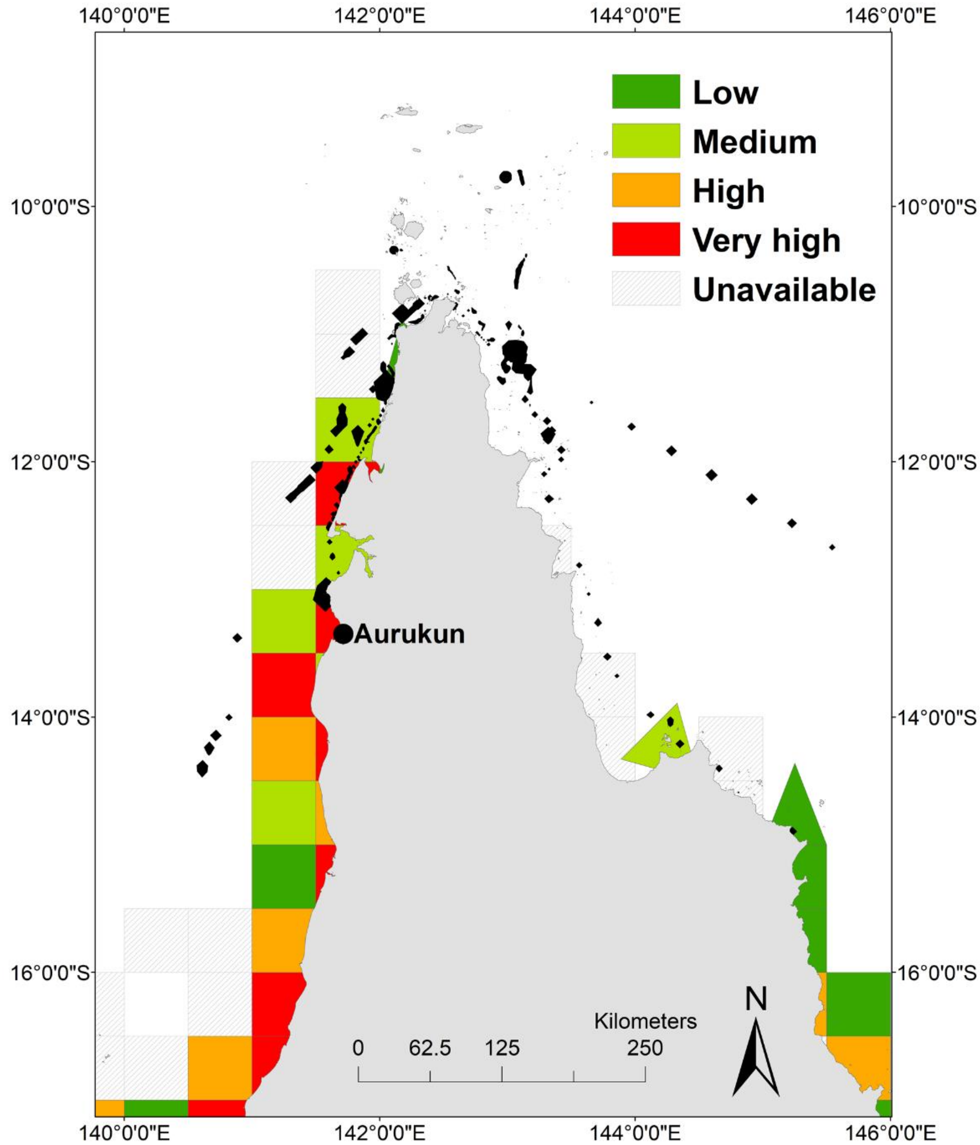

Figure 5.5 Heat map of gillnet and ringnet fishing pressure. Low (20-164), medium (165-456), high (457-1607) and very high (1604-5137) days of exposure overlaid with hawksbill post nesting home range (black polygons).

Ghost net interactions

The total number of ghost nets simulated particle drift tracks in the post-nesting UD was 54,365 (+/- 8064 SD). A mean of 4942 ghost net tracks overlapped with the post-nesting UD (Figure 5.6). The highest ghost net track count (8001-9000) was found off the north coast of Mapoon from the Wenlock to the Jackson Rivers, which overlaps with the highest risk of turtle-net encounter off the coastline north of Aurukun to the waters north west of Norman Creek, and between Mapoon and Nanum of West Cape York (Figure 5.6).

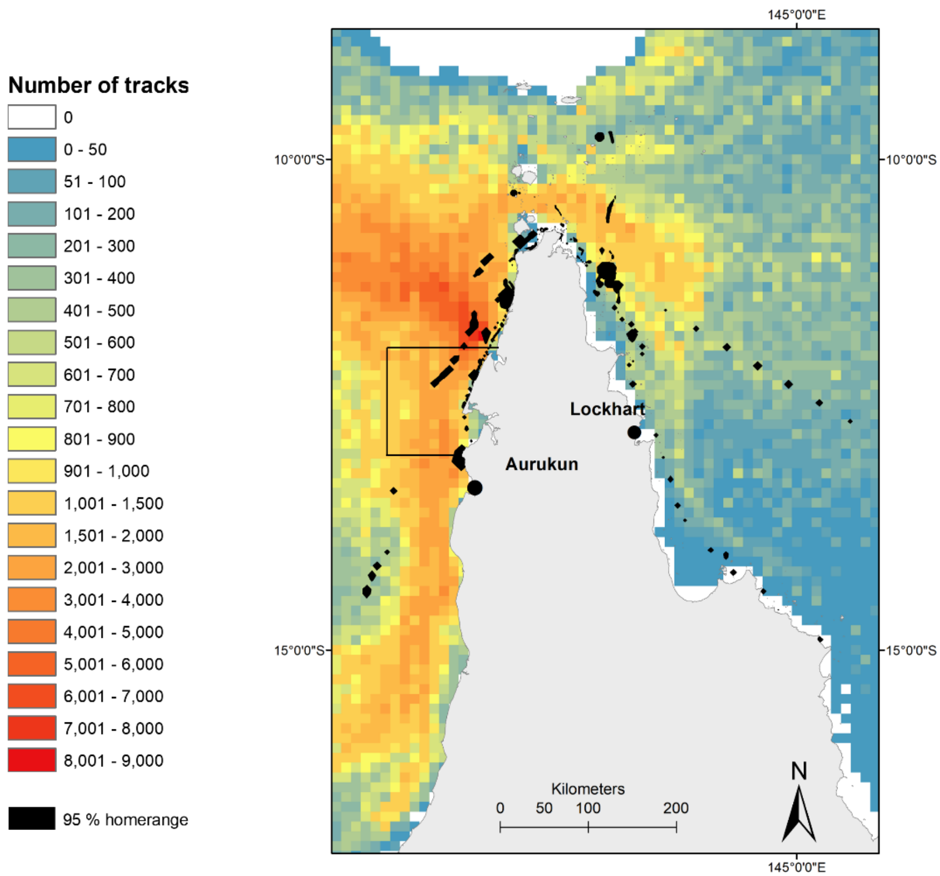

Figure 5.6 Heatmap of potential ghost net tracks in northern Queensland based on daily particle releases and net length found along the Queensland coastline. Black box denotes most 'at-risk' turtle-net encounter area (from Wilcox et al., 2013), overlaid with hawksbill post nesting home range (black polygons). Ghost net data provided by Wilcox *et al.* 2013.

Harvest and predation

Of the modelled post-hatchling distribution proportion in Australia (62.73%), the probability of hawksbill hatchling dispersal in the State of Queensland is 0.01% (4,149 points), Northern Territory 0.001% (693 points), and none in western Australia, with the balance in Commonwealth waters 99.99% (70,511,516 points) (Figure 5.3; Table S5.2). Hatchling dispersal probability was next highest in PNG (31.21%; 35,084,374 points), followed by other neighbouring countries in declining probability for Solomon Islands (3,682,993 points), Indonesia (2,198,683 points), Vanuatu (550,678 points), and New Caledonia (386,106 points) (Table S5.2). Further, an estimated 305.33 km^2 is utilised by post-nesting UD (10.84%) within the Torres Strait Fishery boundary, areas available to harvesters including Papua New Guineans under the Torres Strait Treaty. This is relevant given the ongoing take of hawksbill turtles for their meat and eggs continues throughout north eastern Australia (Commonwealth of Australia, 2017; Table S5.5) and Papua New Guinea (Opu, 2018) within the neQld stock likely geographical range, and should likely be considered a major source of mortality (Commonwealth of Australia, 2017).

For this study, in the absence of any other data, where clutch predation could be quantified for central island Torres Strait (Torres Strait Regional Authority, 2017), total clutch loss to predators (pigs, goannas, scrub fowl and humans) was estimated at 16.9% (95/556) with human harvest accounting for most of the predation recorded (Table S5.4). Extrapolated over 14, 30 and 60 days respectively, 181, 388, 776 clutches may be lost to predation (Table S5.4). Consideration of other known predators of turtles, such as cats and foxes, combined with ALA data, clutch predation was considered low in critical nesting sites of Milman, Aukane, Aureed, Sassie with none recorded on Mimi. These data shows Islands where multi-species predation is present (Figure 5.7). Islands with most predators were Albany, Bara, Cap, Yauk, Guiya, Ullu and Saunders. Of these, Bara and Ullu are key nesting sites with >100 track counts (Torres Strait Regional Authority, 2017).

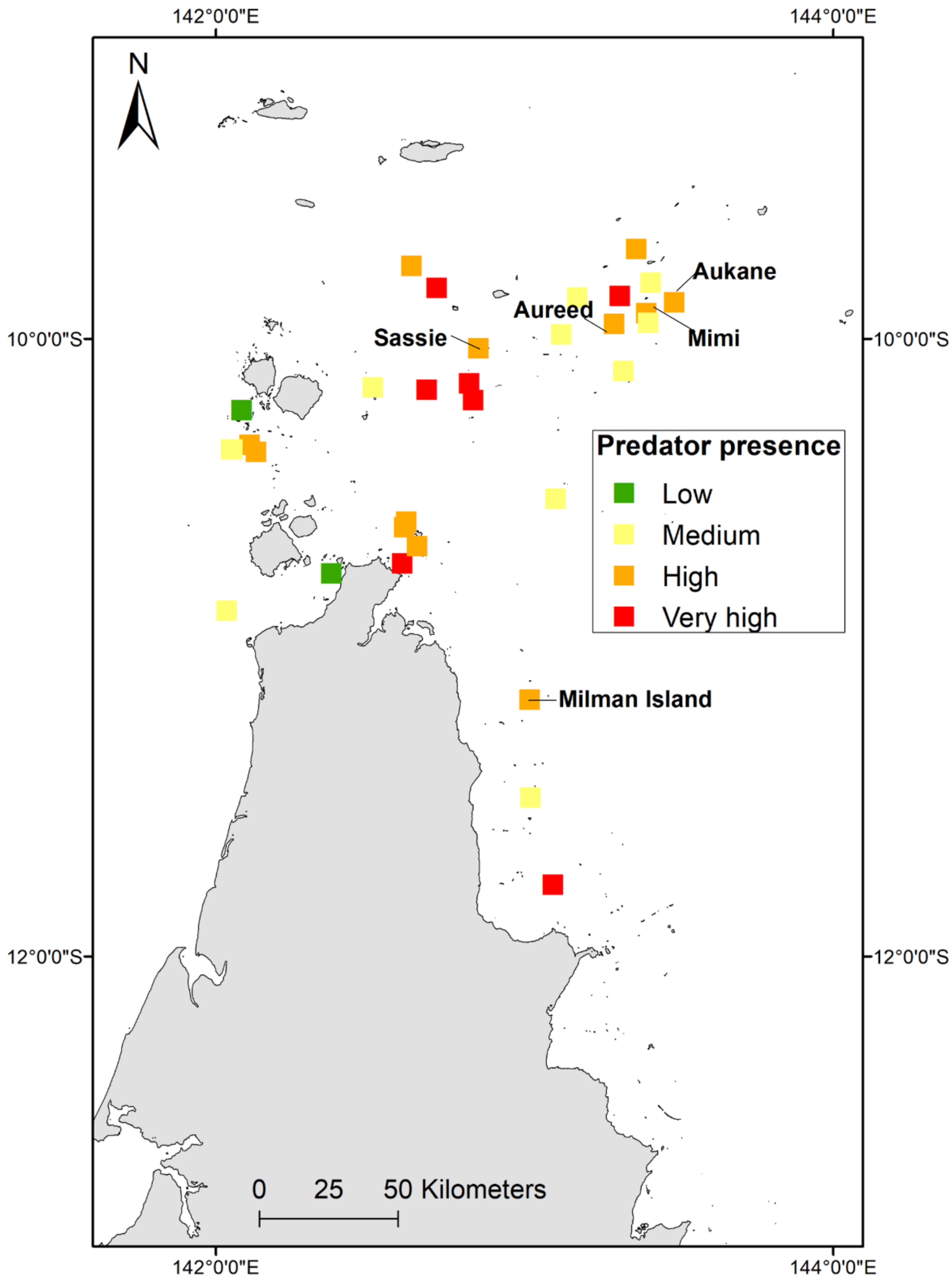

Figure 5.7 Combined multi-species (terrestrial animals including foxes/dingoes, pigs, goannas/monitors, crocodiles, cats, scrub fowl and traditional human harvest) predators on key nesting beaches. Low = 0, Medium = 1, High =2, Very High = 3

Area-based protection measures

Post-nesting home range protection is 28.9% (raw numbers in S3.2), with 26% of this protection in overlapping GBR (Coast) (Qld) (DES) and GBR (Commonwealth) (GBRMPA) Marine Parks. This is compared to only 0.8% of the foraging home range protected by GBR marine parks. Although hawksbills travel within Commonwealth waters, only 2.9% of their home range is protected by Commonwealth Marine Reserves. Similarly, 0.001 % of hawksbill post-nesting home ranges are included within designated Indigenous Protected Areas (IPA). However, all protection is only afforded to just over one quarter of the post-nesting home range used by hawksbill turtles, and those primarily utilising the east coast of Queensland and GBRMP Marine Reserves. The adult females that reside and make up 75% of the post-nesting home range on the western side of Queensland are only 1.9% protected by DAWE Marine Reserves (none in State waters) in their west coast post-nesting home range, as there is limited marine park protection within Torres Strait or Gulf of Carpentaria (Figure 5.8).

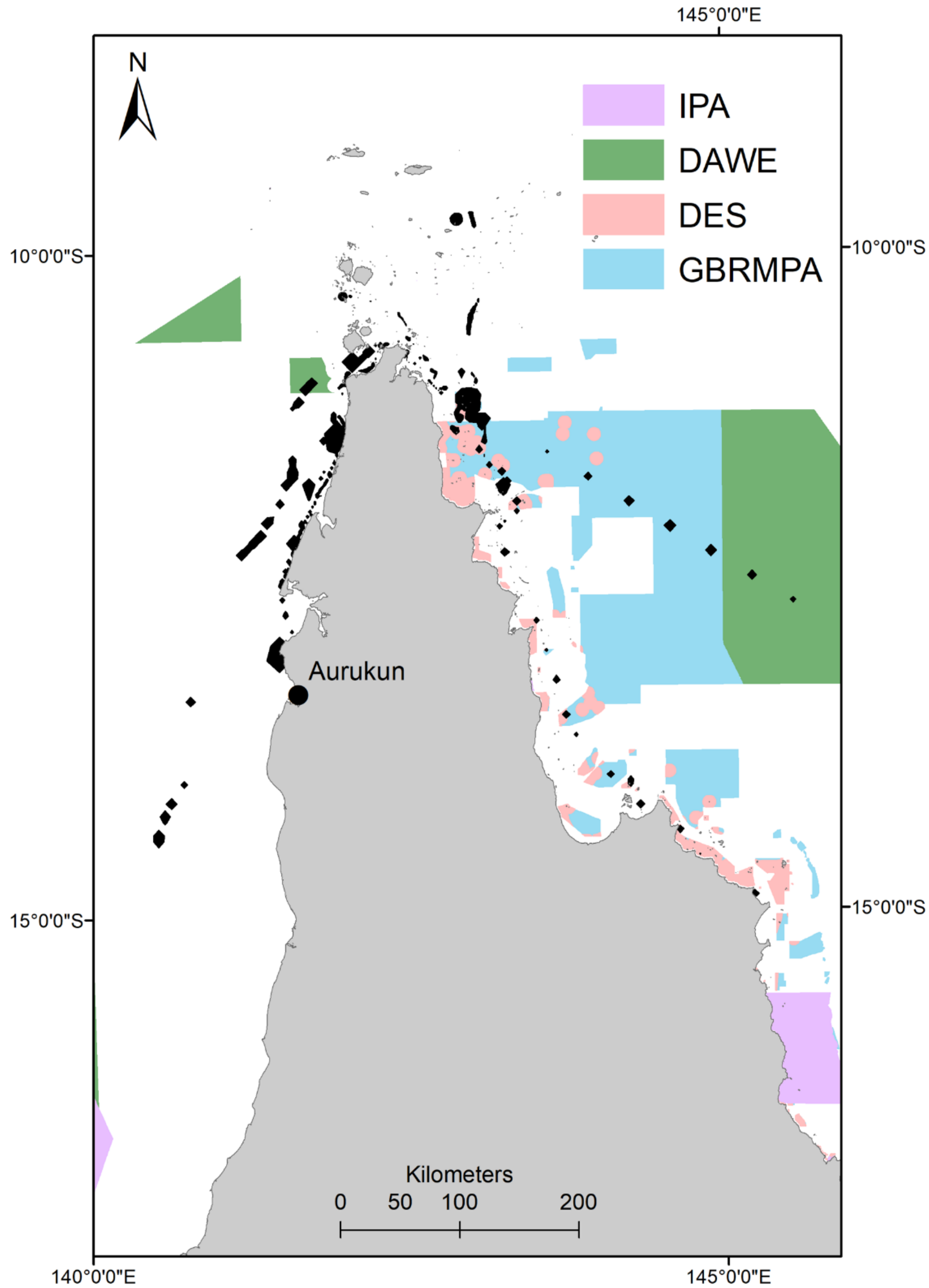

Figure 5.8 Marine reserve (IUCN category I and II) and Indigenous Protected Area overlaid with hawksbill post nesting home range (black polygons). IPA = Indigenous Protected Area; DAWE = Department of Environment, Agriculture and Water (Commonwealth Government of Australia); GBRMPA = Great Barrier Reef Marine Park Authority (Commonwealth Government of Australia); DES = Department of Environment and Science (Queensland Government).

Discussion

Our systematic review and risk analysis did not identify a single, pervasive threat to the Milman Island nesting population or the greater neQld stock for targeted management action. However, after eliminating risks ranked as negligible for the survival of the stock (e.g. sky glow and chemical contamination), climate change, harvest (including eggs), ghost-net interactions and fisheries were ranked as high to very high risks to the stock. Although the mortality from each of these threats could be considered small in isolation, it is important to prioritise any feasible actions that reduce mortality of a small, endangered population that is perhaps only a decade from extinction (Bell et al., 2020). It is also sensible to apply the precautionary principle for threats with high uncertainty yet potentially significant consequences, especially when they are likely to occur.

Post-hatchling dispersal modelling suggested that while most turtles remained on the Australian shelf, neQld hawksbills were likely to settle in foraging areas in other countries, including Papua New Guinea and Indonesia. While this aligns with historical tag returns (Limpus & Miller, 2008; Miller et al., 1998), it also stands in contrast with the fact that none of the 13 turtles tracked in this study, nor the 12 neQld hawksbill turtles tracked in previous studies left the Australian shelf, and all returned to foraging areas in the state of Queensland (Barr et al., 2021; I. Bell unpublished data). This suggests that survival to nesting is low outside of Australian waters, or where turtle fisheries are allowed (e.g. Torres Strait Treaty) and where illegal take is known to continue (LaCasella et al., 2021). It is also possible that the discrepancy between the post-hatchling dispersal modelling results and the foraging areas identified for adult females is because of developmental migration (*senus* Bolten et al. 1998), although there is no evidence of developmental migration for this population from tag recoveries (reviewed by Limpus & Miller, 2008) or for hawksbill turtles elsewhere in northern Queensland (Bell, 2012). Genetic studies linking breeding and foraging hawksbills in their distributed range (e.g. the Torres Strait and PNG) will further inform the disparity between post-hatchling and reproductive female dispersal. Nevertheless, our results emphasise the importance and need for strong protection of the neQld hawksbills that remain in Australia's jurisdictional waters. Even though Cape York Peninsula and Torres Strait are undoubtedly strongholds for the last remnants of this endangered genetic stock, there are no marine protected areas in coastal waters of western Cape York or in Torres Strait.

Considerable uncertainty also remains in the bycatch rates from net fisheries that overlap with core hawksbill foraging habitat, such as the GoCIF fishery and the northern sector of the ECIF fishery, both likely a key source and posing a sizeable risk to the neQld hawksbill stock. Ghost net hotspots also generally overlap with the GoCIF, raising additional risk to this stock's foraging hawksbills. The Commonwealth trawl fisheries overlap with the range of the post-hatchling dispersal and post-nesting migration, and continued low rates of hawksbill and high rates of unidentified turtle bycatch in these fisheries suggest that they pose a small, yet ongoing risk. Even though overall bycatch was the highest in the ETBF over the last 5 years (Table S5.3), a large proportion of the bycatch is likely to be from other genetic stocks.

The new post-nesting tracking data analysed in this paper reinforces earlier results (Barr et al., 2021; Gaos, 2011; Hoenner et al., 2016), in that Milman Island nesters meander along their migratory routes and show fidelity to multiple small foraging grounds with little collective preference or specificity towards a singular/particular foraging ground. We acknowledge that tracking additional individuals is likely to identify additional foraging and migratory habitat but argue that the habitats identified to date are unquestionably important to this endangered stock.

Overall, most tracked nesters to date migrate to foraging grounds on western Cape York and Torres Strait (western Queensland). Although this should be further investigated by genetic studies on the foraging grounds identified in our study, hawksbills nesting elsewhere in the region (such as the Solomon Islands, north-eastern Arnhem and PNG), have not been tracked to foraging grounds in western Cape York and Torres Strait (Hamilton et al., 2021; Hoenner et al., 2016; Madden Hof, unpublished data), further supporting the contention that most hawksbills in western Queensland are likely to be from the neQld population. This is further backed by a foraging genetic study published in Queensland revealing ~84% of hawksbill turtles on the Howick Island group (located around Cape Flattery, east Cape York Peninsula) are from the Solomon Islands stocks, with only ~14% contributed from neQld (Bell & Jensen, 2018). Meaning, any intervention in eastern Queensland will support multi-stocks, but in western Queensland primarily the neQld stock. Given greater residence in western Queensland, greater intervention and protection efforts in this area is likely to be required to rebuild this stock.

Without concerted effort in Australia to reduce known threats, the neQld population may face a similar fate to other species like the eastern Pacific leatherbacks (Ábrego et al., 2020), Vaquitas (Jaramillo-Legorreta et al., 2007), the Yangtze River dolphin baiji (Turvey et al., 2007) amongst several other species known to become unviable or extinct in the wild. However, recovery is possible (e.g. Solomon Island hawksbill stock, (Hamilton et al., 2015); humpback whales, (Bejder et al., 2016)) where guidance to inform threat mitigation or measures to reform population trajectories are enacted.

Recommendations for management and intervention

Climate change

Given that the negative impacts of climate change are already being observed at marine turtle nesting beaches of north Queensland (Jensen et al., 2018), preparing for this eventuality and abating all other threats to the neQld stock should be a management priority. Temperatures within the region of the neQld stock have increased at 0.10-0.15^{o}C/decade over the past 55 years (Australian Government Bureau of Meteorology, 2018). While hawksbill foraging populations throughout the GBR are already skewed to a [natural] higher female ratio (~3 females:1 male; (Bell et al., 2012; Limpus, 2009), a rise in regional incubation temperatures will likely cause additional female sex ratio skewing, and increased risk of reduced hatchling production during periods when nest temperatures exceed lethal temperatures 34^{o}C+ (Dobbs et al., 2010).

Acknowledging that hawksbills nest year-round and while unlikely, if they were able to rapidly adapt to rising temperatures by altering their peak nesting period to cooler months, this study suggests that sex ratio outputs may already be skewing towards an increase in female production at neQld stock nesting beaches. Predicted temperatures under both conservative and extreme emission scenarios (2021-2080) are likely to facilitate all female producing populations at many key nesting sites, including Aukane, Bourke, Mimi and Zuizin. Whereas the most likely nesting beaches to produce males or a more balanced sex ratio under climate projected temperatures are Aureed, Kebi Kein, Yauk and Warral. As both Aukane and Aureed are reported to have high nesting density, early assessment (e.g. Patrício et al., 2021; Staines et al., 2020) to determine realised sex ratios, and intervention (e.g. Smith et al., 2021) to reduce and maintain temperatures, along with protection, should be prioritised for both of these critical nesting sites.

Notwithstanding sea level rise inundation (assessed in this study as coastal erosion but thwart with resolution limitations as it completely covered all key nesting habitats in Torres Strait; Table S5.2), of similar climate change concern are the changes in reproductive periodicity, shifts in latitudinal ranges, and changes in foraging success which are all expected in a hawksbills marine life history phase (Patrício et al., 2021), requiring additional research and action relating to the neQld stock.

Fisheries bycatch and entanglement

The neQld stock utilises habitats that have the potential to interact with three Queensland and three Commonwealth managed fisheries. Significant under-reporting of turtle interactions by commercial fishers is likely in all relevant Queensland and Commonwealth fisheries with the exception of the ETBF post-2015 when electronic monitoring was implemented. The absolute and BPUE values reported, and those estimated within this study, are therefore likely to be a minimum record of turtle bycatch within the study periods. Considered collectively, all fisheries pose a small but cumulative bycatch threat to the neQld hawksbill populations. However, should those fisheries that have no independent observation of catches (Queensland managed fisheries – ECIF & GoCIF, ECOTF and the crab fishery) exhibit the same increases to reported turtle catch as the ETBF when electronic monitoring was introduced, the number of hawksbill turtles' interactions in commercial fisheries could be much higher. While individually, the ETBF, ECIF and GoCIF, TSPF and NPF expose hawksbills to the greatest bycatch threat, mixed hawksbill stocks confound these results except in western Queensland where the neQld stock is likely to dominate and the GoCIF and NPF fisheries are concentrated.

The presence of electronic monitoring and independent observers in the ETBF, NPF and TSP fisheries have provided a higher degree of confidence in bycatch and BPUE calculations for hawksbills. However, scientific observer coverage (2-5%) and electronic footage monitoring review (10%) (ABARES, 2017; AFMA, 2019) of fishing trips per year is low and increases the uncertainty and accuracy of reporting, as demonstrated by continued and in some cases, increasing records of unspecified turtles. The absence of such programs in Queensland fisheries, in particular the ECIF and GoCIF, suggests that estimates should be treated with caution and as underestimates. Extrapolated bycatch data for the gillnet and ringnet fisheries (between 150-162 hawksbills in the period 2005-2019) and estimates based upon historical observed interaction rates in the Queensland FOP (of 651 hawksbill turtles in the period 2005-2019) suggest this fishery may in fact be having a greater impact - in particular, in western Queensland waters from Aurukun to Mapoon, and although mixed stocks, the inshore areas opposite Starcke to Cape Melville and Lockhart. Gillnet fisheries totalled 4990 days/year fished in the home range of hawksbills, with the greatest fishing pressure off west Cape York north of Aurukun, highlighting GoCIF as a key source of risk to the neQld hawksbill stock. GoCIF was also assessed as a high risk to hawksbill turtles in a separate study (Pears et al., 2012; Sporcic et al., 2019).

Overall, species identification, presumed under-reporting and lack of independent fisheries observers in Queensland fisheries are ongoing issues. The coastline north of Aurukun in particular is remote with low rates of compliance monitoring by fisheries patrols, and there have been numerous well publicised cases of illegal fishing from foreign fishing vessels on Cape York and Torres Strait. There is clearly a significant overlap between turtles and fisheries effort that underscores the urgency for better reporting and management plans and there is a clear need for greater scrutiny of fishing effort in hawksbill home ranges.

Whilst the use of turtle exclusion devices (TEDs) has been mandatory since 2001, significantly reducing the capture and mortality of marine turtles in Commonwealth and Queensland trawl fisheries (Brewer et al., 2006), this study found that interactions in the TSPF and NPF remain an ongoing threat to hawksbill (and unspecified turtles). Because hawksbills were reported to be most susceptible to drowning (Limpus, 2009), additional oversight of the application/use of TEDs, species identification training and other bycatch mitigation strategies should be priorities for managers. LEDs attached to fishing nets has proven effective to reduce marine turtle entanglements overseas, but there is no evidence to date that they reduce hawksbill turtle catches (e.g. Gautama et al., 2022; Senko et al., 2022b).

Ghost net interactions

Ghost nets continue to present a serious threat to hawksbills with a hotspot generally overlapping with the GoCIF. With most of the ghost net drift trajectories on the west Cape York (where more than three quarters of the satellite tracked turtles migrate to reach their foraging grounds), it is highly probable and supportive of Wilcox et al., 2013 assessment (of 32.8% hawksbills caught in ghosts nets), that the neQld stock hawksbills are being negatively impacted by ghost nets and are particularly vulnerable along the waters adjacent to Aurukun north to around Crab Island. Considering post-hatchling distribution is highly likely within the net track paths of the Northern Territory and western Queensland, ghost nets may pose an additional threat to earlier life history phases. Ghost net retrieval and records are monitored and kept by indigenous ranger communities of the Western Cape York Threat Abatement Alliance, but additional support is required including international efforts to address use and disposal within the Timor Arafura Seas before entry into the Gulf of Carpentaria and Torres Strait.

Harvest and predation

Hawksbill turtle harvesting continues in PNG with take (legal and illegal) within the Torres Strait Treaty boundary (Commonwealth of Australia, 2010). There is also a noted ATSI preference for hawksbills eggs (Commonwealth of Australia, 2017), and outside of the limited TSRA study (2017), an unquantified number of hawksbill eggs are collected from rookeries throughout Cape York Queensland and the Torres Strait. Turtle take has previously been considered unsustainable (cited p.123, Commonwealth of Australia, 2010).

Highlighted by this study, where we do know over half of the uninhabited islands of the Torres Strait are traditionally harvested for hawksbill eggs in the central Torres Strait island clusters (exclusive of the heavily populated western and inner Torres Strait (Torres Strait Regional Authority, 2017), and combined with a small proportion of terrestrial predation of exotic and native animals already reaching beyond 16.9% of hawksbill clutches outside of peak emergence, the take of hawksbill turtles and their eggs by indigenous communities within Australian and other western Pacific countries (such as PNG) is more than likely hindering the neQld stock recovery. This is notwithstanding the greater harvest accessibility likely yet lack of knowledge or any robust scientific assessment of "lost year" (0-20 year) migration within northern Australia. In this review where harvest levels are quantified and considered high, particularly at key nesting sites e.g. Bara and Ullu, interventions (e.g. Madden Hof et al., 2019) or protection (e.g. no-take areas or seasonal closures) should be considered. Similarly on low clutch loss but medium-high density islands such as Milman, Aukane, Aureed, Sassie and Mimi, full protection should be implemented. Whilst management through non-binding agreements directed towards the sustainable utilisation of marine turtles (including, Traditional Use of Marine Resource Agreements (TUMRAs) within GBRMP management and Conservation Agreements (Indigenous Land Use Agreements) under the *Nature Conservation Act 1994*), could be improved, understanding the social, cultural and economic drivers behind 'take' is fundamental in improving the coexistence between humans and hawksbills, and where loss is considered high, other non-consumptive uses should be explored (Liles et al., 2015; Mancini et al., 2011). As there is evidence of a continued illegal international trade of tortoiseshell and/or whole hawksbill turtles within the Arafura Sea to Coral Sea Region (Commonwealth of Australia, 2010; Department of Environment and Science, 2018), inadequate monitoring and enforcement of trade regulation by signatory States (including Australia, PNG and Indonesia) under the Convention of Trade in Endangered Species (CITES) (Barr et al., 2021) requires attention – particularly improving cooperative implementation of CITES Resolution (adopted at CoP19, November 2022).

Area-based protection measures

A conservation target in Queensland is to provide strong habitat protection for at least 70% of nesting sites for each genetic stock, whereas it has been estimated that only <30% of neQld hawksbill rookeries are protected (Department of Environment and Science, 2018). Our study supports this finding. Although Milman Island and its surrounding waters are highly protected, other nesting sites are overlooked. No hawksbill foraging grounds have been listed as 'critical habitat' under the Commonwealth's *Recovery Plan for Marine Turtles in Australia, 2017* or by the EPBC Act, which would afford legislative protection. With under 3% of the post-nesting hawksbill UD protected by Australia's National Representative System of Marine Protected Areas (NRSMPA), only up to 28.9% within primarily east Queensland Marine Parks and with trivial protection afforded to hawksbills within the Torres Strait and the Gulf of Carpentaria (1.9%), hawksbills migratory routes and foraging areas remain mostly unprotected.

With the ability to link to the NRSMPA and the NCA existing legislative frameworks, the neQld stock *critical habitat* should be identified under the EPBC Act and integrated into the marine bioregional planning process as Biologically Important Areas. Complementary protection (similar to the GBR Marine Parks) should then be afforded to hawksbills home ranges within the Gulf of Carpentaria by State Government and Commonwealth Governments – particularly the area from Aurkun to southern Crab Island. Under customary law, and the TUMRA, ILUA or IPA processes, greater protection of the critical nesting, post-hatchling, migratory and foraging area of the neQld is also urgently required in the Torres Strait. This could also be reflected in stronger conservation measures adopted under the Torres Strait Treaty to curtail harvesting activities (Articles 14 and 20) for the conservation of hawksbills.

Without concerted attention and focus to address cumulative threats and provide protection in the Torres Strait and of the northern coastal waters of west Cape York, it is reasonable to suggest extirpation is likely within the next few decades.

Conclusion

Migratory species such as marine turtles, present specific management challenges, but supported by knowledge of their habitat use and ranging behaviour within all phases of their life history, threat mitigation is possible. For the first time, the neQld stock life history is presented, and relative threat exposure is assessed to pinpoint and offer conservation and protection measures to reverse its likely population trajectory towards extirpation. At no stage is a hawksbill turtle free of predation, fishery interaction or climate change impacts amongst other simultaneous threats. Supported by this study, the cumulative take of hawksbill turtles in northern Australia (and surrounding western Pacific countries) should be considered non-sustainable (Department of Environment and Science, 2018). Urgent protection of post-nesting home ranges, consideration of gillnet and ringnet effort reduction particularly in western Queensland, the introduction of additional bycatch mitigation in all impacting fisheries, deployment of predation reduction mechanisms, employment of climate intervention strategies, and the declaration of critical habitats including “no-take” zones or moratoriums could all collectively be enacted within north-east Australian and cross border with PNG. This is a matter of urgency given the size of the critically endangered population, if the once described “world’s largest” hawksbill stock is to avoid extinction. The suggested cumulative response could simultaneously include:

A. Providing protection to Aukane, Aureed, Sassie and Mimi Island rookeries that are comparable to Milman Island (including a buffered in-water/inter-nesting zone);
B. Further climate assessment and intervention to likely long-term male producing nesting beaches of Aukane and Aureed;
C. Seasonal closure protection from egg take at all critical nesting beaches, and Bara and Ullu Islands;
D. Defining nesting, migration, and foraging grounds as Biologically Important Areas and as EPBC Act ‘critical habitat’ under the EPBC Act (as a requirement of the Recovery Plan);
E. Declaring marine protected areas (or other similar mechanisms) for critical hawksbill habitat within the Gulf of Carpentaria, particularly from Aurkun to southern Crab Island, and increasing customary law management and Torres Strait Treaty (conservation measure) protection in the Torres Strait; and,
F. Urgently re-introducing independent monitoring in all fisheries that interact or that are likely to interact with the neQLD stock, and mandate bycatch reduction measures and/or gillnet regulations to reduce interactions with hawksbill turtles.

