ARTICLES

Integration of Flipper Tagging and Photo-identification Reveals a 40-year Record for an Adult Female Loggerhead Sea Turtle

Kostas Papafitsoros[1,2,#], Dimitris Margaritoulis[2]

[1]*Queen Mary University of London, UK (#k.papafitsoros@qmul.ac.uk)*
[2]*ARCHELON, the Sea Turtle Protection Society of Greece, Athens, Greece*

Multi-decadal records of individual sea turtles can provide valuable insights into several aspects of their biology and ecology, such as maximum attainable lifespan and reproductive longevity (Limpus et al. 2022; Margaritoulis et al. 2023), senescence (Glen et al. 2025), long-term foraging site fidelity, as well as age at sexual maturity (Shimada et al. 2020) when records span from hatchling to adulthood. Furthermore, communicating such long-term individual histories to the public can provide a powerful tool for raising awareness and promoting environmental education (Papafitsoros et al. 2025b).

Traditionally, obtaining records of the same sea turtle over time is achieved through flipper tagging within capture-mark-recapture projects (Margaritoulis et al. 2020). However non negligible tag loss probabilities, make obtaining multi-decadal recordings increasingly difficult, with Passive Integrated Transponders (PIT tags) providing a more reliable but not infallible alternative (Pfaller et al. 2019; Omeyer et al. 2019). Photo-identification (photo-ID) (Papafitsoros et al. 2025a) and genetic tagging techniques (Shamblin et al. 2011), have all emerged as essentially permanent methods for identifying individual turtles, each one accompanied by their own advantages and limitations. However, both methods have been introduced relatively recently compared with the timescales characterising sea turtle life histories, with photo-ID records extending back less than 30 years (Schofield et al. 2008) and less than 20 years for genetic tagging (Shamblin et al. 2011). Thus, neither method alone can currently provide individual histories spanning more than three decades.

Here, we present the case of an adult female loggerhead sea turtle (*Caretta caretta*), "T2737", from Zakynthos Island, Greece, with a documented history spanning at least 40 years: First flipper-tagged while nesting in 1986, T2737 was last observed on a Zakynthos beach in 2007. However, photographic records during the internesting periods, and photo-ID allowed her individual history to be linked across time, despite having lost all her external flipper tags, extending her documented record to 2026.

A long-term tagging programme of nesting females have been running on Zakynthos Island Greece, since 1982, led by ARCHELON, the Sea Turtle Protection Society of Greece, since its foundation in 1984 (Margaritoulis et al. 2020; Margaritoulis et al. 2022). Initially, three types of external tags were used: Monel No. 49 and 681 (National Band and Tag Company, USA) and plastic "Jumbo tags" (Dalton Ltd., UK). Since 2012, PIT tags have also been applied (Trovan Ltd; 11.5 × 2.1 mm). No. 49 Monel tags were discontinued in 1990 due to their large size, and plastic tags were discontinued in 2015 because of potential fishing gear entanglement. Nesting on Zakynthos Island, occurs at six distinct nesting beaches (Sekania, Daphni, Gerakas, Kalamaki, Laganas, Marathonissi). However, tagging has been primarily concentrated at Sekania beach, which hosts the highest nest density (Margaritoulis et al. 2022), and is extended to the remaining five beaches only when logistics and personnel availability allowed. Given that nesting beaches can be used interchangeably by individual females (Katselidis et al. 2004), it is therefore

