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Tumor re-growth, case outcome, and tumor scoring systems in rehabilitated green turtles with fibropapillomatosis

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ABSTRACT: Fibropapillomatosis (FP) is an infectious, neoplastic disease of major concern in sea turtle rehabilitation facilities. Rehabilitating sea turtles that undergo tumor removal surgery often have tumor regrowth and may experience mortality. We evaluated tumor score, removal, and regrowth in rehabilitating green sea turtles with FP in 4 rehabilitation facilities in the southeastern USA during 2009–2017. Of 756 cases, 312 (41%) underwent tumor removal surgery, 155 (50%) of those had tumor regrowth within an average of 46 ± 45 d, and 85 (27%) had multiple (>1) regrowth events. Of 756 turtles with FP, 563 (75%) did not survive after admission into a rehabilitation facility, including 283 (37%) that were euthanized and 280 that died without euthanasia (37%), and 193 survived, including 186 (25%) released and 7 (1%) placed in permanent captive care. Tumor removal surgery increased the odds of tumor regrowth but also enhanced survivorship, whereas tumor regrowth was not a significant predictor of case outcome. Three FP tumor scoring systems were used to assign tumor scores to 449 cases, and differing results emphasize that tumor scoring systems should be applied to the situations and/or location(s) for which they were intended. FP tumor score was not a significant predictor for the event or extent of FP tumor regrowth after surgical excision. Under current rehabilitation regimes, outcomes of rehabilitation for tumored turtles have a low probability of success. The results of this study may be used to help guide clinical decision-making and determine prognoses for rehabilitating sea turtles with FP.

KEY WORDS: Fibropapilloma · Green turtle · *Chelonia mydas* · Tumor · Rehabilitation · Sea turtle · Surgery

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1. INTRODUCTION

Fibropapillomatosis (FP) is an infectious, neoplastic disease that affects all sea turtle species, and has been reported in many locations around the world (Aguirre et al. 1994, 1999, Herbst 1994, Williams et al. 1994, Herbst et al. 1995, D'Amato & Moraes-Neto 2000, Hirama & Ehrhart 2007, Chaloupka et al. 2009, Flint et al. 2010, Duarte et al. 2012, Díaz-Delgado et al. 2019). FP tumors are characterized by cutaneous, ocular, and visceral growths that often debilitate affected animals by inhibiting feeding and movement, obscuring vision, and/or leading to organ failure (Balazs 1986, Jacobson et al. 1989). Over the past 3 decades, FP has emerged as an important disease in green turtles *Chelonia mydas*, which are listed as

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Endangered on the International Union for Conservation of Nature Red List and threatened under the United States Endangered Species Act (Seminoff 2004). In certain green turtle populations of the Caribbean and in Florida and Hawai'i, USA, FP has reached epizootic proportions (Williams et al. 1994, Hirama & Ehrhart 2007, Chaloupka et al. 2009). Although FP prevalence does appear to be decreasing in some regions such as Hawai'i, FP prevalence in Florida may be increasing or at least is stable, since both the total number and the percentage of stranded green turtles with FP have increased since 1995 (Chaloupka et al. 2009, Foley et al. 2015). Additionally, FP is being reported from new localities around the world, including Brazil, West Africa, and the Turks and Caicos Islands, and in more northern latitudes where it has never before been reported (Baptistotte et al. 2005, Loureiro & Matos 2009, Richardson et al. 2009, Duarte et al. 2012, Hargrove et al. 2016).

Stranded sea turtles with FP are often clinically debilitated and/or cachectic and exhibit various abnormalities in clinical pathology data that suggest anemia of chronic disease and chronic antigenic stimulation (Work & Balazs 1999, Aguirre & Balazs 2000, Cray et al. 2001, Hirama et al. 2014, Page-Karjian et al. 2014, Perrault et al. 2017). In sea turtle rehabilitation facilities, FP is a major concern, since extensive quarantine measures are required to accommodate turtles with FP, and because FP tumors can sometimes develop after turtles are admitted for other reasons (e.g. boat strike, fishing gear entanglement) (Page-Karjian et al. 2014). Turtles with severe FP disease often have accompanying co-morbid conditions such as emaciation or poor general health upon admission, buoyancy issues including floating, ileus, boat-strike trauma, and secondary or opportunistic bacterial and fungal infections (Herbst et al. 1995, Work et al. 2004, Page-Karjian et al. 2014, 2015). Furthermore, after FP tumors are surgically removed, there is still a potential for tumor regrowth, since the underlying associated herpesvirus infection (chelonid alphaherpesvirus 5, ChHV5) remains despite tumor removal (Herbst et al. 1995, Lackovich et al. 1999). These clinical factors, along with the infectious and potentially life-threatening nature of FP disease, complicate prognoses and extend rehabilitation times of sea turtles diagnosed with FP.

