Four Decades of Green Turtle (*Chelonia mydas*) Strandings on Hawai‘i Island (1983 – 2022): Identifying Causes and Assessing Trends

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ABSTRACT: Hawaiian populations of green turtles (*Chelonia mydas*) have increased since Federal and State protections were implemented in the mid 1970s, and consequently, reported stranding events have also increased. Analyzing stranding data can provide valuable information for resource managers, policymakers, and the public. This study analyzed Hawai‘i Island data: stranding location, date, size, sex, presence/absence of tumors, stranding status, and cause of stranding. A total of 754 stranded green turtles were reported from 1983 – 2022: 378 stranded on the east (leeward) coast of Hawai’i Island and 376 on the west (windward) coast. Strandings peaked in 2011 and 2018 and were highest from March to August. The most common known cause of stranding was hook-and-line fishing gear (21.4% of total strandings), followed by fibropapillomatosis (7.2%), human take (4.3%), miscellaneous (3.7%), boat impact (3.3%), shark attack (3.2%), and net (2.1%); however, 54.8% of strandings had no known cause. Stranded turtles on east Hawai‘i Island had a higher frequency of fibropapillomatosis, whereas west Hawai‘i stranded turtles showed higher incidence of shark attacks. These results provide the first analyses of stranding data from Hawai‘i Island and provide information that can inform managers and the public about the various types and magnitudes of impacts, anthropogenic and natural, to green turtles so that mitigation measures can be put into practice.

KEY WORDS: green turtles · mortality · fishing gear · fibropapillomatosis · Hawai‘i

INTRODUCTION

Green turtles (*Chelonia mydas*) are the most abundant large marine herbivores found throughout the world and in the Hawaiian Islands (Balazs & Chaloupka 2004). Hawaiian populations of green turtles that were once depleted have increased since their 1974 protection under Hawaiian Law and their 1978 protection under the Endangered Species Act (Balazs & Chaloupka 2004). Green turtles migrate long distances during their lifetime, from nesting to foraging grounds (Meylan & Meylan 2004). In the Hawaiian Islands, over 90% of nesting occurs on the sand islets at French Frigate Shoals, located in the Northwestern Hawaiian Islands. Migration patterns and complicated life history patterns cause green turtles to occupy many habitats during their lifespans including pelagic environments during their early years and during migrations, as well coastal areas in their later years (Meylan & Meylan 2004); therefore, green turtles are susceptible to threats in both offshore and coastal environments (Bolten 2003).

A long history of exploitation has been experienced by green turtles. This species was used for meat by indigenous coastal people around the world, as well as by European royals in the 18^{th} and 19^{th} centuries (Witzell 1994). Hawaiian green turtles have been impacted by harvesting at foraging grounds and nesting grounds, both eggs and female nesters, and by the destruction of their nesting habitat (Balazs & Chaloupka 2004). Since protection began under the Endangered Species Act, a reduction in such exploitation has been seen (Balazs & Chaloupka 2004). However, large marine vertebrates, including green turtles, face other threats, and are often victims of bycatch, becoming accidentally entangled or hooked by commercial or recreational fisheries activities targeted to other species (Lewison et al. 2004). Bycatch is harmful to green turtles because it can cause drowning, and internal/external injuries from hooks and line entanglements.

Another major threat to sea turtle populations is fibropapillomatosis (FP). FP is a debilitating neoplastic disease associated with herpesvirus found in turtles worldwide (Jacobson et al. 1991, Herbst 1994). The disease was first described in green turtles in the Florida Keys in 1938 and affects mostly immature turtles (Herbst 1994). FP is indicated by the presence of internal, external, and oral tumors (Work et al. 2004). Oral tumors are unique to Hawaiian green turtles and are often found in the glottis, making survival difficult (Work et al. 2004). The presence of these tumors can impact the turtles' ability to breathe, swim, dive, forage, and see (Perrault et al. 2021). On Oʻahu, Maui, and Kauai from 1982-2003, FP was the most common cause of stranding, defined as an animal that has been found dead, injured, or exhibits ill health or abnormal behavior (Chaloupka et al. 2008).

A variety of factors, both natural and anthropogenic, can cause sea turtle strandings. The majority of strandings involve sea turtles that died at sea and washed ashore; however, most stranded turtles show no cause of death (Hart et al. 2006). An unknown number of turtles never reach shore. They are eaten by scavengers, sink, and/or decompose while in currents or eddies (Crowder et al. 1995, Hart et al. 2006). Therefore, the number of sea turtle strandings that is recorded is likely a minimal estimate (Hart et al. 2006). Stranding response programs and can provide important insight into the health, welfare, and conservation status of sea turtle populations. Analyses of the data collected by these programs provide valuable information on mortality patterns and can aid regulatory managers (Crowder et al. 1995). Stranding data from

Hawaiʻi Island have not been analyzed previously nor included in earlier studies in the Hawaiian Islands (Chaloupka et al. 2008). The knowledge gained from stranding patterns can be used to establish mitigation measures to reduce strandings and maintain healthy green turtle populations.