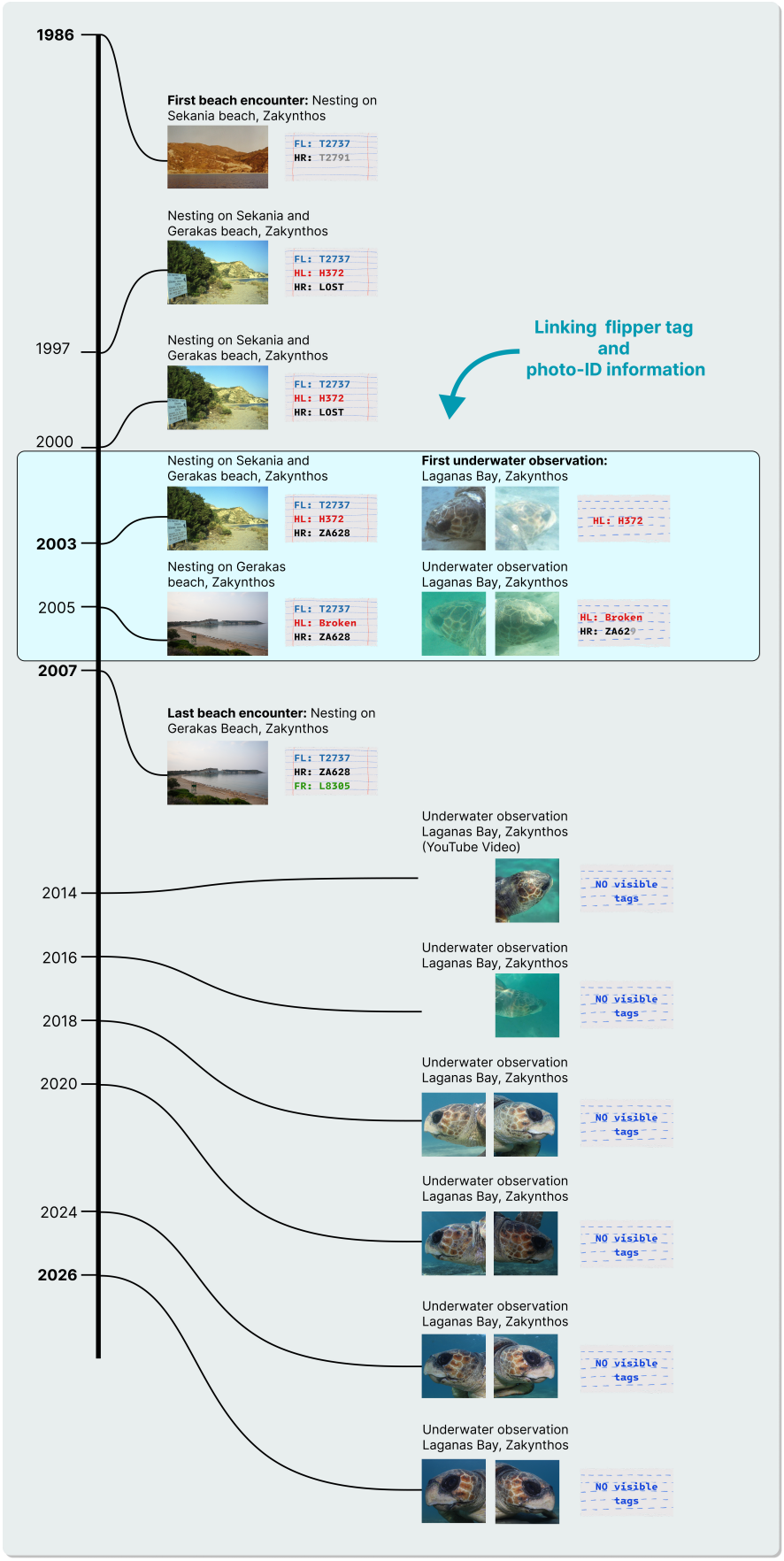

Figure 1. Complete timeline of nesting and underwater observations of the female loggerhead T2737. Photographs by ARCHELON (Sekania beach), Gail Schofield (2003-2005, 2016), KP (2018-2026, Gerakas beach).