To objectively understand the various clinical manifestations of FP, it is necessary to apply a standardized method for quantifying and qualifying the extent of the disease. Several different FP scoring systems have been published, which include various considerations for tumor score designation. A simple but effective approach includes classifying the severity of FP disease based on a visual inspection and/or photographs of an individual turtle's dorsum and ventrum (e.g. Balazs 1991, Hirama & Ehrhart 2007). The first approach for objectively classifying afflicted turtles into 1 of 4 scores (grades 0–3) was based on the maximum size of tumors and had an additional score class (grade 4) for turtles with tumors that physically hampered movement or caused blindness (Wood & Wood 1993). One scoring system developed for green turtles in Hawai'i classifies tumors into 4 categories according to size, and then uses the number of tumors in each size category to assign an overall tumor score. This scoring system has been widely used; however, this approach was not intended to be universal, and may not be as useful in regions outside of Hawai'i, particularly since the various physical manifestations of FP disease can be region-specific (Work & Balazs 1999, Work et al. 2004, Chaloupka et al. 2009, Santos et al. 2010, Torezani et al. 2010, Rossi et al. 2016). A more recently published scoring system attempted to improve upon the previous scoring systems by including not only tumor number and size, but additional variables such as tumor location, morphology, and degree of invasiveness, although this method of classification is likely best suited for a clinical setting rather than in the field (Page-Karjian et al. 2014). Researchers in Brazil developed a system that included measuring each individual tumor and then attempting to estimate the percentage of skin covered by tumors in order to provide a quantitative index to represent FP severity (Rossi et al. 2009). Counting and measuring tumors can be very time consuming, may not be conducive to field conditions or animal welfare constraints, and may also lead to large inter-observer differences in measurements translating to variations in tumor score assignments. That scoring system was later improved upon with an updated 'fibropapillomatosis index', which is based on a weighted sum model that considers the size category and number of tumors and is more user-friendly under field conditions (Rossi et al. 2016).

The objective of this study was to conduct a large-scale, retrospective case series analysis of FP in rehabilitating sea turtles in the southeastern USA, in order to (1) assess FP tumor score and regrowth in rehabilitating sea turtles, and (2) provide information on tumor regrowth and survival in turtles with different tumor scores. Evaluating cases of rehabilitating wildlife can be an extremely valuable approach for improving our understanding of pathogen activity in both captive and free-ranging wildlife, and for developing recommendations for treatment and management of important wildlife diseases (Randall et al. 2012).

2. MATERIALS AND METHODS

We retrospectively evaluated medical records of green sea turtles with FP admitted to the following rehabilitation facilities in the USA during 2009–2017: The Turtle Hospital in Marathon, Florida; Clearwater Marine Aquarium in Clearwater, Florida; Sea Turtle Healing Center at the Brevard Zoo in Melbourne, Florida; and Georgia Sea Turtle Center in Jekyll Island, Georgia. Case data evaluated included minimum straight carapace length (SCL_{min}); FP tumor number, size, and location (right/left eye[s], right/left front/hind flipper[s], carapace, plastron, head, neck, inguinal region[s], tail); whether tumor removal surgery was performed, and if so, how many times; whether tumor regrowth occurred, and if so, how many times, how long after removal, and during what month(s); and rehabilitation outcome (i.e. euthanized, died, released, or permanent captive). For the purposes of this study, turtles that were released and those that were transferred into permanent captive care are grouped together as turtles that survived rehabilitation; turtles that were euthanized for humane purposes and turtles that died without euthanasia are grouped together as turtles that did not survive. A tumor regrowth event was defined as one or more tumors arising at the anatomic site(s) of prior surgical removal.