In the present study, a comprehensive analysis of 39 years of Hawaiʻi Island green turtle strandings is presented to (1) identify the causes of strandings affecting green turtles around Hawaiʻi Island, (2) assess trends in strandings, and (3) identify differences between strandings in west and east Hawaiʻi Island.

METHODS

Data Collection

Data were collected on turtles stranded on Hawaiʻi Island from 1983-2022 by members of the Pacific Islands Fisheries Science Center under the US National Marine Fisheries Services, the University of Hawaiʻi at Hilo Sea Turtle Stranding Response Team, and the Hawaiʻi Preparatory Academy Sea Turtle Response Program. The west and east coasts of Hawaiʻi Island are different in terms of weather, the east coast receives much more rainfall than the west coast, terrain, currents, and population, so the data used in this study were analyzed for the island as a whole, as well as by west and east coast. West Hawaiʻi included locations from Miloliʻi north to Kawaihae, and east Hawaiʻi included locations from South Point north to Hawi (Fig. 1).

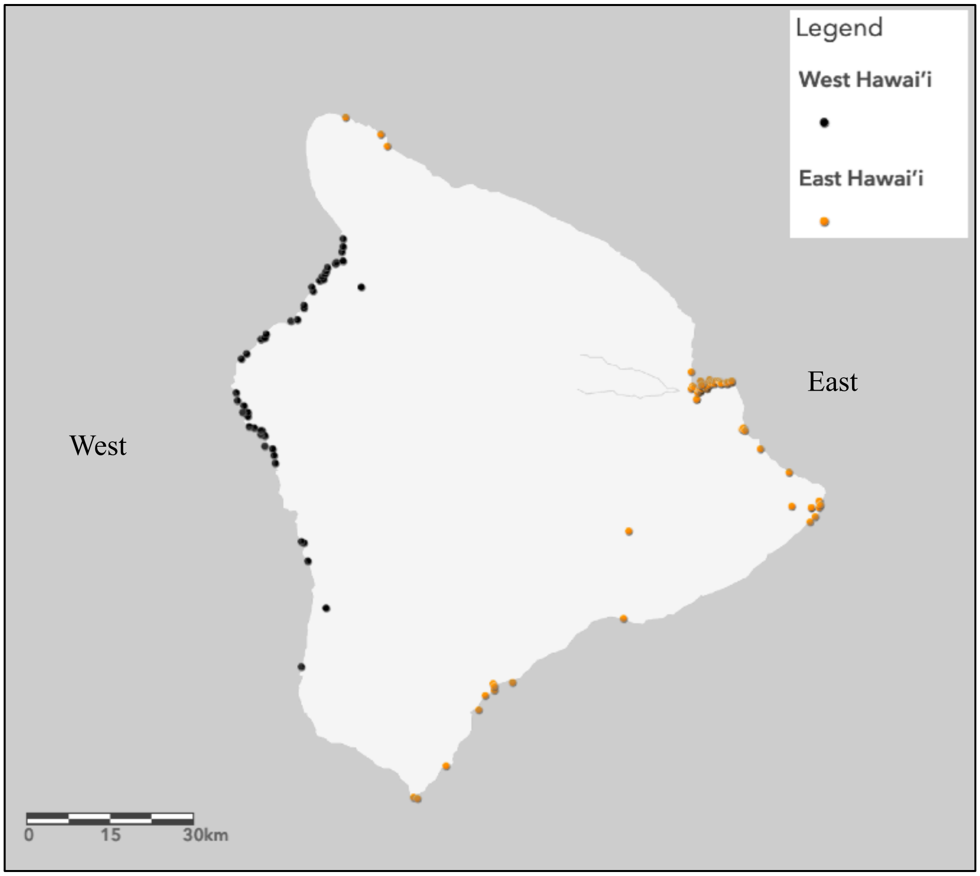


Figure 1. Stranding locations separated into west and east Hawai'i.

