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First Documented Macroscopic Regression of Fibropapillomatosis in a Recaptured Green Sea Turtle (*Chelonia mydas*): A Case Study from Curaçao

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ABSTRACT—Fibropapillomatosis (FP) is a neoplastic disease affecting sea turtles worldwide and is particularly prevalent in green sea turtles (*Chelonia mydas*). Although spontaneous regression of FP has been documented in some populations, observations remain uncommon, and the mechanisms underlying regression are poorly understood. This study documents the first known case of macroscopic FP regression in a free-ranging green sea turtle from Curaçao. Turtle ID 2349 was first tagged in June, 2023 and recaptured after 904 days (2.48 years). The turtle was assessed using morphometric measurements, photographic identification, tumor counts, tumor score, and fibropapillomatosis index (FPI). Identity was confirmed by the retention of an Inconel flipper tag and by comparison of facial scale patterns. The turtle exhibited positive somatic growth during the recapture period, with the straight carapace length increasing from 45.7 cm to 54.6 cm. Tumor burden was reduced from 7 to 2 tumors with complete macroscopic regression at five sites (both periocular regions, the left anterior flipper, the plastron, and one inguinal mass). The two remaining tumors showed a marked reduction in size. The turtle was still classified with a tumor score of FP3, but the FPI decreased from 102.2 to 40.0, indicating a substantial reduction in overall disease burden. Our results show that progression of FP is not necessarily irreversible, and that significant regression can occur in free-ranging green sea turtles without clinical intervention. This case illustrates the need for long-term monitoring and recapture programs to enhance knowledge of FP dynamics, disease recovery, and conservation outcomes in Caribbean Sea turtle populations.

Fibropapillomatosis (FP) is a neoplastic disease characterized by epithelial lesions found globally in sea turtle populations, with green sea turtles (*Chelonia mydas* (Linnaeus, 1758); Cheloniidae) being the most vulnerable (Jones et al. 2016; da Cruz et al. 2024). Tumors can vary in size, shape, and texture (Jones et al. 2016). These tumors often develop on soft tissue, including flippers, neck, and periocular regions, and less commonly on keratinized surfaces such as the carapace and plastron, impairing mobility, vision, and feeling. Visceral tumors also occur in organs such as the lungs, kidney and heart (Jacobson et al. 1989; Work et al. 2004; Jones et al. 2016; Manes et al. 2022). Histological diagnoses specific to green sea turtles classify external and internal tumors as fibropapillomas, myxofibromas, fibromas, papillomas, or low-grade fibrosarcomas, whereas molecular diagnostic methods analyze viral association (Work et al. 2004; Duarte et

al. 2012; Tripepi et al. 2026). FP has strongly been associated with Chelonid alphaherpesvirus 5 (ChHV5). Viral DNA has been detected consistently in FP tumors worldwide, suggesting an important role in disease pathogenesis (Monezi et al. 2016; Lawrance et al. 2018; Work et al. 2020; James et al. 2021; da Cruz et al. 2024). However, ChHV5 alone is not believed to fully explain disease emergence, severity, or geographic distribution. The virus has been detected in healthy turtles and turtles that are asymptomatic for FP, indicating that it could stay dormant and could occur at a latent state, involving other biological or environmental factors as a trigger for the disease (Duarte et al. 2012; Manes et al. 2022; Vanstreels et al. 2023). Though the outbreak of FP is unlikely due to viral mutation of Chelonid alphaherpesvirus 5 (ChHV5) (Herbst et al. 2004). Herbst et al. (2004) showed relatively low genetic variation in ChHV5 isolates from geographically distant sea turtle

populations, suggesting widespread disease emergence was unlikely to be due to the emergence of a novel hypervirulent viral strain. Instead, the authors suggested that environmental cofactors and host-related susceptibility likely play a substantial role in disease expression and progression.

