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Short-Term Effectiveness of Passive Integrated Transponder (PIT) Tags Used in the Study of Mediterranean Marine Turtles

Brendan J. Godley[1], **Annette C. Broderick**[1], **and Sinead Moraghan**[2]

[1]*Marine Turtle Research Group, School of Biological Sciences, University of Wales Swansea, Singleton Park, Swansea, SA2 8PP, United Kingdom [E-mail: MTN@swan.ac.uk];*
[2]*RSPCA Stapeley Grange Wildlife Hospital, London Road, Stapely, Nantwich, Cheshire, CW5 7JW, United Kingdom*

A variety of methods have been utilized in the marking of free-ranging marine turtles to enable subsequent identification of individuals. Information that can be derived as a result of such studies include: data regarding movements, intra- and inter-seasonal nesting behavior, estimation of population size, and growth rates. These are parameters that must be accurately known to allow for successful conservation and management of these threatened and endangered species.

The method most commonly used is external flipper tagging, of which a variety of designs, materials, and protocols have been used in different species due to factors such as tag strength, durability of markings, and retention rates (Balazs, 1982; Henwood, 1986; Eckert and Eckert, 1989; Alvarado et al., 1993). Tag loss has been considered a major confounding factor in many marine turtle studies (Limpus, 1992). In addition, recent concern has been expressed regarding the possible role certain tag types might have on the likelihood of incidental capture in net-based fisheries (Nichols et al., 1998).

Although most studies continue to use traditional flipper tags, a possible long-term alternative has been identified in the use of internal Passive Integrated Transponder (PIT) tags (Fontaine et al., 1987; Parmenter, 1993). After several years of use, this technique has allowed estimation of external flipper tag loss and revision of previous over-estimates of nesting numbers (McDonald and Dutton, 1996).

Since 1992, an annual, intensive tagging program of Mediterranean green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles has been undertaken at Alagadi Beach, northern Cyprus (Broderick and Godley, 1996). Here, plastic stock tags (Jumbo tags and Supertags, Dalton Supplies Ltd., UK) have been used to tag 78 green turtles and 122 loggerhead turtles. Tags are placed on the trailing edge of both fore-flippers in the position recommended by Limpus (1992). Given the possible advantages of marking using PIT tags, an initiative has been developed using this technique. This note summarizes the results of the first two seasons of the use of this technique and presents data regarding its short-term usefulness.

Methodology. — During the laying process all nesting female turtles at Alagadi, northern Cyprus (35°33'N, 33°47'E) were checked for existing tags or tagging scars. In addition to external flipper tags, females nesting in 1997 and 1998 were also marked using PIT tags (Identichips, AnimalCare Ltd., UK). Individual PIT tags measured 11 ± 1 mm x 2 mm and were injected using a modular system consisting of an injecting handle and single-use, sterile unit fitted with a 2.1 cm, 12 gauge cutting needle. PIT tags were cross-compatible with scanners marketed by AVID, Destron, or Trovan. All injections were undertaken immediately following the cessation of laying, when the turtles were covering eggs, but before the commencement of camouflaging. PIT tags were injected into the shoulder musculature ca. 5 cm from the carapace margin at the site suggested by Dutton and McDonald (1994) for use in leatherbacks (*Dermochelys coriacea*). Bilateral implantation was undertaken in a large proportion of individuals. PIT tags were checked for function before and after injection using hand-held scanners and also when females returned to lay a subsequent clutch later in the season. Scanners operated at 125 kHz.

Results. — A total of 64 nesting females were marked using PIT tags (35 green turtles: 20 bilaterally and 15 unilaterally; 29 loggerheads: 18 bilaterally and 11 unilaterally).

Of the 35 green turtles, 28 were re-sighted within the same season (18 bilaterally marked individuals; 10 unilaterally marked individuals). Bilaterally marked individuals were re-sighted on a total of 42 occasions; the proportion of individual PIT tags successfully detected was 92% (77 of 84), however, all individuals were re-identified on each occasion on the strength of PIT identification alone, as at least one PIT tag was detected in every case. Unilaterally marked individuals were re-sighted on a total of 17 occasions with PIT tags being detected every time (100%). Thus the proportion of PIT tags which were detected in green turtles was 93% (94 of 101), with 100% re-identification of individuals.

Of the 29 loggerheads, 18 individuals were re-encountered (13 bilaterally marked; 5 unilaterally marked). Bilaterally marked individuals were re-sighted on 15 occasions and both PIT tags were detected in 12 cases. However, at least one PIT tag was detected on the other occasions. Thus, a 90% PIT tag detection rate with 100% re-identification of individuals was attained. There were five re-sightings of individuals marked with a single PIT tag, with one individual failing to be identified by PIT tag reading alone. Thus for unilaterally marked individuals an 80% rate for PIT tag detection and re-identification of individuals was obtained.

The 89% (27 of 31) detection rate of PIT tags in loggerheads was comparable to that of green turtles. The results were not significantly different between species ($\chi^2 = 0.43$, $p = 0.512$, d.f. = 1). In addition, although 94% (17 of 18) of loggerheads were re-identified on the strength of PIT tags alone, this was not significantly different from the 100% in green turtles ($\chi^2 = 0.02$, $p = 0.882$, d.f. = 1).

Apart from slight hemorrhage, on no occasion were any deleterious post-injection effects observed. All injection sites had healed well after one internesting interval of 10–15 days, no wound infection or swellings were detected. In addition, qualitative observations of the behavior of turtles during tagging suggested that reaction to the PIT tagging process was less than that to traditional tagging. It may be that PIT tagging is less noxious to marine turtles than traditional methods.