Average (±SD) values were calculated for the following data points: SCL_{min}; number of tumor removal surgeries; number of tumor regrowth events; days between tumor removal and regrowth; number of tumor regrowth events per tumor score category (Page-Karjian et al. 2014 scores only); and tumor scores for each of the 3 FP scoring systems evaluated. Average SCL_{min} data were compared between turtles that did and did not have tumor regrowth using a Mann-Whitney *U*-test for non-parametric data (as determined by the Shapiro-Wilk test) with $\alpha = 0.05$. The numbers of tumor regrowth events per month were analyzed using second-order polynomial regression with $\alpha = 0.05$. Two-tailed Fisher's exact tests with $\alpha = 0.05$ were used to evaluate the relationships between case outcome (survived versus did not survive) and whether tumor removal surgery was performed; and between case outcome and whether tumor regrowth occurred. Binary logistic regression was used to analyze the relationship between total number of tumor removal surgeries and tumor regrowth incidence.

Fibropapilloma tumor scores were assigned to all turtles for which relevant case data were available. Tumor scores were designated by a single experienced reviewer using a combination of tumor measurement data and photographs. Thus, tumor scores (1–3; including [1] mildly, [2] moderately, and [3] severely afflicted) were assigned using 3 different tumor classification systems: one outlined by Work & Balazs (1999); one outlined by Page-Karjian et al. (2014); and one outlined by Rossi et al. (2016). The average tumor scores for each of the 3 scoring systems were compared using a Kruskal-Wallis rank sum test for multiple independent samples with $\alpha = 0.05$, and post-hoc Dunn's test with p-values adjusted by the Benjamini-Hochberg false discovery rate method. The total number of turtles that survived or did not survive rehabilitation was calculated for each tumor score category for all 3 scoring systems, and multiple logistic regression was used to evaluate the odds of surviving rehabilitation for the 3 tumor scoring systems evaluated in this study (Work & Balazs 1999, Page-Karjian et al. 2014, Rossi et al. 2016). Since the Page-Karjian et al. (2014) scoring system was developed specifically to evaluate FP score in rehabilitating sea turtles, we used the scores from this scoring system and multiple logistic regression analysis to determine whether tumor score, number of days to first tumor regrowth event, and/or total number of tumor regrowth events were significant predictors of case outcome. These 3 explanatory variables were first assessed for collinearity to ensure that they were independent of each other before inclusion in the model. Because SCL_{min} data were limited, they were not included in the multiple logistic regression model but were analyzed separately. A Kruskal-Wallis 1-way ANOVA with $\alpha = 0.05$ was used to compare the average of the following for each of the 3 tumor scores: SCL_{min}; number of regrowth events for turtles that did experience regrowth; and time to first regrowth (in days). Statistical analyses were conducted using SPSS statistical software v.24 (IBM).

3. RESULTS

Overall, medical records of 756 rehabilitating green sea turtles with FP were analyzed. SCL_{min} data were available for 329 turtles, and of those, the average (±SD) SCL_{min} was 37.94 ± 7.45 cm (range = 4.03–63.10 cm; Fig. 1). Of the 756 total cases of green tur-

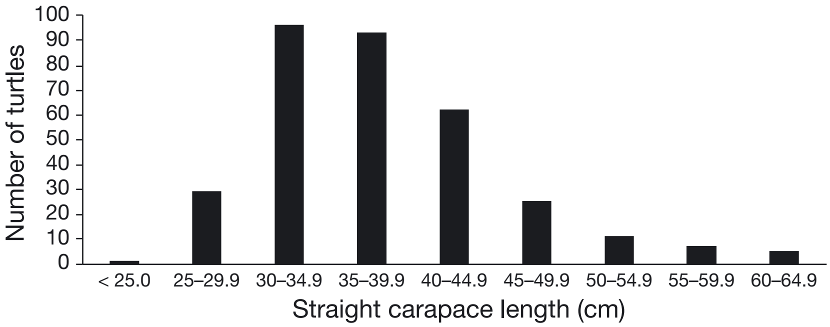

Fig. 1. Straight carapace lengths (cm) of green turtles afflicted with fibropapillomatosis, reported as number of turtles per size class