Collectively, these studies support the understanding of fibropapillomatosis as a multifactorial disease influenced by compromised ecosystems (Reséndiz et al. 2021), host susceptibility (Manes et al. 2023), and exposure to pollutants (Valenzuela et al. 2026). Presence of heavy metals and toxins produced by harmful algal blooms support the notion that FP may arise from harmful contamination and toxicological exposure that compromises physiological health of sea turtles (Keller et al. 2004; Perrault et al. 2017; Reséndiz et al. 2021). These environmental stressors are of particular concern in nearshore developmental habitats where juvenile green sea turtles forage and reside for extended periods, potentially increasing long-term exposure to contaminants and disease-promoting conditions. Juvenile, medium-sized turtles that rely on nearshore foraging habitats are the most susceptible (Work and Balazs 1999; Hargrove et al. 2016). FP has been documented throughout the Caribbean, but it was not until 2025 that the first scientific report of FP in Curaçao was published, tracking habitat use and documenting tumor scores of infected sea turtles (Tripepi et al. 2025). The study documented a range of FP presentations, including mild and severe external tumor burdens distributed across the eyes, flippers, axillary regions, and plastron and tumor severity was quantified using tumor score following Work and Balazs (1999).

Rehabilitation and conservation efforts are focused on surgical removal of obstructive tumors, wound management, and dietary and hydration support (Jones et al. 2016; Monezi et al. 2016). Surgical intervention often involves laser surgery, electrocautery, cryotherapy, or conventional excision techniques to remove tumors that impair vision, feeding, swimming, or buoyancy control. Post-operative treatment commonly includes antibiotic therapy, pain management, fluid support, nutritional rehabilitation, and long-term monitoring to assess wound healing and tumor recurrence (Page-Karjian et al. 2014; Diggins et al. 2022). Recurrence of FP following surgical removal has been frequently docu-

mented, with some rehabilitated turtles developing new tumors within months after treatment, emphasizing the chronic and multifactorial nature of the disease and complicating rehabilitation efforts made to restore mobility, vision, and overall health of treated sea turtles (Work et al. 2004; Page-Karjian et al. 2014).

Although tumor recurrence complicates rehabilitation efforts, spontaneous regression of FP lesions has been documented in free-ranging and rehabilitated green sea turtles, although such observations remain relatively uncommon and poorly understood (Hirama and Ehrhart 2007; Guimarães et al. 2013; Patrício et al. 2016; De Montgolfier et al. 2025). Evidence of partial and complete tumor regression has been reported from geographically distinct regions including Florida, Brazil, and the Caribbean, suggesting that regression may occur under a variety of ecological conditions (Guimarães et al. 2013; Pérez et al. 2024; De Montgolfier et al. 2025). Guimarães et al. (2013) documented regression of fibropapillomas in juvenile green turtles captured in southeastern Brazil, while De Montgolfier et al. (2025) reported similar observations in juvenile green turtles from Martinique. Furthermore, regional assessments within the Caribbean have identified variability in disease severity and tumor burden among affected individuals, supporting the possibility that FP progression may not always follow a linear trajectory (Patrício et al. 2016; Cazabon-Mannette and Phillips 2017).

These findings suggest that some turtles may be able to achieve partial immune-mediated recovery. Some proposed mechanisms for regression include improved immune function, reduced environmental stressors, changes in habitat quality, and decreased viral activity. However, the biological and environmental drivers of tumor regression remain poorly understood.

In this study, we report a case of regression seen in Curaçao following the recapture of sea turtle ID 2349 part of a study published by Tripepi et al. (2025). Sea Turtle ID 2349 was previously captured in 2023, and tumors were observed on the eyes, hindlimb, forelimb, and plastron. This case study documents the first known longitudinal observation of macroscopic FP regression in a free-ranging green sea turtle from Curaçao and provides evidence of substantial reductions in both tumor abundance and disease severity over a 2.48-year interval.

MATERIALS AND METHODS

A green sea turtle (*Chelonia mydas*, ID 2349) was hand-captured by divers in June, 2023 at the dive site known as “Turtle Island” in Caracasbaai, Curaçao (12°04'37"N, 68°51'58"W) as part of a study investigating habitat use and the occurrence of FP in green sea turtles in Curaçao conducted by Tripepi et al. (2025). In December, 2025, the same individual was recaptured at the same location to assess somatic growth and FP tumor development. Following recapture, the turtle was transported to shore using a floating device constructed from PVC tubes and netting.

