

Reducing the Impact of Tagging on Flatback Turtles Using Double Passive Integrated Transponder Tags

SABRINA FOSSETTE^{1,*}, ANTON D. TUCKER¹,
ANDREA WHITING², RYAN DOUGLAS¹,
JAMES GEE¹, KELLY HOWLETT³,
KELLIE L. PENDOLEY⁴, ROBERT T. PRINCE¹,
JASON ROSSENDELL⁵, PAUL A. WHITTOCK⁴,
AND SCOTT WHITING¹

¹Biodiversity and Conservation Science, Department of
Biodiversity, Conservation and Attractions, 17 Dick Perry
Avenue, Kensington, Western Australia, 6151 Australia
[Sabrina.fossette-halot@dbca.wa.gov.au;

Tony.tucker@dbca.wa.gov.au; Ryan.douglas@dbca.wa.gov.au;
James.Gee@dbca.wa.gov.au; Bob.prince@dbca.wa.gov.au;
Scott.Whiting@dbca.wa.gov.au];

²Biomaths Consulting, PO Box 1212, Bentley DC, Western
Australia, 6983 Australia
[Au.whiting@gmail.com];

³Care for Hedland, PO Box 436, Port Hedland, Washington 6721
USA
[kellyhowlett35@hotmail.com];

⁴Pendoley Environmental, 12A Pitt Way, Booragoon, Western
Australia, 6154 Australia
[kellie.pendoley@penv.com.au, paul.whittock@penv.com.au];

⁵Rio Tinto, 152-158 St Georges Terrace, Perth, Western
Australia, 6000 Australia
[jason.rossendell@riotinto.com]

*Corresponding author

ABSTRACT. – All monitoring programs on the west coast of Australia have trialed a new mark–recapture protocol to address tag loss in individual flatback turtles (*Natator depressus*) during recent nesting seasons (2020, 2021, 2022). This protocol aligns with ethical considerations for the tagging of marine megafauna. In addition to increasing retention rate of identification tags, this new protocol is expected to decrease the potential long-term health impacts of tagging on this species.

Being able to identify individual marine turtles by mean of an artificial external or internal tag (e.g., flipper tag, passive integrated transponder [PIT] tag, wire tag, shell etching) has allowed researchers to collect fundamental mark–recapture data on these species and has increased our understanding of population abundance and trends (Santos et al. 2021), individual

movements and habitat use (Barr et al. 2021), as well as life history parameters (growth rates, survival rates; Bjørndal et al. 2019). Each tagging technique, however, has its own benefits and limitations that should be carefully considered before choosing a long-term marking approach for a specific population (Reisser et al. 2008; Buteler et al. 2022).

For most marine turtle species and populations, flipper tagging is the main technique used to identify individuals (Balazs 1999). Turtles are marked in 1 or both front flippers, 1 or both rear flippers and sometimes a combination of front and rear flippers with various tag types and sizes used (e.g., Suggett et al. 1998; Balazs 1999; Limpus et al. 2009). Protocol for mark–recapture programs requires the application of at least 2 tags. Reading flipper tags does not require any specific equipment and therefore is accessible by anyone encountering a turtle on a beach or at sea (i.e., scientists, rangers, general public, fishermen, divers), which in turn increases the likelihood of an individual being resighted throughout its life and across its range of movements (Carr 1967; Pradel 1996; Lazar et al. 2004; Shimada et al. 2020). Traditionally, this approach was used so that turtles captured by fishermen would be recorded, and tag returns contributed to our understanding of long-distance connectivity (e.g., Suggett et al. 1998; Lazar et al. 2004; Bell et al. 2018). Loss of external tags is, however, common and confounds which tagged individuals may be identified. This results in previously tagged turtles going unrecognized, in turn reducing the reliability and scientific value of data collected and undermining the primary goal of tagging programs (Mrosovsky 1976; Limpus 1992; Bjørndal et al. 1996; Rivalan et al. 2005; Casale et al. 2017; Nishizawa et al. 2018; Pfaller et al., unpubl. data). Loss rates after 5 yrs for flipper tags may reach up to 60% in green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles (Casale et al. 2017; Nishizawa et al. 2018; Omeyer et al. 2019; Table 1). Flatback turtles also suffer high rates of flipper tag loss (e.g., up to 30%; Limpus et al. 1984; Parmenter 1993; Pendoley Environmental, unpubl. data; Table 1). Long-term tagging programs require turtles to be retagged if they have lost their tags, with some individuals being tagged multiple times during their life.