ACKNOWLEDGEMENTS AND CONTRIBUTIONS

We would like to acknowledge Dr Ian Bell and the Queensland Government's Department of Environment and Science for their ongoing support, and both theirs and the Apudthama Indigenous Rangers contribution to the satellite tracking field work. Without them this project would not have been a reality. We greatly appreciated the remote transportation from the Apudthama Rangers, NPA Cape York Coast Guard, John Charlton's Strait Runner and Queensland Parks and Wildlife Service Reef Ranger. We also thank the Sea Turtle Foundation and Western Cape Turtle Threat Abatement Alliance for their field work assistance. To Dr Ben Gilby, Kevin Lay, Dr Martin Taylor, Dr Michelle Ward and Dr Ben Gilby we thank you for your spatial data and analysis assistance. Finally we'd like to acknowledge and thank the World Wide Fund for Nature, its donors and sponsors and the University of the Sunshine Coast for funding this work, and especially thank Wildlife Computers for their generous donation of 10 satellite trackers.

CMH conceptualised and designed the study and organised access to all datasets. CMH undertook all the field work and performed the threat assessments. CMH, CS, SM, KA, JM performed the statistical and spatial analyses. CMH wrote the first draft of the manuscript, CS, SM, JM contributed to writing sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

Chapter 6: From Rookeries to Foraging Grounds: Understanding Regional Connectivity and Genetic Diversity in Hawksbill Turtles

This chapter includes a co-authored manuscript that has been published in Frontiers in Marine *Science.*

Madden Hof, C.A., Desbiens, A.A., Kinch, J., Fitzsimmons, N., Versace, H., Amon, A., McIntyre, N., Townsend, K. & Jensen, M.P. (2023). From Rookeries to Foraging Grounds: Understanding Regional Connectivity and Genetic Diversity in Hawksbill Turtles. Frontiers in Marine Science (Accepted)

Abstract

This study investigated the genetic structure, diversity, and migratory patterns of hawksbill turtles (*Eretmochelys imbricata*) from two nesting locations in Papua New Guinea (PNG) using mitochondrial DNA (mtDNA) sequencing and satellite telemetry. Tissue samples collected from nesting female hawksbill turtles (n=75) in PNG revealed a total of 6 haplotypes from the Conflict Group site and 5 haplotypes from Kavieng site, with the Conflict Group and Kavieng samples significantly differing from one another and all other known Asia-Pacific stocks. This finding expands our understanding of the genetic stock structure of hawksbill turtles in the Asia-Pacific region, resulting in 9 Management Units (MUs) now published. Satellite tracking of 15 hawksbill turtles revealed that all individuals migrated from the Conflict Group westerly towards foraging areas in eastern Australia (93%) and PNG (7%). With a mean migration path distance of 1241 ± 108 km, three distinct migration strategies were used by the 10 hawksbill turtles that made it to their foraging grounds in the I) eastern Torres Strait, II) Far North Queensland, and III) western PNG waters. A broad scope of home-range strategies and sizes (95% UD) were used, and in comparison to other studies further postulates that hawksbills are connected to non-specific foraging grounds associated with food source availability. This study provides, for the first time in PNG, essential insights into hawksbill turtle population structure and connectivity in the western Pacific region, highlighting the importance of effectively conserving and managing this critically endangered species as distinct population stocks. Furthermore, we make recommendations for national and

regional conservation strategies and transboundary management to ensure the long-term survival and recovery of western Pacific's hawksbill turtle populations.

Introduction

The hawksbill turtle, *Eretmochelys imbricata*, is found in subtropical marine systems worldwide, but many populations are declining, particularly in the Indian and Western Pacific regions (Mortimer & Donnelly 2008; Hamann et al., 2022; Madden Hof et al., 2023a). Although Australia was reported to have one of the world's largest remaining hawksbill nesting populations (Limpus 2009; Limpus & Miller 2008), expiration as early as 2032 was recently predicted for the north-east Queensland (neQld) genetic stock (Bell et al., 2020). This raises concerns that hawksbill populations in neighbouring countries, with less protection, may face similar trajectories. Hawksbill turtles, considered "Critically Endangered" internationally, are listed differently throughout the western Pacific. For example, hawksbills are considered "Vulnerable" under Australian legislation but not listed in or protected by any laws in Papua New Guinea (PNG) (IUCN Red List 2015; EPBC Act 1999; Kinch & Burgess 2009; Kinch 2020a). This disparity is concerning because hawksbills are among the least-studied of the six marine turtle species (Limpus, 2008). With broad information gaps across Asia-Pacific (Hamann et al., 2022; Madden Hof et al., 2023a), substantial new information is required to inform immediate and effective management and conservation action.

There is a shortage of research on hawksbills in PNG, with only a limited number of studies to date. Previous work has focused primarily on broad historical analysis (Pritchard 1978; Spring 1982a, b) or short-term population assessments, primarily restricted to the Milne Bay Province (MBP) (Kinch, 2003; Wangunu et al., 2004).

Louisiade Archipelago has the largest area of reef in the MBP (at about 7,980 km^2; Skewes et al., 2011) and is thought to support one of the largest populations of hawksbills nesting in PNG at the Engineer, Deboyne, Conflict and Jomard Group of Islands (Kinch, 2020a). Although sea turtles were monitored at the Jomard Group in 2003 (Kinch 2003a) and on two separate occasions in the Conflict Group of Islands (Conflict Group) (Wangunu et al., 2004; Aigoma 2009), there are currently no peer-reviewed publications on the genetic population structure, dynamics or trend estimates. The only demonstration that hawksbill populations are declining is provided by reports showing overexploitation (Wangunu et al., 2004). Although limited flipper tag returns have shown some connectivity between foraging ground in Australia and rookeries across the Bismarck-Solomon Sea region (Barr et al., 2021; Bell & Jensen 20018; Limpus, 2009), there are also no published satellite tracking records to show migratory routes between nesting and foraging grounds.

According to a recent satellite telemetry study by Madden Hof et al. (2023b), the neQld stock's geographical range is likely limited to Australian waters. While this study also revealed a dominance of the neQld stock in western Queensland (western Torres Strait and western Cape York), the neQld stock shares east coast Queensland waters with mixed genetic stocks, including the Solomon Islands, Vanuatu, and foragers of unknown origin (Broderick et al., 1994; Bell & Jensen, 2018, FitzSimmons & Limpus, 2014; Hamilton et al., 2015; Limpus, 2009 Vargas et al., 2016). Likewise, hawksbill turtles nesting in the Solomon Islands also migrate to the east coast of Queensland, Australia to forage (Hamilton et al., 2021). Limited tag returns show that turtles from eastern PNG use foraging areas along the Great Barrier Reef (Ange Amon pers. comm; Bell & Jensen, 2018; Hayley Versace pers. comm; Limpus, 2009). Yet, it remains unknown if hawksbill turtles nesting within PNG are part of the Solomon Islands or neQld genetic stocks, also referred to as Management Units (MU's), or if they are distinct.

In response, a conservation-based not-for-profit organisation, the Conflict Island Conservation Initiative (CICI), instigated a long-term saturation tagging program of hawksbill and green turtles (*Chelonia mydas*) at the Conflict Group in MBP, to monitor the populations and assess the level of poaching effort with the view to protect turtle populations and their habitats within a marine protected area. Local people from the Engineer Group of Islands and the Deboyne Group of Islands harvest sea turtles and their eggs from the Conflict Group for consumption and trade (Kinch 2003b, 2020b). Historically, the Conflict Group has been granted as freeland title from 1846–2016 that includes various proposed developments, from sponge and pearl farms to the establishment of coconut plantations to produce copra and the developments of private island dominion of several bio-engineered islands and marinas. Today, the Conflict Group is owned and managed by Ian Gowrie-Smith, an Australian businessman, resulting in the establishment of CICI. Since 2016, saturation flipper tagging programmes have been conducted in the Conflict Group (CICI 2018, 2019;

CICI and Coral Islands Ltd. 2021; CICI and Coral Islands Ltd 2022), with nesting hawksbill turtle numbers adequate for undertaking satellite tracking and genetic studies, which is a first for PNG.

Along a similar timescale, a conservation program began in 2013 at Lissenung Resort and the nearby islands of Ral and Edmago in New Ireland Province, PNG. Local people frequently harvest sea turtles from these islands. The conservation program includes nest monitoring on three islands and management of a hatchery to protect hatchlings, as well as providing education, awareness and employment opportunities. Over the years, the conservation program has protected more than 16,000 hawksbill hatchlings which enabled the program to undertake wider genetic studies of hawksbill turtle populations in PNG.

Molecular (DNA) sampling provides a time-efficient and cost-effective way to assess the genetic stock structure and geographical boundaries of individual stocks and can be used to connect turtles at foraging areas to their nesting population origin (stock origin). Based on mitochondrial DNA (mtDNA) there are currently seven distinct MU's for hawksbill turtles in the Asia-Pacific region (Vargas et al., 2016, Nishizawa et al. 2016; Wahidah and Syed Abdullah 2009) encompassing one or more rookeries. Many gaps remain however, limiting the use of accurate genetic stock assignments (LaCasella et al. 2021). In this case, satellite tracking studies can pinpoint migration paths and foraging ground home ranges, enhancing our comprehension of hawksbill fine-scale orientation, navigation, fidelity and habitat use (refer citations in Barr et al., 2021). By combining these methods, we can gain a much deeper understanding of the spatial dynamics of marine turtle populations, which is crucial for effective conservation planning and management.

Using a combination of satellite telemetry and genetic analysis, this study aimed to determine the stock structure of hawksbill turtles in PNG and the migration paths of MBP hawksbill turtles to their foraging grounds to assess their connectedness to the western Pacific and broader Asia-Pacific region, and inform future management and protection of hawksbills in PNG.

Materials and Methods

Sample sites

This study was carried out at two hawksbill turtle nesting locations in PNG, separated by an approximate distance of 920 km (Figure 6.1).

Conflict Group of Islands (10° 46' 10.992'' S; 151° 45' 26.2512'' E) is located approximately 150 km southeast of Alotau in the Louisiade Archipelago within MBP. The Conflict Group consists of 21 uninhabited islands, except for a small resort on Panasesa. The main islands include Irai, Gabugabutau, Tupit (Tobiki), Panarakuum, Kolavia, Muniara, Aroroa, and the Reef Islands. Both satellite tracking and genetic sampling were conducted at the Conflict Group during the nesting season (November–March) from 2017 to 2020.

Kavieng (2° 34' 25" S; 150° 47' 43" E) is located at the northern tip of the New Ireland Province. Since 2013, Ral island, Edmago island and the larger Lissenung Island, have been monitored for turtle nesting by the owners of Lissenung Resort. These islands are located to the west of the Kavieng township and remain unoccupied, except for a small resort on Lissenung. From mid-September to the end of March, a conservation project relocates marine turtle eggs to incubate in the resort hatchery. From 2015–2021, genetic samples from one hatchling per nest were collected and donated to this study.

Genetic sampling

At the Conflict Group, a total of 39 tissue samples were collected from nesting female hawksbill turtles across multiple islands from 2017 to 2020. Skin samples (<0.5 cm^2) were collected using a scalpel blade from the front or rear trailing flipper and stored in 2 ml cryo-vials in >70% ethanol. At the Conflict Group, all nesting hawksbills were tagged with a titanium tag (Limpus 1992), and measured for curved carapace length (CCL) before being released.

At Kavieng, 56 tissue samples were collected from hawksbill hatchlings on Ral, Edmago, and Lissenung Islands from 2015 to 2021. No nesting females were encountered at the Kavieng sites, but nests were translocated to a protected hatchery. One tissue sample was collected from a single hatchling from each nest and stored in 2 ml cryo-vials in >70% ethanol. All samples were stored (-20 °C) and transferred to Griffith University in Australia for long-term storage and analysis.

All research was conducted under PNG's National Research Institute approval. All genetic samples were transported to international universities for analysis under CITES permits 018140 and 022064 (export) and WT2019--000439 and PWS2021-AU-001689 (import).

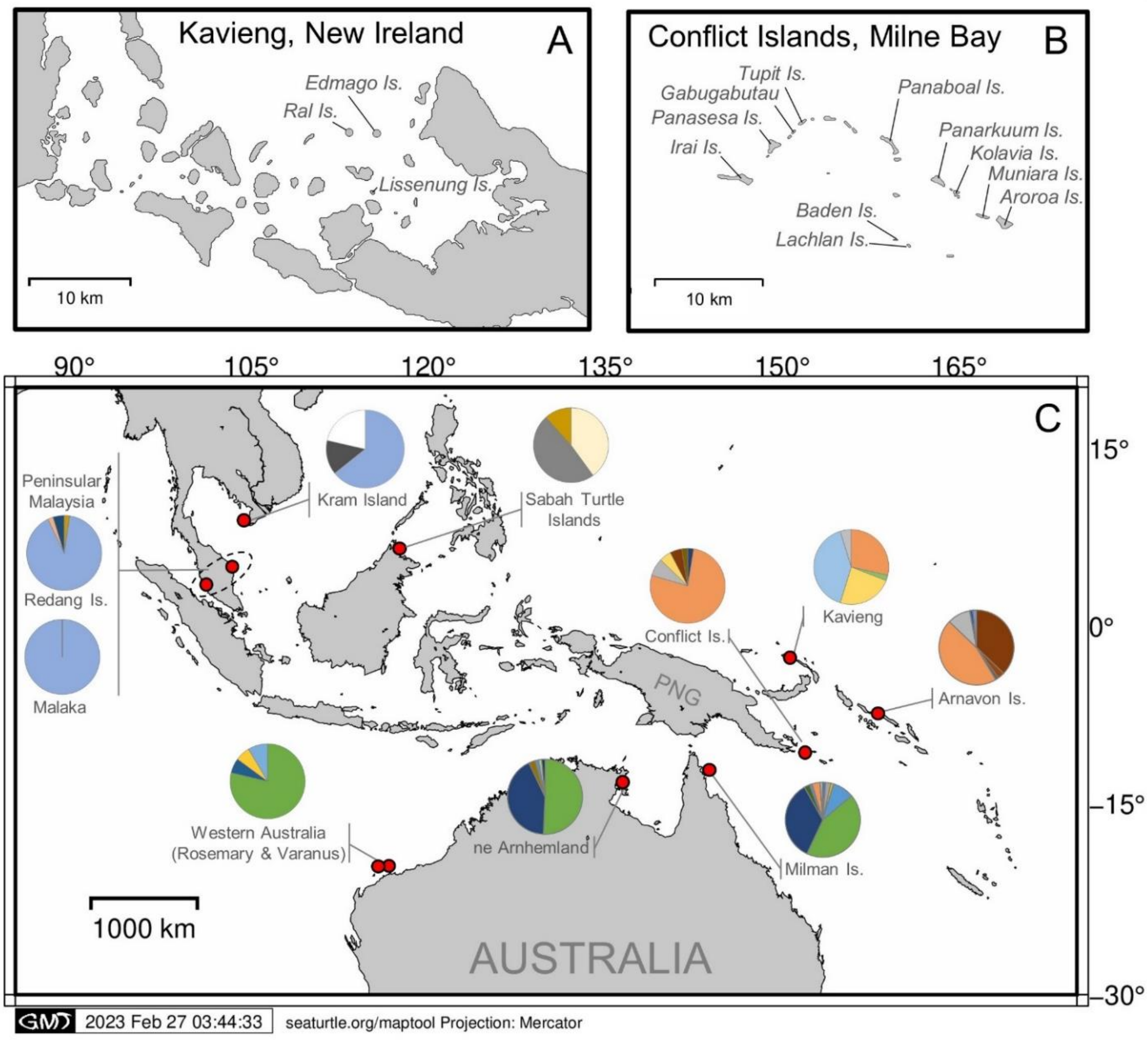

Figure 6.1: Locations of hawksbill turtle genetic sampling in **A)** Kavieng, New Ireland Province and with the addition of satellite tagging, in **B)** the Conflict Group of Islands, Milne Bay Province. **C)** Sampling locations and haplotype frequencies (shown as pie graphs) across Asia-Pacific.

Laboratory analysis

Genomic DNA was obtained from all samples using the salting out extraction method described in Jensen et al. (2013). The control region (or d-loop) of the mitochondrial genome was amplified to generate about 800 base pair sequences using LCM-15382 (5' GCT TAA CCC TAA AGC ATT GG 3') and H950g (5' GTC TCG GAT TTA GGG GTT TG 3') primers (Abreu-Grobois et al. 2006), PCR reactions were carried out in a 25 µl reaction volume. The PCR cycling parameters were as follows: an initial 4 min of DNA denaturation at 95°C, followed by 36 cycles of 25 s at 95°C, 25 s at the annealing, temperature, and 30 s at 72°C, followed by a final 2 min of extension at 72°C. The annealing temperature consisted of 2 cycles at 56°C, 2 cycles at 54°C and 33 cycles at 52°C. Each PCR setup included negative controls to detect contamination, and the PCR products were visualized on 1.2% agarose gels stained with SYBR Safe DNA Gel Stain (Thermo Fisher Scientific). The PCR products were purified, and sequenced by Macrogen Inc. (Seoul, Korea).

Raw sequences were edited using the software Geneious 6.1.7. (https://www.geneious.com). (Applied Biosystems, Foster City, California, USA). Each sequence was manually inspected for uncalled and miscalled bases, and all variable positions were confirmed by comparing sequences from the forward and reverse strands. Haplotypes were assigned by comparing aligned sequences to the ShellBank database (global marine turtle reference database; www.shellbankproject.org), which contains a reference library of published hawksbill haplotype sequences, and by searching the GenBank database (http://www.ncbi.nih.gov). The standardised nomenclature was used to name the new haplotypes using the EiIP prefix for Indo-Pacific hawksbill haplotypes, followed by the next number in order. New haplotypes were submitted to GenBank (http://www.ncbi.nih.gov). The sequences were then aligned, edited, and cropped at a standard cropping site of approximately 770 bp using Geneious Prime.

Population genetic analysis

We analysed all 39 Conflict Group hawksbills confirmed as independent nesting individuals through flipper tags. For Kavieng, a total of 52 samples were sequenced, but after excluding hatchling samples likely to be from the same mother, only 42 samples remained and were used for the final analysis. When the mother could be sampled (and tagged), one hatchling from each nest may represent the nesting female since they carry the same copy of mtDNA. However, since hawksbill turtles may lay 1–5 nests within a season, it is important to avoid pseudo-sampling (i.e. sampling the offspring from the same mother in consecutive nests). To ensure individual hatchlings from different mothers were selected, we applied a conservative 10 to 18-day window, the renesting interval for hawksbill turtles when hatchlings with the same haplotype could originate from the same mother. This was assumed for up to four consecutive nests. This let us rule out any hatchlings born during that time with the same haplotype, increasing the chance that samples represented individual nesting individuals (Table S6.1). Although we do not know the remigration interval for hawksbill turtles in PNG (but likely 2-9 years (Limpus, 2009)), and given the harvest pressure, the likelihood of re-sampling the same mother is reduced but pseudo-sampling across years cannot be ruled out. Furthermore, we observed no substantial differences in haplotype frequencies between the strategies (not removing samples and removing samples). Given these results, we are confident that regardless of the strategy applied, it will not significantly affect the study's outcomes.

In addition to samples from rookeries in Kavieng and the Conflict Group we included data from nesting hawksbill turtles in Thailand at Kram Island (Wahidah and Syed Abdullah 2009), Malaysia at Malaka Island, Redang Island, and Sabah Turtle Islands (Nishizawa et al. 2006, Vargas et al. 2016, Wahidah and Syed Abdullah 2009), in Australia at Western Australia, northeast Arnhemland in the Northern Territory and north Queensland (Vargas et al. 2016, Bell and Jensen 2018, LaCasella et al. 2021), and from the Solomon Islands (Vargas et al. 2016, LaCasella et al. 2021) (Table S6.2). We first tested for any significant genetic structure across years and studies to combine various published datasets from the region. These included five data sets from Sabah Turtle Islands in East Malaysia (Vargas et al. 2016, Nishizawa et al. 2016, Wahidah and Syed Abdullah 2009), three datasets from Malaka (Nishizawa et al. 2016, Wahidah and Syed Abdullah 2009) and three datasets for Redang (Vargas et al. 2016, Nishizawa et al. 2016) in Peninsular Malaysia, two datasets from Milman Island (Vargas et al. 2016LaCasella et al. 2021) and two datasets from Arnavon, Solomon Islands (Vargas et al. 2016 LaCasella et al. 2021) (Table S6.2). All subsequent analyses were performed on pooled datasets across locations and years were appropriate.

Population structure was tested using pairwise F_{ST} comparisons and exact tests of population differentiation with the software Arlequin v 3.5.1.2 (Excoffier and Lischer 2010). To determine significance, a probability level of $P < 0.05$ was used. A first round of pairwise comparisons tested temporal trends within previously published rookeries collected across different years and studies to determine if these could be combined or if haplotype composition had changed significantly over time. A second set of pairwise comparisons tested previously identified genetic stocks against the two new sites at the Conflict group and Kavieng to assess the overall stock structure. Significance values for F_{ST} were obtained from 10,000 permutations. Exact tests of population differentiation were conducted with 100,000 permutations and 10,000 dememorization steps (Raymond and Rousset 1995). Finally, haplotype (Hd) and nucleotide (π) diversity were calculated for each Management Unit using Arlequin v 3.5.1.2 (Excoffier and Lischer 2010). Haplotype diversity was assessed following Nei (1987), and nucleotide diversity was computed using Tamura and Nei's model (1993).

Post-nesting tracking and analysis

Sixteen Argos satellite tags (SPOT6, Wildlife Computers, Seattle, Washington, USA) were attached after oviposition to nesting hawksbill turtles found on various islands of the Conflict Group during the 2017-2018 and 2018-2019 nesting seasons (Figure 6.2; Table S6.3). As per Godley et al., (2002), satellite tags were attached anteriorly to the hawksbill turtles carapaces and were released when the epoxy (Sika AnchroFix -3+) had completely cured to avoid turtles rubbing off the tag. The tags were additionally painted with International Micron 66 anti-fouling paint to prevent algal growth and other fouling organisms. All turtles' curved carapace lengths (CCL) were measured and individually numbered titanium flipper tags were applied prior to release.

The Argos satellite system (http://www.argos-system.org/) was used to relay location data, and the Wildlife Computer Portal was used to store the received data. Filtering of all tracks and analysis was conducted in R Statistical Software (V4.0.0; R Core Team 2021). Argos locations were first filtered using the R package SDLfilter (Shimada et al. 2016) to remove duplicates and positions with location errors of > 1km, i.e., only Argos classes 0, 1, 2 and 3 were retained. Locations between which swimming speeds were deemed implausible (> 5 km/hr as per Shimada et al. 2012) were also removed. The remaining track locations were intersected with spatial polygons of land masses, and any fixes that overlapped were discarded. We visually assessed the trajectories of each turtle to classify track segments as either inter-nesting, migratory or foraging behaviours. The start of the migration period was defined as the point when individuals showed directed and continuous movement away from nesting areas. We considered foraging behaviour had begun following a significant decrease in overall swim speed and the cessation of directed movement.

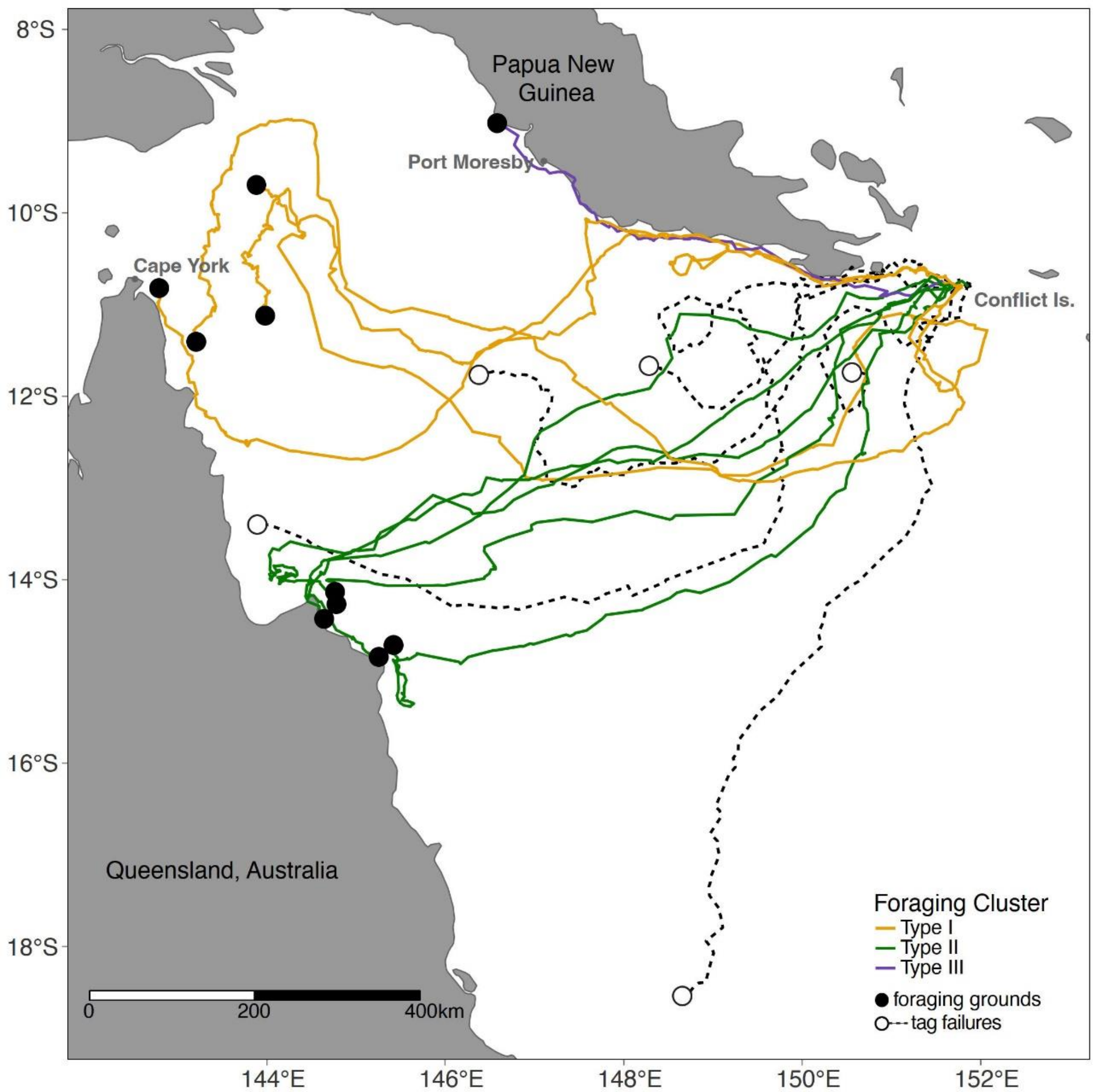

Figure 6.2 Satellite tagging locations of hawksbill turtles. Migratory routes and foraging ground end points (shown as circle). Foraging ground clusters (Type I,II,III) shown in colour as per legend. See Table S6.3 for tag and turtle details.

To describe migration, we calculated swimming speed, distance, and total duration for each turtle. For turtles that arrived in foraging areas (n = 10), we quantified foraging activity by estimating the 50 and 95% utilisation distributions (UDs) using minimum convex polygons implemented using the adehabitatHR package (Calenge 2006, 2015). We assumed the 50% UD contour to represent each turtle's core centre of activity and that the 95% UDs represented overall foraging areas. Turtles were classified into foraging groups based on the spatial clustering of their foraging home ranges.

Results

Genetic structure and diversity

Sequence data from ~770 bp fragments of mtDNA were used from 39 nesting females at the Conflict Group and from 42 hatchlings from Kavieng (Table S6.2). We identified a total of 6 haplotypes from the Conflict Group. The most common was haplotype EiIP-33 (84.6%), followed by EiIP-34, EiIP-59, EiIP-93, EiIP-09 and EiIP-114 all found a low frequency (<8%), with no new haplotypes identified. From Kavieng, we identified a total of 5 haplotypes, with the most common being haplotype EiIP64 (39%), followed by EiIP-33 (29%), EiIP-59 (24%), EiIP-39 (2%) and one newly discovered haplotype, EiIP-150 (5%) (Genbank Accession: to be added) (Table S6.2).

Given that multiple studies have been conducted from these sites over many years, the first step was to test for temporal variation in rookeries with data from several studies collected across multiple years. Both pairwise F_{ST} and exact tests showed no significant differentiation across studies or years within the same location except for samples from Sabah Turtle Islands from 2014 (Nishizawa et al. 2016) which were significantly different from other years within Sabah Turtle Island (F_{ST} = 0.07817 - 0.15951, $P < 0.05$), and exact test ($P < 0.05$) (Table 6.1). As a result, all samples within rookies were combined, with the exception of Sabah Turtle Islands, which were separated into East Malaysia "Old" (1998-2008) and East Malaysia "New" (2014) in subsequent analyses. A similar result was found in Nishizawa et al. (2016).

The haplotype frequencies of samples from the Conflict Islands was significantly different from those of the Kavieng rookeries for both the exact test ($P < 0.0001$) and F_{ST} (F_{ST} = 0.270, $P \leq 0.01$; Table 6.1). Moreover, the Conflict Group and Kavieng samples each differed significantly from the

Asia-Pacific hawksbill stocks in Malaysia, Australia and the Solomon Islands (Figure 6.1, Table 6.1). Both the exact test and F_{ST} indicated high significance differentiation, except for Milman Island and Arnhem Land, which showed significant differences for the exact test (P = 0.0084) but not for the F_{ST} test (F_{ST} = 0.0059, P = 0.2129) (Table 6.1). Due to breeding seasonality (predominantly summer vs winter nesting), these genetic stocks have already been deemed separate MUs (Vargas et al., 2016). This represents at least nine hawksbill MUs now characterised in the Asia-Pacific region (Figure 6.1).

Estimated nucleotide diversity ranged from very low in Peninsular Malaysia (0.00027) to high in Milman Island (0.01994), with intermediate levels at Conflict Group (0.00263) and Kavieng (0.00138) (Table S6.4). Haplotype diversity was highest at Kavieng (*h* = 0.7120 ± 0.0346), relatively low at Conflict Group (0.4062 (±- 0.0969), and lowest at Peninsular Malaysia (0.0901 (± 0.0421) (Table S6.4).

Satellite tracking

All turtles tagged were “primary” or “within season recaptured” turtles (meaning caught for the first time or within the nesting season), with a mean CCL of 80.9 (s.d.=,2.60, range = 77.5 to 86.3 cm, n = 16) and mean curved carapace width (CCW) of 71.9 (s.d. = 3.24, range = 66.1 to 76 cm, n = 8) (Table S6.3). Fifteen hawksbill turtles were tracked for a total of 4476 days ranging from 53 to 747 days (mean ± SE = 298 ± 66). The sixteenth hawksbill stopped tracking within 27 days and did not leave the vicinity of the initial tagging location before tag failure. Upon tag assessment, no apparent cause to the failure could be attributed, including poaching. This turtle was excluded from all remaining analyses.

Migration to foraging areas

All 15 satellite-tagged turtles migrated from the Conflict Group westerly towards their distinct foraging grounds. Fourteen of the turtles (93%) migrated towards eastern Australia, while only one individual (7%) stayed within PNG coastal waters, north of Port Moresby and Redscar Bay. Four tracked turtles stopped transmitting in the Coral Sea while on a migratory trajectory towards the eastern coast of Queensland, and the other stopped tracking within PNG not far from the Conflict Group.

Table 6.1 Matrix of population differentiation showing pairwise FST values below the diagonal and exact test results above the diagonal. Pairwise FST values represent the genetic differentiation between populations, with values ranging from 0 (no differentiation) to 1 (complete differentiation). The significance level (p-value) is indicated P ≤ 0.01 (**), P-value ≤ 0.05 (*), or non-significant (P-value) > 0.05 (n.s.) For the exact test results indicate the actual p-values with standard deviation (±).

	Malaysia old	Malaysia New	Kram Island	Peninsular Malaysia	Western Australia	Arnhemland	Milman Island	Arnavon Is	Conflict Islands	Kavieng
Malaysia old		0.00015 +-0.0001	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000
Malaysia New	0.10258 **		0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000
Kram Island	0.34771 **	0.4121 **		0.00049 +-0.0002	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000
Peninsular Malaysia	0.59193 **	0.68631 **	0.33261 **		0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000
Western Australia	0.44036 **	0.50473 **	0.56511 **	0.80324 **		0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000
Arnhemland	0.36353 **	0.41366 **	0.43252 **	0.68658 **	0.20657 **		0.00840 +-0.0027	0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000
Milman Island	0.30779 **	0.35082 **	0.35551 **	0.61118 **	0.18176 **	**0.00588** **n.s.**		0.00000 +-0.0000	0.00000 +-0.0000	0.00000 +-0.0000
Arnavon Island	0.32602 **	0.37239 **	0.38092 **	0.64975 **	0.47442 **	0.38914 **	0.31811 **		0.00000 +-0.0000	0.00000 +-0.0000

Conflict Islands-PNG	0.42198 **	0.48471 **	0.5387 **	0.80133 **	0.6115 **	0.49336 **	0.40757 **	0.16405 **		0.00000 +-0.0000
Kavieng-PNG	0.29785 **	0.34626 **	0.34774 **	0.67455 **	0.46236 **	0.36568 **	0.29334 **	0.21839 **	0.26973 **	

Only 10 satellite-tagged turtles reached their foraging grounds (Figure 6.2; Table 6.2). Of the ten turtles that reached their foraging ground, the total migratory path distance ranged from 537 to 1715 km, with a mean migration path distance of 1241 ± 108 km, and an average straight-line migration distance of 854 ± 35 km (Table S6.5). The migration duration ranged from 24 to 65 days (mean = 38 ± 4), at an average swimming speed of 1.67 km/h ± 0.14 (Table S6.5).

The migration pattern and foraging ground selection of the tracked turtles resulted in distinct clustering and were described as one of the following three groups (Figure 6.3; Table 6.2): **Type I**, turtles migration ending in foraging grounds of the Torres Strait, Far North Queensland (n=4 individuals); **Type II**, settlement in Northern Queensland (n=5 individuals); and, **Type III**, the turtle that remained foraging in PNG waters (n=1 individual).

All turtles chose individual foraging grounds located on reefs surrounding remote coral reef islands or submerged coral reefs on the eastern outer barrier reefs of Australia or adjacent to the eastern Queensland mainland. On average, the distance from these coral reef foraging ground home ranges to shore was 37.05km ± 13.05 km (Table 6.2). The Type III cluster showed much larger, and Type II showed much smaller overall and core home ranges (Table 6.2). Foraging home ranges (95% UD) ranged in size from 7.97 km^2 (Type II) to 208.6 km^2 (Type III) (mean = 74.59 ± 19.14), and core home ranges (centre of activity; 50% UD) ranged in size from 2.34 km^2 (Type II) to 12.5 km^2 (Type III) (mean = 5.98 ± 0.96) (Table 6.2).

Table 6.2 Home range analysis using minimum convex polygons (MCP) for ten hawkbill turtles during their foraging period.

PTT	Foraging date range	Foraging group	No. foraging days	No. foraging locations	Minimum distance to mainland (km)	50% MCP (km^2)	95% MCP (km^2)
49861	13.04.2018 – 28.01.2020	Type I Torres Strait /FNQ	655	1514	132.35	4.75	48.10
49864	01.04.2019 – 30.05.2020	Type I Torres Strait /FNQ	425	977	14.31	4.00	54.24
49903	07.04.2018 – 05.09.2019	Type I Torres Strait /FNQ	516	964	86.22	3.42	58.14
49917	07.04.2018 – 03.02.2019	Type I Torres Strait /FNQ	302	192	39.87	5.36	58.96
49868	01.02.2019 – 05.04.2019	Type II Northern QLD	63	84	4.43	7.88	43.47
49870	09.03.2019 – 08.11.2019	Type II Northern QLD	244	627	29.57	7.09	152.89
49871	11.03.2019 – 02.08.2019	Type II Northern QLD	144	340	25.56	8.45	81.43

49891	04.04.2018 – 15.01.2019	Type II Northern QLD	286	224	23.87	2.34	32.08
49900	07.02.2018 – 07.03.2018	Type II Northern QLD	28	7	0.43	3.99	7.97
49869	03.02.2018 – 20.01.2020	Type III PNG Resident	716	1505	13.86	12.50	208.62
Mean ± SE	-	-	-	-	**37.05 ± 13.05**	**5.98 ± 0.96**	**74.59 ± 19.14**

Type I cluster turtles foraged in the very northern Great Barrier Reef complex (40%), in the vicinity of the index nesting beach for the northeast Queensland hawksbill turtle stock (neQld stock), Milman Island, as well as the key nesting beach in the Torres Strait, Aukane. No turtle foraged west of these reef systems. Type II cluster turtles foraged near Howick Group of Islands between South Warden Reef and Lizard Island (50%), a well monitored long-term tagging site for the neQld stock (Bell & Jensen, 2018). Type II home ranges were closer to shore (on average) in comparison to the other clusters, likely due to the proximity of the reef complex to the mainland. Type III cluster turtle foraged along the coastline near Port Moresby (10%). As of yet, limited coral reef studies have been undertaken in this locality in PNG to inform reef type and structure.