The turtle's identity was verified by inspecting the existing Inconel style 681 metal tags (National Band and Tag Company, Newport, Kentucky, U. S. A.) on the left front flipper, provided through the WIDECAST Marine Turtle Tagging Centre (MTTC), Barbados. Additionally, the recapture was confirmed through photographic identification by facial recognition of the lateral head profiles. The unique arrangement of the temporal, post-ocular, sub-temporal, tympanic, and central facial scales was compared against the 2023 facial pictures. During the recapture, the turtle was tagged with a passive integrated transponder (PIT; tag number 900226002086822), enabling reliable identification during future recapture events. Standard morphometric parameters were recorded to evaluate somatic growth over the 2.48-year interval period following the standardized field data collection methodologies established by Sea Turtle Conservation Curaçao (STCC) based on Bolten (1999). Straight Carapace Length (SCL) and Straight Carapace Width (SCW) were measured using a Hogetex vernier caliper (± 0.1 cm). SCL was measured from the pre-axial nuchal scute to the terminal posterior tip of the longest post-central scute. SCW was measured at the widest point of the carapace. Curved Carapace Length (CCL) and Curved Carapace Width (CCW) were measured along the identical anatomical axes using a flexible fiberglass measuring tape (± 0.1 cm). Total tail length was measured using a flexible fiberglass measuring tape (± 0.1 cm) from the midline of the posterior margin of the plastron to the end of the tail (Bolten 1999).

The turtle was visually inspected to assess FP severity, and all present tumors were documented. Tumors were counted, measured along their longest axis using a flexible fiberglass measuring tape (± 0.1 cm),

and assigned to one of four size categories: (A) number of tumors <1 cm, (B) number of tumors 1 to 4 cm, (C) number of tumors >4 to 10 cm, and (D) number of tumors >10 cm (Work and Balazs 1999). Photographs of each tumor were taken to allow for direct comparison against the baseline photographs from the initial 2023 capture. After completion of the physical assessment, the turtle was immediately released at the capture site.

To quantify somatic growth over the inter-capture period, absolute growth was calculated as the total difference between carapace dimensions and tail length. Annualized growth rates (cm/year) were calculated exclusively for the SCL and the CCL, as carapace length serves as the primary standard for somatic growth. This was calculated by converting the inter-capture interval into decimal years and then dividing the absolute increase in carapace length by the decimal-year interval (Bjorndal et al. 2000, 2017, 2019). Carapace width (CCW, SCW) and tail length measurements were excluded from growth rate annualization.

Data analysis was conducted to quantify disease severity and document macroscopic regression. Based on the abundance of tumors within each size class, the individual was assigned an overall tumor score ranging from 0 to 3. This tumor score characterizes the clinical progression of FP, classifying the individual as unaffected (Score 0), mildly afflicted (Score 1), moderately afflicted (Score 2), or severely afflicted (Score 3) (Work and Balazs, 1999).

To further quantify FP severity, we calculated the fibropapillomatosis index (FPI) based on the formula of Rossi et al. (2016): $FPI = 0.1 \times NA + 1 \times NB + 20 \times NC + 40 \times ND$.

The Fibropapillomatosis Score Southwest Atlantic classification was used to determine the disease burden as no FP (FPI = 0), mild (FPI <40), moderate ($40 \leq FPI < 120$), or severe (FPI ≥ 120) (Rossi et al. 2016). Macroscopic tumor regression was confirmed by comparing the 2025 tumor counts, measurements, tumor score, FPI scores, and photographs directly against the 2023 baseline data.

RESULTS

On December 17, 2025, green sea turtle ID 2349 was recaptured in Caracasbaai, Curaçao. The identity was confirmed through the presence of an original Inconel style 681 tag with number WE11160 affixed to the left front flipper (Fig. 1, panels A and C). The tag on

