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Differential Tag Retention in Caribbean Hawksbill Turtles

ROBERT P. VAN DAM[1] AND CARLOS E. DIEZ[2]

[1]*P.O. Box 9020708, Old San Juan, 00902 Puerto Rico [E-mail: rvandam@compuserve.com];*
[2]*Negociado de Pesca y Vida Silvestre, Departamento de Recursos Naturales y Ambientales, P.O. Box 9066600, San Juan, 00906 Puerto Rico*

ABSTRACT. – We used four types of individually coded tags (monel and inconel metal alloy, plastic, and passive integrated transponder [PIT]) to identify individual hawksbill turtles (*Eretmochelys imbricata*) in the near-shore waters of Mona and Monito Islands, Puerto Rico. A multiple tag application protocol was followed for most turtles. The recapture and examination of 121 turtles up to 5 years after tag application allowed us to evaluate differential tag retention rates. Plastic tags outperformed all other examined tag types, with 100% retention recorded for 42 tags applied to 42 turtles. Retention rates for the other tag types generally declined with time. Listed in order of decreasing retention rates they were: plastic, PIT, inconel alloy, and monel alloy tag types. The attachment of multiple tags per turtle together with regular replacement of lost tags promises to be effective for the long-term identification of most hawksbill turtles in our study area.

KEY WORDS. – Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; methodology; tag loss; tag retention; Puerto Rico

The ability to distinguish individuals is an important requirement for most demographic research with turtles. Workers have explored a variety of identification methods for marine turtles, including internal and external coded tag application (e.g., in *Natator depressus*, Parmenter, 1993), and documentation of characteristic, naturally occurring body marks (e.g., "pink spots" in *Dermochelys coriacea*, McDonald and Dutton, 1996). Long-term tagging efforts on marine turtles face many challenges, caused among other things by: 1) the wide range of turtle body weights, spanning up to four orders of magnitude from hatchling to adult, 2) the inherently corrosive and frequently abrasive marine environment, and 3) an array of turtle behaviors (e.g., nesting, scraping, mating) that may place great stress on any externally attached objects.

Optimum tagging protocols are likely to differ by turtle species, habitat type and conditions, and research objectives. The evolution towards such protocols typically take many years, but is a required preamble for research into marine turtle population dynamics over periods that may span decades.

In this study we examine retention rates of four tag types on hawksbill turtles (*Eretmochelys imbricata*) found in the near-shore areas of Mona Island (18°05'N, 67°56'W) and nearby Monito Island, Puerto Rico. These areas encompass a variety of hard bottom habitat types serving as feeding grounds for a high-density aggregation consisting of turtles ranging from very small juveniles to large adults (for further habitat descriptions see van Dam and Diez, 1996, 1997, 1998).

METHODS

We began in-water censusing of hawksbill turtles at Mona and Monito Islands in 1992. These surveys were made annually and, with some exceptions, were mostly conducted in the period from July to October. Sighted turtles were captured by hand through free diving or with the aid of scuba and were brought aboard a small research vessel for application of tags and/or inspection of existing tags. Upon completion of processing, animals were released as close as possible to the location of capture. This approach represents a mixed longitudinal sampling design (Chaloupka and Musick, 1997).

Four types of individually coded tags were employed in this study: monel metal alloy, inconel metal alloy, passive integrated transponder (PIT), and plastic (Fig. 1). Metal alloy tags were self-piercing style 681 (National Band and Tag Company, Newport, KY). Plastic tags were yellow or light blue colored Jumbo Rototags (Dalton Supplies Ltd., Nettlebed, Henley-on-Thames, Oxon, United Kingdom). PIT tags were style TX1400L (Destron-Fearing, South St. Paul, MN) and interrogated at 125kHz with a Destron/IDI Series HS5105L reader.

Concern for the well-being of smaller turtles as well as economy of tags, and fluctuating supplies of the different tag types precluded testing all tag types over the entire turtle size range. We adopted a tagging protocol as outlined in Table 1, and followed it as closely as possible. Application of plastic tags commenced in 1993 and the use of monel tags was discontinued in 1994, when inconel tags became available to us.