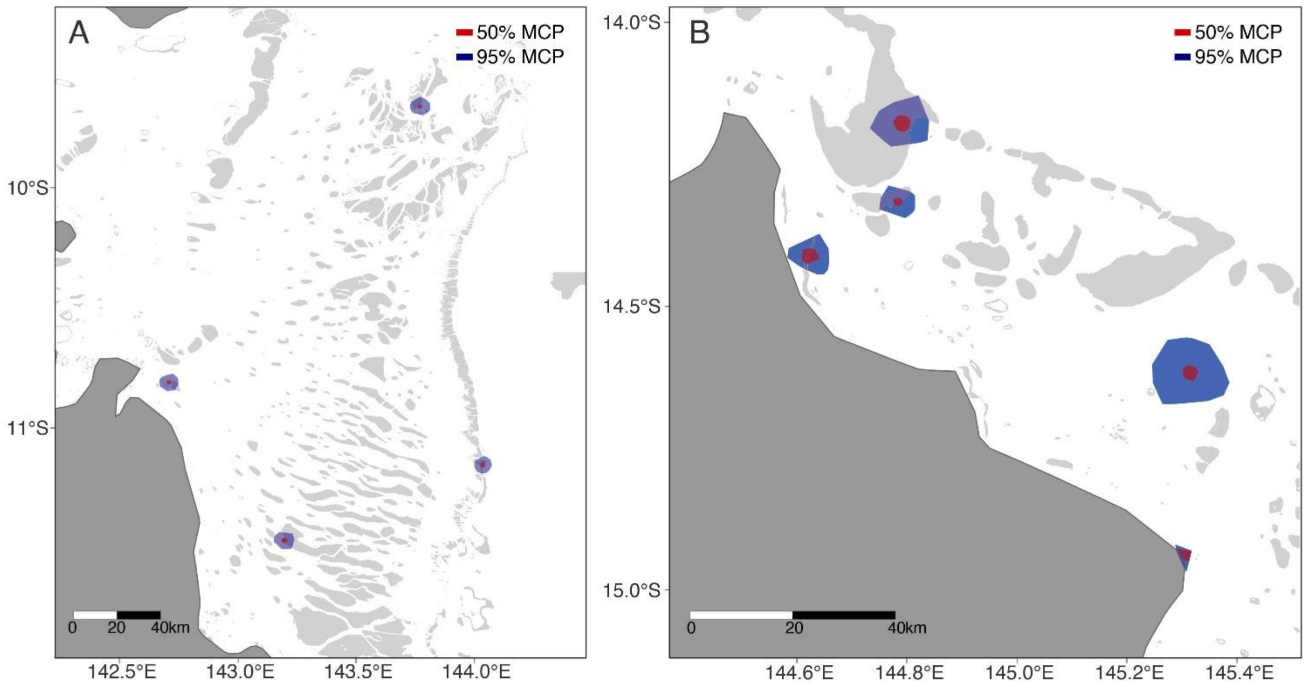

Figure 6.3 Type I and Type II home ranges. Type III not shown. Red circles denote 50% UD, blue circles 95%UD.

Discussion

Our genetic results show that the Conflict Group and Kavieng samples were each significantly differentiated from all other known Asia–Pacific genetic stocks and should be considered two independent MU's - Milne Bay Province (MBP MU) and eastern New Ireland Province (eNIP MU), respectively. This expands our understanding of the genetic stock structure of hawksbill turtles in Asia-Pacific, resulting in nine MU's for this region. In addition, satellite tracking revealed that all 15 tagged turtles migrated from the Conflict Group westerly towards foraging areas in eastern Australia and PNG. Together, these results provide important new insights into the population structure and connectivity of hawksbill turtles in the western Pacific region.

On a region-wide scale, pairwise F_{ST} and exact tests showed no significant genetic differentiation across studies and years within the same location except for Sabah Turtle Island samples from 2014, which were significantly differentiated from samples taken in other years. A likely explanation, also proposed by Nishizawa et al. (2016), is that the there was a higher frequency of the EiIP48 haplotype and a lower frequency of the EiIP49 haplotype in 2014 could be due to incomplete sampling in previous years. However, despite the fact that sea turtles typically maintain a stable genetic composition over time, changes can occur.

Similar to green turtles, there seems to be limited dispersal of hawksbill nesting females (lineage) between the nine hawksbill turtle rookeries across geographical seascapes of the western Pacific Ocean with significant genetic differences among rookeries located more than 500 km apart (Dethmers *et al.,* 2006; Dutton *et al.,* 2014). However in northern Queensland specifically, this differs for both green and hawksbill turtles in that hawksbills are more closely linked to northeast Arnhem Land stocks than western Pacific stocks, whereas green turtle stocks of northern Queensland are less similar to western Queensland and more closely linked to New Caledonia in the south western Pacific (Dethmers et al. 2006; Jensen et al. 2019). Identification of the two new MU's for PNG improves the baseline data for conducting these mixed stock analyses to determine population origin of hawksbill turtles at feeding grounds and in harvests (LaCasella et al. 2021)) in the western Pacific.

Based on flipper-tag returns, hawksbill turtles have been shown to make reproductive migrations from regional western Pacific rookeries, including New Ireland and Milne Bay Provinces, to foraging grounds at the Howick Group of Islands (Great Barrier Reef, north eastern Queensland, Australia) (Bell & Jensen, 2018). This was corroborated by Lissenung Resort (pers comm. Ange Amon) and CICI (pers comm. Hayley Versace). A new haplotype was identified in the Kavieng samples (EiIP-150; GenBank Accession ID: to be added). Interestingly, two previously orphan haplotypes (EiIP-39 and EiIP-59) found in foraging hawksbills at the Howick Group of Islands (Bell & Jensen 2018) and in tortoiseshell products from the Solomon Islands (LaCasella et al. 2021) have now been identified in the Conflict Group (EiIP59) and Kavieng (EiIP-39, EiIP-59), providing a likely origin for those samples. This study also corroborated this finding using satellite tracking from the Conflict Group whereby 10 out of 15 satellite-tracked hawksbill turtles migrated to eastern Queensland and half of these (50%, n = 5) foraged nearby the Howick Group of Islands.

As with other studies, the Conflict Group hawksbill turtles meandered along their post-nesting migratory routes and showed fidelity to multiple small foraging grounds with little collective specificity towards a singular/particular foraging ground (Gaos, 2011; Hamilton *et al.,* 2015; Madden Hof, 2023b). Yet there was some preference for following a general migratory pathway and selecting specific foraging ground reefs as a collective (or cluster; Type I, II, III). Yet, Type III cluster was based on a small sample size (n=1), making it necessary to conduct further research to draw more conclusive results. However, staying local seems to be a relatively uncommon behaviour among hawksbill turtles in this region. The Solomon Islands genetic stock also utilises these cluster pathways and foraging grounds, whereby 93% of the Arnavon satellite-tagged hawksbill turtles migrated across the Coral Sea to reside in PNG or Australia (Hamilton *et al.,* 2021). This highlights the regional importance of these waters and migratory cluster pathways for western Pacific hawksbill populations. Of particular interest is the highly similar mean migration speed (1.63 km h^{-1} and 1.67 km h^{-1}, respectively). The mean migration of hawksbills from PNG (1241 km) is greater than most studies, for example, in Hawaii (218 km, Parker *et al.,* 2009), Eastern Pacific (113 km, Gaos *et al.,* 2012a), Northern Territory (Australia) (349 km, Hoenner *et al.,* 2016), and US Virgin Islands (67 km, Hart *et al.,* 2019), except for the Solomon Islands (2028 km, Hamilton *et al.,* 2021).

Where size and use of turtle foraging home ranges is connected to adequate habitat and food sources (Barr *et al.,* 2021; Hoenner *et al.,* 2016), the present study also showed a broad scope of home-range strategies and sizes (95% UD) that differed to other studies, even when other genetic stocks share the same coastal waters of eastern Queensland (e.g Solomon Islands and neQld stocks). For example, the mean home range (95%UD) of hawksbill turtles that made it to their foraging grounds in eastern Queensland from the Solomon Islands (Arnavon) genetic stock was 5.5km^2, compared to Torres Strait tracked turtles at 1.4km^2, and the PNG genetic stock at 25.3km^2. Of similarity, between the Solomon Islands and PNG genetic stocks, was the greater home range (95%UD) utilised in PNG (23.5km^2, 4 times larger; and 208km^2, 8 times larger, respectively) in comparison to the Australian reefs, further postulating that hawksbills forage and are connected to non-specific foraging grounds associated with food source availability.

Implications for management

The aim of this study was to assess if hawksbill turtles at the Conflict Islands and Kavieng were individual genetic stocks or if they were connected to each other or other western Pacific stocks in the Solomon Islands or Australia. This study's findings emphasise that the two newly described PNG genetic stocks need to be managed as demographically separate MU's, but their migratory and foraging life history also links them to Australia's management and conservation action. The importance of Australia's habitat in supporting multiple (mixed stock) hawksbill turtle populations has been highlighted by other recent studies (neQld, Madden Hof *et al.,* 2023b; Solomon Island, Hamilton *et al.,* 2021; Torres Strait, Barr *et al.,* 2021; Vanuatu, Jim *et al.,* 2022). This highlights the need for greater national and regional cooperation, particularly given the decline in the neQld hawksbill stock (Bell *et al.,* 2020) and the likely decline of other western Pacific hawksbill populations (Pilcher *et al.,* 2021). Also, sea turtle harvesting for meat and eggs in Australia and PNG is a traditional fishery undertaken by traditional owners in coastal and islander communities. Within PNG, shells are also used to make utilitarian items such as needles and limes spatulas, decorations such as earrings and bracelets, and for ceremonial purposes or trade (Kinch & Burgess, 2009). Despite efforts to track harvest levels in PNG, accuracy is complicated due to the remote nature of harvesting locations and limited government presence (Kinch, 2020a). Small-scale artisanal fisheries (Eley, 1998; Kwan, 1991) and market surveys (Hirth & Rohovit 1992; Kinch & Burgess 2009) have reported evidence of hawksbill turtles (with particular concern raised for MBP) being heavily targeted by local inhabitants of the Louisiade Archipelago (Kinch, 2020b). These findings align with an assessment of exploitation in PNG, which identified MBP as one of three targeted harvest locations in need of intervention (Opu, 2018).

Ineffective, unregulated or complete lack of management and/or protection at hawksbill rookeries or foraging grounds is likely to negatively impact the PNG population and other western Pacific stocks (Bell & Jensen, 2018; Madden Hof *et al.,* 2023a). In the context of PNG, no marine turtle, with the exception of the leatherback turtle, is protected by PNG's legislation (e.g. *Fauna (Protection and Control), 1976* (Kinch, 2006)). There are no laws, regulations, or quota limits to harvesting hawksbill turtles or to sell, offer or consign sale or be in possession. The *International trade (Fauna and Flora) Regulation, 2014* does prescribe that it is illegal to trade to and from PNG in CITES-listed fauna (which includes hawksbill turtles). The taking of hawksbill turtles by Papua New Guineans within Australia's EEZ (i.e. the Torres Strait Protected Zone) is also allowed under the *Torres Strait Treaty, 1985* as long as they are traditional inhabitants of 'Treaty' Villages conducting "traditional fishing". However, each Party should to its best endeavours identify and protect fauna that are or may become threatened with extinction (Article 14(1)(a) *Torres Strait Treaty, 1985*; Kinch, 2020a). However, inhabitants assignment, regulations and enforcements are limited (Busilacchi *et al.,* 2018).

There are, however, many other laws that could support sea turtle conservation in PNG (refer, Kinch, 2006, 2020a), including the *Organic Law on Provincial Governments and Local-level Governments, 1997*, which allows for the development of local-level conservation laws (under Sections 42 and 44) and could potentially be used to ban or limit hawksbill turtle and egg take, and establish nesting beach closures. Additionally, the *Fisheries Management Act, 2016* provides the framework to regulate hawksbill turtles as a sustainable fishery. While all potential options require scientifically based assessments of PNG's hawksbill turtle population status and trajectory that are informed by annual harvest rates, applying the precautionary principle could at least ensure a level of protection as an intermediary step. Initial protection could be afforded through the uplisting of hawksbill turtles as a 'Protected Species' under the *Flora and Fauna Protection and Control Act, 2014*, alongside a review and strengthening of the *Torres Strait Treaty, 1985*. In acknowledging the role of marine turtles in local communities, it is suggested the strengthening of these policy and legislative options be considered and planned in consultation, with and in recognition of, communities and their rights to sea turtle resources. This should be done alongside improvements to the local community economy and provision of alternatives to the reliance on hawksbill turtles for subsistence, trade and culture. Ongoing research by CICI and the World Wide Fund for Nature is already underway working to fill these critical assessment and research gaps (CICI, 2021; Madden Hof *et al.,* 2023a).

In eastern Australia, where most of the Conflict Group hawksbill turtles forage, hawksbill turtles will also require further national and transboundary management and protection. Hawksbill turtles are protected and managed across a raft of Commonwealth and State legislation, policy and recovery strategies in Australia. Still, harvesting can occur by Australian Aboriginal and Torres Strait Islanders under the *Native Title Act, 1994*. Under this Act and other frameworks, (e.g. Torres Strait Turtle Fishery), there are no legislative or regulated quota limits to harvesting. Instead, communities are encouraged to self-manage and permit their catches through their local traditional LORE, and as such, there are no quantifiable harvest rates. While there are few geo-political strategies in place to protect transboundary marine turtle populations in this region (Bell & Jensen, 2018), given PNG shares its hawksbill populations with Australia (and beyond), joint and concerted co-management efforts should now be explored to ensure future conservation and protection across PNG's hawksbills full life history. This study will help facilitate these discussions and underpin the development of conservation strategies to protect hawksbill turtles throughout their life history and the western Pacific range.

ACKNOWLEDGEMENTS AND CONTRIBUTIONS

We would like to express our sincere appreciation of the dedicated CICI turtle monitors, CICI volunteer interns, and the staff of Lissenung Resort for assisting in sample collection. Without you, we would not have been able to undertake this research. We would particularly like to thank the CICI turtle monitors of the 2017-2018 and 2018-2019 nesting seasons, Dr Ian Bell, Natalie Robinson, Coen Madden Hof, Amaya Madden Hof, Blake Seccombe and Brian Seccombe for assisting in satellite tracking deployment. We sincerely thank the World Wide Fund for Nature, its donors and supporters, and the University of the Sunshine Coast for funding this project, including a small research grant provided by Dr Kylie Scales.

CMH conceptualised and designed the study and undertook most of the field work except for Kavieng, AA conducted this field work. HV contributed to the Conflict Island field work. NF, NMc, CMH performed the laboratory analysis. AD, JM, CMH performed the statistical analyses. CMH wrote the first draft of the manuscript, MJ and AD contributed to writing sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

Chapter 7: Single Species Action Plan for the hawksbill turtle (Eretmochelys imbricata) in South-east Asia and the western Pacific Ocean region

Convention of Migratory Species (2022). Single Species Action Plan for the Hawksbill Turtle (Eretmochelys imbricata) in South-East Asia and the Western Pacific Ocean Region. [Website: https://www.cms.int/en/document/single-species-action-plan-hawksbill-turtle-south-east-asia-western-pacific]

Preface

Resource capacity and mobilisation is a key issue many governments, universities and community groups face in managing species, especially those that are geographically widespread, such as marine turtles. Where marine turtles are subject to multiple threats on different spatial and temporal scales, priortisation of populations, threats, effort, and action is required to effectively manage their conservation status (Hamann *et al.,* 2010; Wallace *et al.,* 2011). Given unsustainable use and trade has been identified as a major threat to the hawksbill turtles in the western Pacific Ocean region, CMS Parties expressed clear guidance that any development of a Single Species Action Plan for Hawksbill Turtles in South-East Asia and the Adjacent Western Pacific (SSAP) should focus only on actions that address use and trade of hawksbill turtles (CMS Decision 13.70c). Stemming from the western Pacific Ocean region assessment (Chapter 1) and policy review (Chapter 2), the SSAP was drafted by prioritising primarily existing commitments and actions. These actions were already embedded within at least one existing policy framework and/or mandate for delivery amongst various countries or range states. This priortisation was used for the purposes of identifying key research needs for this thesis and for the SSAP. Links between the SSAP actions and policies or mandates are listed in the following chapter tables, and a description of 'Ways of potential delivery' was also added to each action to assist with implementation.

The published SSAP under the Convention on the CMS of Wild Animals and IOSEA MoU (as adopted by Range States at the Plenary Meeting on 2 June 2022) is presented in this chapter, modified slightly to remove significant repetition with other chapters (e.g. Tables) and inclusive of a summarised priority action section for ease of access. A statement by Melanie Virtue, CMS Secretariat confirms my role as the lead author on this international plan (see Appendix 2).

Introduction

Hawksbill turtles (*Eretmochelys imbricata*) are found throughout the tropical and subtropical oceans of the world. Globally, hawksbill turtles are considered Critically Endangered under the IUCN Red List of Endangered Species. Like other marine turtle species, hawksbills turtles are of great cultural significance to many Indigenous Peoples and Local Communities (IPLCs). This Plan recognizes the traditional rights that IPLCs have to hawksbills, and the need to include traditional ecological knowledge in the sustainable management and conservation of the species.

CMS Parties first discussed the need for a Single Species Action Plan (SSAP) for hawksbill turtles in South-East Asia and the adjacent western Pacific at COP12 in 2017. Growing concern specifically about the status of hawksbill turtle populations in these regions communicated by experts and substantiated by findings of relevant reviews (e.g. IOSEA 2014) and other investigations (e.g. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) 2016) led to the adoption of Decision 12.17 b), in which this plan was envisaged to cover trade, use and other threats. The CMS mandate was presented to Signatory States of the IOSEA Marine Turtle MOU in 2019, and a corresponding activity to cooperate with CMS in the joint development of a draft SSAP was agreed to, bearing in mind that the SSAP would cover part of the MOU range, and extend much further eastward.

CMS Parties expressed the clear guidance that the SSAP should focus only on actions specifically needed for hawksbill turtles, rather than try to cover recommendations that would address the needs of marine turtle species and other threats such as coastal development and climate change more broadly (and covered by Decision 13.70 a) and b)). Accordingly, further analysis of existing and new publications (for example, refer CITES Secretariat 2019; Gomez and Krishnasamy 2019; Ingram *et al.,* 2021; Kitade *et al.,* 2021; Miller *et al.,* 2019) and consideration of expert opinion led to the more restricted focus for the SSAP on just trade and use, as foreseen in Decision 13.70 c) (2020).

This SSAP seeks to integrate the actions necessary to address trade and use at both the domestic and the international level. To achieve this, existing policies and mandates were reviewed and collated (see CMS/IOSEA/Hawksbill-SSAP/Inf.5) and the most urgent high priority actions identified and included in this SSAP, to assist governments in implementing their commitments in a cohesive way. Accordingly, both the Secretariat for the Pacific Regional Environment Programme (SPREP) and the CITES Secretariat were consulted and engaged in the development of this SSAP.

Noting that the scope of this Action Plan is focused on the South-East Asia and Western Pacific region (refer section 3.2 for a list of countries included), reports have identified that hawksbill populations in other regions are also threatened by use and trade. The actions contained within this SSAP may be relevant for implementation and uptake in other regions, including through other mechanisms, such as the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC). The scope of this SSAP focuses on the South-East Asia and Western Pacific region because it was considered that the threats to hawksbill turtles from unsustainable use and trade required focus, and many countries required additional support, capacity building and resources to tackle the issue.

This integration of mandates and actions addressing both the domestic and international levels is especially important given the migratory nature of hawksbill turtles which in many cases exist in multiple stocks and at multiple life-history stages within countries. This creates complex linkages between community and commercial uses, something that can best be addressed through consolidation and prioritization of actions addressing use and trade at all levels.

Development of this SSAP

This SSAP was drafted by the CMS Secretariat in collaboration with the CMS partner organization WWF and the University of the Sunshine Coast. It was shared with the Advisory Committee and the Illegal Trade Working Group of the IOSEA Marine Turtle MOU, the Scientific Council of CMS and all Range States for written comments. A revised draft was put before three sub-regional meetings of the Range States for their more detailed comments (10-12 May 2022). A consolidated draft incorporating these further comments was presented in advance of the Range State plenary meeting (31 May - 2 June 2022) for final changes and adoption by that meeting. The plan, as adopted by the Range States, will be presented to the 14th Meeting of the Conference of the Parties to CMS and the 9th Meeting of Signatory States to the IOSEA Marine Turtle MOU for endorsement.

Biological Assessment

Taxonomy

Common names:

English – Hawksbill
French – Tortue imbriquée
Spanish – Tortuga de carey
CLASS: REPTILIA
ORDER: TESTUDINES
FAMILY: CHELONIIDAE
SPECIES: Eretmochelys imbricata (Linnaeus, 1766)

There is one extant species for the genus and there are no valid subspecies currently recognized.

Global Distribution

Hawksbill turtles have a circumglobal distribution in the world's tropical oceans, and to a lesser degree in subtropical waters in of the Atlantic, Indian, and Pacific Oceans (Mortimer and Donnelly 2008). They are believed to inhabit coastal waters of at least 100 countries (Groombridge and Luxmoore 1989). In the Atlantic and Eastern Pacific Ocean, there are breeding aggregations in Antigua and Barbuda, Barbados, Costa Rica, Ecuador, El Salvador, Guadeloupe, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico, and US Virgin Islands (Gaos *et al.,* 2010; SWOT Report 2008). In the Indian Ocean and South-East Asia region (IOSEA), there are breeding aggregations in 32 countries (Hamann *et al.,* 2022). In the Western Pacific Ocean, there are breeding aggregations in Australia, Papua New Guinea, Solomon Islands, Palau, Republic of the Marshall Islands, Samoa, American Samoa, Vanuatu, Fiji, French Polynesia, and Tonga (Madden Hof *et al.,* 2022). For more information, please refer to the Hawksbill Assessments for IOSEA (Hamann *et al.,* 2022) and Western Pacific Ocean region (Madden Hof *et al.,* 2022b).

Distribution in South-East Asia and the Western Pacific

There are currently six regional management units (RMUs) for hawksbill turtles in the region covered by this Action Plan (Wallace *et al.,* 2010a). These are, 1. North-East Indian, 2. *West Pacific/South-East Asia, 3. West Central Pacific, 4. South-East Indian, 5. South-West Pacific and 6. *South Central Pacific (Figure 7.1). Those marked by with an asterix (*) were scored as putative (i.e., were based on nesting records but lacking other biological or genetic evidence) and may require modification as data become available.

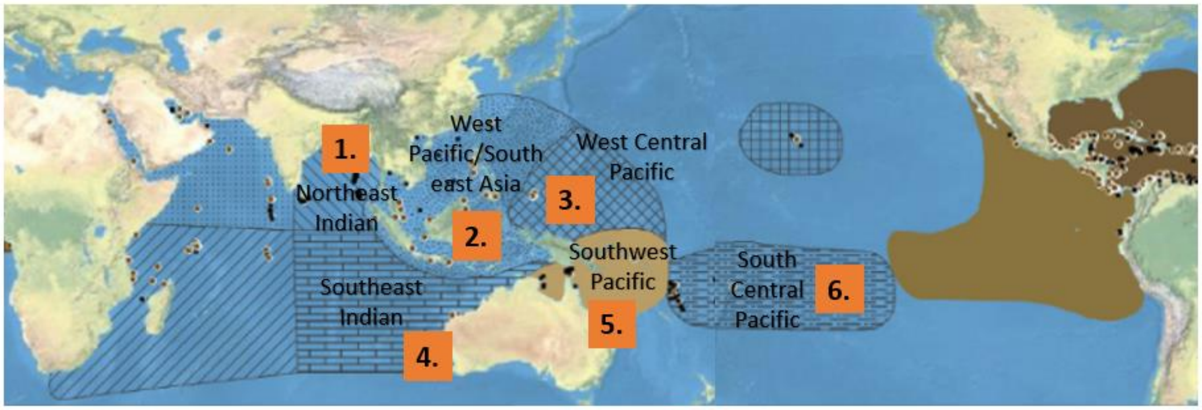

Figure 7.1. RMUs in the South-East Asia region. (Adapted from Wallace et al 2010a).

These RMUs are currently under review at a global scale. Within these RMUs, there are at least seven currently identified distinct populations/management units (MUs, or genetic stocks) of hawksbill turtles that nest within the Action Plan region. In the West Pacific/South-East Asia RMU there are three: Sulu Sea (Malaysia), western Peninsula (Malaysia), Gulf of Thailand (Kho Kram) (postulated MU), where in the South-East Indian RMU, only the East Indian Ocean MU has been identified (FitzSimmons and Limpus 2014; Vargus *et al.,* 2016). The majority of hawksbill RMUs in the western Pacific have not yet been assessed for genetic population structure, except for the South-West Pacific RMU of which it has three: North Queensland, North-East Arnhem Land, and the Solomon Islands genetic stocks (Vargus *et al.,* 2016). Efforts to collect and analyze genetic samples are underway in a number of countries (see Madden Hof *et al.,* 2022; refer World-Wide Fund for Nature ShellBank program and the Asia-Pacific Marine Turtle Genetic Working Group).

Migration Patterns

Hawksbill turtles are highly migratory and have been shown to travel vast distances between foraging and nesting sites, although nesting females can also migrate short distances and may often be more sedentary that other sea turtle species (Parker *et al.,* 2009; Gaos *et al.,* 2012a). In the western Pacific, migratory connectivity for hawksbill turtles is poorly understood overall.

Nevertheless, satellite telemetry and tag recoveries have revealed the Coral Sea as a key foraging area for hawksbill turtles in the western Pacific (Limpus 2008; Pilcher 2021; Madden Hof *et al.,* 2023a). Hawksbills have been reported foraging throughout the Coral Sea after post-nesting migrations from the Conflict Islands in Papua New Guinea (CICI 2018; Madden Hof *et al.,* 2023b), the Arnavons in Solomon Islands (Hamilton *et al.,* 2015), Vanuatu (Miller *et al.,* 1998), and various sites in the Great Barrier Reef (Miller *et al.,* 1998). Linkages of similar distances are demonstrated between American Samoa and the Cook Islands (Tagarino *et al.,* 2008), as well as Guam and Pohnpei in the Federated States of Micronesia (Gaos *et al.,* 2020). There have been numerous tracking and foraging area studies undertaken on populations in Australia (indicating, for example, that hawksbills nesting in Western Australia tend to remain in Australian jurisdiction; Fossette *et al.,* 2021). However, hawksbill migration elsewhere in South-East Asia has not been extensively studied. Fifteen hawksbill turtles from Malaysia's Melaka nesting beaches (one island and two mainland sites) were satellite tracked between 2006-2013. Nearly all of these tracked turtles migrated southwards along the Malaysian coastline towards Singapore or the Riau Islands (Pilcher *et al.,* 2019). Flipper tag recoveries and satellite studies in the Turtle Islands, Malaysia revealed hawksbill migrations into the southern Philippines, along the east coast of Kalimantan in Indonesia and retention in Sabah's waters (Joseph 2017; Pilcher *et al.,* 2019). There have also been tracking studies of a few individuals undertaken in Singapore and Timor Leste, but data remains unpublished. Further research on the spatial distribution, habitat utilization, and genetic relationships of hawksbill populations across the South-East Asia and western Pacific region is needed.

Population Productivity and Trend

The only index nesting sites for hawksbills in the western Pacific Ocean are the Arnavon Islands (Solomon Islands) and Namena Lala Island (Fiji), while the South-East Asia region has index nesting beaches in Australia, Indonesia, Malaysia (Peninsular and Sabah), Singapore, and Thailand (for a full list of index beaches in the South-East Asia region, see Hamann *et al.,* (2022)). Given the lack of long-term mark-recapture studies, there are few recent peer-reviewed publications assessing annual trends in hawksbill nesting abundance available for most of the region covered by the Action Plan, except for the western Pacific countries of the Solomon Islands (increasing), north-east Australia (decreasing), and for South-East Asia countries, the Turtle Islands Heritage Protected area (Sulu Sea; probably decreasing).

The most recent region-wide assessment of trends (2008) estimates Pacific Ocean hawksbill populations to be at least 75% lower than historical levels (with an estimated 4,800 nesting females remaining in 2008) and in the Indian Ocean, estimates to be at least 92% lower than historical levels (with an estimated 2,100 nesting females remaining in 2008; Mortimer and Donnelly 2008). That assessment reported hawksbill populations in many countries were depleted and/or declining in both the western Pacific Ocean (e.g., most of Micronesia, American Samoa, Palau, among others) and South-East Asia (e.g., India, Chagos Islands, Maldives, Myanmar, Viet Nam, Philippines, Malaysia, among others).

Only two populations have more recently been reported to be likely stable, one in Thailand (although it is increasing from a highly depleted baseline), with the other population stable or increasing in Western Australia (Hamann *et al.,* 2022).

Within its remit, SPREP is currently (2022) undertaking an extinction risk assessment which may further inform decision makes of trends in annual nesting patterns for hawksbill populations in the western Pacific Ocean region. In the absence of recent quantified nesting census figures, and a lack of data on the stability of foraging area populations, the reported estimated trends and likely trajectory for hawksbill populations across the entire Action Plan region is of significant concern. Yet, addressing priority and other threats alongside habitat protection, can result in recovery as seen in some hawksbill populations in the western Indian Ocean (e.g., Seychelles and Chagos Archipelago; refer Mortimer 2011; 2017; 2020).

Threats from Anthropogenic Sources

Current knowledge on threats to hawksbills in the South-East Asia and western Pacific Ocean regions has been recently synthesized by Hamann *et al.,* (2022) and Madden Hof *et al.,* (2022), respectively. While hawksbill populations are affected by an array of additional threats (e.g., marine debris, climate change and coastal development), the issues most relevant to use and trade are extracted from those reviews and are presented here. These are categorized and described as: tortoiseshell trade; human use of turtles and eggs; and, fisheries bycatch, targeted catch and illegal, unreported and unregulated (IUU) fisheries – acknowledging the overlap and interlinking of these threats.

The need to address threats to hawksbills in the region is supported by Wallace *et al.,* (2011), who found that hawksbill turtles had the largest proportion of RMUs (7 out of 13 globally) assigned to the High Risk-High Threats category compared to other marine turtle , and are therefore most at risk of extinction. When grouping those seven RMUs by ocean basin, four occur in areas encompassed by this SSAP: North-East Indian Ocean, West Pacific Ocean, South Central Pacific and West Central Pacific (Wallace *et al.,* 2011). While the spatial boundaries of these RMUs are currently being reviewed, these findings and the need to address use and trade threats to hawksbill turtles were supported by IOSEA (2014) and CITES Secretariat (2019) assessments, alongside other more recent publications (e.g., Kitade *et al.,* (2021) and Ingram *et al.,* (2021)).

Under IUCN's Marine Turtle Specialist Group conservation assessment region categorization, Australasia, South Asia, and West Indian regions were also considered where marine turtle RMUs were at High Risk-High Threats (Work *et al.,* 2021).

Tortoiseshell Trade

Large-scale commercial trade in tortoiseshell products occurred across the Indian Ocean for around 2,000 years, with considerable expansion since the 18th century and far into the 20th century (Mortimer and Donnelly 2008). From 1950 to 1986, for example, Japan imported around 1.3 million large-sized hawksbill turtles and 310,598 kg (8,394 per year) of raw hawksbill shell (bekko) from countries in the IOSEA region (Groombridge and Luxmoore 1989).

Despite a global ban by CITES on the international commercial trade in hawksbill turtles, their parts and derivatives since 1977 (and a reservation lifted by Japan in 1992), an active illegal trade network (concentrated in South-East Asia) has created a renewed demand for turtles and turtle products (Gomez and Krishnasamy 2019). Miller *et al.,* (2019) observed that trade in hawksbill shell was underestimated (originally 1.4 million to 9 million over a 150-year period) and that the current trade likely overlaps with the observed extent of modern-day IUU fishing activities, which may involve participation by small-scale fisheries (see Riskas *et al.,* 2018; Vuto *et al.,* 2019). Indeed, vessels from China and Viet Nam have been apprehended in the Philippines, Malaysia, Indonesia, and Australia for illegally taking, trading, or storing hawksbill turtles (IOSEA 2014; Miller *et al.,* 2019). Another study found that marine turtles (including hawksbill turtles) were illegally trafficked internationally from Indonesia, Malaysia, and the Philippines (Gomez & Krishnasamy 2019). Further, from January 2015 to July 2019, at least 2,354 whole turtles, both alive and dead, were seized in 163 law enforcement incidents, and over 91,000 eggs were seized (of which over 75,000 were seized just in Malaysia), together with close to 3,000 shells and 1.7 tonnes of turtle meat (Gomez & Krishnasamy 2019) (species unknown). Viet Nam was also implicated in this study for its role in international trafficking as a source, transit, and destination country. The most recent hawksbill turtle trade assessment in Japan revealed that there are still significant attempts to add illegally sourced hawksbill raw scutes (and tortoiseshell) into the domestic supply chain (Kitade *et al.,* 2021). Between 2000 and 2019, Japanese customs reported 564kg of hawksbill tortoiseshell seized in 71 incidents, representing some 530 hawksbill turtles (with over half seized between 2015 and 2019 alone) (Kitade *et al.,* 2021).

The continuing trade in hawksbill turtle shell and tortoiseshell products poses a serious threat to the recovery of hawksbill populations in the South-East Asia and western Pacific Ocean (Hamman *et al.,* 2022; IOSEA 2014; Madden Hof *et al.,* 2022c). Recently in the Solomon Islands, Vuto *et al.,* (2019) reported the local sale of hawksbill shell in 3 of the 10 communities surveyed, with evidence of sales to overseas buyers in Honiara. In the past, levels of export of tortoiseshell from the Solomon Islands were among the ten highest globally (Groombridge and Luxmoore 1989), and while these may have decreased, export may still be occurring. In Papua New Guinea, Kinch and Burgess (2009) noted that the trade in hawksbill turtles was ongoing in coastal towns, mainly in the form of tortoiseshell items for domestic buyers, and potentially targeting international tourists even though export is illegal. Also in Papua New Guinea, Opu (2018) found that turtle harvest were concentrated in Manus, Milne Bay, and Western Provinces. Media reports and anecdotal reports from government stakeholders suggest the tortoiseshell trade is still active in Palau despite a 2018 ban (Reklani 2021). While attempts are made to estimate trade and the resultant mortalities of hawksbills, the reports of illegal trade in hawksbill shells occurring in multiple western Pacific Ocean countries warrant further study.

Human Use of Turtles and Eggs

Hawksbill turtles have a high degree of cultural significance in many countries across the South-East Asia and western Pacific Ocean regions and are a traditional food with eggs and meat consumed, and shells used in customary practices and trade (Frazier 1980; Groombridge and Luxmoore 1989; Pilcher 2021; Ingram *et al.,* 2022). Papua New Guinea, Australia, and the Solomon Islands were ranked in the top five for legal marine turtle take (all species) globally (Humber *et al.,* 2014). Despite their global critically endangered status (and varied conservation status between countries), hawksbill turtles in many countries are treated as an untapped (unregulated) fishery resource and are entangled in the transition from a subsistence to cash (trade) economy (Opu 2018). But as natural assets, it is the loss of hawksbill turtles and the habitats on which they depend that will result in the loss of basic goods and services (e.g., food and raw materials, pest and competitor control, nutrient cycling, ecotourism, existence value) underpinning many communities in the region (refer Hoegh-Guldberg *et al.,* 2016; Brander *et al.,* 2021). A loss of hawksbill turtles also means a loss of cultural and customary practices.