For each stranded turtle, the following information was collected: date of stranding, stranding location, stranding status (alive/dead), and cause of stranding. Data on species, sex, straight carapace length (SCL), curved carapace length (CCL), and the presence or absence of tumors indicative of fibropapillomatosis were also recorded whenever possible. SCL was used in size analyses because it was reported more frequently than CCL. In cases where CCL was recorded, but not SCL, CCL was converted to SCL using the following linear regression function: SCL = 1.245 +0.913*CCL, $R^2 = 0.996$ (Chaloupka et al. 2008). Determination of size classes of turtles followed Balazs (1980): juvenile = post hatchling to 65 cm SCL, subadult = 65 to 81 cm SCL, adult = >81 cm SCL.

The primary cause of stranding was based on direct observation and/or necropsy when available. Causes of stranding were classified into eight categories used previously by Chaloupka et al. (2008): fibropapillomatosis (FP), line and hook fishing gear, net and gillnet fishing gear, boat impact, shark attack, human-take, miscellaneous, and unknown. FP strandings were turtles that had gross evidence of external tumors (Chaloupka et al. 2008). Fishing gear strandings were identified by obvious signs of an interaction or entanglement with the particular gear (line/hook or net) (Boulon 2000, Chaloupka et al. 2008). Boat impact strandings were recognized by the presence of a crushed carapace or deep cuts from propellers or hulls of boats (Boulon 2000, Guimaraes et al. 2021). Shark attack strandings included turtles with deep incisions or removal of soft tissue or body parts (Stacy et al. 2021). Human-take (take is defined under the Endangered Species Act as “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct”) strandings were turtles with obvious evidence of having been butchered or poached, often accompanied with spear wounds (Boulon 2000). Miscellaneous strandings included turtles with natural, non-anthropogenic causes not fitting in any of the other categories (e.g., natural disasters and internal diseases confirmed by necropsy), and unknown strandings were those for which no cause could be determined (Chaloupka et al. 2008).

Statistical methods

Chi-square (X^2) goodness of fit tests were used to determine if there were equal proportions among months of stranding, stranding status, causes of stranding, and sex of stranded turtles for all of Hawaiʻi Island (McFee & Murphy 2002). When comparing west and east Hawaiʻi, contingency tables and chi-square tests of independence were used. All analyses were performed using the statistical software R version 4.0.3 (R Core Team 2020). Statistical significance was accepted at $p < 0.05$.

RESULTS

Stranding summary

A total of 754 green turtles stranded on Hawaiʻi Island from June 1983 - June 2022. Of those strandings, 376 (49.9%) of those strandings were located on the leeward or west coast of Hawaiʻi Island, while 378 (50.1%) were located on the windward side or east coast of Hawaiʻi Island.

Temporal trends

The number of strandings on Hawaiʻi Island have fluctuated over the years but have shown an overall increase (Fig. 2). Strandings rose after 1983 and leveled off until 1987 when strandings significantly declined. After 1987, strandings once again increased. Two main peaks in strandings were seen throughout the years, one in 2011 and one in 2018. For all of Hawaiʻi

Island, strandings were most frequent from March – August, peaking in June (Fig. 3A). West Hawai‘i showed a similar trend with March – August having the highest monthly strandings, peaking in March (Fig. 3B). East Hawai‘i showed fewer strandings per month, with one main peak in June (Fig. 3C). For both west and east Hawai‘i, the months of September, November, and December had the lowest monthly strandings, but October showed a large spike.