tles with FP, 312 (41%) underwent tumor removal surgery. For these 312 turtles, the number of tumor removal surgeries ranged from 1–17 per animal; 215 (69%) turtles had more than one surgery, the average number of surgeries was 4 ± 3 per animal, and the number of regrowth events ranged from 0–9 per turtle (Fig. 2). Tumor regrowth was seen in 155 of 312 (50%) turtles within an average of 46 ± 45 d (range = 2–245 d). There was a total of 332 regrowth events for the 312 turtles that had tumor removal surgery, and multiple regrowth events were observed in 85 of 312 (27%) turtles; for these, the average time to the first tumor regrowth was 50 ± 52 d. The majority of the turtles with tumor regrowth had 1 (70 of 155, 45%) or 2 (47 of 155, 30%) regrowth events during rehabilitative care. The average number of regrowth events was 2 ± 2 per turtle. Of the 756 turtles with FP, 563 (75%) did not survive rehabilitation, including 283 (37%) that were euthanized and 280 (37%) that died without euthanasia; 193 (26%) survived, including 186 (25%) that lived to be released, and 7 (1%) that were placed in permanent captive care. The decision for placement in captive care was made by the attending veterinarians based on a turtle being deemed non-releasable due to its apparent inability to survive in the wild. Common causes for being deemed non-releasable included permanent blindness and unresolved floating (FWC 2016).

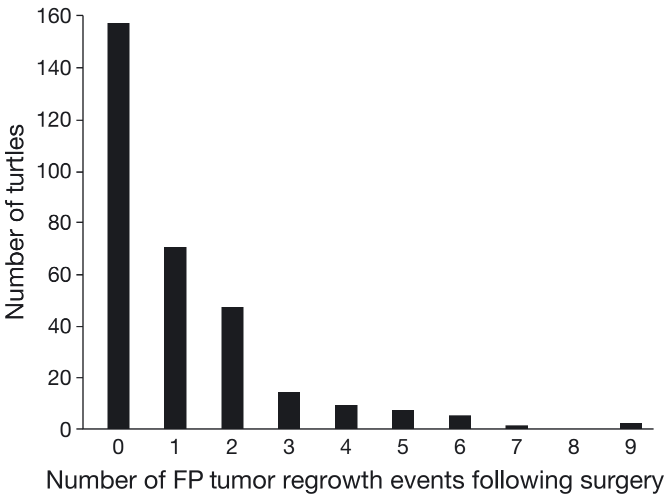

Fig. 2. Number of fibropapillomatosis (FP) tumor regrowth event(s) for 312 green sea turtles that underwent tumor removal surgery

A statistically significant relationship was observed between the total number of tumor removal surgeries and whether or not tumor regrowth occurred (odds ratio = 2.56, [90% CI = 2.06–3.18, $p < 0.001$), suggesting that for each additional surgery performed, the odds of tumor regrowth increase by approximately 2- to 3-fold. Based on the results of a Mann-Whitney *U*-test, average SCL_{min} did not significantly differ between turtles that did and did not have tumor regrowth following surgery ($p = 0.17$). The proportion of total tumor regrowth events by month was found to be: January, 7%; February, 7%; March, 8%; April, 9%; May, 13%; June, 13%; July, 7%; August, 8%; September, 7%; October, 6%; November, 9%; December, 7%. Polynomial logistic regression analysis indicated that there was no statistically significant trend with regards to the total number of tumor regrowth events observed per month ($r^2 = 0.30$, $p = 0.20$).

Of the 756 cases of rehabilitating green turtles with FP, there were 449 cases for which detailed tumor data and photos were available and for which an accurate FP tumor score could be designated. For each of these 449 cases, 3 published FP tumor scoring systems were used to designate 3 FP tumor score values (1–3) per individual turtle. The average (±SD) tumor score was 2.26 ± 0.67 using the Work & Balazs (1999) scoring system, 2.53 ± 0.64 using the Page-Karjian et al. (2014) scoring system, and 1.88 ± 0.78 using the Rossi et al. (2016) scoring system. All of these averages significantly differed from one another, as determined by a Kruskal-Wallis test ($H_2 = 69.89$, $N = 449$, $p < 0.0001$) with post-hoc Dunn's analysis (all $p < 0.004$). Based on tumor score categories designated using only the Page-Karjian et al. (2014) scoring system, average SCL_{min} did not significantly differ between tumor scores 1–3 ($H_2 = 4.84$, $N = 330$, $p = 0.09$). For turtles that had tumor removal surgery, neither the average number of tumor regrowth events ($H_2 = 2.48$, $N = 310$, $p = 0.29$) nor the average number of days to first regrowth (H_2 = 5.38, N = 153, p = 0.07) significantly differed between tumor scores 1–3 assigned using the Page-Karjian et al. (2014) scoring system.