Discussion. — It is apparent that in the short-term, PIT tagging yielded high levels of re-identification (100% for green turtles; 94% for loggerheads). Re-detection levels for individual PIT tags were not as high (93% in green turtles; 89% in loggerheads).

It is likely that failure to re-detect PIT tags was for one of the following reasons: 1) intrinsic tag failure, 2) detection failure of an existing functional tag by the investigator, and 3) loss of the tag through the injection hole, soon after the time of application but before the wound had healed. Preliminary observations suggestive of the latter two causes were noted during this study. Marking bilaterally would appear to possibly help counteract these types of failures.

Assuming long-term retention and function of PIT tags over several years, the utilization of such a technique would enable remigration patterns to be more accurately assessed, since loss of conventional tags can confound such studies. In addition, given concern as to the possible long-term effects of some traditional tagging methods, both in marine turtles (Nichols et al., 1998) and other species (Culik et al., 1993) and our qualitative observations regarding reactions to the tagging process, PIT tagging would appear to be an extremely useful tool in the study of marine vertebrates.

If use of this technique became widespread (with readers being made available to individuals who might have previously reported traditional tag returns), it might offer the numerous advantages of traditional tagging without concomitant deleterious effects. Major provisos on the usefulness of this technique are firstly, that all PIT tags should be able to be detected by all readers and secondly, there is a need to standardize implantation sites in all species to ensure the greatest possible likelihood of data recovery by different operators. If these criteria are not met, the value of the technique beyond the proximate, local scale is severely reduced.

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On the Turtles of Hainan Island, Southern China

RON W.F. DE BRUIN[1] AND HARALD G. ARTNER[2]

[1]*Beltmolen 49, 2906 SC Capelle a/d Ijssel, Netherlands [Fax: 31-10-408-9471; E-mail: debruin@heel.fgg.eur.nl];*
[2]*Maria Ponsee 32, 3454 Sitzenberg-Reidling, Austria*

Hainan Island in the South China Sea is the southernmost province of China. It has an area of 32,000 km^2 and a subtropical climate, with winter temperatures averaging 21°C. In the mountains, however, temperatures may become significantly lower. Smith (1923a) reported that frost is not uncommon at high altitudes, and in January he experienced freezing fog in the morning at an altitude of 1200 m. From March through October the weather becomes hot and humid; typhoons may strike and most rain falls in this period. We measured average day temperatures of 35°C in May.

As part of the "one country, two systems" policy, Hainan was designated a special economic zone by China in early 1988. At that time the human population of the island consisted mainly of the original inhabitants, the Li and Miao minority groups. Today, as a result of being a special economic zone, Hainan has a population of more than 7 million, the majority of them being Han Chinese coming from Indonesia, Malaysia, and mainland China. The Li and Miao are the people profiting the least from the economic developments; they inhabit remote mountainous areas and subsist through agriculture and hunting.

The northern and western coastal plains of the island are intensively exploited: rice fields, rubber plantations, eucalypt species, *Casuarina* sp., and sisal plantations dominate the landscape. On the northeastern plain there is much industrial development on the outskirts of Haikou. On the eastern plains there is agriculture and rapidly developing Chinese tourism.

Central Hainan comprises a series of mountains, the Limu Ling Shan and Wuzhi Shan, the highest peak being Wuzhi Shan (Five Finger Mountain), reaching 1890 m. Many mountains are still covered with primary rainforest, but there is considerable cultivation and deforestation in the valleys and on many slopes.

Hainan has 13 Nature Reserves (Li and Zhao, 1989), most of them set up to protect large mammals like the Hainan deer (*Cervus eldi hainana*) and Hainan black headed gibbon (*Hylobates concolor hainanus*), or to protect whole ecosystems. The level of protection maintained in these reserves is difficult to determine. We have only been on the border of Jianfengling Nature Reserve in the southwest. Our interpreter told us it was prohibited to enter the reserve, and that it was impossible to visit it. However, Pack-Blumenau (1997) visited Bawangling Nature Reserve (close to Jianfengling, and also created to protect the mountain rainforest ecosystem) recently, and found that local people still poach in the reserve. Li people are forced to hunt for subsistence, and little is done to prevent this.

One of the first accounts on chelonians of Hainan was that of Siebenrock (1906). At that time only *Clemmys schmackeri* (= *Mauremys mutica*) was known to occur there. Based on material from Hainan provided by Steindachner, Siebenrock extended the distribution of *Ocadia sinensis* and *Pelodiscus sinensis* to Hainan. In addition, he described a new softshell: *Trionyx steindachneri* (now *Palea steindachneri*). Smith (1923a) published an elaborate account of his travel to Hainan in 1923, but he had little success collecting chelonians — he was only able to obtain one *O. sinensis* from the market in Haikou. Schmidt (1927) examined material collected by Pope during an 8-month stay on Hainan in 1922–23. Based on Pope's material, Schmidt extended the ranges for *Platysternon megacephalum*, *Sacalia bealei*, *Cuora trifasciata*, *Pyxidea mouhotii*, and *Pelochelys cantorii* to Hainan. Pope (1935) reported nine turtle species on Hainan Island. Li (1958) described *Clemmys bealeii quadriocellata* and *Cyclemys flavomarginatus hainanensis* from southeastern Hainan. Hu et al. (1975) elevated the latter to species level and included it in the genus *Cuora* as *C. hainanensis*. However, most authors now consider it synonymous with *C. galbinifrons* (see Iverson and McCord, 1992a).

Both Iverson (1992) and Zhao and Adler (1993) reported 15 non-marine species of turtle to occur on Hainan: Iverson included *Chinemys nigricans* as possibly occurring on Hainan, whereas Zhao and Adler reported *Geoemyda spengleri* to occur there. Recently, two new species of