All tags were applied to the anterior flippers using appropriate applicators. Metal tags were attached through the center of the first or second most proximal large scute of the flipper's trailing edge. Plastic tags were applied to the same position (Fig. 2) after making a ca. 4 mm hole with a leatherpunch. Immediately following application, external tags were inspected for proper closure. PIT tags were injected subcutaneously in a direction away from the shell about 1–2 cm anterior to the first most proximal scute of the right anterior flipper. Cyanoacrylate was used to seal the PIT

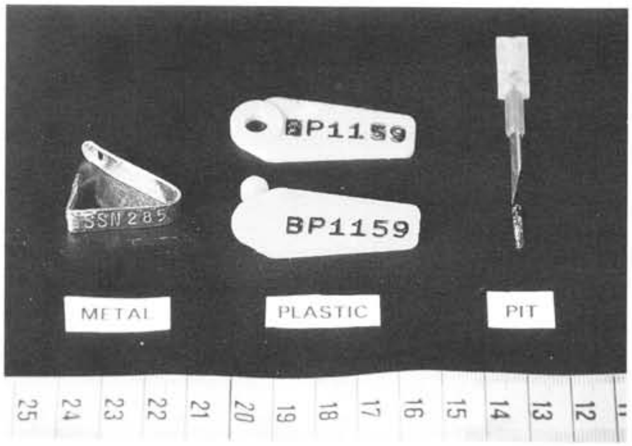

Figure 1. Metal, plastic, and PIT tags employed in this study. The metal tag shown is inconel alloy and identical in size to the monel tags used.

tag insertion wound. PIT tags were read both before and after injection to verify tag integrity.

For each recaptured turtle the retention status of previously applied tags was recorded, lost tags were replaced, and any tag anomalies (e.g., corrosion, biofouling) noted. Tag loss was detected by identification of turtles that still retained additional tags. For each of the four different tag types we applied the following probability equation:

$$p_i = b_i/(a_i+b_i) \qquad [1]$$

with **i** = elapsed time in whole years since tag application;
- $\mathbf{a}_i$ = number of tags confirmed present on sampled turtles, **i** years since application; and
- $\mathbf{b}_i$ = number of tags no longer present on sampled turtles, **i** years since application.

We used Equation 1 as an estimator for the probability of tag loss as a time-series (following Limpus, 1992). Standard error of this probability was calculated using:

$$SE_{pi} = \sqrt{[p_i(1-p_i)/(a_i+b_i)]}$$

with 95% confidence limits of $p_i = 1.96 \pm SE_{pi}$. Elapsed time in years since tag application was calculated by rounding to the nearest whole year the actual elapsed time between tag application and tag detection upon turtle recapture. Each turtle captured was measured using Haglof tree calipers; carapace length reported is straight-line distance between the nuchal notch and posteriormost marginal tip (SCL).

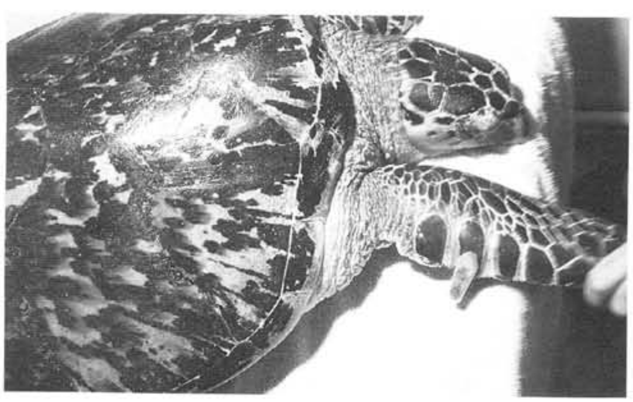

Figure 2. Plastic tag exhibiting minor abrasion wear after 4 years since application to a hawksbill turtle.

Table 1. Tagging protocol adopted for hawksbill turtles on feeding grounds at Mona and Monito Island. SCL is straight carapace length measured from the nuchal notch to the posteriormost marginal tip.