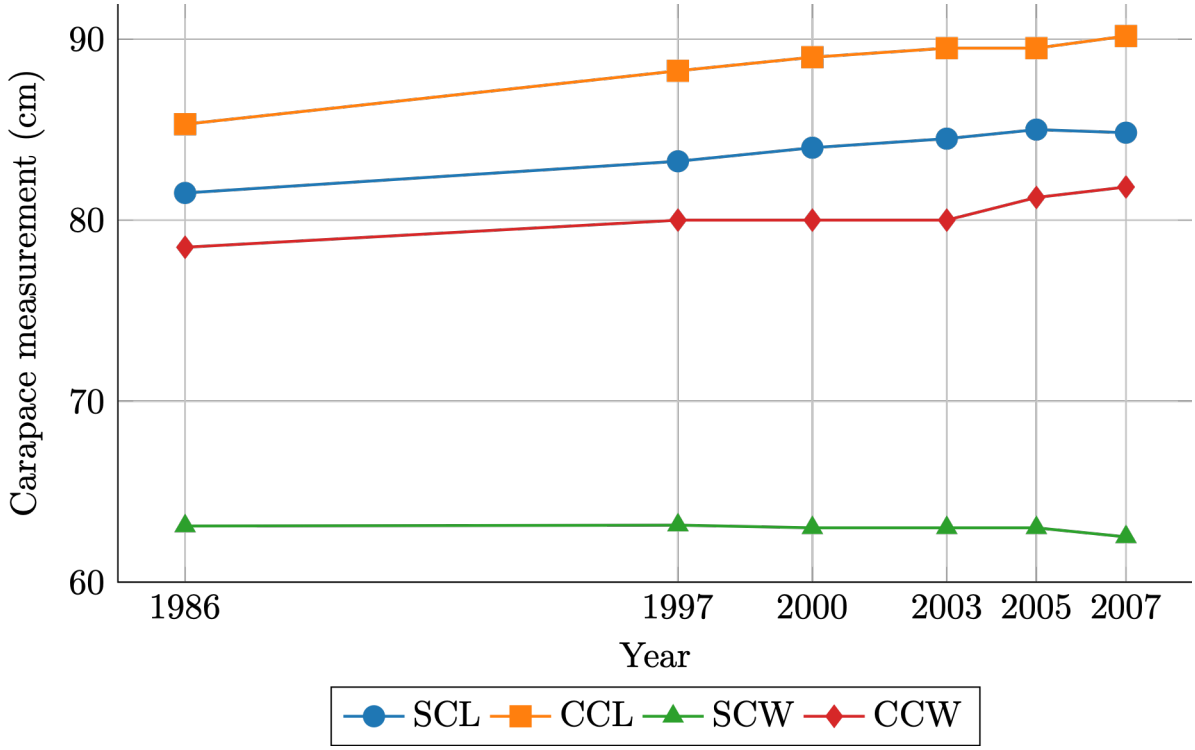

Figure 2. All the recorded carapace measurements for T2737 over the years (1986-2007). When multiple observations were available within the same year, the corresponding measurements were averaged.

possible for a previously tagged female to nest on Zakynthos in a given year without being recorded.

A photo-ID project also exists on Zakynthos since 2002, initiated by Gail Schofield and gradually undertaken by the first author (Schofield et al. 2008; Schofield et al. 2020; Papafitsoros et al. 2021). The project mainly relies on underwater photographs taken at the shallows of Laganas Bay (May-October) which is the main internesting area for the breeding females (Schofield et al. 2006; Schofield et al. 2007; Zbinden et al. 2007). During underwater encounters, photographs of the turtle's full body and head are taken, with individual identification primarily based on comparisons of facial scale patterns. The master photo-database was constructed entirely through visual inspection (manual matching), aided by the classification of facial scale patterns into distinct groups (Schofield et al. 2008; Papafitsoros et al. 2025a). When present, plastic Jumbo tags are also photographed whenever possible. Their code numbers are typically clearly visible during underwater observations, in contrast to those on Monel tags. Underwater survey effort has varied over the years, and it is estimated that about 50% of breeding females use the photo-ID survey area during their internesting period (Schofield et al. 2007). Consequently, not all females breeding in a given year are encountered and photographed, analogous to beach-based tagging.