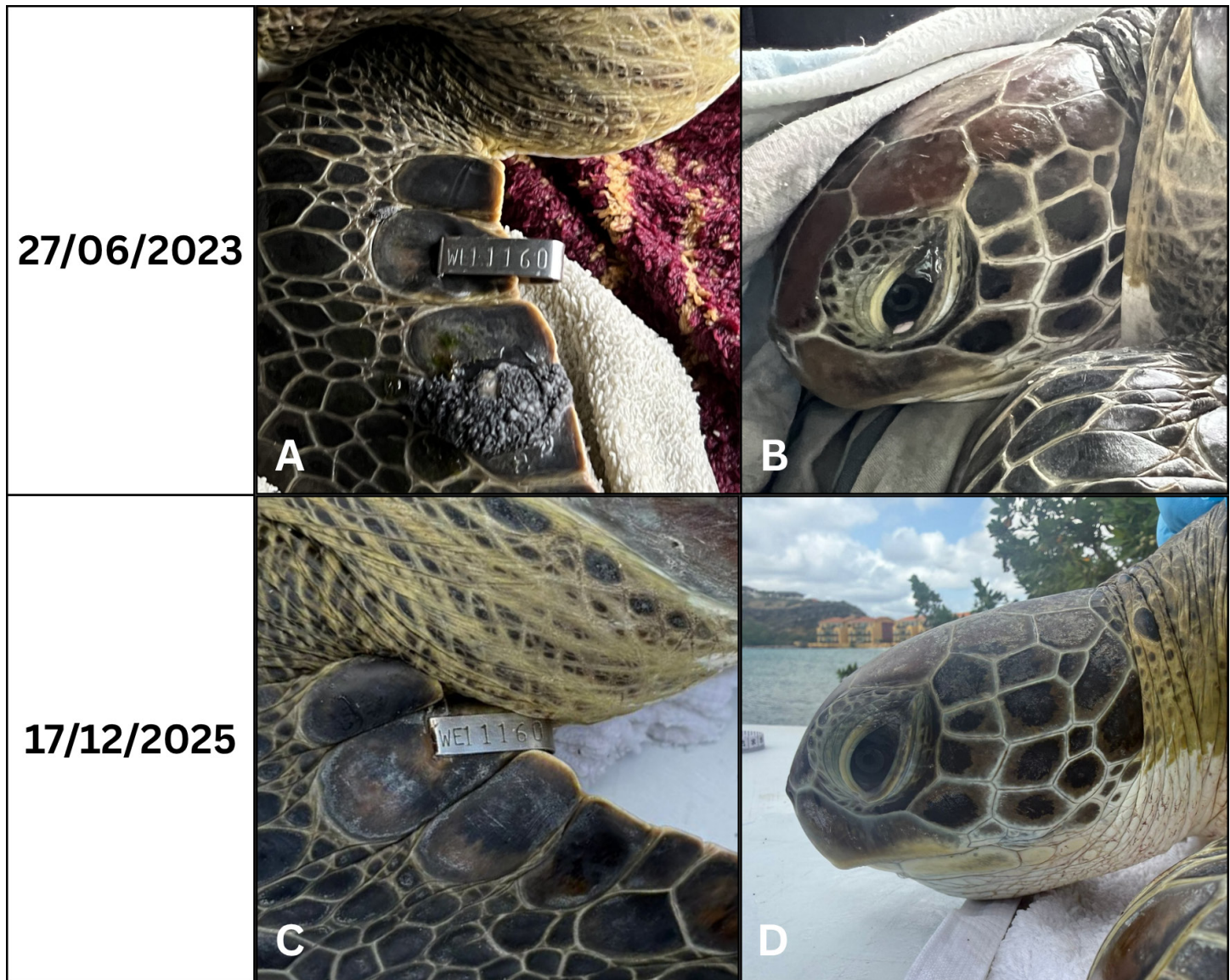


FIGURE 1. Identity confirmation of green sea turtle (*Chelonia mydas*, ID 2349) between initial capture (2023) and recapture (2025). Verification is demonstrated through retention of the original Inconel flipper tag (WE11160) on the left anterior flipper (A, C) and matching facial scale arrangements on the left lateral head profile (B, D).

the right side, WE11153, applied in 2023 was lost since the deployment. Additionally, recapture was confirmed through facial recognition. Comparison of the temporal, post-ocular, sub-temporal, tympanic, and central facial scale arrangements showed a perfect match with the pictures of 2023 (Fig. 1, panels B and D).