Turtle Size (SCL)	Anterior Flippers Right	Anterior Flippers Left
Small juveniles (< 23 cm)	none	PIT
Juveniles (23–33 cm)	metal	metal and PIT
Subadults (34–60 cm)	metal (or plastic)	plastic (or metal) and PIT
Large subadults and adults (> 60 cm)	metal (or plastic)	plastic (or metal)

RESULTS

From 1992 to 1997 we captured, tagged, and subsequently recaptured 121 identifiable hawksbill turtles, ranging from 20.0 to 78.5 cm SCL at initial capture. A total of 357 tags was applied to these animals, with the loss of 48 tags subsequently confirmed. A large majority of turtles were triple-tagged. Fig. 3 illustrates the distribution of the applied and lost tags, by type and turtle size at tag attachment. Table 2 and Fig. 4 summarize the data obtained for tag loss and retention in hawksbills.

Plastic tags outperformed all other tag types, with no detectable tag loss occurring in the four year period since commencing their application (100% retention recorded for 42 plastic tags applied to 42 turtles). Plastic tags on recaptured turtles were typically covered with a film of red filamentous and/or calcareous algae. Minor abrasion wear was apparent at the outer trailing edges of plastic tags on several turtles (Fig. 2), but never compromising tag integrity. No heavy biofouling of plastic tags was observed.

Eight PIT tags were lost or could not be read; these were on turtles throughout our sample size range (20–60 cm SCL). The observed steady decline in probability of PIT tag retention with time (Fig. 4) indicates that tags continued to be lost or failed throughout the five year period monitored. In a few turtles PIT tags were detected at some distance from the original injection site, confirming tag travel within the body. One turtle was carrying the PIT tag at the tip of its flipper.

In the initial phase of our study and after detection of several cases of rapid metal tag loss by turtles < 23 cm SCL, we discontinued application of metal tags to these small juveniles. The adopted tagging protocol (Table 1) resulted in a data set of applied inconel and monel alloy tags heavily biased towards turtles in the size range from 23 to 34 cm (Fig. 3). Inconel tags appeared to perform better than monel tags

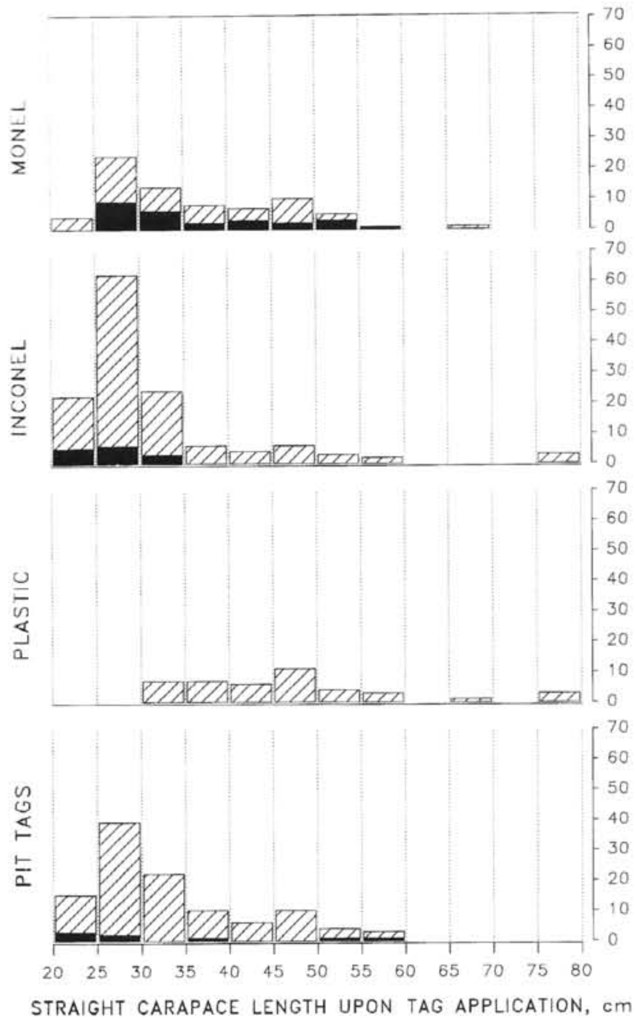

Figure 3. Distribution of the four tag types evaluated in this study, by turtle size at tag attachment. Only data on tags applied to turtles subsequently recaptured are included. Solid bars indicate tags confirmed as lost; hatched bars are tags confirmed present at the most recent turtle recapture.

over the first three years, although overlapping 95% confidence intervals for all years preclude firm statistical support for this observation. Monel tags still attached after three years had a good chance of persisting for two more years. Older monel tags frequently appeared pitted at the surface and along the edges, suggesting a greater susceptibility to corrosion than inconel alloy tags.