Female loggerhead T2737 was first recorded nesting on Sekania beach in July 1986 and was subsequently observed nesting on Sekania and Gerakas beaches in 1997 and 2000. She was recorded again on both beaches in 2003, when she was still bearing her original Monel tag T2737, as well as the plastic Jumbo tag H372, which had been applied in 1997. A new plastic tag, ZA628, was also applied in 2003. During the same year, a female loggerhead was photographed, whose accompanying metadata included the tag number H372. We note that a photograph showing the tag itself is not available; however, the tag number is documented in the metadata accompanying the photograph, which was made available to

the first author in the context of the study in



Figure 3. Full-body photographs of T2737 showing the carapace injuries sustained between 2020 and 2024 and their subsequent healing.

Schofield et al. (2020). T2737 was subsequently observed nesting on Gerakas Beach in 2005, still bearing the tags T2737 and ZA628. However, the tag H372, which had been applied to the left hind flipper, was recorded as broken. In the same year, the same female photographed two years earlier was observed again, as confirmed by photo-ID. The accompanying metadata included a broken tag on the left hind flipper, as well as the tag ZA629 (again no photograph of the tag is available), rather than ZA628. Nevertheless, the photo-ID match between the 2003 and 2005 photographs, the record of a broken hind left flipper tag, and the potential for confusion between the digits "8" and "9" on weathered tags suggests that these underwater observations correspond indeed to T2737 and that "ZA629" represents a tag-reading error. The turtle was last recorded nesting on Gerakas beach, in 2007, when she bore three tags, T2737, ZA628 and a newly applied L8305. We note that no PIT tags were ever applied to T2737. A series of underwater observations followed after 2014; we note that between 2007 and 2014

the underwater survey effort was minimal. Initially, the turtle appeared in a YouTube video uploaded in 2014 (https://youtu.be/f-YY4tvJIDQ?si=W6WeVt8nHXONa__Z). She was subsequently photographed underwater in 2016 and in 2018, 2020, 2024, and 2026. No external flipper tags were visible during any of these underwater encounters, with individual identity instead established through photo-ID. The complete timeline of nesting and underwater observations is summarised in Fig. 1.

The curved carapace length (CCL), visually estimated from the underwater observations between 2018 and 2026, was approximately 90-95 cm. This is consistent with her last recorded CCL measurement of 90.5 cm on Gerakas beach in 2007. All available carapace measurements of T2737 over the years are shown in Fig. 2.

Notably, in early June 2024, T2737 was observed with multiple parallel cuts on her carapace, presumably caused by a boat propeller, see Fig. 3. Her previous observation had been in July 2020, when these injuries were not present. Based on their appearance in 2024, the injuries were assessed to have occurred recently, and thus likely closer to the 2024 than the 2020 observation.

Directly observed histories of adult sea turtles spanning 40 years or more are extremely rare. To our knowledge, one of the few documented examples in the wild is the flatback turtle “X23103” and the Loggerhead turtle “X-8400”, both from Mon Repos, Woongarra Coast, Australia, with a reproductive history spanning 47 and 44 years respectively (Limpus et al. 2022). At the time of writing, the longest reported reproductive history for a Mediterranean loggerhead spans 37 years, also from an individual from Zakynthos (Margaritoulis et al. 2023). Although T2737 has not been observed nesting since 2007, several lines of evidence strongly suggest that she may have remained reproductively active in subsequent years, potentially extending her reproductive history beyond currently the above record of 37 years for this population. First, her in-water behaviour between 2018 and 2026, including spending prolonged periods resting on the seafloor, is consistent with the typical interesting behaviour of female loggerheads at this site (Schofield et al. 2006; Fossette et al. 2012). Second, T2737 exhibited characteristic scars on the neck region (e.g. see the 2024 photograph on the left in Fig. 3), consistent with mating injuries caused by bites from male loggerheads during courtship and copulation. Third, her most recent nesting records were from Gerakas beach, which may partly explain the absence of subsequent nesting records, as ARCHELON has not conducted systematic night-time tagging surveys on this beach since 2010. Finally, with the exception of 2022, T2737 has been observed in the water every two years since 2014, which is consistent with the typical remigration interval of breeding females in this population. However, we cannot entirely rule out the possibility that T2737 was present in Laganas Bay in a given year without breeding.