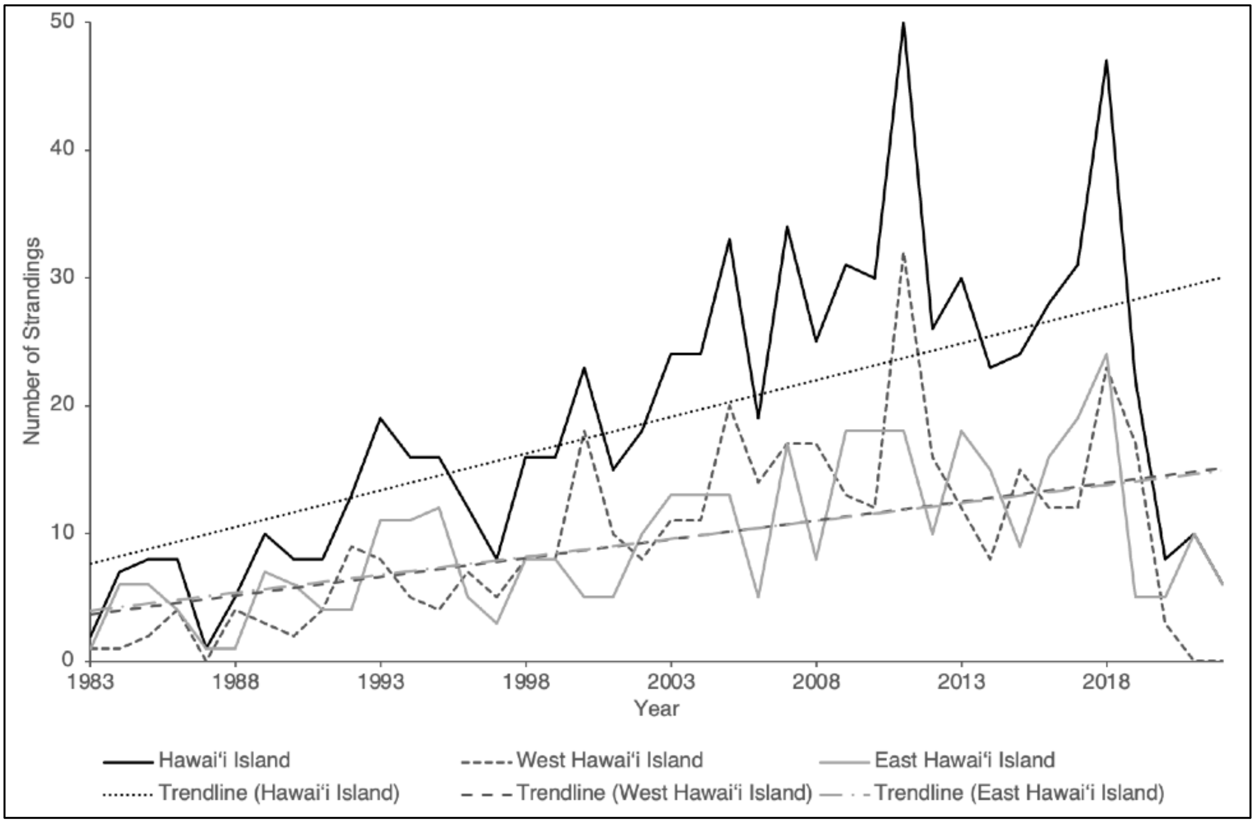
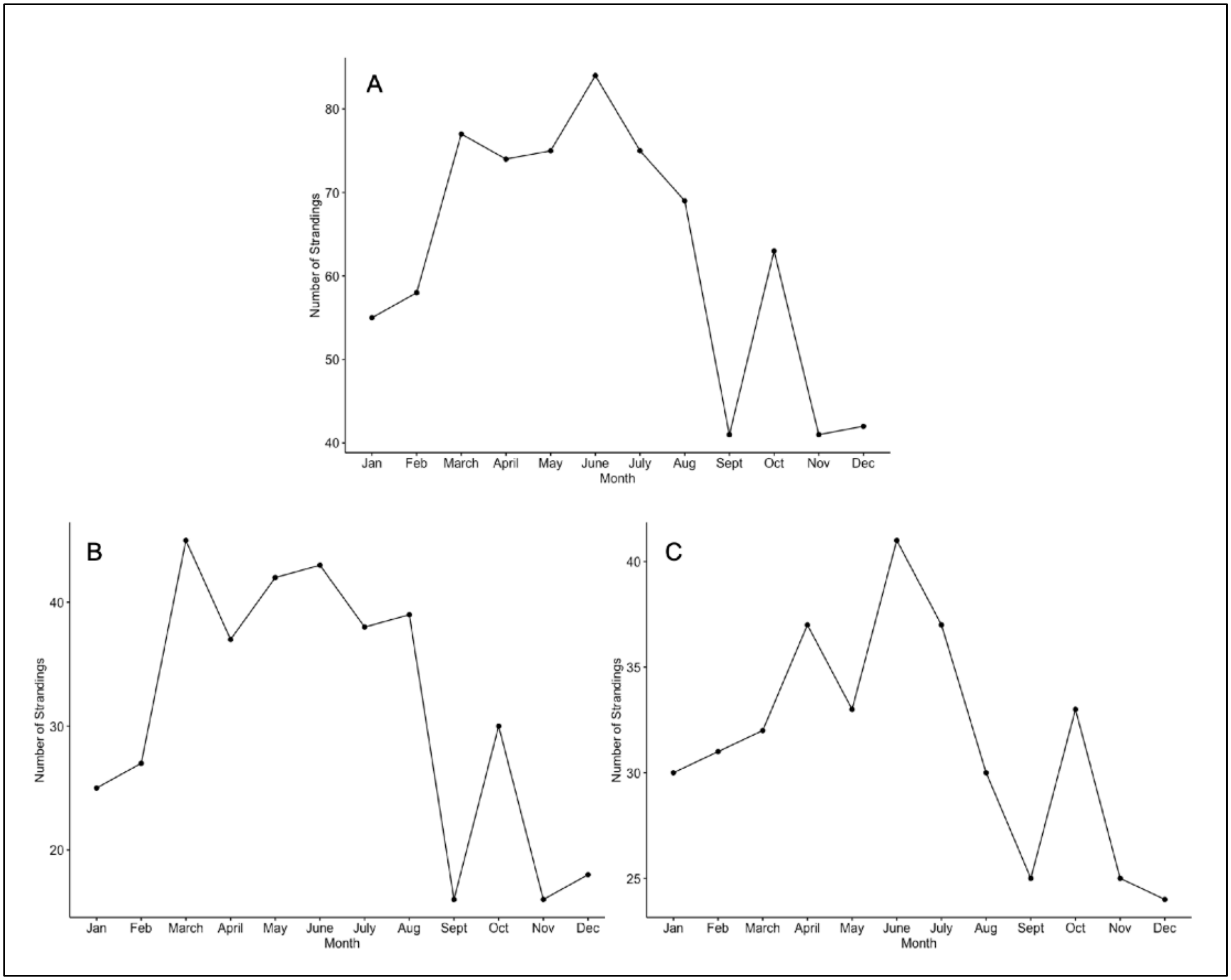