The use and trade of hawksbill turtles and eggs continues in the South-East Asia region (IOSEA 2014; Gomez and Krishnasamy 2019). While the take and trade of hawksbill turtles, eggs, and various products are prohibited throughout much of the South-East Asia region, depleted hawksbill populations are nonetheless threatened by the ongoing illegal trade that involves several nations (Hamann *et al.,* 2022; Ingram *et al.,* 2022). To investigate this issue, the CITES Secretariat, with support from the CMS Secretariat, commissioned a study on the legal and illegal international marine turtle trade, with case studies in Madagascar, Mozambique, Malaysia, and Viet Nam (CITES 2019). Other studies have examined the illegal capture and commercial use of turtles in varying locations within the IOSEA region (see IOSEA 2014; Riskas *et al.,* 2018; Gomez and Krishnasamy 2019; Miller *et al.,* 2019; Williams *et al.,* 2019). A synthesis of the complementary findings of these studies are reported in Hamann *et al.,* (2022), with the following highlighting its key points:

1) There are major knowledge gaps regarding the species used (meat and eggs), the sociocultural and economic drivers underpinning illegal use and trade, and the types of use and motivations occurring in each country and/or South-East Asia sub-region.

2) IUU fishing is likely to have significant impacts on hawksbill turtle populations in the South-East Asia region due to its involvement in illegal turtle fisheries and links to wildlife trafficking operations.

3) Seizure records show that trade occurs between South-East Asian countries.

4) The trade is more likely to be deliberate than opportunistic, with organized trade networks supplying domestic and international markets (e.g., Malaysia, Viet Nam, Indonesia, China). Amid increased scrutiny of the turtle trade (largely driven underground), online platforms are being used to sell turtle products, including hawksbill shell (e.g., Indonesia, Malaysia).

5) There is a lack of enforcement of existing domestic legislation, as well as weak monitoring, control and surveillance of coastal fisheries that are abetting the illegal capture and trade, both domestic and international, of hawksbills.

In the western Pacific, hawksbill turtles and their eggs are harvested in every RMU, despite laws banning these practices in many countries (Wallace *et al.,* 2010). Data are generally sparse on legal and illegal turtle and egg harvests, as documentation of these is inconsistent or unrecorded. Further, monitoring turtle harvest over vast distances between atolls and islands is logistically challenging. There are nevertheless a small but growing number of studies documenting use and trade of hawksbill turtles, eggs, and products, including several recent studies that estimate quantities taken.

Maison *et al.,* (2010) indicated that there have been uncontrolled, long-term harvests of eggs and females in the Federated States of Micronesia that are likely to have had an impact on current population numbers. In the Republic of the Marshall Islands, turtles (primarily greens, but also hawksbills) have historically been a food source and played an important cultural role. Egg collecting and harvest of turtles while they are onshore is prohibited at all times, but current levels of illegal exploitation are unknown (Maison *et al.,* 2010). In Palau, hawksbill turtles are taken to support a tradition of gift exchanges of *toluk* (Pilcher, pers. obs.), despite traditional closures and a current moratorium banning the take of turtles or eggs while onshore (Maison *et al.,* 2010). In the Cook Islands, turtles are occasionally killed and eaten at Tongareva, Rakahanga, Manihiki, and Palmerston, and probably at other atolls, although the true level of direct take remains unclear for the Cook Islands (White 2012). There are no estimates or reports of adult or egg harvests for Kiribati, Nauru, Niue, the Pitcairn Islands, Tokelau, Tuvalu, or Wallis and Futuna.

In Papua New Guinea, Opu (2018) found that the highest catches of turtles (all species) occurred in Manus, Milne Bay, and Western Provinces. These catch numbers were likely to underestimate the true degree of turtle harvest in Papua New Guinea, given the limitations of the survey method and that many landed turtles were likely used for personal consumption or in the barter trade.

Acknowledging an increasing hawksbill population at the Arnavons (Hamilton *et al.,* 2015), Vuto *et al.,* (2019) provided a recent update on turtle harvests in the Solomon Islands. Modelled data (based on coastal community location, footprint of fisheries and existing average catch rates in localities not typical of turtle harvesting) estimated that 9,473 turtles were harvested each year by mostly (92%) free divers (95% CI: 5,063 to 22,423), with hawksbill turtles accounting for 2,435 turtles (26%) of the estimated total harvest. Juvenile turtles comprised 1,860 (76%) of estimated hawksbill captures, the remaining were adult-sized turtles (equating to 575; >75cm in carapace length, sex unknown, but likely caught near nesting localities). Hawksbill turtles were most commonly used for subsistence purposes (82%) and were most likely to be consumed by the family of the fisher that captured the turtles. However, the shells of 88% of hawksbill turtles harvested were sold to local buyers, who then on-sold to Asian buyers in Honiara. Hawksbill turtle products were far more likely to be illegally sold (32%) than green turtle products (12%) because of the domestic and international market for tortoiseshell.

In Vanuatu, there is a strong programme of local turtle monitors that aid in protecting turtles and convincing local communities to participate in turtle conservation efforts (Hickey and Petro 2005). It is estimated that turtle harvest in the past may have been in the region of 1,500 turtles per year, although they suggest that much of this harvest has since ceased (Hickey and Petro 2005). However, a recent survey found that people still catch turtles intentionally to eat and sell (Shaw, unpublished data). While this survey sample is not representative of the island chain as a whole, it does indicate that updated estimates of take and trade are needed.

A recent study found that the use of marine turtles for aquatic wild meat is likely to be far more widespread in terms of frequency and species than reported, especially amongst Indigenous People and Local Communities (IPLCs) (Ingram *et al.,* 2022). The full extent of any legal or illegal harvest in the South-East Asia and western Pacific Ocean region is difficult to estimate because many uses by IPLC are not reported. Estimating levels of domestic take and trade are urgently needed to understand whether take and trade are having an effect on the population (Gomez and Krishnasamy 2019; Hamann *et al.,* 2022; Ingram *et al.,* 2022; Madden Hof *et al.,* 2022b).

Collaborative efforts to understand the socio-cultural drivers and annual levels of hawksbill turtle harvest and trade are underway. In collaboration with relevant governments, the World Wide Fund for Nature (WWF) and SPREP are supporting the delivery of a sociocultural survey in Papua New Guinea, Fiji, and Tonga. The project is part of WWF's broader Marine Turtle Use and Trade Initiative (MTUTI), which will collect and synthesize data on turtle use, trade, and genetics to advocate for targeted policy action to recover Asia-Pacific hawksbill turtle populations.

While marine turtles provide many economic benefits, the values of which are not well documented. In 2004, Troëng and Drews undertook a global assessment of the direct consumptive use (food and materials), non-consumptive use (ecotourism), and non-use (existence and bequest) values of marine turtles. Since then, there have been a number of studies on the economic value of the ecosystem services provided by marine turtles (refer literature review by Brander *et al.,* 2021), but these mainly focused on cultural, recreation, tourism or use for food. Very few studies have used economic methods to estimate the value of ecosystem services (provisioning, regulating, cultural) provided by marine turtles in monetary terms. Brander *et al.,* (2021) estimated the value of provisioning (harvest) services to be US$800 per year and non-use (existence and bequest) values of over US$45 billion per year in the Asia-Pacific region. The report concluded that there are significant opportunities to deliver massive economic benefit by capturing the public's support for investment in turtle conservation and management, whereby governments could work with other stakeholders to develop innovative financing mechanisms that can tap into this willingness to pay. The report also suggested governments could work collaboratively to develop initiatives to ensure that coastal communities earn more from conserving marine turtles than from harvesting them.

Bycatch and IUU Fishing

Incidental capture (bycatch) in commercial and small-scale fisheries is globally recognized as a major threat to marine turtle populations (Alverson *et al.,* 1994; Lewison *et al.,* 2004; Bourjea *et al.,* 2008). In the IOSEA region, legal fisheries are considered to be a key threat to marine turtles despite the absence of quantitative data (Bourjea *et al.,* 2008; Williams *et al.,* 2019). Many governments of Signatory States of the IOSEA Marine Turtle MOU and regional fisheries management organizations (RFMOs) have implemented bycatch reduction and/or observer programmes to address the issue and understand impacts. However, the effectiveness of these mitigation measures is rarely evaluated, and bycatch records are typically examined at the level of individual fisheries, making cumulative impacts hard to discern (Riskas *et al.,* 2016). In their review of bycatch literature in the IOSEA region, Hamann *et al.,* (2022) indicate that bycatch of hawksbill turtles from longline and purse seine fisheries (both pelagic fisheries) is very low, while bycatch from gillnets and coastal artisanal fisheries are likely to have the highest impact on turtle populations due to their nearshore habitat preferences.

In the western Pacific Ocean region, commercial fisheries are dominated by longline and purse seine fisheries for tuna and tuna-like species. Monitoring of these fisheries in high seas areas is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC), an RFMO. Peatman *et al.,* (2018a) estimated that hawksbill turtles accounted for 16% of turtle bycatch in purse seine fisheries in the WCPFC area from 2003 to 2017, with a mean of 36 hawksbills per year (range 15-75). Hawksbill bycatch is recorded in longline fisheries, with a mean of 1,126 individuals (range 534-1,598) caught per year in WCPFC longline fleets (Peatman *et al.,* 2018b). Yet because not all bycatch incidences result in mortalities, and observer coverage is not sufficiently uniform nor normally distributed across the fishery (Peatman *et al.,* 2018b), these figures should be used as indicative of the magnitude of the threat, not the precise quantities. Also, given the predominantly nearshore habitats of hawksbill turtles (Gaos *et al.,* 2012b), and the deep-water operations of longline fleets, interaction rates with hawksbills are not high compared to other marine turtle species. This is supported by data in Peatman *et al.,* (2018a), where hawksbills account for only 4.9% of all interactions.

Small scale fisheries are responsible for substantial levels of sea turtle bycatch and targeted catch in a number of regions (refer Sabah, Malaysia study site in Moore *et al.,* 2010). They largely operate and overlap more acutely with hawksbill habitat in nearshore or coastal waters using a variety of gears, including gill, set and drift nets, trawls, seines, longlines, traps, and others (Lewison 2013). Research has shown that small-scale fisheries can have high levels of turtle bycatch that directly cause population declines (Lewison and Crowder 2007; Peckham *et al.,* 2007; Alfaro-Shigueto *et al.,* 2011). In the South-East Asia region, small-scale fisheries are ubiquitous and likely constitute the majority of the fisheries workforce (Teh and Sumaila 2013). However, robust data for hawksbill turtle bycatch in these fisheries is largely unavailable. There is only one published example of a small-scale fisheries bycatch assessment in Malaysia (Pilcher *et al.,* 2009), in which an estimated 988 hawksbill turtles were taken in small-scale fisheries in a single year (extracted from data in Pilcher et al 2009).

In the western Pacific Ocean region, small-scale fisheries are widespread, often operating in remote areas and at levels that have not been quantified. Although a study commissioned by the CITES Secretariat (2022) surmised that bycatch and active targeting of marine turtles in small-scale fisheries is unlikely to contribute to the international trade of hawksbills, Vuto *et al.,* (2019) provided evidence to the contrary from the Solomon Islands. Vuto *et al.,* (2019) reported that hawksbill turtle products are far more likely to be sold illegally than green turtle products, and that the shells of 88% of hawksbill turtles harvested were sold to local buyers, who then on-sold to Asian buyers in Honiara. Because hawksbill turtles inhabit coral reef habitats and shallow coastal waters, they are highly vulnerable to bycatch, targeted catch, and mortality in the small-scale fisheries occurring in almost every country in the western Pacific Ocean region. As poachers have been documented encroaching on the national waters of the Coral Triangle and western Pacific countries (Lam *et al.,* 2011), and amid growing evidence of the role of small-scale fisheries in facilitating the turtle trade (IOSEA 2014), a better understanding of hawksbill interactions with small-scale fisheries (bycatch and targeted catch) across the broader western Pacific region and beyond is urgently needed.

IUU fishing is a pervasive issue for fisheries management in every ocean basin (Agnew *et al.,* 2009). Vessels engaged in IUU fishing are far less likely to comply with conservation mandates intended to reduce bycatch and mortality of non-target, vulnerable species, including marine turtles (MRAG 2005). In countries where intentional turtle take (or retention of turtle bycatch) by fishers is prohibited, if it occurs it would be considered illegal and could be categorized as IUU fishing. Illegal take of hawksbill turtles by coastal fisheries has been recorded throughout South-East Asia (i.e., Indonesia, Malaysia, Philippines, and Viet Nam) (IOSEA 2014) and the western Pacific Ocean (i.e., CNMI, Fiji, Guam, Palau, Solomon Islands, and Vanuatu) (see country summaries in Work *et al.,* 2020). However, more information regarding take levels and size classes is needed to inform risk assessments and potential avenues for implementing effective mitigation measures.

The connection between IUU fishing and marine turtle use and trade is only recently being investigated. A report recently commissioned by the CITES Secretariat indicates that IUU fisheries are likely the main source of hawksbill turtles for international trade (CITES Secretariat 2022). Similarly, Riskas *et al.,* (2018) found that IUU fishing posed a threat to marine turtle populations in the South-East Asia region, and that in certain regions IUU fishing is associated with poor fisheries management and wildlife trafficking. Lam *et al.,* (2011) and IOSEA (2014) noted the involvement of small-scale fishing vessels in the trafficking of hawksbill turtles and products in East and South-East Asia, while Miller *et al.,* (2019) noted that current patterns of IUU fishing may mirror historical illegal trade routes of hawksbill turtles. However, since IUU fisheries are by definition cryptic and difficult to study directly (Christensen 2016), their role in the contemporary scale of trade in hawksbill turtles remains unclear.

There is little documented information on hawksbill turtle interactions with illegal commercial fisheries in the western Pacific Ocean. IUU fishing incidence is estimated to be lower in the western Pacific than in many other seafood-sourcing regions globally, and has decreased in the Pacific Islands region relative to a 2016 assessment of data from 2010-2015 (MRAG Asia Pacific 2021). This is attributable to the concerted and ongoing cooperative efforts by Pacific countries and partner organizations (e.g., the Pacific Islands Forum Fisheries Agency, the Pacific Community, or the Western and Central Pacific Fisheries Commission) to increase monitoring, control and surveillance of fleets operating in the region.

Threat Prioritization

Given the already refined scope of this SSAP of use and trade as mandated by CMS COP13, the threat prioritization process to determine the relative impact of threats normally undertaken in other SSAPs was not considered necessary in this case.

In doing so, we recognize that threat levels of bycatch and take will differ as a result of the geographical range and specific life history traits of each hawksbill population, including those that are shared (connected) among countries in the Indian, South-East Asian, and western Pacific Ocean regions. As a result, hawksbill turtle range states within the scope of this plan are encouraged to consider the impacts of use and trade in the context, not only of their local situation (nationally) but also regionally and internationally. As such, the prioritized activities listed below in section 4 are considered appropriate at national, regional, and international scales.

For more information on other threats to hawksbill turtle populations in the area covered by this SSAP, please refer to the Hawksbill Assessments for IOSEA (Hamann *et al.,* 2022) and Western Pacific Ocean region (Madden Hof *et al.,* 2022b).

Policies and Legislation Relevant for Management

International Conservation and Legal Status of the Species

IUCN Status (Red List)	CMS	CITES
Critically Endangered A2bd: A) Population reduction in the following: 2. An observed, estimated, inferred or suspected population size reduction of 80% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying): b) an index of abundance appropriate for the taxon d) actual or potential levels of exploitation	Appendix I and II App. I lists migratory species that have been assessed as being in danger of extinction throughout all or a significant portion of their range. Parties that are a Range State to these species shall endeavour to strictly protect them by: - prohibiting the taking of such species, with very restricted scope for exceptions; - conserving and where appropriate restoring their habitats; - preventing, removing or mitigating obstacles to their migration and controlling other factors that might endanger them. App. II lists migratory species which have an unfavourable	Appendix I Lists species currently threatened with extinction from international trade. CITES prohibits international trade in wild-taken specimens of these species except when the importing country certifies that the import is for primarily non-commercial purposes.

	conservation status and which require international agreements for their conservation and management, as well as those which have a conservation status which would significantly benefit from the international co-operation that could be achieved by an international agreement. Migratory species may be listed both in Appendix I and Appendix II.	

National Legislation Relevant to the Species

There are varying levels of national and state laws, legislative frameworks, and policies afforded to hawksbill turtles throughout the South-East Asia and western Pacific region. An overview of relevant national legislation by country relevant to the Hawksbill Turtle are provided in Table S7.1 and is available at https://www.cms.int/en/document/single-species-action-plan-hawksbill-turtle-south-east-asia-western-pacific as a separate document to allow updates as and when required.

Upon reviewing the relevant national legislation of 38 States within the scope of this Action Plan, the following issues were identified:

First, the majority of national legislation reviewed does not have conservation and protection provisions designated for the hawksbill turtle. Rather, the species is included in broader conservation and protection regimes intended for "marine resources", "living aquatic species" or "fish" which may narrow down to "reptiles" and, on occasion, "turtles". As a result, legal provisions are not tailored to the specific circumstances of the hawksbill turtle.

Second, there is a lack of designation of the hawksbill turtle as a "protected" species or further conservation status designation (e.g., "endangered") in national legislation. In some cases, this is because legislation does not provide provisions for protection or conservation status designation, or because hawksbill populations assessments have not yet been undertaken to allow such designation. To that end, the national legislation of many States does not reflect either the International Union for the Conservation of Nature (IUCN) "critically endangered" global Red List status of the hawksbill turtle, or the status of the population occurring within a country's jurisdiction, potentially undermining the urgency with which the hawksbill turtle needs to be protected.

Third, there are instances where national laws on the protection of the hawksbill turtle bifurcate. Where there are such official designations for the "protected" or "endangered" status of the hawksbill turtle which give the species enhanced protection, a number of States also recognize the customary rights of the local communities, including take and subsistence. There are a few nations with total bans on all forms of take, use and trade in place. In other cases, there are laws that specify size or catch limits (i.e., domestic quotas), use traditional use permit systems, or rely on management plans to manage harvest levels. As such, national legislation protecting both the hawksbill turtle and the customary rights of local communities is an important issue that requires a delicate balance.

Fourth, the wide range of penalties prescribed across the reviewed States' national laws helps highlight a difference in deterrence. The variety of penalties based on, among others, the offender being a natural or a legal person, the fine being a maximum fixed amount or the market value of the species or any part thereof, or the violation being a recurring offence, gives rise to differing levels of deterrence, making certain States' national legislation inconducive to achieving the long-term protection of the hawksbill turtle.

Lastly, different types of legislation across different jurisdictions (e.g., from national to state/provincial, to local laws) are used by States to protect and/or manage hawksbill turtles. For example, wildlife laws to designate "protected" status and govern use and trade; fisheries laws to regulate fishing and hunting activities/quotas; protected area laws to conserve and manage habitat. Combined, these laws offer strengthened conservation, management and protection to the hawksbill turtle. Yet there are many States that only use one form of legislation. In some cases, different laws are used across jurisdictions that are conflicting, which can be problematic when managing a highly migratory species that travels between countries and is afforded different levels of protection across its range.

Framework for Action

Goal

To address unsustainable use and trade of hawksbill turtles in the South-East Asia and Western Pacific Ocean region and build resilience in the populations

Objectives, Actions and Results

The objectives, results and corresponding actions to address the threats associated with take, use and trade of hawksbill turtles are set out in the tables below.

There are **23 actions in this SSAP**. These were consolidated based on CMS/IOSEA/Hawksbill-SSAP/Inf.5 Policy Review as Background to the Development of a Single Species Action Plan for Hawksbill Turtles in South-East Asia and the Adjacent Western Pacific, all of which are already embedded within at least one existing policy framework and/or mandate for delivery among various countries or range states. The links between the SSAP actions and these policies or mandates are listed in the table. A description of '*Ways of potential delivery*' has also been added to each action to assist with implementation.

Actions are prioritized as essential (red), high (orange), medium (yellow). No low priority was assigned given the urgency of addressing these threats. **Timescales** are also attached to each Action based on its prioritization and urgency of delivery, using the following scale:

- Immediate: to be initiated with a view to completion within the next year
- Short: to be completed within 3 years

- Medium: to be completed within the next 5 years
- Ongoing: currently being implemented and should continue

A top seven action list has been prioritized as immediate or urgently required to be delivered within the next year. Some actions have associated funding or resources already committed.

Thirteen actions are prioritized for delivery within the next three years and three within the next five years. Given concern over the known declines, and in many cases, the unknown trajectory of many populations, as well as the gaps in our knowledge of hawksbill turtles in these regions, utmost urgency is required. As such, potential delivery mechanisms and partners have also been indicated to guide collaborations and support for delivery.

Summary of prioritised actions

Seven actions were identified for immediate delivery (complete within a year). These actions are a collection of research, policy reform and multi-stakeholder collaboration priorities including, to:

- **Conduct** a review of protective legislation and identify problematic inconsistencies between countries; and, update, complete, and implement Marine Turtle National Plans of Actions that also address legislative reforms for incidental catch in all fisheries (including small-scale community fisheries) and practical modifications of fishing gear, and traditional management and regulation of domestic quotas, if any, and any user rights relating to habitat critical for hawksbill turtles (amongst others) *[Actions 1.1.1; 1.2.1]*
- **Improve** and strengthen internal, bilateral, and international law enforcement and related cooperative activities, surveillance, compliance, and response where take is legal and where illegal activities occur *[Actions 1.1.4]*
- **Continue** and/or collect genetic samples to determine the population of origin (e.g., nesting), geographic boundaries of stocks (e.g., foraging) and the genetic diversity

between regional stocks to inform research, investigations and prosecutions, and policy decisions nationally and internationally *[Action 2.3.3]*

- **Establish** a network of hawksbill habitat and migratory protection sites and of habitats requiring greater protection, and a baseline for the conservation status and distribution of hawksbill turtles in the different countries/regions *[Actions 1.2.1; 2.3.4]*
- **Research** the scale and impact of national and international artisanal, semi-industrial and industrial fisheries and their linkage to illegal trade, and where gaps exist, hawksbill genetic identity, life history, population trends, habitat needs, migration routes, and other biological and ecological aspects *[Actions 2.3.1; 2.3.4]*

These actions remain highly relevant, although timelines for delivery remain ambiguous given the time between adoption of the SSAP (by a limited number of Range States on 2 June, 2023) and endorsement scheduled for the up-coming CMS CoP14 (in October, 2023) and 9th Meeting of Signatory States to the IOSEA Marine Turtle MOU (in 2024). Although limited progress is expected to date, some work has been advanced by government and not-for-profits, for example, the uptake of marine turtle genetic traceability (under ShellBank), national law enforcement effectiveness assessment and rapid reference prosecutors guide completion for some countries (under the TRIPOD project), and a marine turtle legislation review underway by the World Wide Fund for Nature, supported by the CMS, IOSEA and CITES policy fora.

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
Objective 1: Review and where necessary improve legislation, policy, compliance and enforcement of hawksbill turtle take, use and trade in at least half of SSAP countries in South-East Asia and the Adjacent Western Pacific by 2025.							
1.1 Legislative reviews and, if necessary, reforms are made in each country that result in greater protection from unsustainable use and trade of hawksbill turtles.	1.1.1	Conduct a review of protective legislation and identify problematic inconsistencies between countries	• *Contribute and participate in WWF's marine turtle legislative and baseline status review* • *Undertake as part of National and Regional Plans of Action for marine turtles*	I/R	Immediate	CMS, IOSEA MOU, SPREP, IAC	1, 3, 4, 5, 7
	1.1.2	Enact new laws on hawksbill turtle conservation related to use and trade, seeking to remove any problematic inconsistencies (including between countries) within national legislation, and alter legislation to fully implement international commitments related	• *Prioritize as a result of 1.1.1* • *CMS Parties can ask for support from the CMS Secretariat*	R/N	Short	National Governments	1, 3, 5, 8

[1] **Level**: (R) Regional; (N) National; (I) International

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		to hawksbills, where necessary and appropriate					
	1.1.3	Relevant authorities commit to building capacity and undertaking training to improve the implementation and enforcement of national regulations and regional/international treaties, instruments or initiatives that apply to the unsustainable take and use of hawksbill turtles	• *Identify and articulate resource needs and raise funds to increase human and material resources, build field-level capacity at national and regional levels, including for enforcement* • *Seek to participate in existing training sessions and programs provided by IGOs, NGOs and others (e.g., CITES local enforcement training, CTOC training)*	R/N	Short-Ongoing	NGOs, IGOs, Financial Institutions, National Governments, SPREP, CTI-CFF, CITES	1, 2, 3, 5, 6
	1.1.4	Improve law enforcement activities, surveillance, compliance and response (detection, confiscation, monitoring and reporting) as necessary where	• *Prioritize as a result of 1.1.1* • *Participate in WWF's ShellBank*	N/R	Immediate - Short	National Governments, CTI-CFF, INTERPOL, ASEANAPOL,	1, 2, 3, 5

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
	hawksbill turtles are exploited in coastal areas and at transaction points, both where take is legal and where illegal activities occur.	• *Implement findings and outputs of National Assessments, Rapid Reference Guides and/or undertake self-assessment (e.g., ICCWC) for other countries* • *Seek to participate in existing training sessions and programs provided by NGOs and others (e.g., CTOC training), or seek/provide funding for new*			local community groups	
	1.1.5 Address any shortcomings in the criminal justice process with regard to illegal activities involving hawksbill turtles.	• *Build awareness in prosecution services of the seriousness of wildlife crime as an organized crime and improve capacity, including through the preparation of manuals to guide the prosecution of*	N/R	Immediate - Short	National Governments, UNODC	2

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
			wildlife crimes (e.g., Rapid Reference Guides), and guidelines on evidential handling and forensic analysis				
1.2 Conservation actions and targeted management plans are developed that address unsustainable use and trade of hawksbill turtles, where appropriate reflected in newly-enacted	1.2.1	Update, complete and implement Marine Turtle National Plans of Action (CTI-CFF or equivalent management plans), community-led traditional use agreements, and in consultation with other range states, CTI-CFF Regional Plan of Action (RPOA) and SPREP's Regional Marine Turtle Action Plan 2023-2028, ensuring that they	• *Make an assessment of gaps and seek support from CITES Secretariat to deliver CITES Turtle Decisions (as per Turtle*	R/N	Immediate	CTI-CFF, SPREP, CMS, IOSEA MOU, IAC, National Governments, local community groups	1, 2, 3, 4, 5, 7, 9, 10

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
legislation, and are enforced	address relevant recommendations in CITES information document CoP18 Inf. 18and related Decisions 18.211-18.213 (and any relevant new Decisions or Resolutions), and: • Surveillance and enforcement of trade in hawksbill meat and parts; • Legislative reform for incidental bycatch in all fisheries (including small-scale community fisheries) and practical modifications of fishing gear; • Traditional management and regulation of domestic quotas, if any, and any user rights relating to habitat critical for hawksbill turtles • Identification, based on satellite tracking, tag recovery and genetic data, of a network of hawksbill habitat and migratory protection sites and of habitats requiring greater protection.	*Decision 18.210 - 18.217)* • *Engage relevant researchers and NGOs to assist, and where needed, seek funding support to develop and/or finalize CTI-CFF NPOA or other national management plan/strategy* • *Participate WWF's Turtle Use Project* • *Contribute to existing SPREP processes to finalize and endorse work plan* • *Commit to working with CTI-CFF to develop RPOA*				
	1.2.2 Where domestic harvest of specimens of hawksbill turtles, including eggs, is legal, ensure any	• *Prioritize as part of 1.2.1 and 1.1.1*	N/R	Short	National Governments,	2, 3

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
	domestic harvest quotas are established based on robust science-based methods and the principles of sustainability, including accounting for existing use in other States that share hawksbill turtle stock(s)	• *Participate in WWF's Turtle Use Project*			local community groups	

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
Objective 2: Increase action and improve accountability to further monitor and report on hawksbill take, use and trade nationally and cooperate regionally to exchange data, share intelligence and strengthen collaborations							
2.1 Accountability and action in detecting and monitoring is enhanced, improving the control and reporting of illegal trade and fishery/vessel activity	2.1.1	In a standardized manner, collect illegal wildlife trade data and using all available technologies ascertain key trade routes, methods, volumes, and trade 'hot-spots' that can be used for monitoring trade in hawksbill turtles; and submit comprehensive and accurate information on illegal trade in marine turtles in national annual illegal trade reports to the CITES Secretariat and other relevant bodies (e.g., CTI-CFF, TRAFFIC WiTIS database).	• *Prioritize as part of 1.1.1* • *Participate in WWF's ShellBank* • *Respond to CITES Turtle Decision notifications and submit annual illegal trade reports.* • *Seek guidance on a 'standardized'*	N	Ongoing - Short	CITES, CTI-CFF, National Governments, NGOs, Universities and Research Institutes	1, 2, 3, 5

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
			approach and/or methodology to collect consistent and comparative trade data within and between countries relevant to the question at hand (for example, TRAFFIC market survey methodology, WWF's socio-cultural use and trade survey methodology, or following CITES/CMS trade questionnaires). • *Seek guidance of available technologies and facilitate the development and dissemination of new technologies.*				
	2.1.2	Increase action where necessary to tackle the illicit financial flows associated with hawksbill turtle trafficking and related corruption, including increasing use of financial investigation techniques	• *Approach UNODC, Wildlife Justice Commission or similar to assist with in-country or*	N	Immediate - Short	National Governments, UNODC	11

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		and public/private collaboration to identify criminals and their networks	*regional assessment* • *Partner with ACAMS* • *Work with the private sector to seek support and delivery*				
	2.1.3	Improve accountability for the practices (e.g., handling, release, record keeping) undertaken by all vessels and improve the associated monitoring and control at landing sites	• *Submit comprehensive and accurate national annual illegal trade reports to the CITES Secretariat and other relevant bodies (e.g., CTI-CFF, TRAFFIC's WiTIS database etc.)* • *Ratify the Agreement on Port State Measures (PSMA or Port State Measures Agreement) to prevent, deter and eliminate illegal, unreported and*	N	Short	National Governments, FAO (via Port State Measures Agreement), RFMOs	3, 5

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
			unregulated fishing.				
	2.1.4	Continue and/or establish national and regional bycatch mitigation programmes for industrial and artisanal fisheries (also community/small-scale fisheries), particularly where additional management is required, to enhance their use (including gear modifications, TEDs) and reduce bycatch.	• *Prioritize as part of 1.2.1 and 1.1.1*	N/R	Short	National Governments	2, 4
	2.1.5	Continue and/or establish national and regional observer programmes to assess and quantify fishery impact/overlap to hawksbill turtle populations, stocks and distribution, and prioritize areas, stocks, fisheries for additional management.	• *Work with the private sector to seek support and delivery*	N/R	Medium	National Governments	2, 4
2.2 Improved collaboration, cooperation and intelligence sharing to all relevant policy fora (local, national, regional and international) and	2.2.1	Increase intra- and interregional collaboration and exchange of actionable intelligence between source, transit, and destination countries to address the illegal take and trade of hawksbill turtles,	• *Submit comprehensive and accurate national annual illegal trade reports to the*	N/R	Short	National Governments, CITES, ICCWC, INTERPOL, ASEANAPOL, UNODC, RFMOs	1, 2, 3, 5, 11, 12, 13, 14, 15

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
between all South-East Asia and Western Pacific Ocean countries results in better coordinated efforts to address unsustainable take and trade of hawksbill turtles		and coordinate efforts to identify and address fishing interactions with hawksbill turtles in the high seas.	*CITES Secretariat and other relevant bodies (e.g., CMS National Reports, IOSEA Marine Turtle MOU National Reports, CTI-CFF, TRAFFIC's WiTIS database etc.)* • *Ratify the Agreement on Port State Measures (PSMA or Port State Measures Agreement) to prevent, deter and eliminate illegal, unreported and unregulated fishing.*			and other Regional Fishery Bodies, CTI-CFF	
	2.2.2	Strengthen internal, bilateral, and international cooperation in enforcement by collaborating with IGOs and NGOs to ensure the issue of marine turtle trade is raised where necessary on the agendas of relevant multilateral agreements and fora, and	• *Increase cooperation between fisheries and environment ministries*	R	Ongoing - Immediate	National Governments, IGOs incl. CITES, CMS, IOSEA MOU, NGOs, INTERPOL, UNTOC, FAO, RFMOs	1, 2, 3, 5

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		meetings of other relevant organizations					
2.3 Research and evaluation undertaken enables baselines and scale of impact of take, use and trade to be determined	2.3.1	Enhance research to further capture the scale and impact that national and international artisanal, semi-industrial and industrial fisheries, including illegal, unreported, and unregulated fishing, have on hawksbill turtle populations and their linkage to illegal trade including through the use of on-board observer data, fishing	• *Coordinate research activities among partners* • *Align with the activities identified as part of 1.2.1 and in review of 1.1.1* • *Incorporate research questions*	N	Immediate - Ongoing	NGOs, National Governments, World Bank, Universities and Research Institutes	1, 2, 3, 5

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		community surveys, and other methods where appropriate	*into national research strategies*				
	2.3.2	Evaluate social, cultural, and economic values of hawksbill turtles, both intrinsically and in terms of their use and trade, and investigate the drivers that underpin the use and trade of hawksbill turtles and products	• *Coordinate research activities among partners* • *Align with the activities identified as part of 1.2.1 and in review of 1.1.1* • *Incorporate research questions into national research strategies* • *Participate in WWF's Turtle Use Project*	N/R/I	Short	NGOs, National Governments, Universities and Research Institutes	1, 2, 5

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
	2.3.3	Continue and/or collect genetic samples of hawksbill turtles using standardized methods and conduct reliable analysis to determine the population of origin (e.g., nesting), geographic boundaries of stocks (e.g., foraging) and the genetic diversity between and within stocks. Compile and map data to support, for example, research, investigations and prosecutions, and policy decisions nationally and internationally.	• *Align with the activities identified as part of 1.2.1 and 1.1.1* • *Participate in WWF's ShellBank* • *Participate in the Asia Pacific Marine Turtle Genetic Working Group* • *Incorporate research questions into national research strategies*	N	Ongoing - Immediate	National Governments, Universities and Research Institutes	1, 2, 3, 5
	2.3.4	Research and establish a baseline for the conservation status and distribution of hawksbill turtles in the different countries/regions and where gaps exist, further study hawksbill genetic identity, life history, population trends, habitat needs, migration routes,	• *Seek support, financial and technical assistance from Universities, Research Institutes, IOSEA Marine Turtle MOU Advisory Committee, IGOs,*	N/R	Ongoing - Immediate	National Governments, Universities and Research Institutes, IGOs, NGOs, local community groups	1, 2, 3, 5

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
	and other biological and ecological aspects, as necessary	*NGOs or local community groups* • *Coordinate research activities among partners* • *Align with the activities identified as part of 1.2.1 and in review of 1.1.1* • *Incorporate research questions into national research strategies* • *Contribute to the Coral Triangle Atlas, SPREPs TREDs database, CMS TurtleNet, and other databases as appropriate* • *Participate in WWF's Turtle Use Project and ShellBank* • *Participate in the Asia-Pacific Marine Turtle*				

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		Genetic Working Group • *Contribute and participate in WWF's marine turtle legislative and baseline status review*				
2.4 Established best practice standards and protocols are used to guide and deliver on-ground monitoring and management of hawksbill turtles	2.4.1 Review existing research methods and monitoring protocols to ensure standard best practice monitoring guidelines and monitoring systems are used for hawksbill turtles, publish and provide training where required, and apply to existing or newly established index nesting and foraging sites to ensure monitoring of populations is carried out as precisely and accurately as possible so information can be shared amongst range states to improve knowledge of the status, distribution, numbers (trend) and state of health (refer Activity 2.3.3.and 2.3.4).	• *Seek support, financial and technical assistance from Universities, Research Institutes, IOSEA Marine Turtle MOU, IGOs, NGOs or local community groups* • *Contribute to the IUCN Marine Turtle Specialist Group (SSC) and SPREP's sea turtle monitoring guideline updates* • *Coordinate research activities among partners*	I/N	Short - Medium	National Governments, CMS, IOSEA MOU, Universities and Research Institutes, IGOs, NGOs, local community groups	1, 2, 4, 5, 9, 10

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		• *Align with the activities identified as part of 1.2.1 and in review of 1.1.1* • *Incorporate research questions into national research strategies*				
	2.4.2 Define and identify habitat critical for hawksbill turtle stocks at different life history stages with a particular focus on the trans-boundary nature of life-cycle stage requirements, migratory patterns, and related protection strategies and adequately protect critical areas including through but not limited to marine protected areas (refer Activity 3.1.3).	• *Seek support, financial and technical assistance from Universities, Research Institutes, IGO, NGOs or local community groups* • *Coordinate research activities among partners* • *Align with the activities identified as part*	R/N	Short	National Governments, IGOs, CTI-CFF, NGOs, Universities and Research Institutes	2, 9

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		of 1.2.1 and in review of 1.1.1 • *Incorporate research questions into national research strategies*				
Objective 3: Further research and evaluate the level of impact trade and fishery activity have on hawksbill populations and deliver on-ground implementation projects by 2027						
3.1 Awareness, education and sustainable alternatives reduce poaching, overexploitation and trade in hawksbill turtles	3.1.1 Work with local communities, including youth and women, turtle consumers, religious leaders as appropriate, in taking further steps to understand use and trade, including with a view to reducing unsustainable practices, and to raise community and political awareness, information sharing and education on such matters as: • the conservation status of hawksbill turtles, • possible health issues involved in consumption,	• *Seek support, financial and technical assistance from Universities, Research Institutes, IGO, NGOs or local community groups* • *Coordinate research activities among partners* • *Align with the activities identified as part*	N	Short	NGOs, National Governments, local community groups, health sector, economists	1, 2, 3, 4, 5

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		• the illegal trade including online, • existing regulations and the importance of promoting the conservation of the species through compliance with policy, and • formulation of effective economic incentives (supported by financial or technical assistance) to reduce poaching (refer Activity 3.1.3)	*of 1.2.1 and in review of 1.1.1* • *Incorporate research questions into national research strategies* • *Seek economist expertise on how to capture the publics willingness to pay for marine turtle conservation (e.g., WWF's Asia-Pacific Marine Turtle Economic valuations (and in-country reports))* • *Participate in WWF's Turtle Use Project*				
	3.1.2	Building on Activity 2.3.2, examine motivations for both legal and illegal harvest and use of hawksbill turtles and their eggs, and where such use exceeds sustainable limits, assess the sustainability of, recommend and implement alternative livelihood options for communities which depend on	• *Seek support, financial and technical assistance and advice from Universities, Research Institutes, IGO,*	N	Short	National Governments, NGOs, local community groups	1, 2, 3

Result	Actions		Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
		marine turtles, include subsistence users in decision making, and seek financial and technical support to address this item (also refer Activity 1.2.2 on domestic trade)	*NGOs or local community groups* • *Coordinate research activities among partners* • *Align with the activities identified as part of 1.2.1 and in review of 1.1.1* • *Incorporate research questions into national research strategies* • *Participate in WWF's Turtle Use Project*				
	3.1.3	To reduce poaching and the exploitation of hawksbill turtle products, establish economically and environmentally effective direct incentive (i.e., economic) schemes (e.g., employment/payment) to deter illegal poaching, or establish effective indirect incentives (developing and fostering alternative sustainable livelihoods such as eco-tourism, use religious	• *Seek support, financial and technical assistance from Universities, Research Institutes, IGO, NGOs or local community groups*	N/R	Medium	National Governments, CMS, IOSEA MOU, NGOs, local community groups, donor organizations	1, 2, 5, 11

Result	Actions	Ways of Potential Delivery	Level[1]	Priority & Timescale	Suggested Partners	Related Mandates
	edicts to curb turtle consumption) for turtle users (also refer Activity 3.1.1)	• *Coordinate research activities among partners* • *Align with the activities identified as part of 1.2.1 and in review of 1.1.1* • *Incorporate research questions into national research strategies* • *Seek economist expertise on how to capture the publics willingness to pay for marine turtle conservation (e.g., WWF's Asia-Pacific Marine Turtle Economic valuations (and in-country reports))* • *Participate in WWF's Turtle Use Project*				

Related Mandates:

(1) IOSEA Marine Turtle MOU Conservation and Management Plan 2009
(2) IOSEA Marine Turtle MOU Work Programme 2020-2024
(3) CITES CoP18 Turtle Decisions 2019
(4) Sulu Sulawesi Marine Turtles Action Plan 2011
(5) Pacific Islands Regional Marine Species Programme 2022-2026
(6) Tools of the International Consortium on Combating Wildlife Crime (ICCWC)
(7) Inter-American Convention Hawksbill Conservation Resolution 2017
(8) MOU ASEAN Sea Turtle Conservation and Protection
(9) CTI-CFF Regional Plan of Action 2012
(10) Ramsar Convention Resolution XIII.24
(11) London Declaration 2018
(12) UNTOC
(13) UN Convention Against Corruption
(14) PSMA
(15) UNCLOS

ACKNOWLEDGEMENTS AND CONTRIBUTIONS

I would like to thank Dr Kim Riskas (KR) for her assistance in drafting the background to the SSAP, Dr Colman O'Criodain for his advice in synthesising the SSAP and for the CMS interns who assisted me with the national legislative overview table.