DISCUSSION AND CONCLUSIONS

As with most evaluations of tag retention on free-ranging marine turtles, this study was conducted in an open environment where individual turtles could not be monitored continuously, nor conditions be controlled. The type of sampling conducted resulted in information that may be less complete than desired, and places certain limitations on the reliability of results. For example, turtles that lost all applied tags before recapture would be incorrectly categorized as new, untagged turtles, leading to an underestimation of tag loss rates. Despite such potential shortcomings, the data collected can still provide useful insight into the effectiveness of the different tags employed.

Plastic Jumbo Rototags outperformed the three other tag types evaluated in this study. These tags are not the same as the Allflex plastic tags tested by Limpus (1992) and Alvarado et al. (1988) and do not appear to suffer the reported brittleness or loss of readability through abrasion. We judged Jumbo Rototags too large for application to the smallest turtles encountered in our study area and we did not test retention on turtles smaller than 34 cm SCL (body mass < 5 kg) to avoid burdening such animals. Based on the observed performance of plastic tags, we recommend their use on larger immature hawksbill turtles for conditions similar to those of our study area.

The PIT tag loss rates measured by us lie close to the values determined by Parmenter (1993) for similar tags

Table 2. Loss of four types of tags applied to hawksbill turtles at Mona and Monito Islands. Tag types and definition of p_i and SE_{pi} are detailed in the Methods section.

Tag Type	Years Since Application (i)	Tags Confirmed Present	Tags Confirmed Lost	p_i	SE_{pi}	95% Confidence Limits
Monel	1	40	4	0.091	0.043	[0.006, 0.176]
	2	29	8	0.216	0.068	[0.084, 0.349]
	3	22	18	0.450	0.079	[0.296, 0.604]
	4	17	14	0.452	0.089	[0.276, 0.627]
	5	9	6	0.400	0.126	[0.152, 0.648]
Inconel	1	101	8	0.073	0.025	[0.024, 0.122]
	2	54	9	0.143	0.044	[0.056, 0.229]
	3	31	7	0.183	0.063	[0.061, 0.307]
Plastic	1	30	0	0.000	0.000	
	2	19	0	0.000	0.000	
	3	13	0	0.000	0.000	
	4	4	0	0.000	0.000	
PIT	1	70	5	0.067	0.029	[0.010, 0.123]
	2	47	5	0.096	0.041	[0.016, 0.176]
	3	30	3	0.091	0.050	[<0.00, 0.189]
	4	13	2	0.133	0.088	[<0.00, 0.305]
	5	5	1	0.167	0.152	[<0.00, 0.465]

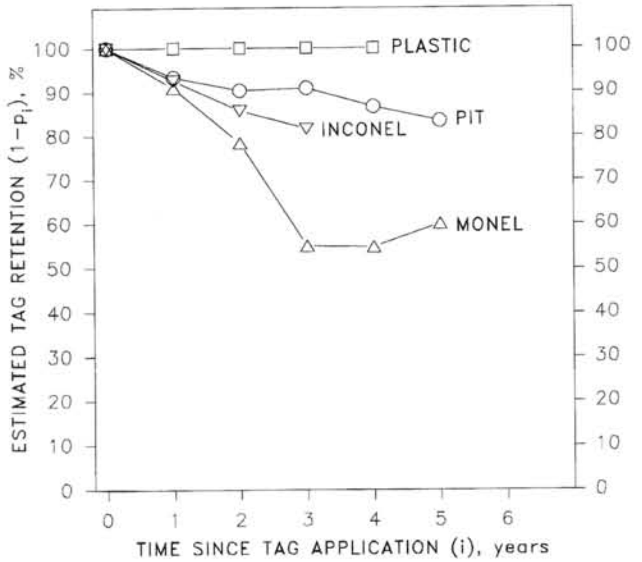

Figure 4. Estimated tag retention probabilities as a function of time for the four tag types evaluated.