Figure 2. Number of strandings from 1983 – 2022 for all of Hawai‘i Island, west Hawai’i, and east Hawai‘i.

Figure 3. Number of strandings for all years combined by month for A) all of Hawai‘i Island, B) west Hawai‘i, and C) east Hawai‘i.



Causes of stranding

Causes of stranding were not proportional ($X^2 = 1397$, $p = < 2.2 \times 10^{-16}$). Of the 754 stranded turtles, 413 (54.8%) had no known cause of stranding that could be determined (Fig. 4A). The most common known cause of stranding was hook-and-line fishing gear, accounting for 161 (21.4%) strandings. Hook-and-line fishing gear strandings have greatly increased over the years (Fig. 5) (Fig. 6). Strandings with FP as the chief cause of stranding have remained low, however the number of strandings per year have also slightly increased (Fig. 7). A significant association was found between cause of stranding and location of stranding, with west and east Hawai‘i having different major causes ($X^2 = 69.8$, $p = 1.6 \times 10^{-12}$). Hook-and-line fishing gear was the most common cause of stranding for west (20.2%) and east (22.5%) Hawai‘i Island. However, the second most common cause of stranding in west Hawai‘i was miscellaneous (6%), and that differed from east Hawai’i where FP (14%) dominated (Fig. 4B) (Fig. 4C). For both west and east Hawai‘i, shark attack and boat impact strandings have increased over time (Fig.8) (Fig. 9). A reduction in human take strandings over time is seen on east Hawai‘i, and a peak of miscellaneous strandings is seen in 2011 on west Hawai‘i (Fig. 8) (Fig. 9).