CAMH conducted the priority-setting and drafted the SSAP including the action table and priority setting. CAMH and KR drafted the background to the SSAP using Chapter 1 as a basis. CAMH and CMS Secretariat edited and finalised the SSAP based on Signatory State negotiations prior to endorsement.

Chapter 8: General Discussion

Synthesis of key findings and implications

The focus of this thesis was to use empirical science to inform what policy and mitigation management is required to recover the neQld and PNG hawksbill populations of the western Pacific Ocean region - a species and region that has been identified as severely lacking in scientific certainty with large gaps in knowledge and classified as one of the most endangered regional management units (Wallace *et al.,* 2010; Wallace *et al.,* 2011).

Scientific data that exists on the population structure, status and trends, biological and ecological nesting and foraging patterns, and threats to hawksbill turtles within the western Pacific Ocean region is scattered, highlighting the need to summarise this knowledge for use in designing and implementing effective policy and management action.

In Chapter 2, I reviewed and synthesised ~60 scientific papers, grey literature articles and reports to present a synopsis of the conservation status and current state of knowledge of hawksbill turtles for the region. The results of this assessment revealed that the likely trajectory for hawksbill populations across the entire western Pacific Ocean region is of significant concern.

Hawksbill turtles were recorded nesting in at least 16 (out of 22 assessed) countries and were found to occur, and in some cases to migrate between, almost every country in the western Pacific Ocean region. Yet, many countries lacked information on hawksbill population structure (i.e. age class distribution, sex ratios and/or genetic composition) and other population variables, such as the proportion of sex ratios at different life stages, growth rates and survivorship. The Solomon Islands is the only country in this assessment where hawksbill populations had been genetically assigned to management units. There were also substantial gaps identified in the knowledge of hawksbill turtle foraging areas, habitat use (oceanic and coastal), diets, levels of direct harvest, and threats. Where assessments could be made, population trends varied but reported to be generally in decline with some populations already considered extirpated; for example, the Solomon Islands (increasing), Republic of the Marshall Islands (declining), most of Micronesia (declining), Palau (likely declining), Guam (likely extirpated), Vanuatu (likely declining).

Nevertheless, countries in the western Pacific Ocean region have adopted a variety of regional and international agreements aimed at protecting hawksbill turtles and their habitats, or at mitigating threats that may directly or indirectly affect them. On a national scale, hawksbill management and protection varies from country to country (refer Chapter 2 and Chapter 3) but where management efforts is in place, recovery is possible. While many dedicated organisations, individuals, communities, and governments have achieved conservation gains, findings reported in Chapter2 indicated that much more work is needed to prevent further declines. Providing a single point of reference, policy and resource managers can use this resource to inform how to address research, knowledge, and policy gaps, and to aid building their regional strategies and stronger regulation approaches to conserve hawksbill turtles across the western Pacific Ocean region. As a matter of attention, where management units have not yet been defined, efforts to do so through genetic research and consistent nesting beach monitoring should be prioritised. This Chapter was used as the basis for developing the CMS SSAP.

There are varying levels of national and state laws, legislative frameworks, and policies afforded to hawksbill turtles throughout the South-East Asia and western Pacific region. In Chapter 3, I assessed and provided an overview of relevant commitments and mandates that countries have already made to conserve, manage, and protect hawksbill turtles in this region. From these, I consolidated a list of 49 actions from 16 most relevant sources (those that more directly seek to address hawksbill turtle take and trade) and grouped them into four different categories: 1) Improve Legislation, Policy and Enforcement; 2) Enhance Regional Cooperation; 3) Furthering Research, Monitoring, Implementation and On-Ground Management; and 4) Awareness, Education, Capacity Building and Resources Required. Sixteen priority actions (those that should be implemented in the short-term, are already underway and/or are already in part financially supported) were highlighted. This Chapter was also used as the basis for developing the CMS SSAP.

Conservation knowledge underpins conservation action. In response to the need to further develop a baseline for the conservation status and distribution of hawksbill turtles in different countries of the region, and given the prediction that the neQld stock had declined > 90% by 2020, quantification of the population trend and trajectory of the neQld stock was urgently needed. In Chapter 4, I contributed to the final 3 years of field-based data collection, and using a long term capture-mark recapture data set, assessed the population trend and trajectory of the neQld stock. Results showed that the nesting population on Milman Island, GBR (representative of the neQld stock) continued to decline by 57% (number of nesters) and 58% (number of clutches laid) over the past 28 years. Even though high levels of protection are afforded to Milman Island (where there is also little to no traditional take of nesting turtles or their eggs), the population is likely to extirpate as early as 2032 (between 2032-2037 nesting seasons). These results indicated that rapid and ongoing decline may be a result of historical and contemporary hawksbill take in unprotected foraging areas within the stock's geographical range, possibly leaving an older cohort of 'protected' adult turtles to survive. The results of an observed decline in the average size of Milman Island nesters also supports the notion of contemporary overexploitation as the reduction in body size is characteristic of an exploited population which can also affect the resilience and capacity of populations to recover. While I also found that annual survivorship was high, it was in comparison to other studies including the hawksbill GBR foraging ground assessment in Bell *et al.,* (2012) of which 15% was comprised of the neQld stock. The Chapter 4 study showed high annual survivorship but an overall decline of adult females, which could be explained by failed hatching success at nesting beaches, and/or low survival through to maturation. This Chapter highlighted the need to further understand the cause[s] of the Milman Island population and greater neQld stock nesting beach decline. To do so, I purported that a better understanding of the location and threats within foraging areas and breeding migration routes was essential and that confirmation of Milman Island's suitability to represent the neQld stock and its possible genetic connectedness to others (e.g. PNG) was critically needed. Until threats to the stock are better spatially quantified and defined, I suggested interim moratoriums on turtle take should be considered. At the same time, Milman Island nesting beach monitoring should continue to determine the effectiveness of any conservation action put in place.

Encompassing these indications that historical and contemporary overexploitation may be the driver of the neQld stock decline, this deduction was notably made without significant knowledge of this populations' life history distribution, foraging ground identification, connectivity to neighbouring genetic stocks, and full assessment of threats. A poor understanding of the relative importance and spatial distribution of threats to this population has been a major impediment of the ability of decision makers to propose effective interventions, mitigation measures, or recovery actions. In Chapter 5, I used empirical data and threat based assessments to spatially identify the neQld stock life-history distribution, migratory paths, and foraging grounds, and the likely threats to pinpoint and offer conservation and protection measures to reverse its likely population trajectory towards extirpation. In summary, tracking migration pathways to foraging ground locations of hawksbill turtle's, overlaid with threat exposure datasets, quantified and qualified the threatening and non-threatening risks posed to the population, in essence leaving those 'undefined' (e.g. unquantified take, underreported bycatch) as realistic threats driving population decline.

Of significance, results of this work revealed that no satellite tracked turtle left the Australian continental shelf and there was a clear dominance of post-nesting migration in western Queensland. In contrast, the post-hatchling dispersal model predicted a concentration of hawksbills in the Torres Strait to Gulf of Papua region, including some foraging areas outside of Australian waters. Given allowances of exploitation to indigenous people and local communities, survival to breeding is likely to be low.

Although no single pervasive threat was identified in the threat-risk assessment, several policy and management recommendations were provided, including reducing overharvesting, increasing fishery bycatch mitigation (and gillnet/ringnet effort reduction), addressing ghost gear interactions, and strengthening protected area management (particularly in post-nesting home ranges in western Queensland). The declaration of critical habitats, including "no-take" zones or moratoriums, could all collectively be enacted within NE Australia and cross border with PNG. Climate change intervention strategies may also soon be required. These threats were considered to have the potential to impede recovery or result in further declines in the population, requiring immediate attention if this population's trajectory is to be reversed and remain one of western Pacific's strongholds. These results indicate this is a matter of urgency given the size of the critically endangered population, if the once described "world's largest" hawksbill stock is to avoid extirpation.

The neQld stock shares east coast Queensland waters with mixed genetic stocks, including the Solomon Islands, Vanuatu, and foragers of unknown origin (Bell & Jensen, 2018). Limited tag returns show that turtles from eastern PNG use foraging areas along the GBR, although there are no published satellite tracking records to show migratory routes between nesting and foraging grounds. It remains unknown if hawksbill turtles nesting within PNG are part of neQld or neighbouring Solomon Island genetic stocks, or if they are distinct. Thus, **we do not know**

whether they should they be managed as separate management units or as one. Effectual policy and management decisions to reverse declining population trajectories remain impeded without this knowledge. In Chapter 6, I investigated the genetic structure, diversity, and migratory patterns of hawksbill turtles from two nesting locations in PNG using mtDNA sequencing and satellite telemetry. Almost all the satellite tracked Conflict Group of Islands nesting population travelled to the NE coast of Queensland to forage (93%). The migratory paths followed 3 distinct strategies I) eastern Torres Strait, II) Far North 29 Queensland, and III) western PNG waters, to reach their foraging grounds (n=10). Like other studies, a broad scope of home range strategies and sizes were also used, with little specificity shown towards a singular/particular foraging ground.

Using genetics, I also defined two new management units, 1) Milne Bay Province, and 2) eastern New Ireland Province, as the Conflict Group and Kavieng samples (respectively) differed significantly from all other known Asia-Pacific stocks (7 MUs). Previously identified orphan haplotypes in other studies were found in the PNG samples, providing a likely origin.

For the first time in PNG, these findings provide essential insights into the genetic stock structure and connectivity of hawksbill turtles in the western Pacific Ocean region. It emphasises that the two newly described PNG genetic stocks need to be managed as demographically separate MU's, but their migratory and foraging life histories also links them to Australia's management and conservation actions. Given the importance of the NE coast of Australia as a multi-stock hawksbill foraging 'sink', further policy and management is needed to safeguard this western Pacific Ocean stronghold. I made various recommendations, including up-listing hawksbill turtles as a 'Protected Species' under PNG legislation, alongside a review and strengthening of the *Torres Strait Treaty, 1985*. Where there is now empirical evidence to show PNG shares its hawksbill populations with Australia (and beyond), joint and concerted co-management efforts should now be explored between Australia and PNG to ensure future conservation and protection across PNG's hawksbills full life history.

My final Chapter 7 the SSAP for hawkbill turtles, was a consolidation of Chapters 2 and 3 and the new knowledge and outputs of this thesis. I drafted the goal, objectives and corresponding 23 actions for the SSAP. Seven actions were listed as immediate priorities, those that were deemed urgently required to be delivered within the next year. Thirteen actions were prioritised for delivery within the next three years, and three within the next five years. Given utmost urgency is required to address hawksbill unsustainable use and trade, to support uptake of the SSAP, I presented potential delivery mechanisms and likely implementation partners. The most urgent actions were identified (refer Chapter 7 summary of action), latter endorsed by various range States.

In reviewing the 38 States national legislations relevant to hawksbill turtles, I identified that legal provisions are not always tailored to hawksbill turtles. Rather most of the national legislation does not have conservation and protection provisions designation. Instead most are included in broader conservation/protection regimes (e.g. "marine resources", "living aquatic species" or "fish"). I found there was a prevalent lack of designation of the hawksbill turtle as a "protected" species and therefore lack of designated conservation status (e.g., "endangered") in national legislations. In addition, I found national laws bifurcate between use, take and trade and differ among States. For example, in PNG, hawksbill turtles remain unprotected, whereas in Fiji there is currently a total ban on all take, sale, possession and transport. In relation to customary rights, some nations stipulate total bans, others have laws that specify size or catch limits, or provide for traditional use permit systems (i.e., domestic quotas), with many relying on indigenous people and local community management plans to manage harvest levels.

While there were various types of legislation reported to be in existence across multiple jurisdictions (national/state/provincial/local), some were conflicting within/among States, and not all legislative provisions were annotated to be used to the fullest. For example, some States only use wildlife laws to designate "protected" status and govern use and trade, or fisheries laws to regulate fishing and hunting activities/quotas, while others combine with protected area laws to conserve and manage habitat. Furthermore, it was noted there were a wide range of penalties which may or may not aid in deterrence. This led to the development of a national legislative overview table (S5.1) which will be used as a baseline for future legislative assessments (aiding delivery on priority action 1.1.1) and to monitor effective policy reform.

The SSAP produced as a result of the current study, is guiding hawksbill research and conservation efforts across the region highlighting where efforts are most needed, and as a result, are already underway.

Conclusion

A goal of conservation biology is to identify and assess the magnitude of actual or potential impacts on populations to inform management decisions and guide recovery actions. Too often, complete assessments of a specie's life history traits and the threats impacting each stage are not made before mitigation efforts or interventions are put in place. While this is often a result of poor data and low resource availability or priortisation of effort, recovery can be impeded if actions are not based on scientific evidence or directed at the most pressing issues (no matter how politically sensitive) which may otherwise lead to extirpation (e.g Vaquita; Jaramillo-Legorreta *et al.,* 2007) or extinctions (e.g. Bramble Cay melomy's; Gynther *et al.,* 2016) in some species. In the case of the Bramble Cay melomy's extinction in the northern GBR, inaction on its research and conservation were considered paramount in its demise (Fulton, 2017). Relevant to the neQld stock's near extirpation, Fulton (2017) stated that when "*a species is in decline the end point will, sooner or later, be extinction. Act when the decline is noticed, because no practical action is possible after the end point".*

This thesis consolidated the many gaps in knowledge and where research, conservation, management, and protection efforts are needed for hawksbill populations in the 22 assessed countries of the western Pacific Ocean region. Enshrined within a SSAP, countries now have the opportunity to endorse it at the upcoming CMS Conference of Parties, October 2023, and use as a basis to act.

Focussing down on the NE Australian and PNG populations, this thesis revealed there is need to urgently act particularly for the near extirpated neQld stock that spends most of its life history within Australian waters. Because the PNG populations are genetically distinct from the neQld stock (now 3 separate MU's) and because they also mostly reside in NE Australian waters, the responsibility to act primarily sits with the Australian and Queensland State governments, and the indigenous communities of Australia and PNG that remain reliant on hawksbill turtles. The importance of NE Australia's habitat in supporting multiple (mixed stock) hawksbill turtle populations suggests any in-water protection or threat reduction afforded to the neQld stock is likely to also help conserve the PNG populations (and other western Pacific Ocean stocks). This highlights the need for greater national and regional cooperation, particularly given the decline in the neQld hawksbill stock, and the likely decline of other western Pacific hawksbill populations

(Pilcher *et al.,* 2021). This thesis has therefore demonstrated that hawksbill turtle foraging grounds in NE Australia are a ‘sink’ and potentially a last stronghold for multiple western Pacific hawksbill populations.

However, the foraging grounds are also a ‘source’ for take. Cumulative take of hawksbill turtles in northern Australia (and surrounding western Pacific countries) should be considered non-sustainable (Department of Environment and Science, 2018). Given the evidence presented in this thesis, it is reasonable to surmise overexploitation (of eggs and turtles) continues to dampen neQld stock recovery. Low survivorship to maturation is also compounded by fisheries interaction impacts. Acknowledging there was no single pervasive, rather multiple synergistic threats impacting the stock at various life history stages, clear recommendations and practical measures were presented. The Australian and State governments, collectively within NE Australia and cross border with PNG, should act to reduce overexploitation, bycatch impacts particularly gillnet and ringnet effort in western Queensland, undertake ghost gear mitigation, and declare critical habitats or other protective mechanisms including Biologically Important Areas of their nesting and foraging home ranges. Recommended next steps are for governments to begin open dialogue with indigenous peoples and local communities, and the fisheries sectors, to map a way forward to recover the neQld stock and strengthen protection of north Queensland as a stronghold for western Pacific’s hawksbill populations.

Similarly, indigenous communities harvesting hawksbills for eggs, meat and shell requires intervention (Opu, 2018). Made difficult because hawksbill turtles are an unprotected species in PNG with no quotas or records of actual take, however, precautionary principle actions could be taken, including to review and strengthen the *Torres Strait Treaty, 1985*. Otherwise ineffective, unregulated, or complete lack of management and/or protection at hawksbill rookeries or foraging grounds is likely to negatively impact the PNG population.

While there are few geo-political strategies in place to protect transboundary marine turtle populations in this region, and in acknowledging the role of marine turtles in local communities, hawksbills should be up-listed as a ‘Protected Species’ under the *Flora and Fauna Protection and Control Act, 2014* in PNG, and “no-take” or moratoriums considered in NE Australia. These changes should be considered and planned in consultation, with and in recognition of, communities and their rights to sea turtle resources, and as joint and concerted co-management efforts.

This thesis has provided significant new insights into hawksbill ecology and movement, and raised critical recommendations for policy and management interventions required to effectively secure hawksbill turtle populations in NE Australia and PNG before their populations are likely to become extirpated. This thesis is intended to help facilitate these discussions and underpin the development of conservation strategies to protect hawksbill turtles throughout their life history and throughout the western Pacific range.

This is a matter of immediate urgency given the size of the endangered neQld stock, if the once described “world’s largest” hawksbill stock is to avoid extirpation. Without concerted attention and focus to address cumulative threats and provide protection in the Torres Strait and the northern coastal waters of west Cape York, it is reasonable to suggest neQld stock extirpation is likely within the next few decades, with concern that PNG populations may quickly follow suit if they are not already on the trajectory toward extirpation.

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Appendices

***Appendix One*: Ethics approval letter**

USC AUSTRALIA

22 December 2017

Prof Michael D'Occhio
Chair, Animal Ethics Committee
Tel: +61 7 5430 2823
Email: animalethics@usc.edu.au
F29138

Dr David Schoeman
Dr Kylie Scales
Ms Christine Hof

Dear Researchers

Conditional ethics approval for research project: Investigating hawksbill turtle migratory paths and foraging grounds as sinks and strongholds, or targeted sources driving critical population declines (AN/S/17/54)

This letter is to confirm that on 6 December 2017, the Animal Ethics Committee of the University of the Sunshine Coast reviewed and granted ethics approval for the above named project, subject to specific conditions which have now been satisfied apart from the following.

- Clarifying the dimensions and weight of the transmitters to be used; and providing an indication of how this compares to the weight and dimensions of hatchlings and how this may impact the hatchlings.

The Committee is prepared to grant appropal so that the project can commence, subject to the researchers submitting an amendment when the satellite tracker to be attached to hatchlings has been finalised. This should include relevant results from the trials of the new tracker. As such, satellite trackers must not be used on hatchlings until this amendment has been submitted and approved.

The period of ethics approval is from 22 December 2017 to 1 November 2023. The approval number for the activity is AN/S/17/54. The standard conditions of ethics approval are listed overleaf.

If you have any queries in relation to this or if you require further information please contact us at animalethics@usc.edu.au or by telephone on +61 7 5430 2823 or 5459 4574.

Yours sincerely

Prof Michael D'Occhio
Chair, Animal Ethics Committee

<u>Appendix Two:</u> Confirmation of lead authorship of CMS products

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

UN environment programme CMS

Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA Marine Turtle MOU)

To Whom it May Concern

This letter is to confirm that Christine Anne Madden Hof led the development, research and drafting of the following two documents on behalf of the Secretariat of the Convention on the Conservation of Migratory Species (CMS):

- the *Single Species Action Plan for the Hawksbill Turtle in South-East Asia and Western Pacific*, prepared as mandated in CMS Decision 13.70 and IOSEA Work Programme Activity #63, and
- the *Assessment of the Conservation Status of the Hawksbill Turtle in the Western Pacific Ocean Region* (to be published shortly as CMS Technical Series).

She was requested to undertake this work as a leading hawksbill turtle expert and as an affiliate under both the University of the Sunshine Coast and WWF-Coral Triangle Program.

We wish to confirm that she acted as lead author throughout the drafting process, including the revision and finalization of these documents. She also presented and defended this work at three regional workshops held on 10-12 May 2022, and a plenary meeting with representatives of the Range States of the Action Plan held from 30 May to 1 June 2022 (more information available here).

Both these documents are now finalized, with the SSAP endorsed by several Range States, which is a testament to her work.

We thank her for her efforts and this substantial contribution to the work of the Convention.

Yours sincerely,

Melanie Virtue
Head, Aquatic Species Team

Bonn, 27 September 2022

Appendix Three*: *Supplementary Material

Supplementary Tables

Table S2.1 Other relevant international legal instruments, organisations and consortia

International agreements	Description
UN Fish Stocks Agreement	Agreement for the implementation of the provisions of the United Nations Convention on the law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks This text highlights some obligations for the State Party such as surveillance, monitoring, enforcement and control that are provided in articles 18, 19 and 23 of the Agreement. Furthermore, it reinforces the cooperation between States, particularly in the high seas, in order to response to UNCLOS gaps. Finally, as the growing network of RFMOs stems from the UN fish stocks Agreement, RFMOs play a role in conservation and management of marine turtles in adopting, implementing and enforcing measures to combat illegal trade. For instance, transhipment at sea may be an opportunity to facilitate criminality in the fishing sector. Source: https://www.un.org/depts/los/convention_agreements/texts/fish_stocks_agreement/CONF164_37.htm
United Nations Convention Against Corruption	The United Nations Convention against Corruption is the only legally binding universal anti-corruption instrument. The Convention's far-reaching approach and the mandatory character of many of its provisions make it a unique tool for developing a comprehensive response to a global problem. The Convention covers five main areas: preventive measures, criminalization and law enforcement, international cooperation, asset recovery, and technical assistance and information exchange. The Convention covers many different forms of corruption, such as bribery, trading in influence, abuse of functions, and various acts of corruption in the private sector. In the world wildlife crime report published by UNODC in 2016, it has been recorded more than 7,000 endangered species of wild animals and plants illegally traded across 120 countries, where corruption is one of the major facilitators of poaching and trafficking. Source: https://www.unodc.org/unodc/en/treaties/CAC/
United Nations Convention Against Transnational Organised Crime (UNTOC)	The UN General Assembly affirmed the relevance of the UNTOC to fight illicit trafficking in natural resources in its resolution 55/25 of 15 November 2000. The Convention represents a major step forward in the fight against transnational organized crime and signifies the recognition by Member States of the seriousness of the problems posed by it, as well as the need to foster and enhance close international cooperation in order to tackle those problems. States that ratify this instrument commit themselves to taking a series of

	measures against transnational organized crime, including the creation of domestic criminal offences (participation in an organized criminal group, money laundering, corruption and obstruction of justice); the adoption of new and sweeping frameworks for extradition, mutual legal assistance and law enforcement cooperation; and the promotion of training and technical assistance for building or upgrading the necessary capacity of national authorities. Source : https://www.unodc.org/unodc/en/organized-crime/intro/UNTOC.html
Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC)	The Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) is an intergovernmental treaty which provides the legal framework for countries in the American Continent to take actions in benefit of these species. The IAC currently has sixteen Contracting Parties: Argentina, Belice, Brazil, Chile, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Mexico, The Netherlands, Panama, Peru, United States of America, Uruguay, and Venezuela. Source: http://www.iacseaturtle.org/defaulteng.htm
Other Relevant United Nations documents	• United Nations General Assembly Resolution A/RES/75/311: Tackling illicit trafficking in wildlife, 26 July 2021. • United Nations Environment Assembly Resolution 2/14: Illegal trade in wildlife and wildlife products, 27 May 2016. • United Nations, Sustainable Development Goals, 2015-2030 • United Nations Office on Drugs and Crime, World Wildlife Crime Report, Trafficking in protected species, 2020
Other Relevant International Organizations and Consortia	
Asian Development Bank (ADB)	ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 67 members—48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance. Source: https://www.adb.org/
ASEAN Chiefs of National Police (ASEANAPOL)	ASEANAPOL is the Association of National Chiefs of Police from countries under the Association of Southeast Asian Nations (ASEAN). ASEANAPOL is represented by Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. The Association specifically deals with law enforcement and crime control issues in the ASEAN region, and aims to harmonize the efforts undertaken by police forces and law enforcement agencies. Source: http://www.aseanapol.org/

Food and Agriculture Organization (FAO) of the United Nations	FAO is a specialized agency of the United Nations that leads international efforts to defeat hunger. FAO's goal is to achieve food security for all and make sure that people have regular access to enough high-quality food to lead active, healthy lives. Source: https://www.fao.org/home/en
Global Environment Facility (GEF)	The Global Environment Facility was established 30 years ago on the eve of the Rio Earth Summit to tackle our planet's most pressing environmental problems. The GEF is the largest multilateral trust fund focused on enabling developing countries to invest in nature, and supports the implementation of major international environmental conventions including on biodiversity, climate change, chemicals, and desertification. The GEF takes a holistic approach to tackling the poaching crisis by seeking to reduce both the supply and demand that is driving the illegal wildlife trade, as well as developing targeted efforts to curb the actual trafficking.
International Consortium on Combating Wildlife Crime (ICCWC)	The International Consortium on Combating Wildlife Crime (ICCWC) consists of five organizations: the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the International Criminal Police Organization (INTERPOL), the United Nations Office on Drugs and Crime (UNODC), the World Bank and the World Customs Organization, working to bring coordinated support to national wildlife law enforcement agencies and the sub regional and regional enforcement networks that act in defense of natural resources. Source: https://cites.org/eng/prog/iccwc_new.php ICCWC has already developed a wildlife and forest crime toolkit. A number of tools are currently being developed under the auspices of ICCWC. These tools include anti-corruption guidelines that could be used to promote adequate integrity policies and assist member States to mitigate the risks of corruption in the trade chain as it relates to CITES-listed specimens. ICCWC is also delivering a number of activities to support the implementation of national anti-corruption measures and strategies. Source: https://www.unodc.org/unodc/en/press/releases/2017/November/links-between-corruption-and-wildlife-crime-highlighted-at-un-anti-corruption-conference.html
International Criminal Police Organisation (INTERPOL)	INTERPOL is an intergovernmental organisation composed of 194 member countries, facilitating cross-border police cooperation. The INTERPOL Wildlife Enforcement team helps to disrupt and dismantle transnational organized criminal networks involved in the illegal wildlife trade. They assist the member countries to enforce national and international laws and treaties effectively. INTERPOL's General Secretariat has a SubDirectorate devoted to environmental security. Sources: https://www.interpol.int/Who-we-are/What-is-INTERPOL, https://www.interpol.int/Crimes/Environmental-crime/Wildlife-crime
Southeast Asian Fisheries Development Center (SEAFDEC)	**The SEAFDEC** is an autonomous inter-governmental body established in 1967. The mission of SEAFDEC is "*To promote and facilitate concerted actions among the Member Countries to ensure the sustainability of fisheries and aquaculture in Southeast Asia.*" SEAFDEC operates through the Secretariat, located in Thailand, and comprises 11 Member Countries: Brunei Darussalam, Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.

	Source: http://www.seafdec.org/
United Nations Environment Programme (UNEP)	The United Nations Environment Programme (UNEP) is the global authority that sets the environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment since 1972. UNEP works closely with 193 Member States and representatives from civil society, businesses, and other major groups and stakeholders to address environmental challenges through the UN Environment Assembly, the world's highest-level decision-making body on the environment. UNEP supports Member States to ensure that environmental sustainability is reflected in development and investment planning and provides countries with the necessary tools and technologies to protect and restore the environment. Source: https://www.unep.org/
United Nations Office on Drugs and Crime (UNODC)	The frequently transnational nature of wildlife and forest crime make these criminal activities highly relevant to the mandates of UNODC, particularly the United Nations Convention against Transnational Organized Crime (UNTOC) and the United Nations Convention against Corruption (UNCAC). In this connection, UNODC has an important role to play in terms of strengthening the capacity of Governments to investigate, prosecute and adjudicate crimes against protected species of wild flora and fauna, complementing other international legal frameworks that are relevant for the protection of the environment, as for instance the Convention on Biological Diversity (CBD) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). It has developed guidelines on wildlife crime legislation and, in a number of countries, has published guidance to prosecutors engaged in pursuit of wildlife crime. Source: https://www.unodc.org/unodc/en/wildlife-and-forest-crime/mandates.html The UNODC Global Programme for Combating Wildlife and Forest Crime/Sustainable Livelihoods Unit (GP/SLU) is working for and with the wildlife law enforcement community to ensure that wildlife crime, illegal logging, and related crimes are treated as serious transnational organized crimes. Source: https://www.unodc.org/unodc/en/wildlife-and-forest-crime/mandates.html
World Bank	The World Bank, composed of the International Bank for Reconstruction Development and the International Development Association, works with developing countries to reduce poverty and increase shared prosperity. The organisation provides financing, policy advice, and technical assistance to governments, and also focuses on strengthening the private sector in developing countries. The Bank plays a leading role in the international efforts to strengthen governance and law enforcement to combat wildlife and forest crimes. Source: https://www.worldbank.org/ **The World Customs Organization (WCO)**, established in 1952 as the Customs Co-operation Council (CCC) is an independent intergovernmental body whose mission is to enhance the effectiveness and efficiency of Customs administrations. Today, the WCO represents 183 Customs administrations across the globe that collectively process approximately 98% of world trade. As the global centre of Customs expertise, the WCO is the only international organization with competence in Customs matters and can rightly call

	itself the voice of the international Customs community. It provides leadership, guidance and support to Customs administrations to secure and facilitate legitimate trade, realize revenues, build capacity and protect society. Source: http://www.wcoomd.org/en.aspx

Table S4.1 Surveys dates and sample sizes for Milman Island nesting turtle census, and the models that the data were used in: Std.: standard period model; GAM; MSORD and CCL (nester size distribution). Refer to the methods for more details. [1] included in the MSORD model but annual estimates were excluded because of low sample size.

Season	Sampling period	Finished	No. of nights sampled	Models
1990	11/01/1991	27/03/1991	76	Std, GAM, MSORD, CCL
1991	04/02/1992	18/02/1992	15	GAM, MSORD[1], CCL
1992	15/01/1993	03/04/1993	79	Std, GAM, MSORD, CCL
1993	14/01/1994	22/03/1994	68	Std, GAM, MSORD, CCL
1994	26/11/1994	14/02/1995	81	Std, GAM, MSORD, CCL
1995	19/12/1995	13/04/1996	117	Std, GAM, MSORD, CCL
1996	02/12/1996	28/02/1997	89	Std, GAM, MSORD, CCL
1997	23/11/1997	08/03/1998	106	Std, GAM, MSORD, CCL
1998	20/12/1998	02/03/1999	72	Std, GAM, MSORD, CCL
1999	19/12/1999	03/03/2000	74	Std, GAM, MSORD, CCL
2000	-	-	0	-
2001	13/01/2002	14/02/2002	32	Std, GAM, MSORD, CCL
2002	-	-	0	-
2003	14/01/2004	09/02/2004	26	Std, GAM, MSORD, CCL
2004	23/01/2005	20/02/2005	28	Std, GAM, MSORD, CCL
2005	08/01/2006	29/01/2006	22	GAM, MSORD, CCL
2006	14/01/2007	01/02/2007	18	GAM, MSORD, CCL
2007	08/01/2008	17/02/2008	42	Std, GAM, MSORD, CCL
2008	11/2/2009	01/02/2009	22	GAM, MSORD, CCL
2009	10/01/2010	8/2/2010	30	Std, GAM, MSORD, CCL
2010	19/01/2011	15/02/2011	28	Std, GAM, MSORD, CCL
2011	-	-	0	-
2012	-	-	0	-
2013	-	-	0	-
2014	-	-	0	-
2015	26/01/16	6/2/2016	12	GAM, MSORD[1], CCL
2016	19/01/2017	15/02/2017	28	Std, GAM, MSORD, CCL
2017	15/1/18	15/2/18	31	Used to validate model predictions (Std, GAM, MSORD)

Table S5.1: Tracked-turtle summary [CCL, curved carapace length; P, primary; ISR, interseason recapture]

Turtle track ID	Max CCL (cm)	Year tracked	Primary flipper tag number	Tag status & first time tagged date (if known)	Destination direction (east or west Queensland, Torres Strait)	Final location (name; GPS, decimal degrees)	Tracker duration (days)
133403	80.9	2016	QA47369	ISR (1994)	East	Cooktown coast (145.25, -14.9033)	155
133404	82	2016	T75028	ISR	West	Aurukun coast (141.612, -13.1181)	83
133761	81.4	2016	QA49257	P (2017)	West	Mission River coast (141.606, -12.5132)	79
166706	75.1	2017	K81554	ISR (2008)	East	Milman Island (143.103, -12.296)	401
166707	80	2017	K16172	ISR (2001)	East	North pint patch (143.333, -12.296)	425
166708	80.8	2017	QA58727	ISR (1995)	East	Cockburn reef (143.307, -11.799)	366
166709	80.4	2017	QA49441	P (2017)	Torres Strait (east)	Tudu Islands (142.986, -9.7686)	260
166710	76	2017	QA49444	P (2017)	Torres Strait (west)	Canoe Island (142.107, -10.3427)	295
166711	80.4	2017	K99857	ISR (1997)	West	Kowanyama coast (~50km) (140.361, -15.2921)	58
166732	75.3	2017	QA49442	P (2017)	West	Doughboy river (~10km NW) (142.03, -11.393)	265
166733	84.4	2017	K33408	ISR (2001)	West	Aurukun coast (~30km north) (141.572, -13.0339)	345
166734	79	2017	T72537	ISR (2004)	West	Pennefather river (141.706, -12.2377)	116
166735	74.2	2017	T58785	ISR (1995)	Torres Strait (west)	Bamaga (north of) (142.265, -10.7861)	301

Table S5.2: Threat exposure assessment and spatial datasets. Identified hawksbill turtle threat categories in northeast Australia are: (1) fisheries by-catch and net entanglement (2) exotic and native egg predation, (3) unsustainable take, (4) habitat loss and degradation, (5) marine pollution (6) climate change (projected long-term beach erosion; skewed sand temperature sex determination of hatchling).