To our knowledge, there is no published study on the long-term health impact of flipper tags on marine turtles, even though it has been suggested that tagging wounds may be a source of infection (Leong et al. 1989; Witzell 1998; Balazs 1999); flipper tag loss results in damage to the margin of the flippers (Fig. 1), and some flipper tags may be linked to increased likelihood of bycatch (Nichols et al. 1998; Suggett et al. 1998). In flatback turtles, field observations have suggested that flipper tags damage the flippers' scales,

Table 1. Estimated tag loss probability of both titanium flipper tags and passive integrated transponder (PIT) tags in 4 species of marine turtles.

Species	Tag type	Estimated tag loss probability	Reference
<i>Natator depressus</i>	Titanium	0.24 after 2 yrs 0.37 after 5 yrs	Parmenter 1993
<i>Natator depressus</i>	PIT	8% after 2 yrs ^a	Parmenter 1993
<i>Natator depressus</i>	Titanium	3.6%–23.3% per yr ^b	Pendoley Environmental, unpubl. data
<i>Natator depressus</i>	PIT	0.5%–3.7% per yr ^a	Pendoley Environmental, unpubl. data
<i>Chelonia mydas</i>	Titanium	0.42 after 1 yr 0.63 after 5 yrs	Nishizawa et al. 2017
<i>Chelonia mydas</i>	Titanium	0.21–0.25 after 1 yr 0.35–0.67 after 5 yrs	Omeyer et al. 2019
<i>Chelonia mydas</i>	PIT	0.07 after 1 yr 0.10 after 5 yrs	Omeyer et al. 2019
<i>Chelonia mydas</i>	Titanium	0.21 after 3 yrs 0.25 after 5 yrs	Limpus 1992
<i>Chelonia mydas</i> and <i>Eretmochelys imbricata</i>	Titanium	0.13–0.54 after 1 yr	Reisser et al. 2008
<i>Caretta caretta</i>	PIT	0.06–0.07 after 1 yr 0.06–0.07 after 5 yrs	Pfäller et al. 2019
<i>Caretta caretta</i>	Titanium	0.11–0.19 after 1 yr 0.36–0.61 after 5 yrs	Omeyer et al. 2019
<i>Caretta caretta</i>	PIT	0.16 after 1 yr 0.26 after 5 yrs	Omeyer et al. 2019
<i>Caretta caretta</i>	Titanium	0–0.11 after 1 yr 0.19–0.27 after 5 yrs	Limpus 1992

^a Percentage of nesting turtles with complete PIT tag loss but with 1 or both flipper tags remaining.

^b Percentage of nesting turtles with complete flipper tag loss and loss of ID.

which sometimes results in the loss of the first 3 scales of the front flippers after repeated tagging (S. Fossette, August 2020, *pers. obs.*; Fig. 1). In addition, flipper tags are prone to biofouling (Parmenter 1993; Balazs 1999, Fig. 1). If biofouling—in particular barnacle accumulation—becomes excessive, it will produce hydrodynamic drag and tearing that may cause discomfort as well as potential long-term fitness consequences for the individual (Wyneken et al. 2010; Frick and Pfäller 2013). For instance, significant fitness costs have been associated with flipper banding in several species of penguins (Culik et al. 1993; Jackson and Wilson 2002; Gauthier-Clerc et al. 2004) which led to a switch in methodology towards subcutaneously implanted PIT tags.

For flatback turtles, their foraging behavior in relatively shallow coastal environments (Whittock et al. 2016; Thums et al. 2017; Hounslow et al. 2022; Peel et al. in press) may increase the likelihood of heavy biofouling on flipper tags (Fig. 1). For marine turtles in general, this therefore raises an ethical question as thousands of turtles are tagged worldwide annually with little to no quantitative assessments of health or hydrodynamic impacts on tagged turtles. In Western Australia, the lack of understanding about the long-term impact flipper tagging may have on flatback turtles has raised concern by those involved in monitoring programs (i.e., scientists and conservation practitioners). This is particularly so when nesting or foraging turtles have a severe behavioral reaction to flipper tagging, or when observed with heavy biofouling and/or multiple tag scars (Fig. 1).