The interval between the initial capture and recapture spanned 2.48 years (904 days). Over this period, the green sea turtle ID 2349 showed positive somatic growth across all recorded anatomical metrics. Straight Carapace length (SCL) increased from 45.7 cm to 54.6 cm, representing an absolute growth of 8.9 cm

and an annualized growth rate of 3.6 cm/yr. Straight carapace width (SCW) grew from 34.5 to 41.1 cm (an absolute growth of 6.6 cm). Curved carapace length (CCL) showed an increase from 50.0 cm to 59.2 cm, representing an absolute growth of 9.2 cm and an annualized growth rate of 3.72 cm/yr. Curved carapace width (CCW) grew from 42.0 cm to 50.4 cm (an absolute growth of 8.4 cm). Additionally, total tail length increased by 2.5 cm growing from 5.0 cm in 2023 to 7.5 cm in 2025 (Table 1).

Visual inspection and photographic comparison confirmed a clear, macroscopic regression in the pres-

TABLE 1. Somatic growth and morphometric parameters of a green sea turtle ID 2349 over a 904-day (2.48 year) capture interval (2023–2025). Annualized growth rates were calculated exclusively for the SCL and the CCL, as carapace length serves as the primary standard for somatic growth. Carapace width (CCW, SCW) and tail length measurements were excluded from growth rate annualization.

Morphometric Parameter	Initial capture (2023)	Recapture (2025)	Absolute Growth in 904 days	Annualized Growth Rate
Straight Carapace Length (SCL)	45.7 cm	54.6 cm	+8.9 cm	3.60 cm/yr
Straight Carapace Width (SCW)	34.5 cm	41.1 cm	+6.6 cm	—
Curved Carapace Length (CCL)	50.0 cm	59.2 cm	+9.2 cm	3.72 cm/yr
Curved Carapace Width (CCW)	42.0 cm	50.4 cm	+8.4 cm	—
Total Tail Length	5.0 cm	7.5 cm	+2.5 cm	—

ence of FP tumors between initial 2023 capture and the 2025 recapture. In 2023, the individual showed a total of 7 tumors distributed across all four size categories: 2 category A, 2 category B, 1 category C, and 2 category D. The data of 2023 resulted in an initial tumor score of FP3 (severely afflicted) and a fibropapillomatosis index (FPI) of 102.2 classifying the disease burden as moderate.

Upon recapture in 2025, a reduction in both tumor abundance and size was documented, with the total count of tumors reducing to 2. Detailed photographic comparison revealed that all tumors initially classified within category A, B, and C had completely disappeared on a macroscopic level. The tumors initially categorized as category D (tumor located in the right axillary region and the left inguinal region (superior mass)) were reduced to category C. Although the remaining two category C tumors classify this turtle as a clinical tumor score of FP3, the FPI score declined from 102.2 to 40.0, a 61 percent reduction that moved the individual from mid-moderate to the lower boundary of the moderate category. Figure 2 shows the anatomical comparison of tumor presence from 2023 (Fig. 2 panels A, C, E, G, I, K, M, and O) to 2025 (Fig. 2, panels B, D, F, H, J, L, N, and P). Complete macroscopic regression was seen across multiple anatomical zones. Specifically, tumors completely resolved in the bilateral periocular regions (Fig. 2: A vs. B; E vs. F), the posterior margin of the left anterior flipper (Fig. 2, M vs. N), the plastron (Fig. 2, G vs. H; O vs. P), and the inferior mass located within the left inguinal region (Fig. 2, G vs. H; K vs. L). Partial regression was seen for the two largest masses, located in the right axillary region (Fig. 2, I vs. J; G vs. H) and the superior mass in the left inguinal region (Fig. 2, C vs.

D) exhibited marked morphological degradation. Table 2 shows a summary of the anatomical distribution and macroscopic regression status of the FP lesions for turtle ID 2349.

DISCUSSION

In this study, we describe the first record of macroscopic fibropapillomatosis (FP) regression in a free-ranging green sea turtle from Curaçao. Turtle ID 2349 showed large decreases in both tumor abundance and tumor size during the 2.48-year recapture interval. These results are consistent with previous findings that FP progression is not necessarily irreversible and that spontaneous regression is possible in natural settings (Hirama and Ehrhart 2007; Guimarães et al. 2013; De Montgolfier et al. 2025).