Using 2-tailed Fisher's exact tests, turtles that had tumor removal surgery were significantly more likely to survive rehabilitation than turtles that did not ($p <$ 0.001), but tumor regrowth following surgery was not significantly associated with survivorship (p = 0.57). Case outcomes (survived versus did not survive) for each tumor score for the 3 scoring systems are detailed in Table A1 in the Appendix. In total, 57–67% of turtles with tumor score 1, 68–80% of turtles with tumor score 2, and 76–82% of turtles with tumor score 3 did not survive rehabilitation efforts. When the 3 tumor scoring systems (Work & Balazs 1999, Page-Karjian et al. 2014, Rossi et al. 2016) were compared using multiple logistic regression, the odds of survivorship for the Page-Karjian et al. (2014) system were approximately half of the other 2 (Table 1). Tumor score (Page-Karjian et al. 2014 scoring system only), number of days to first tumor regrowth, and total number of tumor regrowth episodes did not significantly affect survivorship, as shown by multiple linear regression ($p > 0.05$).

4. DISCUSSION

The results of this study may be used by caretakers and veterinarians to help guide clinical decision making and determine prognoses for rehabilitating sea turtles with FP. Tumor regrowth may be expected in about 50% of cases involving surgical removal within an average of 46 d, and ~27% of turtles may be expected to undergo multiple rounds of surgery and regrowth. Most (75%) of the turtles that had tumor regrowth in this study had only 1 or 2 regrowth events. The regrowth rates reported here differ from 2 previously reported FP regrowth rates of 0 and 39%, likely due to differences in sample size and triage/treatment protocols between different rehabilitation facilities (Tristan et al. 2010, Page-Karjian et al. 2014). Fibropapilloma tumor regrowth following surgery likely occurs due to the continued presence of presumptive inciting cause(s) (e.g. ChHV5 infection, immunosuppression), even though the clinical signs of disease (FP tumors) are surgically removed. Data from this study indicate that with each additional surgery performed, the odds of tumor regrowth increased by approximately 2- to 3-fold. Triage-based, *a priori* case selection for surgery candidates helps explain the paradoxical finding that although tumor removal surgery was significantly associated with survivorship, tumor regrowth following surgery was not. Specifically, these results may be explained by the fact that the 'sickest' turtles were usually not considered good candidates for tumor resection and were instead elected for euthanasia; and tumor regrowth following surgery was often not considered grounds for euthanasia by the attending veterinarian(s), but rather was considered as an indicator for another round of surgical tumor removal. Tumor score was not a significant predictor for the event or extent of FP tumor regrowth. Consistent with previous reports that FP is of greatest concern in juvenile sea turtles in nearshore habitats, all of the green turtles with FP in this study were classified as juveniles (<65 cm SCL_{min}; Aguirre et al. 1994, 1998, Herbst et al. 1999, Ene et al. 2005, Hirama & Ehrhart 2007, Bresette et al. 2010, Page-Karjian et al. 2014).

The majority (75%) of the turtles with FP in this study did not survive following admission into a rehabilitation facility, irrespective of whether or not tumor regrowth occurred following surgery. Wildlife survivorship in rehabilitation facilities is usually heavily dependent upon triage protocols, and triage procedures at sea turtle rehabilitation facilities often include outright euthanasia for cases of internal tumors or severe FP that irreversibly diminishes an animal's well-being and ability to survive. Successful triage strategies for neoplastic diseases are often accompanied by tumor scoring systems, and FP is no exception. Various tumor scoring systems have been published and used to categorize FP tumors based on tumor number, size, location, and

Table 1. Multiple logistic regression analysis to ascertain odds of surviving rehabilitation for green turtles assigned with tumor scores 1–3 using the 3 fibropapillomatosis scoring systems including that of Work & Balazs (1999) (B/W tumor score), Page-Karjian et al. (2014) (P-K tumor score), and Rossi et al. (2016) (Rossi tumor score). Note that odds of survivorship using the P-K system were approximately half those of the other 2 scoring systems. (*) denotes statistically significant difference ($p \leq 0.05$)