Furthermore, to our knowledge, no comparable case has been reported in the literature in which photo-ID and flipper-tagging records have been combined to reconstruct an individual history spanning such a long period. On Zakynthos, photo-ID has been used for a range of purposes, including the study of aggressive interactions (Schofield et al. 2022), the quantification of ecotourism pressure and documentation of injuries (Papafitsoros et al. 2021), and the estimation of sex-specific survival rates (Schofield et al. 2020) to name a few. The present study further highlights the potential of photo-ID to reconstruct individual life histories interrupted by tag loss, thereby increasing the completeness and robustness of long-term capture-mark-recapture datasets for subsequent population-level analyses.

Finally, although the precise timing and location of T2737’s carapace injury cannot be determined, her case further highlights the ongoing risks associated with boating

activity in Laganas Bay. Despite the legally established speed limit of 6 knots, compliance and enforcement remain limited (Papafitsoros et al. 2021; ARCHELON 2025). Individual cases such as that of T2737, particularly when accompanied by a long and well-documented life history, can provide powerful examples for raising public awareness and increase pressure on the competent authorities to improve protection and enforcement. Indeed, previous fatal incidents involving individually known turtles with exceptional life histories have generated substantial public attention (e.g., https://www.imerazante.gr/2025/08/04/370601).

Overall, the remarkable history of T2737 demonstrates the value of integrating complementary identification methods to reconstruct individual life histories over timescales comparable to the longevity of sea turtles themselves. Such long-term records can provide valuable insights into sea turtle biology and population dynamics, while the stories of individually known animals can also serve as powerful tools for public engagement and conservation.

Acknowledgements

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Literature cited

ARCHELON, the Sea Turtle Protection Society of Greece (2025) Annual activity report Zakynthos Project. https://cms.archelon.saasify360apps.com/uploads/ZAK_SHORT_REPORT_2025_ENG_6beeec81e2.pdf

Fossette S, Schofield G, Lilley MKS, Gleiss AC, Hays GC (2012) Acceleration data reveal the energy management strategy of a marine ectotherm during reproduction. Functional Ecology 26(2): 324–333

Glen CG, Ponciano JM, Gillooly JF, Torres-Sánchez M, Mustin W, Bolten AB, Bjorndal KA (2025) Aging dynamics in captive sea turtles reflect conserved life-history patterns across the testudine phylogeny. Communications Biology 8(1): 1297

Katselidis K, Schofield G, Margaritoulis D (2004) Loggerhead nest site fixity in the rookery of Laganas Bay, Zakynthos, Greece. In: Coyne MS, Clark RD (Comps) Proceedings of the Twenty-First Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-528, pp 78–80

Limpus CJ, Anderson D, Debets K, Ferguson J, Fien L, Limpus DJ, McLaren M, Murnane N (2022) Queensland Turtle Conservation Project: Data Report for Marine Turtle Breeding on the Woongarra Coast, 2021–2022 Breeding Season. Brisbane: Department of Environment and Science, Queensland Government. https://gpcl.com.au/wp-content/uploads/2022/08/1846152-v1-ENV_Report_OS21303767_Data_report_for_Marine_Turtle_breeding_on_the_Woonga.pdf

Margaritoulis D, Dean CJ, Lourenço G, Rees AF, Riggall TE (2020) Reproductive longevity of loggerhead sea turtles nesting in Greece. Chelonian Conservation and Biology 19(1): 133-136