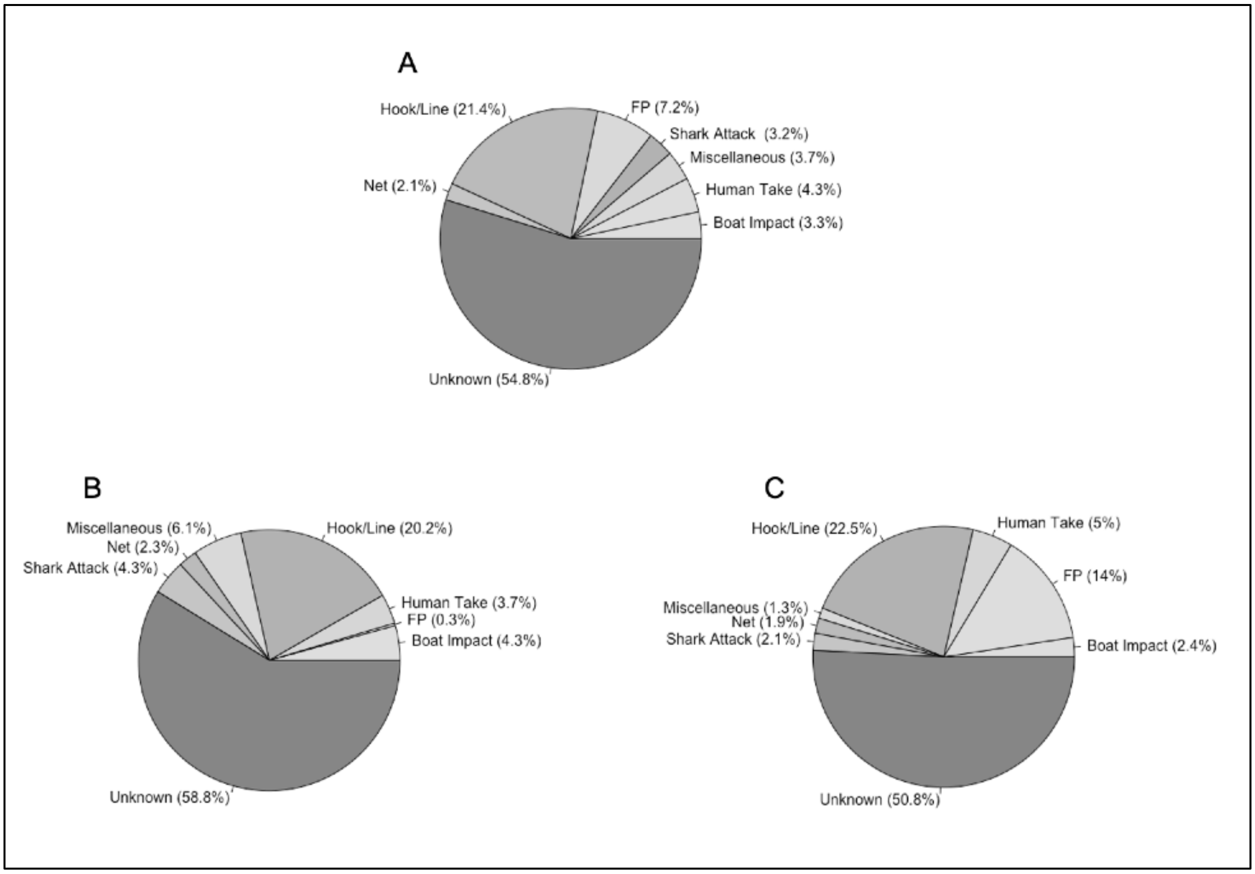


Figure 4. Causes of stranding for A) all of Hawai‘i Island, B) west Hawai‘i, and C) east Hawai‘i.

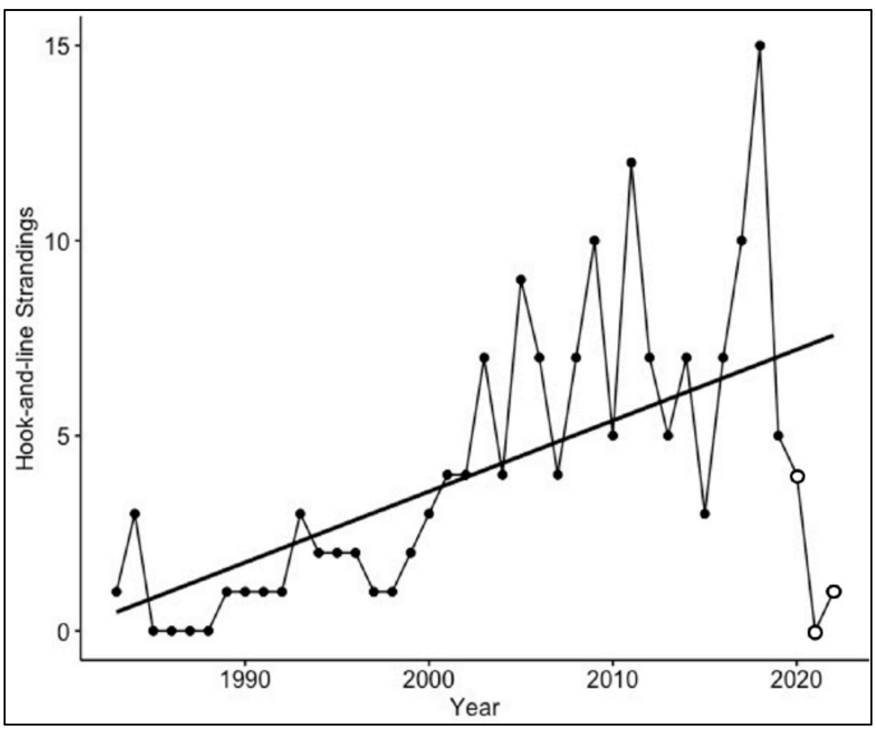


Figure 5. Number of hook-and-line fishing gear strandings from 1983-2022. Open circles from 2020-2022 indicate years stranding reports may have been interrupted by COVID-19.