The macroscopic regressions observed in this study included the total disappearance of tumors in the periocular areas, the plastron, the left inguinal area, and the anterior flipper, and other major tumors showed substantial reductions in size. Although the turtle was still categorized with a tumor score of FP3 (two large tumors), the fibropapillomatosis index (FPI) was reduced from 102.2 to 40.0, indicating a significant reduction in overall disease burden. This finding underscores the importance of combining the tumor score and Fibropapillomatosis Index (FPI) scoring systems to more effectively track FP progression and recurrence over time.

Annualized growth rates calculated for turtle ID 2349 (3.60 cm/yr SCL and 3.72 cm/yr CCL) were consistent with those reported for similarly sized juvenile green turtles in the West Atlantic; Bjorndal et al. (2017) reported mean growth rates of 3.8 cm/yr for

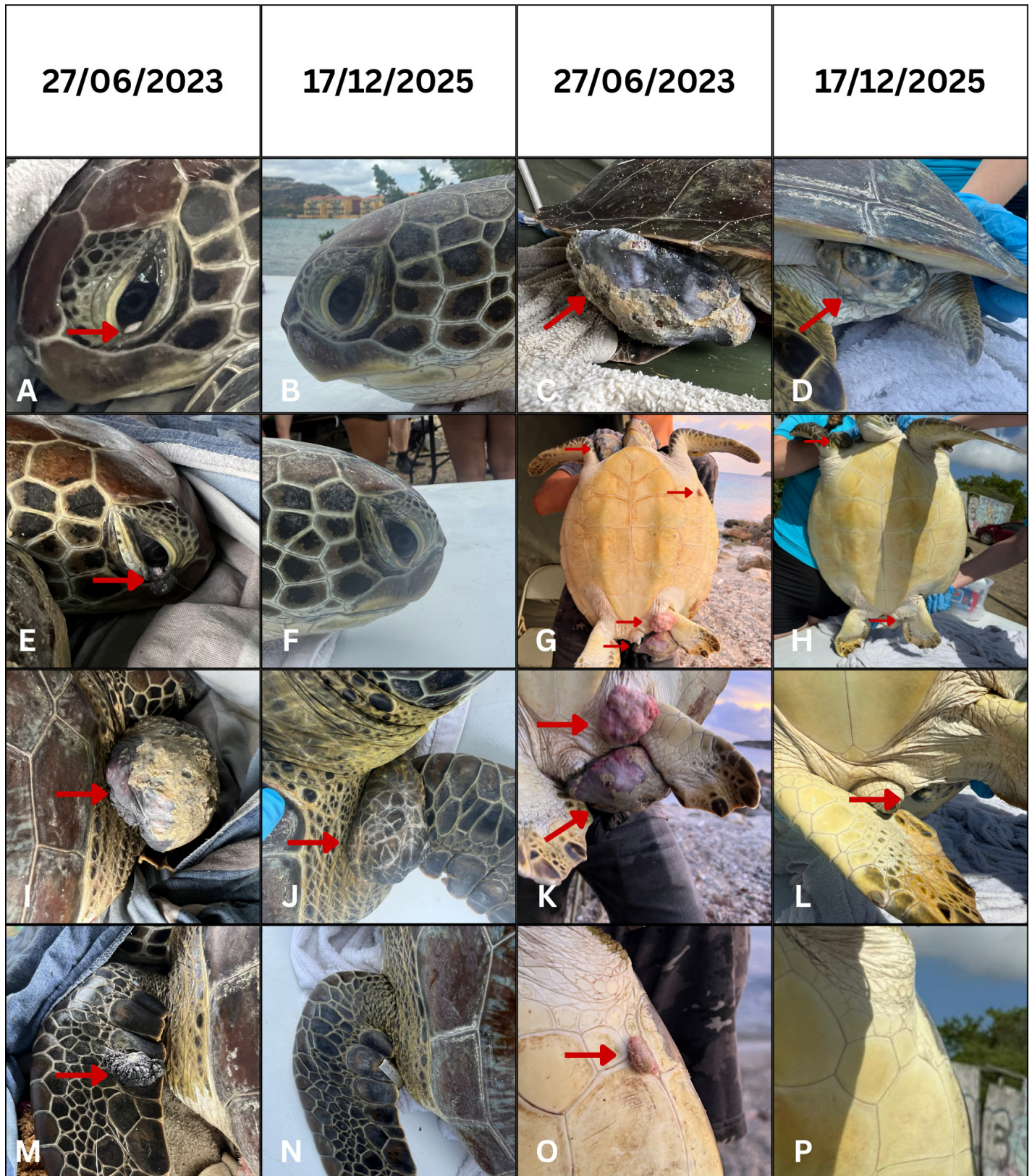


FIGURE 2. Photographic comparison of initial capture (2023) and recapture (2025) of a green sea turtle (ID 2349) showing macroscopic regression of FP. Red arrows indicate tumor sites. The figure demonstrates complete regression of masses in the bilateral periocular (A, B, E, and F), anterior flipper (M and N), and plastron (G, H, O and P) regions, alongside partial regression of masses in the axillary (I, J, G, and H) and inguinal (C, D, G, H, K, and L) regions.

TABLE 2. Anatomical distribution and regression status of FP lesions in green sea turtle ID 2349 between initial capture in 2023 and recapture in 2025. Complete regression indicates total macroscopic disappearance of the lesion, whereas partial regression indicates a reduction in tumor size without complete resolution.

Anatomical Location	2023 Status	2025 Status	Outcome
Right periocular region	Present (<1 cm)	Absent	Complete regression
Left periocular region	Present (<1 cm)	Absent	Complete regression
Right axillary region	Present (>10 cm)	Reduced (>4–10 cm)	Partial regression
Left anterior flipper	Present (1 to 4 cm)	Absent	Complete regression
Left inguinal region (superior mass)	Present (>10 cm)	Reduced (>4–10 cm)	Partial regression
Left inguinal region (inferior mass)	Present (>4–10 cm)	Absent	Complete regression
Plastron	Present (1 to 4 cm)	Absent	Complete regression

turtles measuring 40.0–49.9 cm SCL (range: –0.7–11.9 cm/yr) and 3.5 cm/yr for turtles measuring 50.0–59.9 cm SCL (range: –0.9–11.9 cm/yr). Continued somatic growth alongside tumor reduction indicates that the turtle maintained adequate physiological condition despite earlier severe presentation of FP.