Variable	Coefficient (β)	SE	Wald χ^2	p-value	Odds ratio	95% CI for odds ratio
Intercept	0.60	0.42	2.03	0.15	1.81	0.80–4.10
B/W tumor score	0.06	0.27	0.05	0.82	1.06	0.62–1.82
P-K tumor score	−0.65	0.26	6.26	0.01*	0.52	0.31–0.87
Rossi tumor score	−0.15	0.19	0.60	0.44	0.86	0.59–1.26

degree of invasiveness (Wood & Wood 1993, Work & Balazs 1999, Rossi et al. 2009, 2016, Page-Karjian et al. 2014). The percentage of turtles that survived was inversely related to FP tumor severity (i.e. tumor score), since summarized data from all 3 scoring systems indicate that rehabilitation survivorship for turtles with FP was only 32–43% for turtles with tumor score 1; 20–32% for turtles with tumor score 2; and 18–24% for turtles with tumor score 3. This finding is in alignment with data from another retrospective case series analysis of green turtles in Florida, which showed that of turtles with FP admitted to Florida facilities during 2006–2016, only 21% of turtles with tumor score 2 and 6% of turtles with tumor score 3 survived rehabilitation (Stacy et al. 2018). Therefore, particularly in situations of limited resources, and taking into account any co-morbid conditions, focusing rehabilitation efforts on turtles with lower tumor scores (i.e. 1–2) will help further streamline admission and triage of turtles with FP in rehabilitation facilities, and lead to higher rehabilitation success rates.

The averages of the 3 scoring systems differed significantly. Furthermore, the differences observed in survivorship depending on which scoring system is used underline the fact that FP scoring systems are usually developed based on site-specific data and/or for specific purposes and function best when applied to situations for which they were intended. For example, the Page-Karjian et al. (2014) FP scoring system incorporates tumor size, number, location, morphology, and whether internal tumors are diagnosed or not, and was developed specifically for use with rehabilitating sea turtles to help provide a prognostic indicator (tumor score) based on these factors. Application of this scoring system coupled with rigorous triage and admission criteria for stranded turtles with FP can effectively help reduce facilities' burden in terms of rehabilitating fewer turtles with poor prognoses. More research is needed to define the effects of prolonged captivity and repeated cycles of FP tumor removal and regrowth on FP detection, prognosis, and general turtle health.

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LITERATURE CITED

Aguirre AA, Balazs GH (2000) Blood biochemistry values of green turtles (*Chelonia mydas*) with and without fibropapillomatosis. Comp Haematol Int 10:132–137

Aguirre AA, Balazs GH, Zimmerman B, Spraker TR (1994) Evaluation of Hawaiian green turtles (*Chelonia mydas*) for potential pathogens associated with fibropapillomas. J Wildl Dis 30:8–15

Aguirre AA, Spraker TR, Balazs GH, Zimmerman B (1998) Spirorchidiasis and fibropapillomatosis in green turtles from the Hawaiian Islands. J Wildl Dis 34:91–98

Aguirre AA, Spraker TR, Chaves A, du Toit L, Eure W, Balazs GS (1999) Pathology of fibropapillomatosis in olive ridley turtles *Lepidochelys olivacea* nesting in Costa Rica. J Aquat Anim Health 11:283–289

Balazs GH (1986) Fibropapillomas in Hawaiian green turtles. Mar Turtle Newsl 39:1–3

Balazs GH (1991) Current status of fibropapillomas in the Hawaiian green turtle, *Chelonia mydas*. In: Balazs GH, Pooley SG (eds) Research plan for marine turtle fibropapilloma. NOAA Tech Memo NMFS-SWFSC-156. US Department of Commerce, National Marine Fisheries Service, Honolulu, HI, p 47–57

Baptistotte C, Moreira LMP, Becker JH, Lopes G and others (2005) Frequency of occurrence of tumors in green turtles, *Chelonia mydas* record by project TAMAR-IBAMA in Brazilian coast from years 2000 to 2004. In: Proc 19th Ann Meeting Soc Conserv Biol. Society for Conservation Biology, Brasília, p 14–15 (Abstract)

Bresette MJ, Witherington BE, Herren RM, Bagley DA and others (2010) Size-class partitioning and herding in a group of green turtles *Chelonia mydas*. Endang Species Res 9:105–116

Chaloupka M, Balazs GH, Work TM (2009) Rise and fall over 26 years of a marine epizootic in Hawaiian green sea turtles. J Wildl Dis 45:1138–1142

Cray C, Varella R, Bossart GD, Lutz P (2001) Altered *in vitro* immune responses in green turtles (*Chelonia mydas*) with fibropapillomatosis. J Zoo Wildl Med 32:436–440

D'Amato AF, Moraes-Neto M (2000) First documentation of fibropapillomas verified by histopathology in *Eretmochelys imbricata*. Mar Turtle Newsl 89:12–13