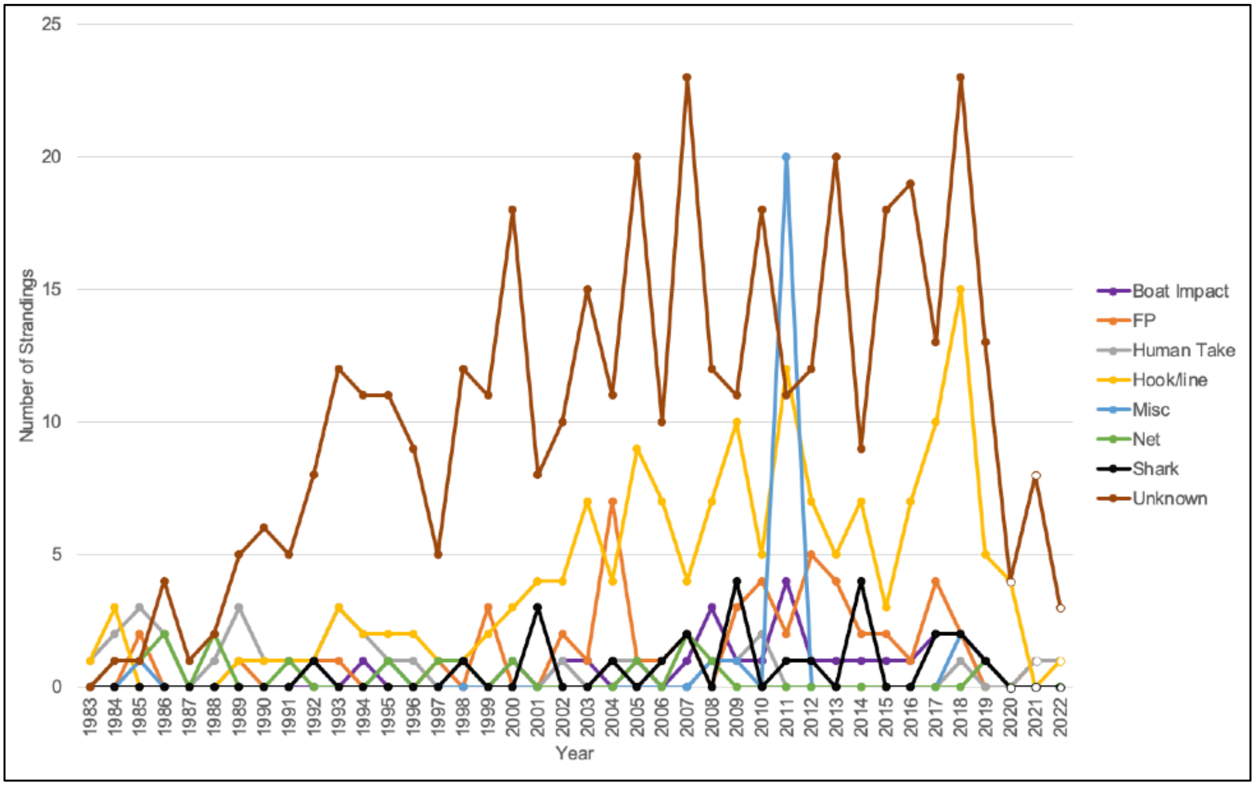


Figure 6. Number of strandings on Hawai‘i Island for each cause from 1983-2022. Open circles from 2020-2022 indicate years stranding reports may have been interrupted by COVID-19.