PIT tagging is often used in combination with flipper tagging (Omeyer et al. 2019). A PIT tag is an electronic microchip that is inserted under the turtle's skin; an external scanning device is required to detect it and read the tag's unique alphanumeric code (Gibbons and Andrews 2004). Earlier models of scanners would only detect one type of PIT tag (single-mode scanners) which was a problem when different types of PIT tags manufactured by different brands were used at different locations to monitor the same species or regional stock. This resulted in compatibility issues and turtles potentially not being identified as tagged. However, multimode scanners, and International Organization for Standardization standard PIT tags are now widely used by marine turtle researchers, thereby reducing this risk. The use of PIT tags is usually benign for turtles (Gibbons and Andrews 2004; Omeyer et al. 2019). Those tags are designed to minimize internal complications as they are encapsulated into a protective glass coating. In addition, the tags induce encapsulation by fibrous connective tissue, which stabilizes their placement (but see Wyneken et al. 2010). Encapsulation is most rapid and effective for long-term retention in highly vascular, resilient tissue such as muscle (Wyneken et al. 2010). There are, however, some reports of infection and irritation at the PIT tag injection site despite proper use of disinfecting techniques during insertion in marine turtles (Dutton and McDonald 1994). As PIT tags have no battery, they should last a turtle's lifetime. However, there is a risk for these tags to be lost, either because of an incorrect application resulting in the tag being



Figure 1. (A, B) Newly deployed flipper tags. (C, D) Flipper tags with heavy biofouling from barnacles. (E, F) Flipper tags with heavy biofouling about to fall off. (G, H) V-shaped tag scars from fallen flipper tags. Images copyright: ©Department of Biodiversity, Conservation and Attractions.

expelled from the body or because the tag migrates deeper into the turtle's body and cannot be detected anymore by a scanner (Wyneken et al. 2010; Omeyer et al. 2019; Pfaller et al. 2019). Movements of a PIT tag within the body may also increase the risk of inflammation and damage while opening a route to infection (van Dam and Diez 1999). Like any methodology, the correct equipment and proper training (i.e., standardized tag placement, insertion angle of needle, speed of insertion) are required to ensure that PIT tagging is effective. When properly injected, PIT tags have a much greater retention rate than external tags (Table 1) and generally increase the likelihood of reidentifying previously tagged animals (Parmenter 1993; Dutton and McDonald 1994; Braun-McNeill et al. 2003; Omeyer et al. 2019; Pfaller et al. 2019). For instance, the annual rate of PIT tag loss estimated at 2 Western Australia flatback rookeries varied between 0.5% and 3.7% and was much lower than the annual rate of flipper tag loss (3.6%–23.3%; Pendoley Environmental, unpubl. data; Table 1).

A New Tagging Protocol. — The flatback turtle is a migratory species listed as vulnerable under Australia's legislation (Environment Protection and Biodiversity Conservation [EPBC] Act 1999) and data deficient under the International Union for Conservation of Nature Red List of Threatened Species. Nesting only occurs in Australia while their at-sea distribution is restricted to the Australian continental shelf (Peel et al. in press). Seven genetic stocks have been identified, with 5 of them located in Western Australia (FitzSimmons et al. 2020). In Western Australia, nesting extends from the Muiron Islands in the southwest to Cape Domett in the northeast, with most islands and large parts of the mainland coastline used as rookeries (Pendoley et al. 2016; Fossette et al. 2021; Tucker et al. 2021). Flatback turtles are being monitored and tagged by 4 monitoring groups at 8 locations encompassing 7 rookeries from 2 different stocks and 1 foraging ground. Until 2019, individuals were either flipper tagged in both front flippers, or both flipper tagged (in 1 or both front flippers) and PIT tagged (in the left shoulder), with some variation in methodology across monitored sites. In this scenario, after initial tagging, turtles may come back with either all tags retained or 1 to several missing tags.