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
Lack of marine protection	adequate protection	GBR Coast (DES and GBRMPA) and C'wealth Marine Park	Protected areas in Australia	Marine and indigenous protected areas allow for a variety of extractive resources. Marine reserves ("no-take" marine national parks equivalent to IUCN category I and II), and Indigenous Protected Areas (IPA) were only included in this assessment. IPA were combined with a C'wealth dedicated IPA spatial layer to ensure full coverage. Total home range equated to = 4,712km2 Indigenous Protected Areas = 0.07km2 Great Barrier Reef Marine Parks = 1251.8km2 DAWE = 140.2km2 Refer Manuscript.	to 2020	CAPAD 2020, https://www.environment.gov.au/fed/catalog/main/home.page IPA, https://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7BC64658F0-95AD-4209-8D1E-F94BD0A4E827%7D	y	y	Very High
		Torres Strait Treaty Boundary	Boundary	Bounds of the Torres Strait. See descriptions provided: https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/torres-strait; https://www.pzja.gov.au/resources/maps ; https://www.afma.gov.au/sustainability-environment/fishing-closures/closure-direction-maps. Refer Manuscript.	n/a	Alcock, M., Taffs, N.J. 2014. Treaties - Australian Maritime Boundaries 2020 (AMB2020) - Geodatabase. Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/140090; https://ecat.ga.gov.au	y	y	n/a

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
						/geonetwork/srv/eng/catalog.search#/metadata/83161			
Fishery by-catch and net entanglement (in ghost nets, fishing gear (line, net and pot) and boat collision)	bycatch/ entanglement & effort/ interactions	QLD Fisheries SOCI reports	Note raw data only	Queensland fishers are required to report interactions with Species of Conservation Interest. This database maintains these reports and presents data for each year at a species level and the fishing gear interacted. This data was tabulated as spatial data is not provided. Refer S3.3.	2006-2019	https://www.data.qld.gov.au/dataset/total-number-of-species-of-conservation-interest-interactions-with-released-conditions/resource/4ad21384-35fe-4ee5-8013-0099d4aa9e65?truncate=30&inner_span=True	y	y	State level: Very High
		QLD East Coast Inshore Fin Fish Fishery Observer data	Note raw data only	Fisheries QLD ran an observer program in the net component of the ECIFFF from 2006 to 2012. Interactions are reported at a species level for each year and include the number of observer days. This data was tabulated as spatial data is not provided. Refer S3.3.	2006-2012	Upon request was provided. SOCI data reported from 2005 was included.	y	Y	

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
		QLD fishing operators/ Activities catch and effort data for all fisheries	Raw data in report form (as spatial data cannot be exported). However, for gillnet and ringnet and trawl exported datasets, were created into heat maps	QFISH is a database maintained by Fisheries Qld as it manages multiple fisheries such as the Commercial Line, Net and Trawl in addition to the Queensland Shark Control Program. The commercial fishing catch and effort data is collected through commercial fishery logbooks. Information from 1990 onwards is presented in QFish, including species catch and fishing effort for various Qld fisheries, which can be refined for a specified time period, fishing method and/or region (but protected as commercial in confidence if a query results in data from less than five commercial fishers). Days fished for gill net and trawl fisheries was extracted from QFISH and created as a spatial layer, number of days fished. Refer manuscript. In comparison to other fisheries, trawl effort was considered low risk, but calculated to have 1387 km^2 of post nesting homerange within trawl fished areas, with a total sum of 39439 days fished/year.	1990-2019	http://qfish.fisheries.qld.gov.au Accessed 12/04/2021	y	Y	
		C'wealth commercial fishing catch and effort data	Raw data in report form only	Catch and effort data by species, year and fishery as reported in fisher logbooks. This data was tabulated as spatial data is not provided.	2002-2018	https://data.gov.au/dataset/ds-dga-b36304ae-4e15-4d5c-abe2-097a57a05b25/details	y	y	Commonwealth: High

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
		C'wealth Fisheries threatened species interactions	Raw data in report form only	AFMA reports threatened species interactions quarterly. Data is available by a species and fishery level. This data was tabulated as spatial data is not provided.	2012-2019	https://www.afma.gov.au/sustainability-environment/protected-species-management/protected-species-interaction-reports	y	Y	
	potential effort/ interaction, and take/trade	Torres Strait Turtle Fishery	Boundary	See descriptions provided: https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/torres-strait; https://www.pzja.gov.au/resources/maps Refer Manuscript.	n/a	https://www.afma.gov.au/sustainability-environment/fishing-closures/closure-direction-maps	y	n	Very High (refer also Harvest)
	entanglement	Ghost nets	particle modelling, net collection / interaction (not where lost)	Ghost net / turtle risk interaction recreated from Wilcox *et al.*,2013. Refer Manuscript.	to 2013	Wilcox *et al.*,2013; verbal discussions regarding representativeness of data with Riki Gunn (ex-GhostNets Australia) and Western Cape Threat Abatement Alliance	y	y	Very High
	bycatch and entanglement & effort/interactions	stranding data for bycatch, entanglement, and ingestion	322 out of 7300 data points (0.44%; all species) combined for tangled, tangled in crab pot, ghost fishing - tangled in discarded	StrandNet is a database maintained by DES, of marine wildlife strandings and deaths. The primary focus of this database is to record information on where sick, injured, dying and dead marine animals have been found in Queensland and assess causes of injury and death, if possible. StrandNet indicates when marine animal deaths occur directly as a result of human causes, which can be used for changes to policy and management. We combined the 5 year dataset and extracted all strandings per	2009-2014	StrandNet, Department of Environment and Science, Queensland Government	y	y	n/a

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Source d (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
			or lost net, drowned in gill net, drowned in net, tangled in fishing, line, tangled in float line, presumed anthropogenic sources of mortality or impact - tangled.	species that related to the threat. A table was developed based on the threat, per latitude and plotted for Queensland. The greatest threat interaction for hawksbill turtles was fishing gear. Refer manuscript. Boat strike accounted for 15% of all hawksbill threats (primarily in higher latitudes).					
Exotic and native predation (including eggs, hatchlings, or adult females by native (e.g. goanna or crocodile) or exotic (e.g. pig) species)	Predation	Known predation	Presence vs absence	The Atlas of Living Australia (ALA) is a collaborative, digital, open infrastructure that pulls together Australian biodiversity data from multiple sources, making it accessible and reusable to the public. We constructed a dataset from Atlas of Living Animals using Explore Your Area function	Accessed 3 March 2021	https://biocache.ala.org.au/explore/your-area	y	y	Moderate
	Predation	stranding data for crocodile, dog or dingo, shark attack, predation or severe bits or death caused by another animal	14 out of 7300 data points (0.002%; all species)	StrandNet (see description above). For hawksbills alone, predation accounted for 2% of all threats.	2009-2014	StrandNet, Department of Environment and Science, Queensland Government	y	y	n/a

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
Unsustainable take [or harvest] (direct (targeted) take of adults, sub-adults and juvenile turtles as whole, or in part for shell, meat, eggs, oil, fat or bones)	unsustainable take areas and/or adequate protection	Harvest	Boundary	An ILUA (Indigenous Land Use Agreement) is a voluntary agreement between a native title group and others about the use of land and waters under the Native Title Act 1993 (Cwlth). A TUMRA (Traditional Use of Marine Resources Agreement) is formal (non-binding) to manage Great Barrier Reef traditional use /take of sea country activities in partnership with the Australian and Queensland governments. No registered or notified ILUA or TUMRA agreements with C'wealth Government or Queensland Government (GBRMPA) neQld stock boundary. No further assessments made.	Current	ILUA and TUMRA agreements (shapefile)	y	n	Very High
		Harvest	Boundary	Indigenous Protected Areas – refer adequate protection above.					
		Harvest	Particle distribution point data *(*note, cumulative exposure was used to depict post-hatchling life history phase)*	The final positions (lat/long) data was extracted from the Connie 3.0 ocean current modelling text files, for all available years 1993-2007. These were then collated for each particle (post hatchling "lost years") across years. Spatial data was then imported into GIS to examine the distribution of data points across Exclusive Economic Zones (EEZ). Number of points and proportions of data points within each EEZ was then calculated by intersecting both layers. Total points equated to 112,419,192, with Australia = 70,516,358; Indonesia =	1993-2007	Connie 3.0 CSIRO Connectivity Interface, https://connie.csiro.au/; Run 15/3/21) Exclusive Economic Zones Boundaries (EEZ) Australian Ocean Data Network CSIRO, sourced under CC license Coastal Waters (State/Territory	Y	Y	

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
				2,198,683; New Caledonia = 386,106; Papua New Guinea = 35,084,374; Solomon Islands = 3,682,993; Vanuatu: 550,678. Refer Manuscript.		Powers) Act 1980 - Australian Maritime Boundaries 2014a – Geodatabase https://data.gov.au/data/dataset/coastal-waters-state-territory-powers-act-1980-australian-maritime-boundaries-2014a-geodatabase			
Habitat use and degradation (both human induced and natural including changes to beach habitat, access barriers, light pollution, vehicle strike, human disturbance, entrapment/stranding hazards)	habitat use / urban activity	Coastal and urban development (Regional planning urban footprint)	Boundary	No further assessments made given important hawksbill nesting beaches are primarily on uninhabited (non-developed) land.	n/a	n/a	n	n	Low
	sky glow	stranding data by street lights, or disoriented by altered light horizons	2 out of 7300 data points (0.003%; all species)	StrandNet. No light pollution threat was identified for hawksbill turtles.	2009-2014	StrandNet, Department of Environment and Science, Queensland Government	y	y	Low
	sky glow	Light glow or pollution	Mulittemporal satellite night-light data combined with linear mixed model analysis	Broadscale artificial light exposure using DMSP-OLS data (and risk assessment) at turtle nests between 1993-2010, inferred low light pollution for neQld stock distribution (refer Kamrowski *et al.*,2012; 2014). Supported by assessments made in this study using www.lightpollutionmap.info that displays VIIRS/DMSP/World Atlas overlays/IAU observatories and the user measurements overlay over Microsoft Bing base layers (road and hybrid Bing maps), VIIRS data	2012-2020	Kamrowski *et al.*,(2014); https://www.lightpollutionmap.info/#zoom=4&lat=-3014851&lon=16524461&layers=B0FFFFFTFFFFFFFF	y	y	

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
				revealed minimal light pollution. No further assessments were made.					
	boat strike	stranding data for boat strike, propeller cuts, fractures and lacerations	313 out of 7300 data points (0.04%; all species)	StrandNet. For hawksbills alone, boat strike accounted for 15% of all threats, but primarily at latitudes south of Townsville (outside of neQld stock distribution).	2009-2014	StrandNet, Department of Environment and Science, Queensland Government	y	Y	Moderate
	potential boat strike/noise/ loss of habitat	shipping channels	Line data	In contrast to fishery bycatch interactions, there is little data to support a negative hawksbill interaction with shipping activity. Whilst incidental turtle mortality is less comprehensively recorded across northern Australia (Limpus, 2009), boat strike StrandNet data suggests a low impact. Very few studies on the impact of noise/sound on turtles and their subsequent behavioural response has been conducted, as such no shipping assessment was made.	2015+	https://www.operations.amsa.gov.au/Spatial/DataServices/DigitalData	y	n	
Marine pollution (including interaction and ingestion of litter, oil spills, nutrients,	Food availability / chemical contamination	Exposure to pollutants (indicative of nitrogen and TSS input) Flood plume maps		Overall, pollutants (sediment, nutrients, pesticides) in eastern Cape York catchments currently present a relatively low risk to adjacent coastal and marine ecosystems, with coral, seagrass and other ecosystems with the Cape York GBR reef are typically in good condition	2017	Scientific Consensus Statement 2017, State of Queensland	n	n	Moderate

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
sediments and pesticides causing toxicity or health issues)		(indicative of freshwater input)		(Waterhouse *et al.*,2017). The greatest influence from degraded water quality is around Princess Charlotte Bay in the wet season, so with limited runoff pollution within neQld stock distribution, no further assessments were made.					
		Stranding data for ingested material of anthropogenic origin, synthetic material	42 out of 7300 data points (0.006%; all species)	Cape York is exposed to the highest risk of emerging contaminants, marine plastic pollution (Kroon *et al.*,2015). In the absence of any other data, using stranding data for hawksbills alone, this equated to 0%. This was corroborated by a recent study (Duncan *et al.*,2021) that found no incidents plastic (> 1mm) ingestion in hawksbill turtles from Queensland (or Western Australia). No further assessment was made.	2009-2014	StrandNet, Department of Environment and Science, Queensland Government	y	y	Moderate
	Disease and ill health	Disease Gut parasites Encephalopathy Pneumonia Septicemia Blood fluke (spirochid) infection Anaemia Liver malfunction, including hepatitsis and necrosis	99 out of 7300 data points (0.01%)	There has been limited study of disease in wild hawksbill turtles (Limpus, 2008). Using StrandNet, for hawksbill turtles, (unconfirmed) disease and ill health accounted for 20% of all threats.	2009 - 2014	StrandNet, Department of Environment and Science, Queensland Government	y	y	Low

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
Climate change (including sand erosion, elevated temperatures, sea level rise, nest inundation or collapse, loss of food source, entrapment/stranding hazards	sea level rise and loss of nesting beaches	Short term storm impacts Long term trends of sediment loss and channel migration	Erosion prone Areas (refer DES, Queensland Government for definition).	Erosion Prone Area overlaid with important nesting beaches resulted in complete coverage for all islands, noting, some data is high quality from high resolution DEM and Lidar, other not (especially if not an inhabited island, may have whole island as EPA). Thwart with resolution limitations for key nesting beaches, no further assessments made, referenced in manuscript.	Current - 2100	Department of Environment and Science Qspatial footprint map. Data downloaded 02/03/2021. The component sea level rise layer only exists for inhabited islands in the Torres Strait. http://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={52B4C820-488C-4B91-B31D-E1CBA02076F1} Use all components version.	y	y	Very High
	feminisation	Sand nest temperature	Monthly values of minimum temperature, maximum temperature, averaged over 20 year periods (2021-2040, 2041-2060, 2061-2080), at	The data used are CMIP6 downscaled future climate projections. The downscaling and calibration (bias correction) was completed using WorldClim v2.1 as a baseline climate. For CMIP6 data, monthly values of minimum temperature and maximum temperature were processed for nine global climate models (GCMs): BCC-CSM2-MR, CNRM-CM6-1, CNRM-ESM2-1, CanESM5, GFDL-ESM4, IPSL-CM6A-LR, MIROC-ES2L, MIROC6, MRI-ESM2-0, and for four Shared Socio-economic Pathways (SSPs): 126, 245, 370 and 585. This produced gridded weather and climate data for historical (near current)	Current - 2080	Data made available from the World Climate Research Programme, which, through its Working Group on Coupled Modelling, coordinated and promoted CMIP6. Spatial layers can be accessed via: https://www.worldclim.org/data/cmip6/cmip6climate.html	y (CMIP6 model data licensed under a Creative Commons Attribution-ShareAlike 4.0 International	y	High

Proposed threat exposure categories (& description of threat)	As a proxy for	Threat components	Data Points	Data description and assessment	Data period	Report, source or spatial layer	Sourced (y/n)	Analysed (y/n)	Risk (Low, Moderate, High, Very High)
			spatial resolution of 10 minutes (expressed as minutes of a degree of longitude and latitude).	and future conditions which enabled the investigation of projected climate changes in minimum and maximum temperatures at nesting beaches. Refer manuscript.			License)		

Legend:

Risk assessment matrix framework, following Commonwealth of Australia, 2017

Likelihood of occurrence (relevant to neQld stock)	Consequences				
	No long-term effect	Minor	Moderate	Major	Catastrophic
Almost certain	Low	Moderate	Very high	Very high	Very high
Likely	Low	Moderate	High	Very high	Very high
Possible	Low	Moderate	High	Very high	Very high
Unlikely	Low	Low	Moderate	High	Very high
Unknown	Low	Low	Moderate	High	Very high

Levels of risk and the associated priority for action are defined as follows:

- Very High – immediate additional mitigation action required.
- High – additional mitigation action and an adaptive management plan required, the precautionary principle should be applied.
- Moderate – obtain additional information and, where multiple threats receive a moderate rating, develop additional mitigation action if required.
- Low – monitor the threat occurrence and reassess threat level if likelihood or consequences change.

Table S5.3: Hawksbill (HB), unspecified (Un-s) and all turtle species (All turtle) bycatch in Queensland and Commonwealth (C'wealth) fisheries, a) absolute and average over all available years, NA = no data reported or available, b) HB, Un-S and adjusted hawksbill interactions per fishery, c) absolute and average HB and adjusted hawksbill interactions over common reporting period (2012-2019) with HB-prop and unsp range provided in shaded box, percentage in red text, d) turtle interaction rates from the QLD Fishery Observer Program in the ECIF (2006-2012) and potential hawksbill interactions, e) BPUE in the ETBF pre and post introduction of electronic monitoring, and f) Extrapolated BPUE, hawksbill turtle and adjusted hawksbill interactions based upon increase in BPUE observed in the ETBF fishery once independent monitoring was introduced.

S3.3a:

	Queensland Fisheries									Commonwealth Fisheries								
	Gillnet & ringnet fisheries (of ECIF & GoCIF)			East Coast Otter Trawl Fishery			East Coast and GoC Crab Fishery			Torres Strait Prawn Fishery			Eastern Tuna and Billfish Fishery			Northern Prawn fishery		
Year	**HB**	**Un-s**	**All turtle**	**HB**	**Un-s**	**All turtle**	**HB**	**Un-s**	**All turtle**	**HB**	**Un-s**	**All turtle**	**HB**	**Un-s**	**All turtle**	**HB**	**Un-s**	**All turtle**
2005	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2006	2	31	223	0	5	14	0	2	2	NA	NA	NA	NA	NA	NA	NA	NA	NA
2007	2	48	191	0	0	7	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
2008	1	3	303	0	0	2	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
2009	0	0	134	0	0	3	0	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	5	1	106	0	0	3	0	0	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
2011	1	3	44	0	0	3	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
2012	0	2	55	0	0	1	1	0	1	0	1	5	0	1	10	2	14	66
2013	3	0	18	0	0	4	0	0	1	0	1	4	0	0	15	2	20	72
2014	0	0	34	0	0	4	0	0	0	0	4	5	0	1	11	1	36	60
2015	0	1	54	0	0	3	0	0	0	0	6	7	2	6	30	1	46	62
2016	4	2	144	0	0	8	0	0	0	1	2	4	1	17	100	0	43	55
2017	1	0	156	0	0	12	0	0	1	0	1	1	2	18	198	1	40	63
2018	1	0	82	0	0	5	0	0	1	0	1	2	5	22	156	0	51	78
2019	0	0	47	0	0	0	0	0	0	1	0	2	8	18	151	1	46	73
2020	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0	0	3	20	94	0	76	107
Absolute	25	91	1,591	0	5	69	1	2	9	2	16	30	21	103	765	8	372	636
Average	1.7	6.5	113.6	0.0	0.4	4.9	0.1	0.1	0.6	0.2	1.8	3.3	2.3	11.4	85.0	0.9	41.3	70.7
Proportion HB	1.7%			0%			14.3%			14.3%			3.2%			3%		

S3.3b:

	HB	Un-s	HB + adjusted hawksbill interactions	All turtle	HB Proportion	HB + adjusted hawksbill interactions
ECIF & GoCIF	25	91	27	1591	1.6%	1.7%
ECOTF	0	5	0	69	0.0%	0%
EC & GoC Crab	1	2	1	9	11.1%	11.1%
TSPF	2	16	4	30	6.7%	13.3%
ETBF	21	103	24	765	2.7%	3.1%
NPF	8	372	19	636	1.3%	3%

S3.3c:

Year	Queensland Fisheries: Gillnet & ringnet fisheries (ECIF & GoCIF): HB	Queensland Fisheries: Gillnet & ringnet fisheries (ECIF & GoCIF): Adjusted HB interactions	Queensland Fisheries: East Coast Otter Trawl Fishery: HB	Queensland Fisheries: East Coast Otter Trawl Fishery: Adjusted HB interactions	Queensland Fisheries: East Coast and GoC Crab Fishery: HB	Queensland Fisheries: East Coast and GoC Crab Fishery: Adjusted HB interactions	C'wealth Fisheries: Torres Strait Prawn Fishery: HB	C'wealth Fisheries: Torres Strait Prawn Fishery: Adjusted HB interactions	C'wealth Fisheries: Eastern Tuna and Billfish Fishery: HB	C'wealth Fisheries: Eastern Tuna and Billfish Fishery: Adjusted HB interactions	C'wealth Fisheries: Northern Prawn fishery: HB	C'wealth Fisheries: Northern Prawn fishery: Adjusted HB interactions	Total HB only	Total (HB+ adjusted HB interactions)	Total all turtles	Extrap HB for ECIF, GOCIF & Crab & other fisheries	Extrap HB+adjusted HB interactions for ECIF, GOCIF & Crab & other fisheries
2012	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	3.0	3.0	138.0	8	8
2013	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	5.0	6.0	114.0	20	21
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	1.0	3.0	114.0	1	3
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0	1.0	1.0	3.0	5.0	156.0	3	5
2016	4.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	1.0	6.0	8.0	311.0	26	28
2017	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	1.0	1.0	4.0	6.0	431.0	9	11
2018	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	1.0	0.0	2.0	6.0	9.0	324.0	11	14
2019	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	8.0	1.0	1.0	1.0	10.0	12.0	273.0	10	12
Absolute	9.0	0.0	0.0	0.0	1.0	0.0	2.0	2.0	18.0	4.0	8.0	8.0	**38.0**	**52.0**	**1,861.0**	87	101
Average	1.1	0.0	0.0	0.0	0.1	0.0	0.3	0.3	2.3	0.5	1.0	1.0	**4.8**	**6.5**	**232.6**	**10.9**	**12.6**
Absolute HB/adjusted hawksbill interaction	9		0.0		1.0		4		22.0		16.0		HB caught/all fisheries/all years		38/1861 = 2%		
Average HB/adjusted hawksbill interaction	0.6		0.0		0.1		0.3		1.4		1.0		HB+HB prop unsp caught/all fisheries/all years		52/1861 = 2.8%		

S3.3d:

QLD FOP days observed	Observed turtle interactions	Interaction rate (turtles/day)	Reported Hawksbill proportion 2005-2019
426	35	0.082	1.67%

Year	Fishing effort (days)	Potential turtle interactions (interaction rate x effort)	Potential HB interactions (Reported HB prop x potential turtle interactions)
2005	39581	3252	54
2006	39253	3225	54
2007	38341	3150	53
2008	38917	3197	53
2009	35242	2895	48
2010	33671	2766	46
2011	32768	2692	45
2012	32633	2681	45
2013	29868	2454	41
2014	27622	2269	38
2015	27739	2279	38

2016	27684	2275	38
2017	26594	2185	36
2018	25492	2094	35
2019	19915	1636	27
		Total potential HB interactions	**651**

S3.3e:

Year	Hawksbills	Unspecified turtles	Adjusted HB interactions	All Turtles	Dead turtles	Effort (hooks)
2012	0	1	0	10	1	6792185
2013	0	0	0	15	3	6777421
2014	0	1	0	11	0	6955085
2015	2	6	0	30	4	8219473
2016	1	17	1	100	15	7823984
2017	2	18	1	198	29	8746936
2018	5	22	1	156	23	7899398

BPUE HB+adjusted HB interactions (2012-2015)	**0.00007**
BPUE HB+adjusted HB interactions (2016-2018)	**0.00041**

S3.3f:

Year	HB	Adjusted HB interactions	Fishing Effort (days)	BPUE HB	BPUE HB Extrap	BPUE HB + adjusted HB interactions	BPUE HB +adjusted HB interactions Extrap	HB at extrap BPUE	HB +adjusted HB interactions at extrap BPUE
2005	5	0	39581	0.000126	0.000745	0.000126	0.000745	30	30
2006	2	1	39253	0.000051	0.000301	0.000076	0.000451	12	18
2007	2	1	38341	0.000052	0.000308	0.000078	0.000462	12	18
2008	1	0	38917	0.000026	0.000152	0.000026	0.000152	6	6
2009	0	0	35242	0.000000	0.000000	0.000000	0.000000	0	0
2010	5	0	33671	0.000148	0.000876	0.000148	0.000876	30	30
2011	1	0	32768	0.000031	0.000180	0.000031	0.000180	6	6
2012	0	0	32633	0.000000	0.000000	0.000000	0.000000	0	0
2013	3	0	29868	0.000100	0.000593	0.000100	0.000593	18	18
2014	0	0	27622	0.000000	0.000000	0.000000	0.000000	0	0
2015	0	0	27739	0.000000	0.000000	0.000000	0.000000	0	0
2016	4	0	27684	0.000144	0.000852	0.000144	0.000852	24	24
2017	1	0	26594	0.000038	0.000222	0.000038	0.000222	6	6
2018	1	0	25492	0.000039	0.000231	0.000039	0.000231	6	6
2019	0	0	19915	0.000000	0.000000	0.000000	0.000000	0	0
							Total	150	162

Table S5.4: Quantified presence (+) versus absent (x) predation by F/D = fox/dingo; P = pig; G/M = goanna/monitor; Cr = crocodile; C = cat; SF = scrub fowl; H = human (traditional harvest) and non-peak clutch loss to predation by P, G, SF and H extrapolated to 14, 30 and 60 survey days at neQld stock key nesting sites.

Key nesting sites	Presence/absence predator data								Non-peak clutch loss to predation (P, G, SF, H)			
	# predator species present	F/D	P	G/M	Cr	C	SF	H	Percentage % (# predated/total recorded nests)	Over 14 days	Over 30 days	Over 60 days
Albany	**3**	+	+	+	X	X	X	X				
Aukane (Au Kein)	2	X	X	X	X	+	X	+	2.1 (2/96)	5	10	20
Aureed	2	X	X	X	X	+	X	+	2.1 (2/95)	5	10	20
Bet Islet (Bara)	**3**	X	X	+	X	+	X	+	15.5 (18/116)	36	77	154
Bourke (Bak)	2	X	X	X	X	+	X	+				
Boydong Island	1	X	X	X	+	X	X	X				
Cap Islet (Mukar)	**3**	X	X	+	X	+	X	+	34.2 (13/38)	46	98	195
Dadali Islet (Canoe)	2	X	X	+	X	X	X	X				
Dayman	0	X	X	X	X	X	X	X				
Dugong Islet (Atub)	1	X	X	X	X	X	X	+				
Garboi (Arden)	1	X	X	X	X	+	X	X				
Hawkesbury (Warral)	2	X	X	+	X	X	X	+				
Igab (Marsden)	2	X	X	X	X	+	X	+				
Kabbikane (Kebi Kein)	1	X	X	X	X	+	X	X				
Lacey	2	X	X	+	X	X	X	+				
Laoyak (Yauk)	**3**	X	X	+	X	+	X	+				
Little Adolphis (Smol Muri)	2	X	X	+	X	X	X	+				

Maitak (Wilson)	0	X	X	X	X	X	X	X				
Milman Island	2	X	X	X	+	X	X	+				
Mimi	1	X	X	X	X	+	X	X				
Mt Adolphus (Muri)	2	X	X	+	X	X	X	+				
Poll Islet (Guiya)	**3**	X	X	+	X	+	X	+	20.7 (6/29)	28	60	120
Saddle (Ullu)	3	X	X	+	X	+	X	+	10 (1/10)	7	15	30
Sassie (Long)	2	X	X	+	X	X	X	+	3 (4/133)	6	13	27
Saunders (Wuthathi)	**3**	X	X	X	+	X	+	+				
Sauraz (Suarji)	1	X	X	+	X	X	X	X				
Gebar (Two Brothers)	2	X	+	+	X	X	X	X	100 (49/49)	49	105	210
Uluf	1	X	X	+	X	X	X	X				
Ului (West)	1	X	X	+	X	X	X	X				
Woody Wallace	1	X	X	X	X	X	X	+				
Yarpar (Roberts)	1	X	X	X	X	+	X	X				
Zuizin (Halfway)	1	X	X	X	X	X	X	+				
								Total clutch loss	**16.9 (95/566)**	**181**	**388**	**776**

Table S5.5: neQld stock harvest history review

Timeline	Harvest history review
18th century-1930s	At least 86,020lb or over 38 ton of tortoiseshell was exported from north Queensland at the time of commercial tortoiseshell trade. Applying a conversion factor of 2lb of tortoiseshell per large turtle (Limpus & Miller, 2008), approximately 43,010 adult-sized hawksbill turtles were taken from the northern GBR and Torres Strait. Other publications suggest this is equivalent to an annual harvest in excess of 1000 hawksbill turtles (Limpus & Miller, 2008; Limpus, 2009).
1932-1968	Whilst seasonal closures to harvesting green turtles and their eggs south of 17°S in Queensland was ordered (with restricted and eased amendments) under the *Fisheries Act* in 1932, 1950 and 1958, no protection was provided to hawksbill turtles. The tortoiseshell industry effectively ceased during the 1940s and became illegal with the protection of hawksbill turtles in Queensland in 1968 (Limpus, 2009).
1970-1994	Unpermitted take remained illegal in Queensland until the *Native Title Act 1994* (section 211) came into effect, allowing Aboriginal and Torres Strait Islander (ATSI) people with legitimate Native Title rights to hunt hawksbills in Australia for traditional (personal, domestic, communal, non-commercial) purposes within their traditional country. ATSI's hunted hawksbills for centuries for tortoiseshell, meat and eggs (Limpus, 2009); today take is generally managed through customary law. However, changes in technology and the disruption of Indigenous culture are a growing challenge to the intensity of take (MACC Taskforce, 2005).
1992-2013	Harvest rates today remain relatively unquantified. A survey sampling 1,147 Indigenous persons in northern Queensland during 2000-2001 estimated a (species unspecified) annual marine turtle take of 3,851 and egg take of 3,976 (Commonwealth of Australia, 2003). Within confined sample survey studies, an estimated annual take of 50 hawksbills per year in 1992 (Harris, 1992a, b) and 75 in 2013 (Humber *et al.,*2014) would suggest an annual Indigenous take of 50-100 hawksbills (Limpus, 2009).
2015+	Today, the hawksbill turtle is not traditionally harvested by ATSI's within the Torres Strait (TSRA, 2015), however, there is a noted preference for hawksbills eggs (Department of Environment and Science, 2018), and outside of the limited TSRA (2017) study, an unquantified number of hawksbill eggs are collected from rookeries throughout Cape York Queensland and the

	Torres Strait. Whilst unknown, the level of hawksbill take (for food and tortoiseshell) in PNG is likely to be substantially high (Kinch & Burgess, 2009) as it also remains an unprotected species, and is likely to be having negative consequences for the neQld stock, noting compliance intervention into turtle and egg poaching by PNG nationals in the Torres Strait (in contravention to the provisions of the Torres Strait-PNG Treaty), also remain unresolved (The Cairns Post, 2017). As there is evidence of illegal international trade of tortoiseshell and/or whole hawksbill turtles out of the Arafura Sea – Coral Sea Region (Department of Environment and Science, 2018), inadequate monitoring and enforcement of endangered species trade regulation by CITES signatory States (including Australia, PNG and Indonesia (as reports of neQld stock being found here; Barr *et al.,*2021) requires attention – particularly implementing Turtle Decisions 18.210 to 18.217.

Table S6.1. Sample information for all genetics samples collected in the study. Shaded haplotypes boxes show samples removed from analysis.