Margaritoulis D, Lourenço G, Riggall TE, Rees AF (2022) Thirty-eight years of loggerhead turtle nesting in Laganas Bay, Zakynthos, Greece: A Review. Chelonian Conservation and Biology 21(2): 143-157

Margaritoulis D, Dean CJ, Lourenço G, Michailidis T, Papafitsoros K, Rees AF, Riggall TE (2023) *Caretta caretta* (Loggerhead Sea Turtle). Reproductive longevity. Herpetological Review 54(4): 639-640

Omeyer LCM, Casale P, Fuller WJ, Godley BJ, Holmes KE, Snape RTE, Broderick AC (2019) The importance of passive integrated transponder (PIT) tags for measuring life-history traits of sea turtles. Biological Conservation 240: 108248

Papafitsoros K, Panagopoulou A, Schofield G (2021) Social media reveals consistently disproportionate tourism pressure on a threatened marine vertebrate. Animal Conservation 24(4): 568-579

Papafitsoros K, Hoh D, Köhnk S, Montagna M, Witzmann J (2025a) Sea turtle photo identification: A practical guide. Research and Management Techniques for the Conservation

of Sea Turtles, IUCN/SSC Marine Turtle Specialist Group (to appear). https://www.researchgate.net/publication/388909753_Sea_Turtle_Photo_Identification_A_Practical_Guide

Papafitsoros K, Tarrit V, Adam L, Stamatiou A, Samlidou G, Panagopoulou A (2025b) "Show us the turtle, learn the story", an interactive platform for personalised engagement with sea turtle conservation in a Mediterranean tourist hotspot. In: Whittock PA, Hyatt E, Belskis LC (Comps) Proceedings of the Forty-Second Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-785, p 76

Pfaller JB, Williams KL, Frick MG, Shamblin BM, Nairn CJ, Girondot M (2019) Genetic determination of tag loss dynamics in nesting loggerhead turtles: a new chapter in "the tag loss problem". Marine Biology 166(7): 97

Schofield G, Katselidis KA, Dimopoulos P, Pantis JD, Hays GC (2006) Behaviouranalysis of the loggerhead sea turtle *Caretta caretta* from direct in-water observation. Endangered Species Research 2: 71-79

Schofield G, Bishop CM, MacLean G, Brown P, Baker M, Katselidis KA, Dimopoulos P, Pantis JD, Hays GC (2007) Novel GPS tracking of sea turtles as a tool for conservation management. Journal of Experimental Marine Biology and Ecology 347(1): 58-68

Schofield G, Katselidis KA, Dimopoulos P, Pantis JD (2008) Investigating the viability of photo-identification as an objective tool to study endangered sea turtle populations. Journal of Experimental Marine Biology and Ecology 360(2): 103-108

Schofield G, Klaassen M, Papafitsoros K, Lilley M, Katselidis KA, Hays GC (2020) Long-term photo-id and satellite tracking reveal sex-biased survival linked to movements in an endangered species. Ecology 101(7): e03027

Schofield G, Papafitsoros K, Chapman C, Shah A, Westover L, Dickson LCD, Katselidis KA (2022) More aggressive sea turtles win fights over foraging resources independent of body size and years of presence. Animal Behaviour 190: 209-219

Shamblin BM, Dodd MG, Williams KL, Frick MG, Bell R, Nairn CJ (2011) Loggerhead turtle eggshells as a source of maternal nuclear genomic DNA for population genetic studies. Molecular Ecology Resources 11(1): 110-115

Shimada T, Limpus CJ, Hamann M, Bell I, Esteban N, Groom R, Hays GC (2020) Fidelity to foraging sites after long migrations. Journal of Animal Ecology 89(4): 1008-1016

Zbinden JA, Aebischer A, Margaritoulis D, Arlettaz R (2007) Insights into the management of sea turtle internesting area through satellite telemetry. Biological Conservation 137(1): 157-162