A change and standardization in methodology for routine monitoring of flatback turtles in Western Australia was implemented during the 2020–2021 nesting season across all monitored rookeries. Under the new protocol, all new individuals receive 2 PIT tags—1 in each shoulder—and a flipper tag in the left front flipper (Fig. 2). Individuals previously single-PIT tagged, but with no flipper tags or tag scars, receive 1 additional PIT tag in the opposite shoulder and a flipper tag in the left front flipper (Fig. 2). Individuals with 2 flipper tags and a PIT tag receive 1 additional PIT tag in the opposite shoulder (Fig. 2). For individuals previously flipper tagged but with 1 or 2 missing tags, these are not replaced, and instead 1 or 2 PIT tags are inserted depending on if the individual was previously PIT tagged or not (Fig. 2). This protocol directs that new turtles only receive 1 flipper tag in their life (applied during initial encounter); lost flipper tags are not replaced anymore, with the medium-term goal being to stop flipper tagging entirely. The application of 1 flipper tag to each untagged turtle at a standardized location (i.e., left front flipper), together with injection of 2 PIT tags, provides a means of accurately estimate tag loss for both methods in double-tagged individuals at all rookeries to improve statistical models (Hyun et al. 2012; Omeyer et al. 2019). Once tag loss estimates have been accurately estimated (after ~5 yrs), the use of flipper tags will be discontinued entirely. While consultations with leaders of all monitoring programs in Western Australia were positive and all fully

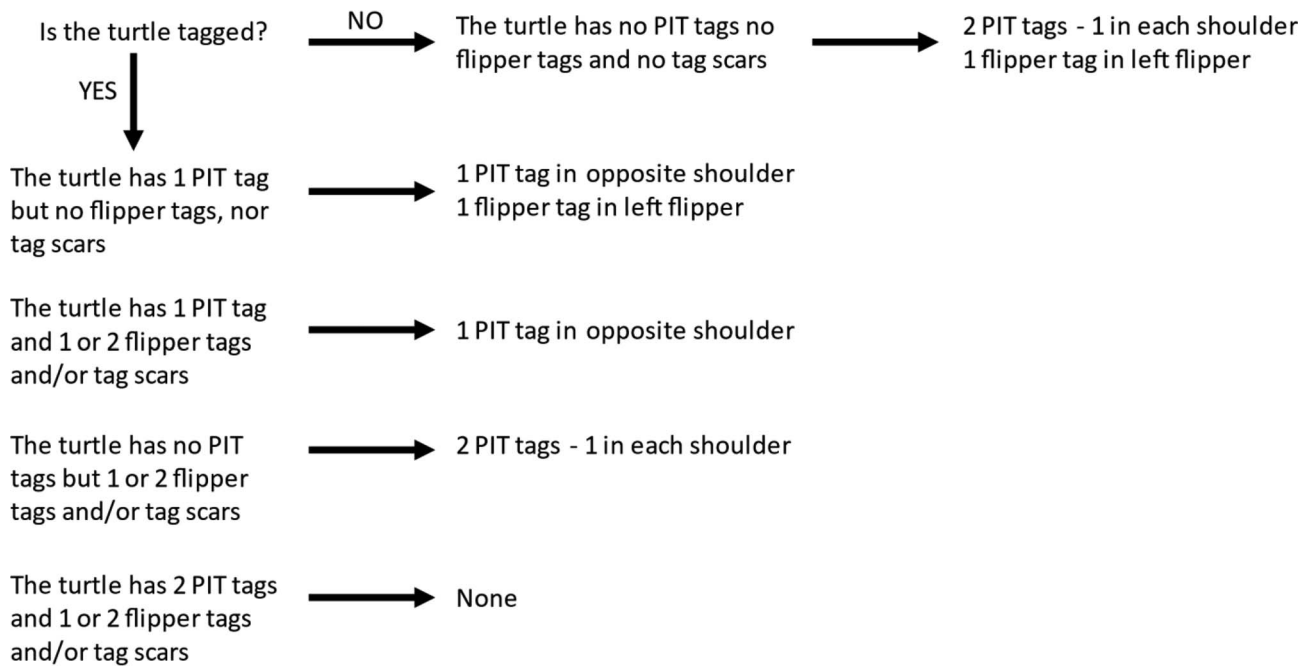


Figure 2. New protocol for tagging of flatback turtles in Western Australia.

supported the adoption of the new methodology, some concerns were highlighted over this change.