Díaz-Delgado J, Gomes-Borges JC, Silviera AM, Einhardt-Vergara J and others (2019) Primary multicentric pulmonary low-grade fibromyxoid sarcoma and chelonid alphaherpesvirus 5 detection in a leatherback sea turtle (*Dermochelys coriacea*). J Comp Pathol 168:1–7

Duarte A, Faisca P, Loureiro NS, Rosado R, Gil S, Pereira N, Tavares L (2012) First histological and virological report of fibropapilloma-associated herpesvirus in *Chelonia mydas* at Príncipe Island, West Africa. Arch Virol 157: 1155–1159

Ene A, Su M, Lemaire S, Rose C and others (2005) Distribution of chelonid fibropapillomatosis-associated herpesvirus variants in Florida: molecular genetic evidence for infection of turtles following recruitment to developmental neritic habitats. J Wildl Dis 41:489–497

Flint M, Limpus CJ, Patterson-Kane JC, Murray PJ, Mills PC (2010) Corneal fibropapillomatosis in green sea turtles (*Chelonia mydas*) in Australia. J Comp Pathol 142: 341–346

FWC (Florida Fish and Wildlife Conservation Commission) (2016) Marine turtle conservation handbook. Florida Fish & Wildlife Conservation Commission, Tallahassee, FL

Foley AM, Minch K, Hardy R, Bailey R, Schaf S, Young M (2015) Distributions, relative abundances, and mortality factors of sea turtles in Florida during 1980–2014 as determined from strandings. Fish & Wildlife Research Institute Report. Florida Fish and Wildlife Conservation Commission, Jacksonville, FL

Hargrove S, Work TM, Brunson S, Foley AM, Balazs GH (2016) Proc 2015 Int Summit on fibropapillomatosis: global status, trends, and population impacts. NOAA Tech Memo NMFS-PIFSC-54

Herbst LH (1994) Fibropapillomatosis of marine turtles. Annu Rev Fish Dis 4:389–425

Herbst LH, Jacobson ER, Moretti R, Brown T, Sundberg JP, Klein PA (1995) Experimental transmission of green turtle fibropapillomatosis using cell-free tumor extracts. Dis Aquat Org 22:1–12

Herbst LH, Jacobson ER, Klein PA, Balazs GH, Moretti R, Brown T, Sundberg JP (1999) Comparative pathology and pathogenesis of experimentally induced and spontaneous fibropapillomas of green turtles (*Chelonia mydas*). Vet Pathol 36:551–564

Hirama S, Ehrhart LR (2007) Description, prevalence and severity of green turtle fibropapillomatosis in three developmental habitats on the east coast of Florida. Fla Sci 70:435–448

Hirama S, Ehrhart LM, Rea LD, Kiltie RA (2014) Relating fibropapilloma tumor severity to blood parameters in green turtles *Chelonia mydas*. Dis Aquat Org 111:61–68

Jacobson ER, Mansell JL, Sundberg JP, Reichmann ME, Ehrhart LM, Walsh M, Murru F (1989) Cutaneous fibropapillomas of green turtles (*Chelonia mydas*). J Comp Pathol 101:39–52

Lackovich JK, Brown DR, Homer BL, Garber RL and others (1999) Association of herpesvirus with fibropapillomatosis of the green turtle *Chelonia mydas* and loggerhead turtle *Caretta caretta* in Florida. Dis Aquat Org 37:89–97

Loureiro NS, Matos D (2009) Presence of fibropapillomatosis in green turtles *Chelonia mydas* at Príncipe Island in the Gulf of Guinea. Arquipelago Life Mar Sci 26:79–83

Page-Karjian A, Norton TM, Krimer P, Groner M, Nelson SE Jr, Gottdenker NL (2014) Factors influencing survivorship in rehabilitating green sea turtles (*Chelonia mydas*) with fibropapillomatosis. J Zoo Wildl Med 45:507–519

Page-Karjian A, Norton TM, Harms CA, Mader DR, Herbst LH, Stedman N, Gottdenker NL (2015) Case descriptions of fibropapillomatosis in rehabilitating loggerhead sea turtles *Caretta caretta* in the southeastern USA. Dis Aquat Org 115:185–191

Perrault JR, Stacy NI, Lehner AF, Mott CR and others (2017) Potential effects of brevetoxins and toxic elements on various health variables in Kemp's ridley (*Lepidochelys kempii*) and green (*Chelonia mydas*) sea turtles after a red tide bloom event. Sci Total Environ 605-606:967–979