Country	Region	Location	Species	Activity	Haplotype	Genetic ID	Date	Age Class	Notes
Papua New Guinea	Conflict Islands	Aroroa Island	hawksbill	Nesting	EiIP-33	PNG-39	12/25/2017	Adult	
Papua New Guinea	Conflict Islands	Aroroa Island	hawksbill	Nesting	EiIP-34	PNG-46	1/2/2018	Adult	
Papua New Guinea	Conflict Islands	Aroroa Island	hawksbill	Nesting	EiIP-59	PNG-61	1/7/2018	Adult	
Papua New Guinea	Conflict Islands	Aroroa Island	hawksbill	Nesting	EiIP-33	F1525	1/8/2020	Adult	
Papua New Guinea	Conflict Islands	Baden Island	hawksbill	Nesting	EiIP-93	PNG-47	1/3/2018	Adult	
Papua New Guinea	Conflict Islands	Gabugabutau	hawksbill	Nesting	EiIP-33	PNG-74	11/17/2018	Adult	
Papua New Guinea	Conflict Islands	Irai Island	hawksbill	Nesting	EiIP-33	PNG-38	12/23/2017	Adult	
Papua New Guinea	Conflict Islands	Irai Island	hawksbill	Nesting	EiIP-33	PNG-66	1/31/2018	Adult	
Papua New Guinea	Conflict Islands	Irai Island	hawksbill	Nesting	EiIP-33	PNG-97	11/12/2018	Adult	
Papua New Guinea	Conflict Islands	Irai Island	hawksbill	Nesting	EiIP-09	PNG-73	12/7/2018	Adult	
Papua New Guinea	Conflict Islands	Irai Island	hawksbill	Nesting	EiIP-33	PNG-99	12/12/2018	Adult	
Papua New Guinea	Conflict Islands	Irai Island	hawksbill	Nesting	EiIP-33	PNG-91	12/17/2018	Adult	
Papua New Guinea	Conflict Islands	Kolavia Island	hawksbill	Nesting	EiIP-33	PNG-31	12/7/2017	Adult	
Papua New Guinea	Conflict Islands	Kolavia Island	hawksbill	Nesting	EiIP-33	PNG-37	12/22/2017	Adult	
Papua New Guinea	Conflict Islands	Lachlan Island	hawksbill	Nesting	EiIP-93	PNG-33	12/21/2017	Adult	
Papua New Guinea	Conflict Islands	Muniara Island	hawksbill	Nesting	EiIP-33	PNG-44	1/2/2018	Adult	
Papua New Guinea	Conflict Islands	Muniara Island	hawksbill	Nesting	EiIP-33	PNG-45	1/2/2018	Adult	
Papua New Guinea	Conflict Islands	Muniara Island	hawksbill	Nesting	EiIP-34	PNG-127	12/20/2018	Adult	

Papua New Guinea	Conflict Islands	Panaboal Island	hawksbill	Nesting	EiIP-59	PNG-95	12/16/2018	Adult		
Papua New Guinea	Conflict Islands	Panaboal Island	hawksbill	Nesting	EiIP-33	PNG-118	12/26/2018	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-114	PNG-35	12/22/2017	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-33	PNG-36	12/22/2017	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-33	PNG-63	1/16/2018	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-33	PNG-64	1/20/2018	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-33	PNG-65	1/20/2018	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-33	PNG-123	11/26/2018	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-33	PNG-96	11/27/2018	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-34	PNG-72	12/16/2018	Adult		
Papua New Guinea	Conflict Islands	Panarakuum Island	hawksbill	Nesting	EiIP-33	PNG-84	12/21/2018	Adult		
Papua New Guinea	Conflict Islands	Panasesa Island	hawksbill	Nesting	EiIP-33	PNG-130	12/24/2018	Adult		
Papua New Guinea	Conflict Islands	Panasesa Island	hawksbill	Nesting	EiIP-33	PNG-149	2/2/2019	Adult		
Papua New Guinea	Conflict Islands	Panasesa Island	hawksbill	Nesting	EiIP-33	F1527	1/11/2020	Adult		
Papua New Guinea	Conflict Islands	Tupit Island	hawksbill	Nesting	EiIP-33	PNG-78	11/21/2018	Adult		
Papua New Guinea	Conflict Islands	Tupit Island	hawksbill	Nesting	EiIP-33	PNG-70	12/23/2018	Adult		
Papua New Guinea	Conflict Islands	Tupit Island	hawksbill	Nesting	EiIP-33	PNG-92	12/23/2018	Adult		
Papua New Guinea	Conflict Islands	Tupit Island	hawksbill	Nesting	EiIP-33	PNG-128	1/10/2019	Adult		
Papua New Guinea	Conflict Islands	Tupit Island	hawksbill	Nesting	EiIP-33	PNG-82	1/13/2019	Adult		
Papua New Guinea	Conflict Islands	Tupit Island	hawksbill	Nesting	EiIP-33	PNG-119	1/30/2019	Adult		

Papua New Guinea	Conflict Islands	Tupit Island	hawksbill	Nesting	EiIP-33	F1526	1/24/2020	Adult	
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	**EiIP-64**	NIP-07	1/27/2015	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 1/9/2015.
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	**EiIP-64**	NIP-11a	12/27/2015	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 1/9/2015.
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	EiIP-33	NIP-01	1/8/2016	Hatchling	
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	**EiIP-39**	NIP-12	2/13/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 1/9/2015.
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	EiIP-64	NIP-20	3/24/2017	Hatchling	
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	**EiIP-64**	NIP-57	4/5/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 3/24/2017.
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	EiIP-59	NIP-68	4/8/2018	Hatchling	
Papua New Guinea	New Ireland	Edmago Island	hawksbill	Nesting	EiIP-64	F2067	1/14/2021	Hatchling	
Papua New Guinea	New Ireland	Lissenung Island	hawksbill	Nesting	EiIP-33	NIP-45	5/5/2016	Hatchling	
Papua New Guinea	New Ireland	Lissenung Island	hawksbill	Nesting	EiIP-33	NIP-46a	7/5/2016	Hatchling	
Papua New Guinea	New Ireland	Lissenung Island	hawksbill	Nesting	EiIP-64	NIP-10	12/5/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-06	1/9/2015	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	NIP-08	1/25/2015	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-21	2/13/2015	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-39	NIP-31	3/14/2015	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-19	1/15/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	NIP-22	1/30/2016	Hatchling	

Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-24	2/4/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-25	2/5/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-NIP-28 new	NIP-28	2/17/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-29	2/17/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-30	2/22/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-34	3/2/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-39	3/26/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-40	3/31/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-02a	11/12/2016	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	NIP-13	2/21/2017	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-14	3/2/2017	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-33**	NIP-15	3/4/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 2/21/2017 [11 days].
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-16	3/6/2017	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-59**	NIP-17	3/12/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 3/2/2017.
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-33**	NIP-18	3/18/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 2/21/2017.
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-64**	NIP-53	3/21/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 6/3/2017.
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-33**	NIP-54	4/3/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 2/21/2017.

Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-NIP-28 new	NIP-26	4/6/2017	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-33**	NIP-56	4/15/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 2/21/2017.
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	NIP-59	11/19/2017	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	NIP-60	12/9/2017	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	NIP-58	12/11/2017	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-33**	NIP-61	12/25/2017	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 1/9/2015.
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-63	1/21/2018	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	NIP-64	1/22/2018	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-65a	1/26/2018	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-64**	NIP-66a	2/6/2018	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 1/26/2018.
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	NIP-67	2/26/2018	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	F2071	11/27/2020	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	F2064	11/30/2020	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	F2063	12/25/2020	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-59	F2065	1/10/2021	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-59**	F2068	1/26/2021	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 1/10/2021.
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	**EiIP-59**	F2069	2/12/2021	Hatchling	Sample excluded from analysis because the nest could be from the same female nesting on 1/10/2021.

Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-64	F2072	2/23/2021	Hatchling	
Papua New Guinea	New Ireland	Ral Island	hawksbill	Nesting	EiIP-33	F2073	3/30/2021	Hatchling	
Papua New Guinea	New Ireland	Unknown	hawksbill	Nesting	EiIP-64	NIP-32	2/22/2016	Hatchling	
Papua New Guinea	New Ireland	Unknown	hawksbill	Nesting	EiIP-33	NIP-41	4/2/2016	Hatchling	
Papua New Guinea	New Ireland	Unknown	hawksbill	Nesting	EiIP-64	NIP-55	Unknown	Hatchling	

Table S6.2. Haplotype frequencies for Asia-Pacific hawksbill turtle management units. Haplotype designations indicate previous and new EilP names and GenBank references for the sequences. References (in order as shown) are: [#] Nishizawa et al. 2016; ^Vargas *et al.,* 2016; * Wahidah et al. 2009;[▲] LaCasella et al. 2022; [♠]This study)

			Haplotype	EiP02	EiP03	EiP04	EiP05	EiP07	EiP08	EiP09	EiP23	EiP24	EiP26	EiP28	EiP29	EiP31	EiP33	EiP34	EiP37	EiP38	EiP39	EiP43	EiP47	EiP48	EiP49	EiP50	EiP51	EiP53	EiP54	EiP57	EiP59	EiP64	EiP80	EiP81	EiP93	EiP110	EiP114	EiP124	EiP125	EiP138	Ei15 (EiIP-17)	Ei_11	EiP-NIP-28-new
			GenBank #	*KT934050*	*KT934051*	*KT934052*	*KT934053*	*KT934054*	*KT934055*	*KT934056*	*KT934070*	*KT934071*	*KT934073*	*KT934075*	*KT934076*	*KT934078*	*KT934080*	*KT934081*	*KT934083*	*KT934084*	*KT964291*	*KT934088*	*KT934090*	*KT934091*	*KT934092*	*KT934093*	*KT934094*	*KT934095*	*KT934096*	*KT934097*	*KT964292*	*MT919665*	*KT934100*	*KT934101*	*MT919678*	*KT072791*	*KT072795*	*KR706175*	*KR706176*	*MT451986*	*HM030866*		
MU/Rookery	**Reference**	**Year**	**Total**																																								
East Malaysia (all)	**-**	**-**	**157**																				**61**	**45**	**43**	**1**	**4**	**1**											**1**		**1**		
East Malaysia (old)		**1998-2008**	**97**																				**37**	**16**	**36**	**1**	**4**	**1**											**1**		**1**		
Sabah Turtle Islands	*Nishizawa et al. 2016*	*1998*	*24*																				*13*	*4*	*6*														*1*				
Sabah Turtle Islands	*Vargas et al. 2016*	*1999*	*25*																				*5*	*7*	*10*	*1*	*2*																
Sabah Turtle Islands	*Nishizawa et al. 2016*	*2003*	*28*																				*10*	*4*	*12*		*2*																
Sabah Turtle Islands	*Wahidah et al. 2009*	*2007-08*	*20*																				*9*	*1*	*8*			*1*													*1*		
East Malaysia (new)		***2014***	***60***																				*24*	*29*	*7*																		
Sabah Turtle Islands	*Nishizawa et al. 2016*	*2014*	*60*																				*24*	*29*	*7*																		
Peninsular Malaysia	**-**	**-**	**87**																						**1**			**83**	**1**									**2**					
Malaka	*Nishizawa et al. 2016*	*1998*	*10*																									*10*															
Malaka	*Wahidah et al. 2009*	*2007*	*29*																									*29*															
Malaka	*Nishizawa et al. 2016*	*2014*	*6*																									*6*															
Redang Island	*Nishizawa et al. 2016*	*1996-99*	*8*																						*1*			*7*															
Redang Island	*Vargas et al. 2016*	*1999*	*23*																									*22*	*1*														
Redang Island	*Nishizawa et al. 2016*	*2011-14*	*11*																									*9*										*2*					
Johor	**Nishizawa et al. 2016**	**1998**	**3**																										**1**							**2**							
Thailand			**14**																									**9**								**2**						**3**	
Khram Island	*Wahidah et al. 2009*		14																									9								2						3	
Western Australia	**-**	**-**	**47**						**37**					**3**					**3**	**4**																							
Varanus & Rosemary	*Vargas et al. 2016*	*2010*	*47*						*37*					*3*					*3*	*4*																							
NE Australia	**-**	**-**	**157**	**1**	**0**	**2**	**1**	**8**	**73**	**60**	**0**	**0**	**2**	**0**	**2**	**2**	**3**	**0**	**0**	**0**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**			**1**	**1**		**0**		**0**	**0**	**0**	**0**		
Groote Eyelant	*Vargas et al. 2016*	*2010*	*71*						*36*	*30*			*2*			*1*																	*1*	*1*									
ne Queensland	**-**	**-**		**1**		**2**	**1**	**8**	**37**	**30**					**2**	**1**	**3**													**1**													
Milman Island	*Vargas et al. 2016*	*2010*	*64*	*1*		*2*	*1*	*6*	*26*	*21*					*2*	*1*	*3*													*1*													
Milman Island	*LaCasella et al. 2022*	*2017*	*22*					2	11	9																																	
Solomon Islands	**-**	**-**	**70**	**0**	**26**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**0**	**0**	**0**	**0**	**32**	**7**	**0**	**0**		**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**			**0**	**0**		**0**		**0**	**0**	**1**	**0**		
Arnavon Islands	*Vargas et al. 2016*	*2010*	*42*		*18*						*2*	*1*					*17*	*3*				*1*																					
Arnavon Islands	*LaCasella et al. 2022*	*2017*	*28*		*8*												*15*	*4*																						*1*			
Milne Bay	***This study***	**2018-2021**	**39**							**1**							**30**	**3**													**2**				**2**		**1**						
Aroroa Island	*This study*		4														*2*	1													1												
Gabugabutau	*This study*		1														*1*																										
Irai Island	*This study*		6							1							*5*																										
Muniara Island	*This study*		3														*2*	1																									
Panaboal Island	*This study*		2														*1*														1												
Panarakuum Island	*This study*		9														*7*	1																									
Panasesa Island	*This study*		3														*3*																										
Tupit Island	*This study*		7														*7*																										
Kolavia Island	*This study*		2														*2*																										
Lachlan Island	*This study*		1																																1								
Baden Island	*This study*		1																																1								
Ireland	***This study***	**2015-2018**	**42**														**12**				**1**										**10**	**17**											**2**
Edmago Island	*This study*		4														1														1	2											
Ral Island	*This study*		32														8				1										9	12											2
Lissenung Island	*This study*		3														2															1											
Unknown	*This study*		3														1															2											
Total			**602**	**1**	**26**	**2**	**1**	**8**	**110**	**61**	**2**	**1**	**2**	**3**	**2**	**2**	**77**	**10**	**3**	**4**	**1**	**1**	**61**	**45**	**44**	**1**	**4**	**84**	**2**	**1**	**12**	**17**	**1**	**1**	**2**	**2**	**1**	**2**	**1**	**1**	**1**		**2**

Table S6.3 Summary of the 16 hawksbill turtles satellite tagged during 2017-2018 and 2018-2019 nesting seasons at the Conflict Group. P = Primary, first time tagged, WSR = within season recapture, CCL = curved carapace length (max length, cm), CCW = curved carapace width, L = laid, X = no lay.

PTT	Primary tag number	Tag status	Nesting season year tagged	Capture date	Nesting Island	Nest Latitude	Nest Longitude	CCL (cm)	CCW (cm)	Nesting activity	Egg count
49861 [Boss Meri]	IGS0586	P	2017	20/01/2018	Panarakuum	-10.77072	151.85168	79.3	n/a	X	n/a
49863 [Koyo]	IGS0601	P	2017	16/01/2018	Panarakuum	-10.76789	151.86184	80.5	73	L	154
49864 [JC]	IGS0816	P	2018	2/01/2019	Panarakuum	-10.76770	151.86168	81	n/a	L	n/a
49866 [Steve]	R56619	WSR	2018	30/12/2018	Tupit	-10.71955	151.74823	77.5	n/a	X	n/a
49867 [Lexi]	IGS0801	P	2017	7/01/2018	Aroroa	n/a	n/a	84.4	76	X	n/a
49868 [Mito]	IGS0167	P	2018	4/01/2019	Irai	-10.76682	151.68625	82	75	L	100
49869 [Conflict]	IGS0954	P	2017	5/01/2018	Kolavia	-10.78090	151.88191	80.3	n/a	X	n/a
49870 [Mose]	IGS0184	WSR	2018	30/12/2018	Panasesa	n/a	n/a	86.3	n/a	L	n/a
49871 [Sally]	IGS0165	P	2018	4/01/2019	Irai	-10.76679	151.68614	79.3	72	L	90
49872 [Luke]	IGS0558	P	2017	10/01/2018	Tupit	-10.71968	151.74809	79.5	66.1	X	n/a
49891 [Jonathan]	IGS0542	P	2017	2/01/2018	Aroroa	n/a	n/a	83.4	70.8	X	n/a

49897 [Lenny]	IGS0684	P	2017	2/01/2018	Muniara	-10.79905	151.89865	81.4	n/a	L	152
49900 [Georgey]	IGS0244	WSR	2017	3/01/2018	Baden	-10.36773	151.38085	81.3	n/a	L [Attempted to nest on Lachlan Island 21/12/17, no lay]	147
49903 [Steven]	IGS0792	WSR	2017	31/12/2017	Irai	-10.76601	151.6971	80.1	n/a	X [Attempted to nest on Panasesa 15/12/17, no lay]	n/a
49917 [Thomas]	IGS0567	P	2017	2/01/2018	Muniara	-10.80005	151.89883	82	73.5	L	n/a
49918 [Plj]	R56606	WSR	2018	5/01/2019	Tupit	-10.72066	151.74951	75.3	69	X [Laid on Tupit Island 21/11/2018]	n/a
							mean +/- s.d.	**80.85 +/- 2.60**	**71.93 +/- 3.24**		

Table S6.4. The table summarizes sample sizes, and haplotype counts , nucleotide and haplotype diversities, for samples collected from different hawksbill (*Eretmochelys imbricata*) Management Units using approximately 770 base pairs of the mitochondrial DNA control region. haplotype diversity (Hd) and Nucleotide diversity (π) were calculated to assess genetic diversity, and the number of unique haplotypes found in each location was determined.

Country/Location		Location	Samples Size	Haplotypes	Hd (standard deviation)	π (standard deviation)	Reference
Malaysia old			97	8	0.6946 (+/- 0.0244)	0.018504 (+/- 0.009269)	
Malaysia new			60	3	0.6028 (+/- 0.0311)	0.017479 (+/- 0.008839)	
Peninsular Malaysia			87	4	0.0901 (+/- 0.0421)	0.000267 (+/- 0.000368)	
Western Australia			47	4	0.3728 (+/- 0.0857)	0.001674 (+/- 0.001188)	
Arnhemland			71	6	0.5710 (+/- 0.0304)	0.019248 (+/- 0.009661)	
Milman Island			86	10	0.6897 (+/- 0.0325)	0.019943 (+/- 0.009969)	
Arnavons			70	7	0.6509 (+/- 0.0344)	0.001753 (+/- 0.001220)	
Conflict Islands			39	6	0.4062 (+/- 0.0969)	0.002629 (+/- 0.001680)	This study
Kavieng			42	5	0.7120 (+/- 0.0346)	0.001376 (+/- 0.001035)	This study

Table S6.5: Summary of Argos satellite-tracking data, including migratory movements for 15 turtles tagged in 2017-2018. * = calculations pertaining only to turtles tracked to arrival at foraging ground (n = 10).

PTT	Tracking date range	No. tracking days	No. tracking locations (filtered)	Migration date range	No. migration days	No. migration locations (filtered)	Migration path distance	Straight-line migration distance	Migration speed (km h^{-1}) ± SE	Arrived at foraging grounds
49861	11.01.2018 – 28.01.2020	747	1727	07.02.2018 – 13.04.2018	65	170	1782	871	1.42 ± 0.08	Yes
49863	09.01.2018 – 11.04.2018	92	260	01.03.2018 – 11.04.2018	41	121	976	609	1.19 ± 0.11	No
49864	20.12.2018 – 30.05.2020	517	1308	20.02.2019 – 31.03.2019	39	153	1326	996	1.73 ± 0.09	Yes
49866	20.12.2018 – 21.02.2019	53	162	03.02.2019 – 21.02.2019	18	55	483	155	1.61 ± 0.15	No
49867	03.01.2018 – 22.03.2018	78	213	02.03.2018 – 22.03.2018	20	60	1023	923	2.85 ± 0.19	No
49868	31.12.2018 – 05.04.2019	95	162	08.01.2018 – 01.02.2019	24	62	1020	883	2.05 ± 0.13	Yes
49869	03.01.2018 – 20.01.2020	747	1581	10.01.2018 – 03.02.2018	24	64	665	588	1.49 ± 0.12	Yes
49870	20.12.2018 – 08.11.2019	313	832	29.01.2019 – 08.03.2019	38	115	1170	817	1.36 ± 0.08	Yes
49871	20.12.2018 – 02.08.2019	214	533	12.02.2019 – 11.03.2019	27	69	1021	844	1.85 ± 0.13	Yes
49872	03.01.2018 – 07.03.2018	63	179	13.02.2018 – 07.03.2018	22	66	537	385	1.00 ± 0.08	No
49891	31.12.2017 – 15.01.2019	380	458	24.02.2018 – 04.04.2018	39	89	1267	876	2.06 ± 0.30	Yes
49900	03.01.2018 – 07.03.2018	63	99	07.01.2018 – 02.02.2018	26	76	1016	818	1.88 ± 0.10	Yes
49903	31.12.2017 – 05.09.2019	613	1276	18.02.2018 – 07.04.2018	48	170	1428	891	1.43 ± 0.07	Yes
49917	31.12.2017 – 03.02.2019	399	500	19.02.2018 - 07.04.2018	47	160	1715	960	1.71 ± 0.07	Yes
49918	31.12.2018 – 12.04.2019	102	247	22.02.2019 – 12.04.2019	49	100	1451	829	1.40 ± 0.10	No
Mean ± SE	-	**298 ± 66**	**636 ± 145**	-	**38* ± 4**	**113* ± 15**	**1241* ± 108**	**854* ± 35**	**1.67* ± 0.14**	-

Table S7.1 Overview of Relevant National Legislation by Country. *Note, where information is missing, Range States did not respond to information requests or was not publicly available.*

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
American Samoa	Endangered	Hawksbill turtles are fully protected under the U.S. Endangered Species Act (ESA) of 1973. The ESA prohibits the take (capture, hunt, harassment, etc.) of hawksbill turtles, as they are listed as endangered under the Act. Federally funded or permitted activities must avoid jeopardy to listed threatened and endangered species and avoid destruction of critical habitat. The ESA also authorizes the designation of critical habitat within the U.S. territory and waters for the hawksbill and permits scientific research and non-federal activities. Regulations specify mitigation resuscitation, and prohibitions for all commercial fishermen for incidentally caught sea turtles and specific regulations are put in place to reduce sea turtle interactions and increase survivorship in gillnets, longline, and purse seine fisheries throughout the country. The Dept. of Marine and Wildlife Resources regulates fishing and hunting activities within U.S. territorial waters. These regulations, located in Chapter 09, Title 24	The Endangered Species Act of 1973 prohibits the take (capture, hunt, harassment, etc.) of all sea turtles.	SEC. 11 of the ESA (a) CIVIL PENALTIES.— (1) Any person who knowingly violates, and any person engaged in business as an importer or exporter of fish, wildlife, or plants who violates, any provision of this Act, may be assessed a civil penalty by the Secretary of not more than $ 25,000 for each violation. Any person who knowingly violates, and any person engaged in business as an importer or exporter of fish, wildlife, or plants who violates, any provision of any other regulation issued under this Act may be assessed a civil penalty by the Secretary of not more than $ 12,000 for each such violation.	National Oceanic and Atmospheric Administration (marine environment) and U.S. Fish and Wildlife Service (terrestrial environment). American Samoa also has a Department of Marine and Wildlife Resources.

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		of the American Samoa Administrative Code, were last amended in 1995. Areas restricted to fishing and/or other activities include the Fagatele Bay National Marine Sanctuary (Section 24.0907-09) and the Rose Atoll National Wildlife Refuge. Section 24.0935 applies to sea turtles and includes prohibitions on importation, exportation, sale of sea turtles, take of sea turtles, and possess, delivery, carrying, transporting or shipping of sea turtles or their body parts. While this section specifically mentions green, hawksbills, and leatherbacks, they should likely apply to any loggerheads encountered.			
Australia	**Commonwealth:** Vulnerable **State:** **QLD:** Endangered **NSW:** Not listed **NT:** Vulnerable **TAS:** Vulnerable **WA:** Vulnerable	Australia has a Federal Government with 8 separate State or Territory Governments. The Australian Government has responsibility for matters in the national interest, and for nonstate/territory areas, which includes the marine environment from 3 nautical miles out to the edge of the Exclusive Economic Zone (EEZ). The State and Territory governments have responsibility for issues within their jurisdictional borders, including State/Territory waters. The Commonwealth *Environment Protection and Biodiversity Conservation Act (1999)* (EPBC Act) is the Australian Governments key piece of	Yes, through Commonwealth and State/Territory implementing legislation, noting the native title rights provided under the Native Title Act 1993 (refer below). The Recovery Plan for Marine Turtles in Australia (2017) identifies threats to the three hawksbill management unit genetic stocks including international trade and indigenous take, as very high to high risk threats. Under the EPBC Act the	The EPBC Act provides penalties (financial and incarceration time) for various offences relating to listed marine turtles. Fines in respect of the illegal killing, injuring, taking, trading, keeping or moving of marine turtles have a maximum of 3,000 penalty units. Note: 1 penalty unit currently = $AUD170. Penalties for offenses relating to turtles exist under other Commonwealth, State and Territory legislation.	Department of Agriculture, Water and the Environment (C ’wealth) Great Barrier Reef Marine Park Authority (C ‘wealth) Australian Fisheries Management Authority (C ‘wealth)

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
	VIC: Not listed **SA:** Not listed **ACT**: Not listed	environment legislation. The EPBC Act gives effect to Australia's international obligations such as CITES, CMS and CBD. Hawksbills are listed as threatened, migratory and marine under the EPBC Act. It is an offence to kill, injure, take, trade, keep or move the species in a Commonwealth area (i.e. Commonwealth waters), unless the person taking the action holds a permit under the EPBC Act, the act is consistent with native title rights under the Native Title Act (1993), or the activity is carried out in accordance with a State/Territory or Australian Government fishery plan of management accredited by the Minister for the Environment. The Recovery Plan for Marine Turtles in Australia (2017) is a Recovery Plan made under the EPBC Act. It was jointly made by the Commonwealth, New South Wales and Queensland Governments. The Recovery Plan sets out the management actions and research required to recover marine turtles in Australia and to remove them from the threatened species list. International take was identified as a very high risk threat for	Minister for the Environment must not make a decision that is inconsistent with a recovery plan and a Commonwealth agency must not take any action that contravenes a recovery plan. In Queensland, protection of islands used as rookeries have been gazetted as National Parks under the Nature Conservation Act 1992. Mandatory inclusion of turtle excluder devices (TEDs) was introduced in the East Coast Otter Trawl Fishery in 2001.TEDs are also in place in all vessels in the Northern Prawn Fishery, Western Australian trawl fisheries and the Torres Strait Prawn Fishery. Section 211 of the Native Title Act 1993 provides a native title right to direct harvest of marine turtles by Traditional Owners, where that harvest is for the purpose of satisfying personal, domestic, or non-commercial communal needs; and in the		

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		all three genetic stocks of hawksbills found in Australia. The Recovery Plan identifies actions to manage this threat. **Implementing legislation: Commonwealth:** Environment Protection and Biodiversity Conservation Act 1999, classified as a Matter of National Environmental Significance. Great Barrier Reef Marine Park Act 1975 protects Hawksbills as a protected species from taking or injuring in the Great Barrier Reef Marine Park. Torres Strait Fisheries Act 1984 **QLD:** Nature Conservation Act 1992 Marine Parks Act 2004 **NSW:** Biodiversity Conservation Act 2016, protected as a native reptile (offense to harm), National Parks and Wildlife Act 1974 **NT:** Territory Parks and Wildlife Conservation Act 2000 **WA:** Biodiversity Conservation Act 2016	exercise of native title rights and interests.		

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		Rookeries and waters within the Torres Strait or western Cape York Peninsula regions, while outside of protected areas, fall under ownership of Indigenous groups. However, under the Torres Strait Treaty, Papua New Guineans are allowed to take hawksbill turtles throughout much of the Torres Strait.			
Brunei Darussalam	Endangered	The Wildlife Protection Act of 1978 (amended in 1984) lists the Hawksbill turtle, as well as the Green and Leatherback turtles in its list of protected animals. Nevertheless, the Hawksbill turtle does not have full legal protection since taking or trading protected species are permitted with appropriate licenses.	The Wild Fauna and Flora Order, 2007 prohibits the trade in any specimen of any species listed in CITES Appendix I without appropriate permits or certificates (Article 47/1a). Any person in possession of a specimen of any species listed in the CITES Appendix is guilty of an offence (Article 48/1).	Engaging in the trade of species listed in CITES Appendix I without appropriate permits or certificates is liable on conviction and possessing specimens listed in the CITES Appendix is liable on conviction: "a) In the case of an individual, to imprisonment for a term not exceeding 5 years, a fine not exceeding $100,000 or both; b) In the case of a corporate body, to a fine not exceeding $200,000" (Article 47/2, 48/2).	Ministry of Primary Resources and Tourism

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
Cambodia	Endangered	The 2006 Law on Fisheries prescribes the rules governing fishery resource management in Cambodia, including the management of marine reptiles. The Sub-decree No: 123 (2009) lists the hawksbill turtle as an Endangered Fisheries Resource.	Article 23 of the Law on Fisheries prohibits, among others, the following activities to take place without a permit: -Catching, selling, buying, stocking, and transporting fingerling or fish eggs and other aquatic animals' offspring or eggs -Transporting, processing, buying, selling, and stocking endangered fishery resources -Buying or selling ornamental shells of rare species. Article 3 of the Law on Fisheries protects the rights on traditional use of fishery resources for local communities.	Article 92 of the Law on Fisheries provides that a transactional fine in the amount of "two to three times of the market price" in cash be given to those that commit, among others, the following fishery offences: -Catching, selling, buying, transporting, collecting, processing and stocking all types of endangered natural fishery products -Exporting and importing all types of natural fishery products of endangered species.	Ministry of Agriculture, Forestry and Fisheries

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
China (incl. Macau)	Class I (Highest level of protection	In 2003, Ministry of Agriculture, P.R.China has issued a regulation stipulating the management measures of bycatch including sea turtle requiring all longline vessels be equipped with de-hookers and encouraging fishing vessels using round hooks.	**Class I** protection prohibits hunting, killing, smuggling or trading the protected animals. Wild animals protection ordinance - chapter 170 (2007) provides for the protection of wild animals (including all reptiles) and their living areas, the prohibition of hunting, possessing and trading animals, nest or eggs.	Jail sentences up to 10 years for those caught violating Class I species.	**Ministry of Agriculture and Rural Affairs** The National Forestry and Grassland Administration
Commonwealth of the Northern Mariana Islands	Endangered	Hawksbill turtles are fully protected under the U.S. Endangered Species Act (ESA) of 1973. The ESA prohibits the take (capture, hunt, harassment, etc.) of hawksbill turtles, as they are listed as endangered under the Act. Federally funded or permitted activities must avoid jeopardy to listed threatened and endangered species and avoid destruction of critical habitat. The ESA also authorizes the designation of critical habitat within the U.S. territory and waters for the hawksbill and permits scientific research and non-federal activities. Regulations specify mitigation	The Endangered Species Act of 1973 prohibits the take (capture, hunt, harassment, etc.) of all sea turtles.	SEC. 11 of the ESA (a) CIVIL PENALTIES.— (1) Any person who knowingly violates, and any person engaged in business as an importer or exporter of fish, wildlife, or plants who violates, any provision of this Act, may be assessed a civil penalty by the Secretary of not more than $ 25,000 for each violation. Any person who knowingly violates, and any person engaged in business as an importer or exporter of fish, wildlife, or plants	National Oceanic and Atmospheric Administration (marine environment) and U.S. Fish and Wildlife Service (terrestrial environment) Commonwealth of the Northern Mariana Islands Department of

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		resuscitation, and prohibitions for all commercial fishermen for incidentally caught sea turtles and specific regulations are put in place to reduce sea turtle interactions and increase survivorship in gillnets, longline, and purse seine fisheries throughout the country. Hawksbill sea turtles are listed under CNMI Public Law 02-51.		who violates, any provision of any other regulation issued under this Act may be assessed a civil penalty by the Secretary of not more than $ 12,000 for each such violation.	Lands and Natural Resources, Division of Fish and Wildlife
Cook Islands	None	The Cook Islands is an independent nation (1965) that has the Queen of England as its Head of State and is in a Free Association with New Zealand. The *Marine Resources Act 1989* provides for the protection and management of fishery resources, the definition of which includes marine turtles. The Environment Act (2003) provides provisions for listing species as protected but only applies to the islands of Rarotonga, Atiu and Aitutaki (it does not apply to any other Outer Island unless otherwise	Cook Islanders have customary rights to harvest natural resources under the Cook Islands Act 1915.		By Order in Executive Council (Queen's Representative)

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		specified by the Queen's Representative by Order in Executive Council). In 2008, two Southern Group islands: Takutea and Mitiaro, developed regulations within the provisions of this Act that directly protects sea turtles in the Cook Islands where traditional use is allowed.			
Federated States of Micronesia	Endangered	Yap State Environmental Quality Protection Act (Y.S.L 3-73) establishes restrictions on the harvest of sea turtles.	The harvest of hawksbill turtles is allowed in FSM, with provisions for minimum size limits for hawksbills and green turtles (27 inches and 34 inches CCL, respectively) and closed seasons (June 1 to August 31 and December 1 to January 31). Harvesting of eggs is not allowed for any species.		Yap State Environmental Protection Agency
Fiji		**Offshore Fisheries Management Regulations 2014** Hawksbill turtles are protected under Regulation 5 of the Offshore Fisheries Management Regulations (OFMR) 2014. One is not permitted to kill, take, land, sell or offer or expose for sale, deal in, transport, receive or possess any fish listed	**Offshore Fisheries Management Regulations 2014** The Offshore Fisheries Management Act (OFMA)2012 defines “fish” means any aquatic plant or animal, whether piscine or not, and includes any oyster	Fine provisions are under: 1. Schedule 11 of the OFMR 2014 states the penalty for breaching Regulation 5. Individual - $10,000 Entity - $20,000 2. Fisheries Act, s.10(1)-(8) states that the penalty for offending against Regulation 20 is	Ministry of Fisheries and the Ministry of Environment

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		in CITES Appendix I & II. Hawksbill Turtles are listed in Appendix I. **Fisheries Act 1941** Under the Fisheries Act 1941, Regulation 20 (1) turtles with a carapace length less than 455 mm are prohibited from being molested, taken, sold, offered or exposed for sale, or killed. In addition, all turtles are not permitted to be harvested during the months of November, December, January and February. Furthermore, 20 (2) states "No person shall be in possession of, sell, offer or expose for sale or export any turtle shell the length of which is less than 455 mm [eighteen inches]". Regulation 9 provides clear instructions on the type of gear that is permitted for the harvesting of sea turtles and it states: "No person shall harpoon any turtle unless the harpoon is armed with at least one barb of which the point projects not less than 9.5 mm [3/8 inch] from the surface of the shaft, measured at right angles to the long axis of the shaft".	or other mollusc, crustacean, coral, sponge, holothurian (beche-de-mer), or other echinoderm, turtle and marine mammal, and includes their eggs, spawn, spat and all juvenile stages and any of their parts. Therefore, hawksbill eggs are also regulated under Regulation 5 of the OFMR 2014 Fisheries Act 1941 Section 20 (1) of the Fisheries Act 1941 states that "No person shall at any time dig up, use, take, sell, offer or expose for sale, or destroy turtle eggs of any species".	"imprisonment for three months or a fine of five hundred dollars or both such penalties" 3. Endangered & Protected Species Act, Part 7 ss.23-2	

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		Endangered and Protected Species Act 2002 The Endangered and Protected Species Act (EPSA) 2002 regulates the import, export, re-export and introduction from the sea of CITES listed species (Sections 9, 10, 11 and 12). Fiji renewed their Sea Turtle Recovery Plan to 2030.			
French Polynesia (France)		Hawksbill turtles are fully protected in French Polynesia (since 1990) under DELIBERATION No. 90-83 AT du 13 Juillet 1990 relative à la protection des tortues marines en Polynésie Française. Destruction and degradation of sensitive habitats is also prohibited.	It is strictly forbidden to harm, own or hunt sea turtles or engage in commerce of any kind pertaining to the sale of shell, meat and eggs.		
Guam (USA)	Endangered	Hawksbill turtles are protected by the Endangered Species Act of Guam and fully protected under the U.S. Endangered Species Act (ESA) of 1973 (USA). The ESA prohibits the take (capture, hunt, harassment, etc.) of hawksbill turtles, as they are listed as endangered under the ESA. Federally funded or permitted	The Endangered Species Act of 1973 prohibits the take (capture, hunt, harassment, etc.) of all sea turtles.	SEC. 11 of the ESA (a) CIVIL PENALTIES.— (1) Any person who knowingly violates, and any person engaged in business as an importer or exporter of fish, wildlife, or plants who violates, any provision of this Act, may be assessed a civil penalty by the	National Oceanic and Atmospheric Administration (marine environment) and U.S. Fish and Wildlife Service

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		activities must avoid jeopardy to listed threatened and endangered species and avoid destruction of critical habitat. The ESA also authorizes the designation of critical habitat within the U.S. territory and waters for the hawksbill and permits scientific research and non-federal activities. Regulations specify mitigation resuscitation, and prohibitions for all commercial fishermen for incidentally caught sea turtles and specific regulations are put in place to reduce sea turtle interactions and increase survivorship in gillnets, longline, and purse seine fisheries throughout the country.		Secretary of not more than $ 25,000 for each violation. Any person who knowingly violates, and any person engaged in business as an importer or exporter of fish, wildlife, or plants who violates, any provision of any other regulation issued under this Act may be assessed a civil penalty by the Secretary of not more than $ 12,000 for each such violation.	(terrestrial environment). Guam's Dept of Aquatic and Wildlife Resources
Hong Kong (China)	Endangered	Appendix 1 of Protection of Endangered Species of Animals and Plants Ordinance (Chapter 586). (2009) includes Cheloniidae spp. (marine turtles, sea turtles). Fisheries Protection Ordinance (Chapter 171). (2000) promotes the conservation of fish and other forms of aquatic life within the waters of Hong Kong and to regulate fishing practices and to prevent activities detrimental to the fishing industry.	Protection of Endangered Species of Animals and Plants Ordinance (Chapter 586). (2009) regulate the import, introduction from the sea, export, re-export, and possession or control of endangered species of wild fauna and flora covered by CITES.	Protection of Endangered Species of Animals and Plants Ordinance (Chapter 586). (2009) Penalties relating to import of specimen of Appendix I species commits an offence and is liable on conviction to a fine at level 6 and to imprisonment for 1 year. Higher penalties for offences relating to specimens of	

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
				Appendix I: fine of $5000000 and to imprisonment for 2 years. Fisheries Protection Ordinance (Chapter 171). (2000) penalties do not exceed $200000 and imprisonment for 6 months. (Amended 68 of 1987 s. 5; 36 of 1998 s. 2)	
Indonesia		Under the Government regulation No 7/1999, Indonesia accords all 6 (six) species of turtles' protection status. Act No. 5 /1990 concerning conservation of living resources and their ecosystems provides prohibition for and sanction of direct harvest of protected species.	No harvest or trade of protected species, whether alive or dead or parts and derivatives, is allowed. Articles 38/1 and 40/1 of the Government Regulation No:60 2007 only allow for the trade, import, export and re-export of unprotected fish species and types of fish that can be traded in accordance with international law.	A maximum penalty of five years imprisonment and up to Rp 200.000.000 in fines.	The Ministry of Marine Affairs and Fisheries
Japan		The Basic Act on Ocean Policy (Act No:33 of 2007) ensures, among others, that the State shall take necessary measures on	Domestic trade of hawksbill turtles is prohibited under the Act on Conservation of Endangered Species of Wild	The Act on Conservation of Endangered Species of Wild Fauna and Flora prescribes penalties of up to five years'	Ministry of Agriculture, Forestry and Fisheries

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		conservation and management of living aquatic resources (Article 17). The Act on Conservation of Endangered Species of Wild Fauna and Flora protects all specimens of all species of sea turtles, including the hawksbill turtle, by prohibiting their domestic trade.	Fauna and Flora, barring permission by the Minister of the Environment, or with a registration of individuals etc. The transfer of parts of shells is also allowed, nevertheless Specified International Species Business Operators must have their notice to the Minister of the Environment and the Minister of Economy, Trade and Industry be accepted in advance (except dealing processed products thereof).	imprisonment or a fine of up to five million yen, or both, for individuals, and up to 100 million yen for corporations in a case of illegal transfer of specimens. In the event of non-compliance of the Specified International Species Business Operators' obligations under the Act, the Minister of the Environment and the Minister of Economy, Trade and Industry may order the suspension of the whole or part of the business for a period not exceeding three months. Both Ministers may also request reports on the business and conduct on-site inspections. If a Specified International Business Operator violates the law, it is subject to penalties of up to six months imprisonment or a fine up to 500,000 yen.	Ministry of the Environment
Kiribati			The Fisheries Regulations of 2019 prohibits the disturbing, taking, receiving or having the possession,	A fine of up $10,000 and, in default, imprisonment of	Ministry of Fisheries and Marine Resources Development

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
			purchasing or selling any turtle species eggs found in Kiribati, including the hawksbill turtle (Article 12/2). Interfering with turtle nests regardless of the species, harvesting turtles while on the beach or the selling, purchasing or exporting any turtle meat or shell is also prohibited (Article 12/2).	maximum 2 years, or both, is prescribed in Article 13/7.	
Lao People's Democratic Republic		The Wildlife and Aquatic Law of 2007 aims to protect and sustainably regenerate aquatic species by restricting anthropogenic pressure on decreasing species and the extinction of aquatic species. The Law classifies species into three categories, namely "prohibition category", "management category" and "common or general category" wildlife and aquatic species. The degree of protection of aquatic species depends on which category the species falls under. The Order No:05/PM of 2018, on Strengthening Strictness of the Management and Inspection of Prohibited Wild Fauna and Flora, aims to strengthen the rules on the hunting, importing,	Article 71 of the Wildlife and Aquatic Law prohibits the catching hunting, stealing trading or possessing species in the prohibition category, in addition to importing, exporting, re-exporting, trans-shipping and transiting species unlawfully. The Penal Code (amended in 2017) prohibits the trading or possessing aquatic species in the prohibited category (Article 334). Importing, exporting, transiting or	The penalty for an offence prescribed in Wildlife and Aquatic Law Article 71 is 3 months to 5 years of imprisonment (Article 72). In the event of damages over 200.000 Kip, individuals, organizations or enterprises in contravention of the law shall pay a fine double the amount of their damages (Article 72, Article 70). Recurring offences shall be fined three times the damages in the prohibition category and two times the damages in the management category (Article 72, Article 70).	Ministry of Agriculture and Forestry

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		transiting, exporting and trading of prohibited and protected species in the Wildlife and Aquatic Law of 2007 and CITES.	moving aquatic species unlawfully with regulations relating to CITES is prohibited (Article 335).	The penalty for an offence prescribed in Article 334 of the Penal Code is an imprisonment of 3 months to five years, with a fine of 3,000,000 to 10,000,000 Kip. The penalty for an offence prescribed in Article 335 of the Penal Code is an imprisonment of 3 months to five years, with a fine double damage value. If the offence is performed as part of an organized group or is recurring ,the offender shall be punished to imprisonment of 5 to 10 years, with a fine triple the damage value.	
Malaysia		In Malaysia, turtles fall under the jurisdiction of Federal *(Fisheries Act 1985)* and related state turtle legislation for individual states waters and territories. Federally, there are no explicit provisions on ban, on possession and trade of hawksbill eggs, meat and shell. Egg	The ban of turtle egg consumption and sale only covers the whole state of Sabah.		The two government bodies that oversee the management and protection of turtles in Sabah are Sabah Parks (only in marine protected areas) and the Sabah Wildlife Department.