Potential Drawbacks of New Protocol. — A change in tagging protocol may impact estimates of life history parameters and statistical models (e.g., capture–mark–recapture model) used to analyze monitoring data (Nishizawa et al. 2018; Pfaller et al. 2018; Omeyer et al. 2019). However, loss rate for PIT tags is low (Omeier et al. 2019, Pfaller et al. 2019, Table 1) and when double PIT tagging is adopted as a standard procedure, this further increases the likelihood of a turtle being identifiable and ultimately improves accuracy of estimates of life history and population parameters (Omeier et al. 2019). In addition, if sampling effort remains constant and comprehensive, switching to PIT tagging only should decrease the time spent processing each turtle. This would, in turn, increase the total number of processed turtles per night, and decrease the number of missed turtles. Overall, the quality and amount of collected data would be improved along with modelled estimates of population parameters. Finally, with the new protocol, even if all tags were lost, the flipper tag scar would be an indication that the turtle is an unidentified recapture. This would be beneficial for calculations of recruitment and tag loss and to indicate to researchers to take extra effort to find a potential PIT tag applied.

Switching to PIT tagging only will limit the ability for fishermen and potentially members of the public to easily identify a turtle, as PIT tags cannot be read without a scanner in hand. In Western Australia, however, bycatch reports of flatback turtles are rare since the nationwide introduction of bycatch reduction devices in fisheries in 2003. Similarly, stranding of

flatback turtles and their discovery by the public is also rare (S. Whiting, January 2023, *pers. comm.*) suggesting that a need for public recovery of a flatback turtle may be less critical than for other species.

Another concern was that PIT tags may be lost or undetected due to the scanner not being able to decode the tag's identity (i.e., compatibility issue), the scanner not being strong enough to read the tag (i.e., low-battery issue, model type with different scanning depths), tag expulsion or movement, and electronic failure. While electronic failure of tags is a possibility, 2 long-term (> 10 yrs) monitoring programs that have used PIT tags on flatback turtles in Western Australia have not reported any cases of faulty tags (Pendoley Environemtal, unpubl. data). Undetected PIT tags do however have the potential to bias collected data. For instance, they may result in turtles being marked with multiple PIT tags at the same location. PIT tags in close proximity can “collide,” resulting in a different PIT tag being detected at each recapture event and creating errors in tagging data.

To reduce those risks, adequate training of the tagging research staff is critical. Research staff should scan tagging locations multiple times and from different angles, consistently search for the presence of more than 1 PIT tag, and always use fully charged scanners (Epperly et al. 2015; Omeyer et al. 2019; Foley et al. 2021). A comparison of the most common models of PIT tag scanners used by marine turtle monitoring teams appears in Table 2 (see also Epperly et al. 2015 and Foley et al. 2021). Information about the ability for scanners to detect multiple PIT tags when present at the same location was not available in any of the user's manuals. Monitoring teams should therefore

Table 2. Characteristics of 5 of the most frequently used passive integrated transponder tag scanners by marine turtle researchers. The first 2 models are most frequently used in Australia.