Randall NJ, Blitvich BJ, Blanchong JA (2012) Efficacy of wildlife rehabilitation centers in surveillance and monitoring of pathogen activity: a case study with West Nile Virus. J Wildl Dis 48:646–653

Richardson PB, Bruford MW, Calosso MC, Campbell LM and others (2009) Marine turtles in the Turks and Caicos Islands: remnant rookeries, regionally significant foraging stocks and a major turtle fishery. Chelonian Conserv Biol 8:192–207

Rossi S, Zwarg T, Sanches TC, Cesar MO, Merneck MR, Matushima ER (2009) Hematological profile of *Chelonia mydas* (Testudines, Cheloniidae) according to the severity of fibropapillomatosis or its absence. Pesqui Vet Bras 29:974–978

Rossi S, Sanchez-Sarmiento AM, Vanstreels RET, dos Santos RG and others (2016) Challenges in evaluating the severity of fibropapillomatosis: a proposal for objective index and score system for green sea turtles (*Chelonia mydas*) in Brazil. PLOS ONE 11:e0167632

Santos RG, Martins AS, Torezani E, Baptistotte C and others (2010) Relationship between fibropapillomatosis and environmental quality: a case study with *Chelonia mydas* off Brazil. Dis Aquat Org 89:87–95

Seminoff J (2004) *Chelonia mydas*. IUCN 2012 Red List of Threatened Species 2004: e.T4615A11037468 doi:10.2305/IUCN.UK.2004.RLTS.T4615A11037468.en. www.iucnredlist.org (accessed 23 July 2018)

Stacy BA, Foley AM, Work TM, Lauritsen AM, Schroeder BA, Hargrove SK, Keene JL (2018) Report of the Technical Expert Workshop: developing recommendations for field response, captive management, and rehabilitation of sea turtles with fibropapillomatosis. NOAA Tech Memo NMFS-OPR-60

Torezani E, Baptistotte C, Mendes SR, Barata PCR (2010) Juvenile green turtles (*Chelonia mydas*) in the effluent discharge channel of a steel plant, Espirito Santo, Brazil, 2000–2006. J Mar Biol Assoc UK 90:233–246

Tristan T, Shaver DJ, Kimbro J, deMaar T, Metz T, George J, Amos A (2010) Identification of fibropapillomatosis in green sea turtles (*Chelonia mydas*) on the Texas coast. J Herpetological Med Surg 20:109–112

Williams EH, Bunkley-Willams L, Peters E, Pinto-Rodrigues B and others (1994) An epizootic of cutaneous fibropapillomas in green turtles *Chelonia mydas* of the Caribbean: Part of a panzootic? J Aquat Anim Health 6:70–78

Wood F, Wood J (1993) Release and recapture of captive-reared green sea turtles, *Chelonia mydas*, in the waters surrounding Cayman Islands. Herpetol J 3:84–89

Work TM, Balazs GH (1999) Relating tumor score to hematology in green turtles with fibropapillomatosis in Hawaii. J Wildl Dis 35:804–807

Work TM, Balazs GH, Rameyer RA, Morris RA (2004) Retrospective pathology survey of green turtles *Chelonia mydas* with fibropapillomatosis in the Hawaiian Islands, 1993–2003. Dis Aquat Org 62:163–176

Appendix.

Table A1. Rehabilitation survivorship for green turtles with fibropapillomatosis (FP) tumor scores 1–3

	No. of turtles that survived rehabilitation (%)	No. of turtles that did not survive rehabilitation (%)	Total
Work & Balazs (1999) FP scoring system			
Tumor score 1	23/58 (40%)	35/58 (60%)	58/449 (13%)
Tumor score 2	54/217 (25%)	163/217 (75%)	217/449 (48%)
Tumor score 3	31/174 (18%)	143/174 (82%)	174/449 (39%)
Page-Karjian et al. (2014) FP scoring system			
Tumor score 1	16/37 (43%)	21/37 (57%)	37/449 (8%)
Tumor score 2	44/136 (32%)	92/136 (68%)	136/449 (30%)
Tumor score 3	48/276 (17%)	228/276 (83%)	276/449 (62%)
Rossi et al. (2016) FP scoring system			
Tumor score 1	54/165 (33%)	111/165 (67%)	165/449 (37%)
Tumor score 2	34/172 (20%)	138/172 (80%)	172/449 (38%)
Tumor score 3	20/112 (18%)	92/112 (82%)	112/449 (25%)
Total	108/449 (24%)	341/449 (76%)	449

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