The mechanisms underlying the spontaneous regression of FP are not well understood. FP is now considered a complex, multifactorial disease involving interactions among ChHV5 infection, host susceptibility, and environmental variables, rather than resulting solely from the presence of the virus (Herbst et al. 2004; Reséndiz et al. 2021). Environmental stressors, including pollution and habitat degradation, may act as co-factors that influence disease development and severity (Perrault et al. 2017; Valenzuela et al. 2026). This study is limited by the fact that regression was assessed in a single individual and was based solely on macroscopic observations and photographic comparisons, without histopathological or molecular confirmation. Therefore, the observed changes can only be interpreted as macroscopic regression, as residual remodeled tissue or subsurface disease could not be excluded without histopathological or molecular assessment. Despite these limitations, this study highlights the significance of long-term monitoring and recapture initiatives to better understand FP dynamics in wild populations. Future investigations using molecular diagnostics, immunological profiling, microbiome characterization, and environmental assessments may provide insight into the biological and ecological factors underlying FP regression and disease persistence.

CONCLUSION

We report the first case of macroscopic regression of fibropapillomatosis in a free-ranging green sea turtle from Curaçao. In turtle ID 2349, tumor abundance and tumor size were substantially reduced throughout a 2.48-year recapture interval, while positive somatic growth was maintained. There was a complete macroscopic regression in many anatomical locations, while the remaining tumors showed a considerable reduction.

These findings are consistent with earlier research demonstrating that FP progression can be dynamic and partial to complete spontaneous regression may occur in wild sea turtle populations without clinical intervention. The study also highlights the significance of long-term surveillance, uniform disease scoring, and recapture programs to better understand the progression, recovery, and survival of FP-affected turtles.

Future studies integrating molecular, immunological, microbiome, and environmental data may help clarify the mechanisms underlying FP regression. Continued monitoring of FP in Curaçao will be important to understand disease ecology within Caribbean Sea turtle populations and to influence regional conservation and rehabilitation measures.

Institutional review board statement

This study received IACUC protocol approval from Thomas Jefferson University, Philadelphia, Pennsylvania, U. S. A. (Protocol #: 23–10–728).

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