Model	Dimensions and weight ^a	Cost	Reads	Scanning distance ^b	Memory capacity	Battery
V8BT RT100 Bluetooth Scanner	155 mm (L) × 82 mm (W) × 33 mm (H) 155 g	\$AU326	ISO 11784/5 FDX-B, FDX-A, EM4102, and HDX All NLIIS and RFID tags	Up to 11 cm	800 IDs	Rechargeable 3.7 V lithium ion battery
Realtrace RT250 Stick Reader	900 mm(L) 460 g	\$AU938	ISO 11784/5 FDX-B and HDX All NLIIS and RFID tags	Up to 14 cm	800 IDs	Rechargeable 3.7 V lithium ion battery
AVID Power Tracker VIII	208 mm (L) × 152 mm (W) × 89 mm (H) 816 g	> \$AU1000	ISO 11784/5 FDX-B, FDX-A (FECAVA), All Avid tags	Up to 17 cm	2000 IDs	Rechargeable 8.4 V NiMH battery
Destron Fearing Global Pocket Reader Plus (GPR+)	202 mm (L) × 80 mm (W) × 36 mm (H) 330 g	\$AU467	ISO 11784/5 HDX, FDX-B, FDX-A (FECAVA), All Trovan and Avid tags	Up to 10 cm	3000 IDs	6 “AAA” 1.5V alkaline or 6 NiMH rechargeable “AAA” 1.2 V batteries
Biomark Global Pocket Reader Plus (GPR Plus)	205 mm (L) × 82 mm (W) × 35 mm (H) 330 g	\$AU830	ISO 11784/5 HDX, FDX-B, FDX-A (FECAVA) FDX-B Bio-Therm13, All Biomark, Trovan and Avid	Up to 43cm	3000 IDs	6 “AAA” 1.5 V alkaline or 6 NiMH rechargeable “AAA” 1.2 V batteries

^a Abbreviations: L, length; W, width; H, height.^b Typical scanning distances will vary depending on types of microchips and positions.



Figure 3. In flatback turtles, passive integrated transponder tags should be deployed either at the left or right front point of the carapace directly under and right up against the shell (left circle) or in the left or right shoulder, 2–3 finger widths (i.e., ~3–4 cm) below the carapace in the muscle halfway between the neck and flipper (right circle). Image copyright: ©Department of Biodiversity, Conservation and Attractions.

assume scanners are unable to do so. As part of the new protocol, equipment has been standardized across all marine turtle monitoring programs in Western Australia to eliminate the risk of compatibility and reading issues. Use of the PetScan RT100-V8 model as a PIT tag scanner is also recommended for all Australian turtle monitoring groups. Finally, in flatback turtles, tags should be deployed either at the left or right front point of the carapace directly under and right up against the shell or in the left or right shoulder, 2–3 finger widths (i.e., ~3–4 cm) below the carapace in the muscle halfway between the neck and flipper (Fig. 3). These locations should reduce the risk of tag migration and potential complications (C. Limpus, July 2023, *pers. comm.*).

Concerns over the cost of PIT tagging compared to the cost of flipper tagging was raised by monitoring groups. In Australia, a flipper tag costs ~AU\$3.00 and a PIT tag ~AU\$4.50. PIT tag scanners cost ~AU \$317 and flipper tag applicators are ~AU\$137 each with refurbishments costing ~AU\$70. As the loss rate of flipper tags is higher than PIT tags, over time, the cost per individual will be lower if turtles are double PIT tagged rather than double flipper tagged with continued replacement. For flatback rookeries in Western Australia, we estimate that tagging costs could be decreased by 10% to 25% over 20 yrs based on prices of tags and tags' readers and applicators and tag loss rates.

Conclusions. — The transition from flipper tagging of flatback turtles in Western Australia to double PIT tagging with the application of a single flipper tag only on new individuals has been a substantial change in methodology with no obvious short-term drawbacks

identified in the field. Regular communication and collaboration amongst the state's monitoring programs has ensured the success of this new protocol, which now means a unified system has been put in place along the entire west coast of Australia. Flatback turtles from Western Australia rookeries largely remain in Western Australian waters but a small percentage of individuals disperse to the Northern Territory waters (Peel et al. in press). It is therefore important to ensure that monitoring programs in the Northern Territory are also equipped with compatible scanners in case they encounter a turtle from Western Australia. Loss rates calculated for both PIT and flipper tags will be estimated after the 2024–2025 nesting season (i.e., using 5 yrs of collected data with new protocol) along with population abundance and mean nightly monitoring effort at selected rookeries. Quantification of full turtle-identity loss (i.e., all tags lost) will be aided by properly identifying and recording flipper tag scars through personnel training. An increase in the amount and quality of data collected at monitored rookeries should provide more reliable estimates of life history parameters and ultimately of population abundance and trends.

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