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		collection is regulated via state legislation for conservation purposes. There are general provisions for killing disturbing, injuring hawksbill turtles (provisions vary among states) in both federal and state legislations. In Sabah, hawksbill turtles are listed as a totally protected species protected under the *Wildlife Conservation Enactment 1997* for state waters. The nesting sites are protected as part of Turtle Islands Heritage Protected Area (TIHPA) and under the *Parks Enactment 1984* for any other protected areas.			
Myanmar:	Completely protected	Sea turtle conservation programme started in Myanmar in 1905 under the Burma Fisheries Act (III - 1905). Protection for turtle hatching areas and turtles was included; also, trespassing on those areas without official consent was prohibited. Since then, the government has enacted several laws to protect marine turtles. More recently, in 1990, Myanmar promulgated the Marine Fisheries Law (DoF), under	Myanmar has enacted legislation to prohibit direct harvest and domestic trade in marine turtles, their eggs, parts and products. Articles 36 and 37 of the Protection of Wildlife and Conservation of Natural Areas Law No:6 1994	Violations against completely protected wild animals are punishable with imprisonment for a term which may extend to 7 years or with fine which may extend to kyats 50,000 or with both (Article 37/1).	

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		which no person shall search for and collect any marine products without a license (Section 40). In Chapter 1, Section (2), Subsection (r) it is mentioned that "Marine Products mean fishes obtained from the sea, aquatic organisms, excrete, scales, bones, skins, plants, etc." The expression also includes marine turtles and eggs. In 1993, the Department of Fisheries declared Notification No. 2/93 for "Sea Turtle Conservation". The new protection of Wildlife, Wild Plants and Conservation of Natural Areas Law (replacing the old Myanmar Wildlife Protection Act of 1936) was enacted in 1994 (Forest Department). The Forest Department Notification No: 583/94 of 1994 lists the hawksbill turtle as completely protected wild animals within Myanmar.	prohibits the killing, hunting or wounding a normally protected wild animal or seasonally protected wild animal without permission, as well as the killing, hunting or wounding of a completely protected wild animal. Possessing, selling, transporting or transferring such wild animal or any part thereof without permission is also prohibited.		
Nauru		The Fisheries Act 1997 and the Nauru Fisheries and Marine Resources Authority Act 1997 call for the protection and conservation of fisheries within Nauru, which broadly include turtles under “living aquatic animals” and their eggs. Nevertheless, neither legislation has provisions on endangered species.			Ministry for Fisheries, and the Ministry of Commerce, Industry and Environment

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		The Environmental Management and Climate Change Act 2020 gives powers to the Cabinet and the Secretary for the Department responsible for Environment and Climate Change the powers to make regulations relating to the conservation of endangered species.			
New Caledonia (France)			It is forbidden to fish for, capture, remove, intentional perturbation, mutilation, destruction, butchering, transport, put for sale, sale, purchase, eat all marine turtle species, dead or alive, including their eggs, and any part of the animals. It is also forbidden to export marine turtles. In case of bycatch all efforts will be taken to free the animals alive and minimize injury. All bycatch has to be declared. Special permits can be issued for scientific studies and stock enhancement.		Ecology and Sustainable Development NC: Fisheries Department All provinces (New Caledonia Govt (NC), Northern Province, Southern Province, Island Province): Environmental Services

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
New Zealand	Listed as vagrant, with the qualifier Threatened Overseas	Hawksbill turtles are fully protected under the Wildlife Act 1953 and have been assessed as Migrant - Threatened Overseas according to the New Zealand Threat Classification System (NZTCS). The Wildlife Act deals with the protection and control of wild animals and birds and the management of game. Marine turtles are absolutely protected under the Act. No-one may kill or have in their possession any such turtle, unless they have a permit.	Yes, through Wildlife Act.		Department of Conservation
Niue		The Niue National Strategic Plan 2016-2026 addresses the importance of protecting and conserving marine resources, and draws attention to the sustainable use and management of resources.	The Domestic Fishing Act 1995 stipulates that the Cabinet may "restrict the export of any species of fish and or their meat or body parts by regulation" (Article 11/1). To that end, the Domestic Fishing Regulations 1996 Article 3 prohibits the export of all turtle species, and Article 7 prohibits the taking,	Exporting in contravention of Article 11/1 of the Domestic Fishing Act 1995 shall be liable to "a fine not exceeding 5 penalty units or to imprisonment for a term not exceeding 6 months, or both such fine and imprisonment" (Article 11/3).	Department of Agriculture, Forestry and Fisheries

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
			killing or bringing ashore all turtle species.		
Palau	Endangered	In 2018, Palau enacted a ten-year moratorium on the harvest and sale of hawksbill turtles or their products in response to concerns that populations were declining. Previously, the harvest of hawksbill turtles was permitted in Palau under domestic fishing laws (24 PNCA 1201), with provisions for minimum size limits (27 inches CCL) and closed seasons from June 1 to August 31 and December 1 to January 31 (Secretariat of the Pacific Community and Bureau of Marine Resources Palau, 2007). Taking of eggs or female turtles while onshore is prohibited at all times. Nesting females, eggs, and habitats are also protected within the Ngerukewid Islands Wildlife Preserve.	Full protection until 2028	1,000 USD first offence, 2,000 second, 3,000 third and 20,000 thereafter	
Papua New Guinea	Not protected	All protected fauna are the property of the State. Only leatherback turtles are protected in Papua New Guinea.	Pursuant to the Fauna (Protection and Control) Act of 1966, the taking or killing of protected fauna is an offense (Article 8), where taking or killing refers to hunting, shooting, killing, poisoning, netting, snaring, spearing, pursuing, taking,	The penalty for an offence prescribed in Article 8 is a fine not exceeding K500.00-K1,000.00 for each protected fauna.	The Department of Environment and Conservation

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
			disturbing or injuring. The buying, selling, offering or consigning for sale, possessing or controlling a protected animal is also considered an offense (Article 9/1). According to the Fisheries Management Act of 1998 (amended in 2015), the rights of customary owners of fisheries resources and fishing rights shall be fully recognized and respected in all transactions affecting the resource or the area in which the right operates (Section 26). The International Trade (Fauna and Flora) Act of 1979 restricts the trade of species listed in CITES, including the Hawksbill turtle.	The penalty for an offence prescribed in Article 9/1 is a fine not exceeding K500.00 for each protected animal.	

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
Philippines	Critically endangered	The *Wildlife Resources Conservation and Protection of 2001* (Republic Act No. 9147) has helped further mobilize efforts to support biodiversity research and implement stronger enforcement interventions to save wildlife from various anthropogenic threats, especially the illegal wildlife trade. Republic Act 11038 known as the "Expanded National Integrated Protected Areas System" enacted in 2018 provides the guidelines in protecting marine turtle habitats.	Use of explosives devices and noxious substances are banned. Republic Act 9147 or the "Wildlife Resources Conservation and Protection Act of 2001" bans the harvest and trade of marine turtles, their eggs and byproducts. Article VIII from Fisheries Act (Act no. 4003) addresses Hawksbill turtle fisheries. Taking of Hawksbill turtles are only allowed providing a license or special permit. Shipment, exportation, fishing, taking, wounding, killing, possessing or trading are prohibited. Fisheries Administrative Order No. 29-1 following rules and regulations regarding the gathering of	REPUBLIC ACT NO. 8550 THE PHILIPPINE FISHERIES CODE OF 1998 SEC. 97 on Fishing or Taking of Rare, Threatened or Endangered Species. - It shall be unlawful to fish or take rare, threatened or endangered species as listed in the CITES and as determined by the Department. Violation of the provision of this section shall be punished by imprisonment of twelve (12) years to twenty (20) years and/or a fine of One hundred and twenty thousand pesos (P120,000.00) and forfeiture of the catch, and the cancellation of fishing permit.	Department of Environment and Natural Resources Bureau of Fisheries and Aquatic Resources

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
			aquatic turtle eggs particularly in the Turtle Island Group, Turtle Islands: The annual concession fee for gathering turtle eggs for all the seven (7) islands consisting of the Turtle Island shall not be less than P10,000.00 per annum.		
Pitcairn Islands (UK)		The Endangered Species Ordinance of 2004 provides for the protection of, among others, endangered species, and regulates the trade of such species. In September 2016, the Government of Pitcairn Islands designated the entire Exclusive Economic Zone (EEZ) and territorial sea of Pitcairn Islands as a Marine Protected Area (MPA) under the Pitcairn Islands Marine Protected Area Ordinance 2016. As such, 99.5% of the MPA constitutes a no take zone, where no extraction activities are allowed.	The export or import of any specimen of a species listed in CITES Appendix I, II or III is prohibited by Article 3/1 of the Endangered Species Ordinance. The Pitcairn Islands Marine Protected Area Ordinance 2016 Section 8 prohibits fishing within the designated area, where fishing refers to “catching, taking, or harvesting of fish or other marine life” (Section 3).	Exporting or importing any specimen of a species as prescribed in Article 3/1, shall be liable: “(a) on summary conviction in the Magistrate's Court, to a fine not exceeding $1000 or imprisonment for a term not exceeding 18 months; or (b) on conviction on information by the Supreme Court, to a fine not exceeding $1,000,000 or imprisonment for a term not exceeding 5 years “ (Article 3/6). A person engaging in activities in breach of Section of the Pitcairn Islands Marine Protected Area	Environmental, Conservation & Natural Resources Division

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
				Ordinance 2016 shall be liable to imprisonment for up to 12 months or a fine of up to $50,000, or both, in the event that the offender is a natural person. In the case of an offender other than a natural person, the person shall be liable to a fine up to $500,000.	
Republic of Korea	Marine Organisms Under Protection	Conservation and Management of Marine Ecosystems Act: Article 19 sets plans to conserve, protect, reproduce and restore marine organisms under protection. Article 25 addresses the importance of the designation and management of MPAs. Article 46 addresses restoration of marine ecosystems where the major habitats or spawning areas of marine organisms under protection are destroyed or damaged, which endangers the existence of species.	Conservation and Management of Marine Ecosystems Act: Article 20 prohibits against capturing, collecting, transplanting, processing, distributing, storing or damaging marine organisms under protection; and installing explosives, nets or fishing gear, or use harmful substances or electric currents to capture these species.	Punished by imprisonment with labor for not more than 3 years or by a fine not exceeding 30 million won: Any person who captures, collects or damages marine organisms under protection, or who installs explosives, nets or fishing gear or uses harmful substances or electric currents, so as to capture or damage marine organisms under protection. Punished by imprisonment with labor for not more than 2 years or by a fine not exceeding 20 million won: Any person who transplants, processes, distributes or stores marine organisms under protection; and to Any person	Ministry of Oceans and Fisheries

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
			Article 42 restricts imports and exports, except holding a permission from MOF. Article 20 prohibits capturing, collecting, transplanting, processing, distributing, storing or damaging marine organisms under protection, and installing explosives, nets or fishing gear, or use harmful substances or electric current.	who exports, imports, ships out or brings in marine organisms under protection without permission. Punished by imprisonment with labor for not more than 1 year or by a fine not exceeding 10 million won: Any person who obtains permission by fraud or other wrongful means. Article 63-2 (Aggravated Punishment of Capturing Marine Organisms under Protection). Aggravated punishment: Where anyone is punished by imprisonment with labor for committing a crime under subparagraph 2 of Article 61 or subparagraph 1 of Article 62 for the purpose of trade, he/she shall be imposed concurrently by penalty more than two folds and less than ten folds of the value which he/she has acquired or may acquire through such trade.	

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
Republic of the Marshall Islands	Endangered	The Endangered Species Act 1975 ensures the protection of endangered species of fish, shellfish and games within the territory of the Marshall Islands. A subsequent Regulation dating 1976 listed the hawksbill turtle as an endangered species. The Fisheries Act (amended in 2017) manages and controls living and non-living resources within the Fishery Waters of the Marshall Islands, with a part dedicated exclusively to limitations on taking turtles. The Jaluit and Namdrik atolls in the Marshall Islands are the breeding areas of the hawksbill turtle and the green turtle, and they are declared as wetlands of international importance.	Section 306 of the Endangered Species Act 1975 prohibits the taking, engaging in commercial activity with, holding possession of, or exporting any threatened or endangered species. Section 309 further prohibits the import of endangered species. However, the taking of endangered species by way of traditional rights does not constitute a breach of prohibited activities (Section 307/4). Section 215 of the Fisheries Act prohibits taking or intentionally killing of the hawksbill turtle while on shore, as well as the taking of their eggs unless authorized. Paragraph two provides that “No hawksbill turtle shall be taken or killed except for subsistence fishing and where its shell is at least	Under Section 312 of the Endangered Species Act 1975, a person guilty of an offence prescribed in the Act shall pay a fine of up to $10,000 or be liable to a term of imprisonment of up to one year, or both. Offences committed against the provisions in Section 215 titled “Limitations on Taking Turtles” of the Fisheries Act, shall pay a fine of up to $10,000 or be imprisoned up to six months, or both.	The Marshall Islands Marine Resources Authority

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
			twenty-seven inches when measured over the top of the carapace shell lengthwise.” Paragraph 5 further prohibits buying, selling, displaying for sale, offering for sale or otherwise marketing any turtle or turtle product.		
Samoa		There are no Acts that deal exclusively with endangered species.			Ministry of Natural Resources and Environment
Singapore		Cheloniidae spp. and *Dermochelys coriacea* are protected under Wildlife Act 1965 and Wildlife (Protected Wildlife Species) Rules 2020. The Endangered Species (Import and Export) Act contains provisions to control the trade of CITES-listed animals. The Fisheries Act provides for the protection and conservation of fisheries within Singapore. Nevertheless, the Act	The Endangered Species (Import and Export) Act prohibits the import, export, re-export or introduction from the sea any CITES-listed species, as well as possessing or selling such species (Section 4/1, Section 4/2).	The Endangered Species (Import and Export) Act prescribes a fine not exceeding $50,000 for each scheduled species (but not to exceed in the aggregate $500,000) or imprisonment for a term not exceeding 2 years, or both, for any person in breach of Section 4/1, and 4/2.	National Parks Board

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		does not contain provisions on endangered species.			
Solomon Islands		The Fisheries Regulations in 1993 banned the sale, purchase and export of any turtle product, which saw the legal trade in hawksbill turtle shell cease. The regulations under the 2015 Fisheries Management Act provide the current policy framework for turtle conservation in Solomon Islands. Under the existing legislation, only the leatherback turtle (Dermochelys coriacea) is fully protected. Other marine turtle species can be harvested for subsistence purposes. However, the sale of any turtle product (meat, eggs or shell) is banned, as is the harvesting of turtle eggs or a nesting turtle (Fisheries Management Prohibited Activities Regulations, 2018).	Taking, landing, selling, dealing in, transporting, receiving, buying, possessing or trading any turtle that has been wholly or partly processed, declared as protected or endangered is prohibited (Section 31/2).	Fisheries Management Act 2015 prescribes a fine not exceeding 500,000 penalty units or to imprisonment of up to 6 months, or both (Section 31/3). Pursuant to Fisheries Management (Prohibited Activities) Regulations 2018, fishing or any retaining, being in possession of, selling, buying or exporting any nesting turtle has a penalty of 40,000 penalty units or 4 months imprisonment, or both. Selling, buying or exporting any turtle has a penalty of 40,000 penalty units or 4 months imprisonment, or both. Destroying any turtle nest or eggs, turtle with a tag attached, or tag attached to a turtle has a penalty of 40,000 penalty units or 4 months imprisonment, or both.	Ministry of Fisheries and Marine Resources

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
Taiwan (China)		Fisheries Act (2018) is enacted to conserve and rationally utilize aquatic resources and sets regulations for conservation and management of aquatic organisms (Chapter 5).	Fisheries Act (2018) Article 44 states that the competent authority may promulgate regulations on the following matters: (1) Restriction or prohibition of the catching, harvesting, or processing of aquatic organisms. (2) Restriction or prohibition of the sale or possession of aquatic organisms or the products made therefrom.	Fisheries Act (2018) Violation to Article 44(1) and (2) shall be subject to imprisonment not exceeding three years, short-term imprisonment, or in lieu thereof or in addition thereto a fine of not exceeding one hundred and fifty thousand New Taiwan Dollars.	Council of Agriculture
Thailand		Chapter 5 of the Royal Ordinance on Fisheries , B.E.2558 (2015) set measures for conservation and management of aquatic animal resources and ecosystem in a sustainable manner based on a precautionary approach. Section 56 states: "No person shall catch aquatic animals in an aquatic species sanctuary..."	Section 61 of the Royal Ordinance on Fisheries, B.E.2558 (2015) states "No person shall have in possession aquatic animals or aquatic animal products for commercial purposes knowing that these aquatic animals or aquatic animal products are acquired through wrongdoings..."	The provisions of Chapter 11 of the Royal Ordinance on Fisheries, B.E.2558 (2015) aim to provide criminal sanctions which are adequate in severity: Section 138 "Any person violating section 56 or section 70 shall be subject to a fine of between five thousand baht and	Department of Fisheries

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		Section 58 states that no person shall engage in activities that are harmful to aquatic animals. Section 63 prohibits building any kind of structure that may block the passage of aquatic animals or preempting the natural growth of aquatic animals. Section 66 "No person shall catch aquatic mammals, rare aquatic animals or aquatic animals near extinction". Section 70 "No person shall engage in a fishing operation during a season of aquatic animals' ovulation and egg-spawning, larvae rearing or during any other period of time designated for the protection of aquatic animals".	Section 65 prohibits the importation, exportation, bringing in transit, culturing or possession of any kind of aquatic animal.	fifty thousand baht, or to a fine of five times the value of the aquatic animals obtained from the fishing operation. In whichever case, the higher fine shall apply". Section 140. Any person violating section 58 shall be subject to a fine of between three hundred thousand baht and five hundred thousand baht. Section 143. Any person violating section 62 or section 63 shall be subject to a fine of between ten thousand baht and one million baht and shall dismantle any such structure or fitting or restore the fishing ground back to its normal state, or pay the compensation expenses..."	
Timor Leste		A Joint Ministerial Order No: 18/MAP/MCIA/II/2017 establishing the List of Protected Aquatic Species listed in	Article 3 of the Joint Ministerial Order prohibits the collection and capture of hawksbill turtles. Article 4	A person in breach of Articles 3 and 4, shall be liable for the suspension of their fishing permit for a period of one to 6 months	Ministry of Agriculture and Fisheries

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		its Annex I all sea turtles, thereby the hawksbill turtle, as protected species.	further prohibits harvesting eggs. The Penal Code further prohibits the hunting, fishing, trading or trafficking of, in whole or in part, endangered species or species at risk of extinction (Article 218).	(Article 161 of the Decree Law No:6/2004 of 21 April 2004). In the event of a second offence within 12 months, the offender shall have their fishing permit revoked, without eligibility to obtain a new permit for up to 24 months. A person guilty of an offence prescribed in Article 218 of the Penal Code shall be liable to a fine or imprisonment of up to 5 years.	
Tokelau		There are no national protections for hawksbill turtles in Tokelau. Rules and regulations are determined separately for each atoll and village of Tokelau.			
Tonga		The Fisheries Management (Conservation) Regulations 2008, which implements the Fisheries Management Act 2002, has a dedicated "Species Conservation and Management" part where Article 24	Article 24 of the Fisheries Management (Conservation) Regulations 2008 prohibits the disturbing, taking, having in possession, selling or	Any person who fishes or engages in a related activity in relation to protected or endangered species, subspecies, class or type of fish, shall be liable	Ministry of Fisheries

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		prescribes rules for the protection of turtles. While leatherback turtles, female turtles of any species and eggs of any turtle species enjoy full legal protection, male turtles are not fully protected during open season in Tonga.	purchasing any turtle eggs, as well as interfering with, destroying or disturbing turtle nests. Moreover, using a spear or spear gun to capture, kill or take any species of turtles is prohibited. Fishing, capturing, possessing, destroying female turtles is prohibited year round, however male turtles may be fished, captured, possessed, sold or purchased in the open season so long as they meet the size specifications.	on conviction to a fine not exceeding $25,000 (Fisheries Management Act 2002, Section 19/5) Knowingly landing, displaying for sale, selling, receiving, dealing in, transporting or possessing protected or endangered species, or having reasonable cause to believe so, shall be convicted to a fine not exceeding $100,000 (Section 19/7).	
Tuvalu		The Marine Resources Act 2006, aiming to ensure the long-term conservation and sustainable use of living marine resources, enables the Minister to declare any stock or species of fish, including turtles and their eggs, as protected (Section 11/1). The Conservation Areas Act provides a degree of protection to turtles in Section 14.	If declared as a protected species, the Marine Resources Act 2006 prohibits fishing for, landing, displaying for sale, dealing in, transporting, receiving, possessing or buying or selling (Section 11/2). The Conservation Areas Act prohibits the hunting, killing or capturing of any turtle in	Any person guilty of an offence prescribed in Section 11/2 shall be fined $50,000 plus the fair market value of the subject fish in the market for which it is reasonably supposed to be destined, and to imprisonment for 6 months (Section 11/2). Any person in contravention of the Conservation Areas Act Section 14/2 shall be liable for a	Ministry of Fisheries and Trade

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
			conservation areas designated in the Act (Section 14/2).	fine of $5,000 or to imprisonment for 28 months (Section 14/4).	
Vanuatu		Take of sea turtles has been prohibited in Vanuatu since 2005 (Fisheries Act No. 55 of 2005). In 2009, an amendment to the 2005 prohibition was passed, which closed earlier loopholes and prohibited the killing of any sea turtle species. Provisions of the law allow for traditional harvests through application to the Department of Fisheries (Rice *et al.*, 2018). The Vanuatu Fisheries Department has recently begun training community members to monitor fisheries violations at the village level, including for turtle related offenses (Hickey 2020 in Work *et al.*, 2020). The Fisheries Act No:10 of 2014 provides provision for the management, development and regulation of fisheries. To that end, it enables the Minister to make regulations prescribing measures for the protection of, among others, turtles (Section 147/2,x). The Fisheries Act also establishes a Vanuatu Observer Programme which records, collects and reports information on, especially, protected or	The Fisheries Regulations Order 2009 prohibits the taking, killing, possessing, exporting, selling, or purchasing the hawksbill turtle (Section 59/1,a,il), including its shell (Section 59/1,b) and eggs (Section 59/1,f). It is also prohibited to disturb a turtle nest (Section 59/1,c). Harming, capturing, killing, consuming selling, purchasing, exporting or destroying any turtle species (hatchlings, juveniles or adults) by use of any weapon is also prohibited (Section 59/1,g).	A person in contravention of Section 59 of the Fisheries Regulations Order 2009 is guilty of an offence and is liable to a fine of up to VT 200,000 in case of a natural person, or VT 1,000,000 in case of a legal person (Section 75).	Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		vulnerable species including turtles for scientific, management and compliance purposes (Section 113). Fisheries Regulations Order 2009 further provides detailed provisions on the conservation and protection of marine turtles. The International Trade (Flora and Fauna) Act [Cap. 210] and the International Trade (Flora and Fauna) Regulations (Order No. 2 of 1991) implement CITES within Vanuatu.			
Viet Nam	Listed in the Vietnamese Red Data Book (2007) Listed in the Decree No: 160/2013/ND-CP (2013) as *Endangered, Precious and Rare Species Prioritized in Protection*	The Vietnamese government prohibited the domestic use of marine turtles in 2002 (Decree 48/2002/ND-CP). In 2004, the Vietnamese Ministry of Fisheries launched the Marine Turtle Conservation Action Plan for Viet Nam to 2010 and a revised plan for 2016 to 2025. Additionally, a circular from the Ministry of Fisheries dating 30 March 2006 which supplements a Government Decree dating 4 May 2005, as well as a Government Decree dating 2014 further prohibit the catching and commercial exploitation of	The Biodiversity Law prohibits the "hunting, fishing, exploiting bodily parts of, illegally killing, consuming, transporting, purchasing and selling species on the list of endangered precious and rare species prioritized for protection; illegally advertising, marketing and consuming products originated from species on the list of endangered precious and rare species	Compensation for damages (Biodiversity Law, Article 75) The CITES Vietnamese 2018-2020 Implementation Report states that "For all violations of CITES Appendices I and II (ivory, rhino horn, lizard, marine turtle...), Viet Nam put on trial with the highest sentence of 12 years in imprisonment and VND 660 million." (Indicator 1.7.3f)	Ministry of Agriculture and Rural Development, and Ministry of Natural Resources and Environment

Country	National Protection Status	Law protecting species	Legal protection from killing, egg harvesting and trade	Penalties	Responsible Authority
		marine turtles and their products in Viet Nam. The Biodiversity Law (20/2008/QH12) of 2008 and the Fisheries Law (18/2017/QH14) of 2017 provide for additional protection of aquatic species, including the Hawksbill Turtle.	prioritized for protection.” (Article 7) Article 244 of the 2015 Vietnamese Criminal Code (amended in 2017) prescribes up to 15 years’ imprisonment for offences against regulations on protection of endangered and rare species.	To that end, Annex 1 of the 2018-2020 Implementation Report listed 5 offences for Hawksbill Turtle crime, with penalties ranging from 2 years to 10 years’ imprisonment and fine.	
Wallis and Futuna (France)					

Supplementary Figures

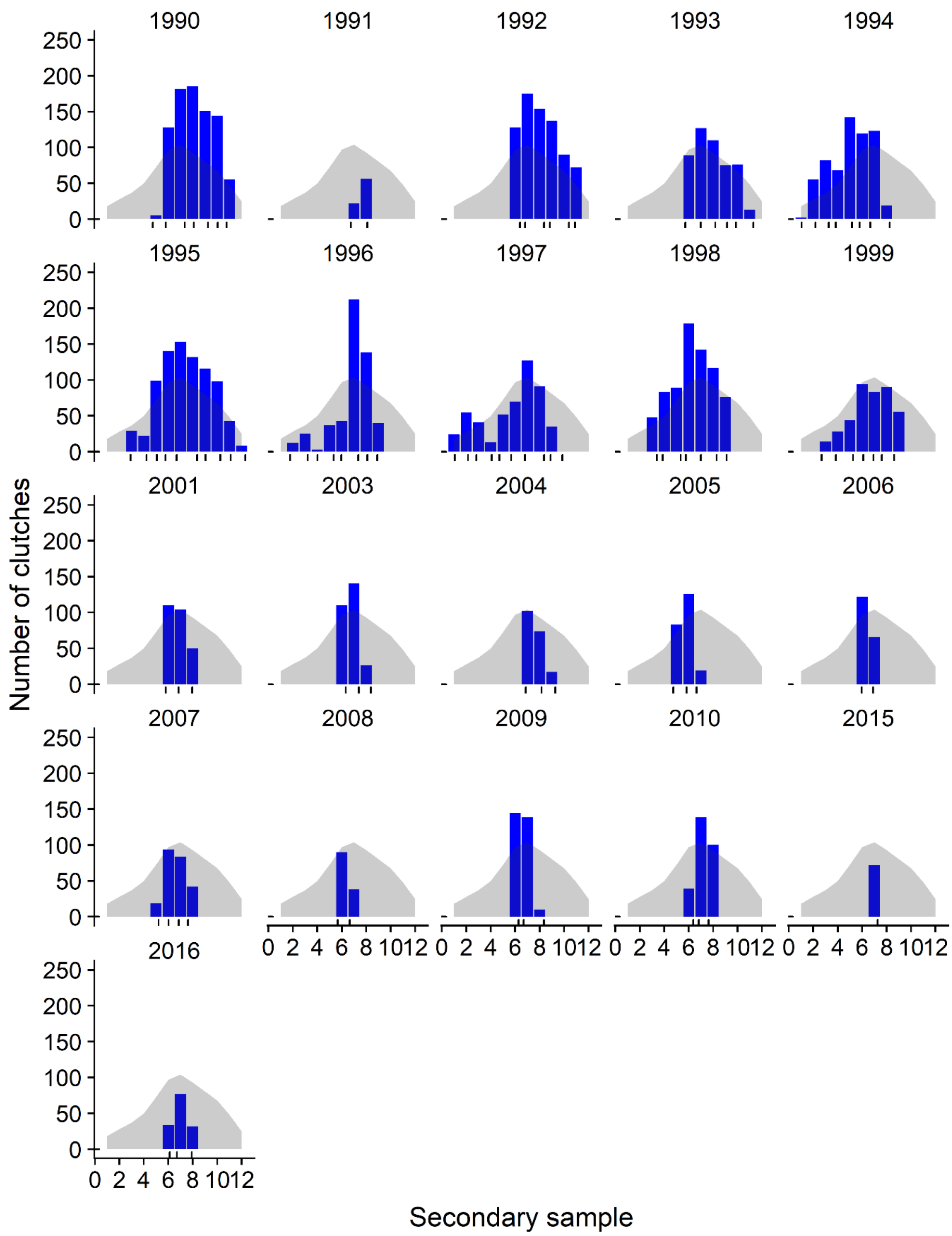

Figure S4.1: number of clutches laid per nesting year and secondary sample (fortnights from November 15 to April 20 of each year). The grey shaded area represents the overall average (GAM).

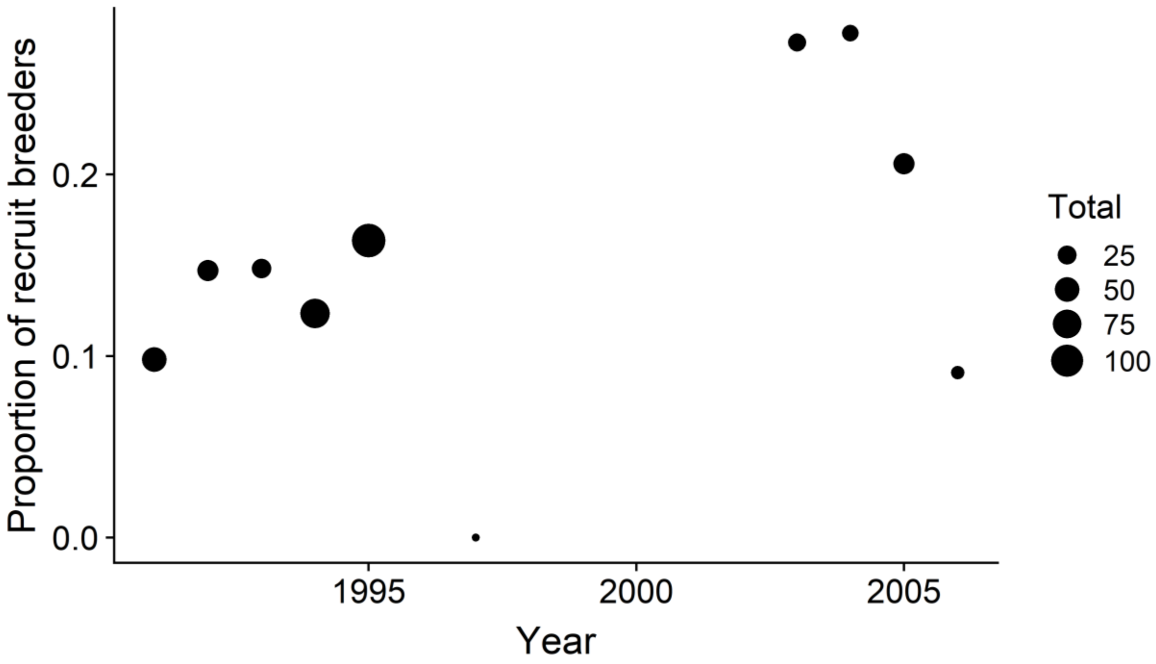

Figure S4.2: proportion of new recruit hawksbill turtles nesting at Milman Island 1990-2006, where the size of the points is proportional to the total number of turtles that were examined (from 6 turtles in 1997-1998 to 110 turtles in 1995-1996).