in *Natator depressus*. He found that 8% of PIT tags injected into the shoulder of nesting turtles became unreadable after two years. In contrast, McDonald and Dutton (1996) reported a 100% retention rate for PIT tags injected into shoulder muscle of *Dermochelys coriacea* over a three year period. Failures in reading PIT tags may be attributed to factors such as physical tag loss, tag migration into tissue beyond the range of the tag reader, and tag or reader malfunction. Whereas physical loss and migration of PIT tags may be mitigated by prudent selection of injection location and procedures, the tags do appear to occasionally fail though remaining externally unblemished (R. Horst, *pers. comm.*). We were not able to determine the cause of PIT tag reading failures in the turtles we handled. The tag migrations observed in several turtles suggest that subcutaneously applied PIT tags may not always become anchored through encapsulation by connective tissue. Intramuscular injection, as used in other turtle species, is not an option for the smallest *Eretmochelys* found in our study area, because these animals lack sufficient muscular bulk. Further exploration of PIT application protocols in a wide size range of hawksbill turtles are needed to determine the optimal tagging procedure for the species.

Performance of both types of metal alloy tags utilized in our study was inferior to either plastic or PIT tags. The observed monel tag retention rates (Fig. 4) suggest a complex underlying set of loss factors, that may include varied corrosion susceptibility between separate batches of tags as reported by Bjorndal et al. (1996), and potential electrochemical differences in microhabitats used by the turtles. Inconel tags seemed much less affected by corrosion and we infer from the observed tagging scars that most losses were due to tags tearing out, for example when snagged on projections in the reef environment. This risk appears diminished with larger turtles that have thicker and tougher flipper tissue anchoring the tags, and accordingly we detected no inconel tag losses in turtles over 35 cm SCL (Fig. 3).

Applying multiple tags to turtles can greatly diminish the chance of misidentification of individuals. With the adopted tagging protocol (Table 1) we can reasonably expect only very few tag loss misidentifications of turtles in our study area. For example, of those turtles tagged with two inconel tags and one PIT tag, the composite probability of complete tag loss after three years would be 1 in 324 animals (assuming loss factors are independent). In practice, this probability is further reduced in our study by replacement of lost tags in recaptured animals. Juvenile turtles < 23 cm SCL tagged by a single PIT tag appear at greatest risk of subsequent misidentification. Discernible tagging scars were not evident on any untagged turtles captured in our study area to date.

Identification methods using the inherent variation present in body features between individual turtles hold some promise as a means of identification complementary to tagging. Many hawksbill turtles have conspicuous and characteristic deformities, usually of the carapace, that should prove to be reliable identifiers. We are currently also exploring identification methods using head scalation, similar to the photoidentification methods adopted for *Dermochelys* by McDonald and Dutton (1996), that could become valuable, provided their use can be simplified and reliability confirmed. Such methods would be especially useful as a complement to PIT tagging in juvenile turtles < 23 cm SCL, which are too small to reliably mark with conventional external tags.

RESUMEN

Para marcar tortugas de carey (*Eretmochelys imbricata*) en las aguas cercanas a las Islas Mona y Monito (Puerto Rico) fueron utilizados cuatro tipos de marcas: de aleación de monel, de aleación de inconel, de plástico y del tipo "passive integrated transponder" (PIT). La mayoría de las tortugas fueron sujetas a un protocolo de marcaje múltiple. Con la recaptura y examinación de 121 tortugas hasta 5 años después del marcaje inicial fue posible la evaluación diferencial de tasas de retención. La retención de las marcas plásticas fue superior a la de los otros tipos de marcas examinadas, con 100% de retención detectado para 42 marcas colocadas en un igual numero de tortugas. En general hubo una disminución de la tasa de retención de los otros tipos de marcas con el tiempo. En orden de mejor a peor retención fueron: plásticas, PIT, aleación de inconel, y aleación de monel. La colocación de multiples marcas por tortuga junto con el reemplazo regular de marcas perdidas promete ser efectivo para la identificación a largo plazo para la mayoría de las tortugas de carey en nuestra zona de estudios.

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