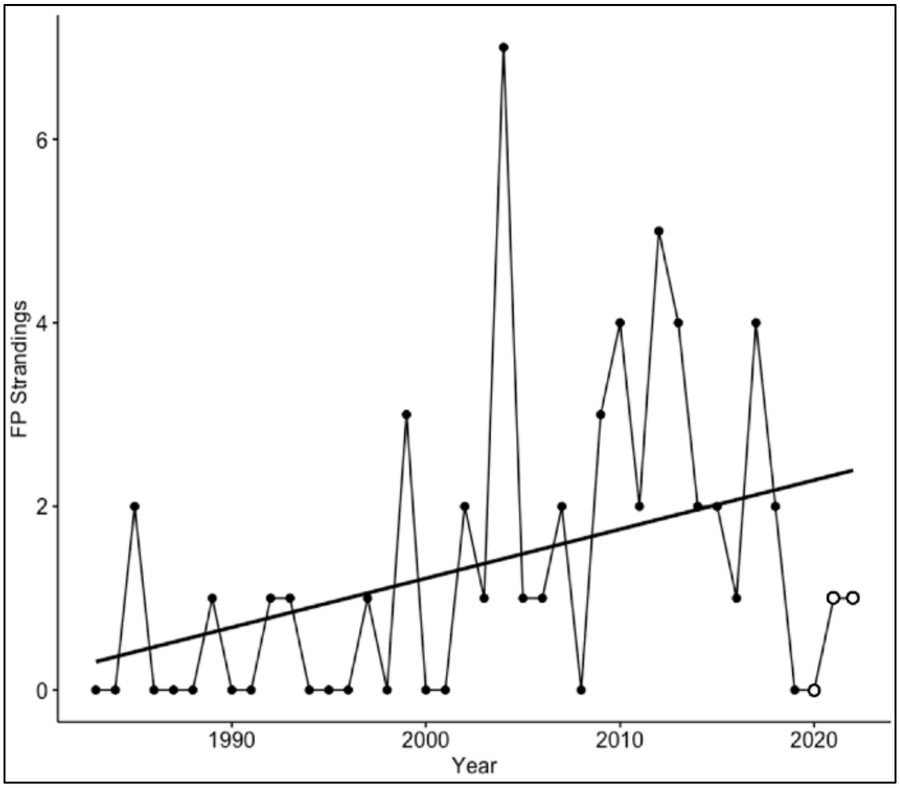


Figure 7. Number of strandings with FP as the chief cause of stranding from 1983-2022. Open circles from 2020-2022 indicate years stranding reports may have been interrupted by COVID-19.

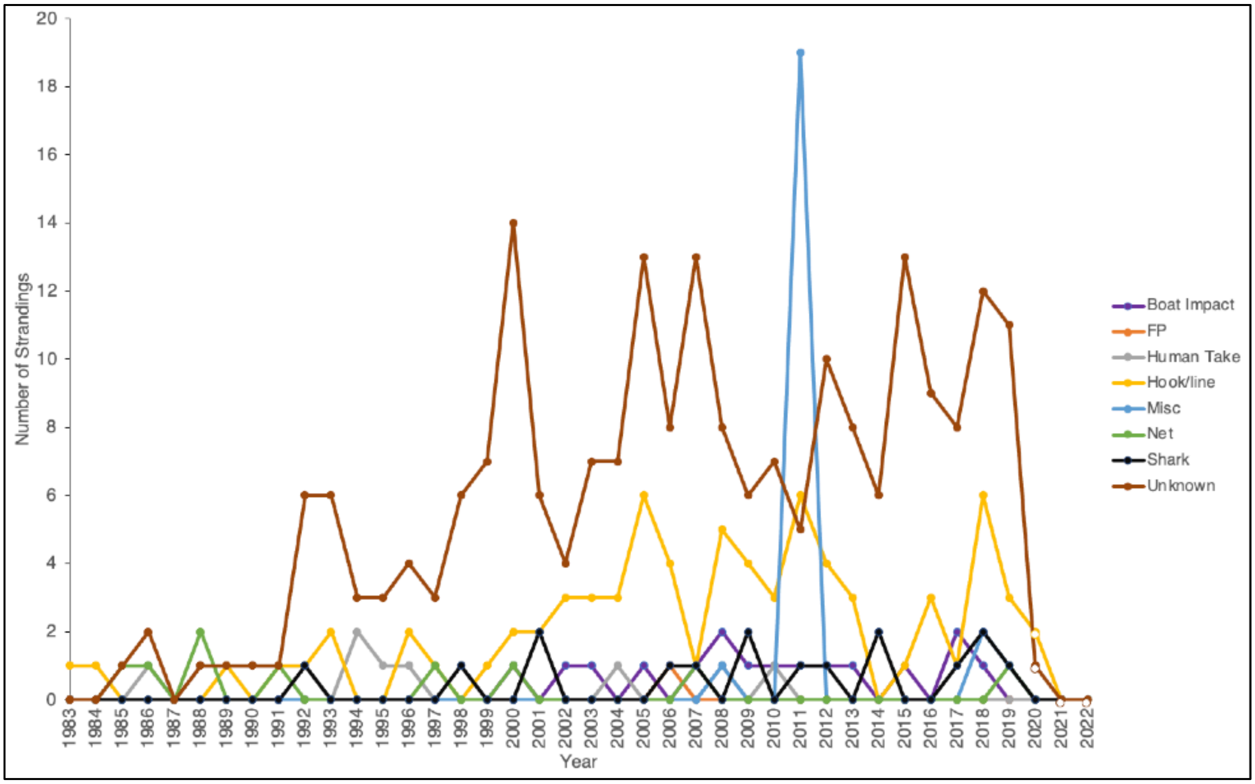


Figure 8. Number of strandings on west Hawai‘i Island for each cause from 1983-2022. Open circles from 2020-2022 indicate years stranding reports may have been interrupted by COVID-19.

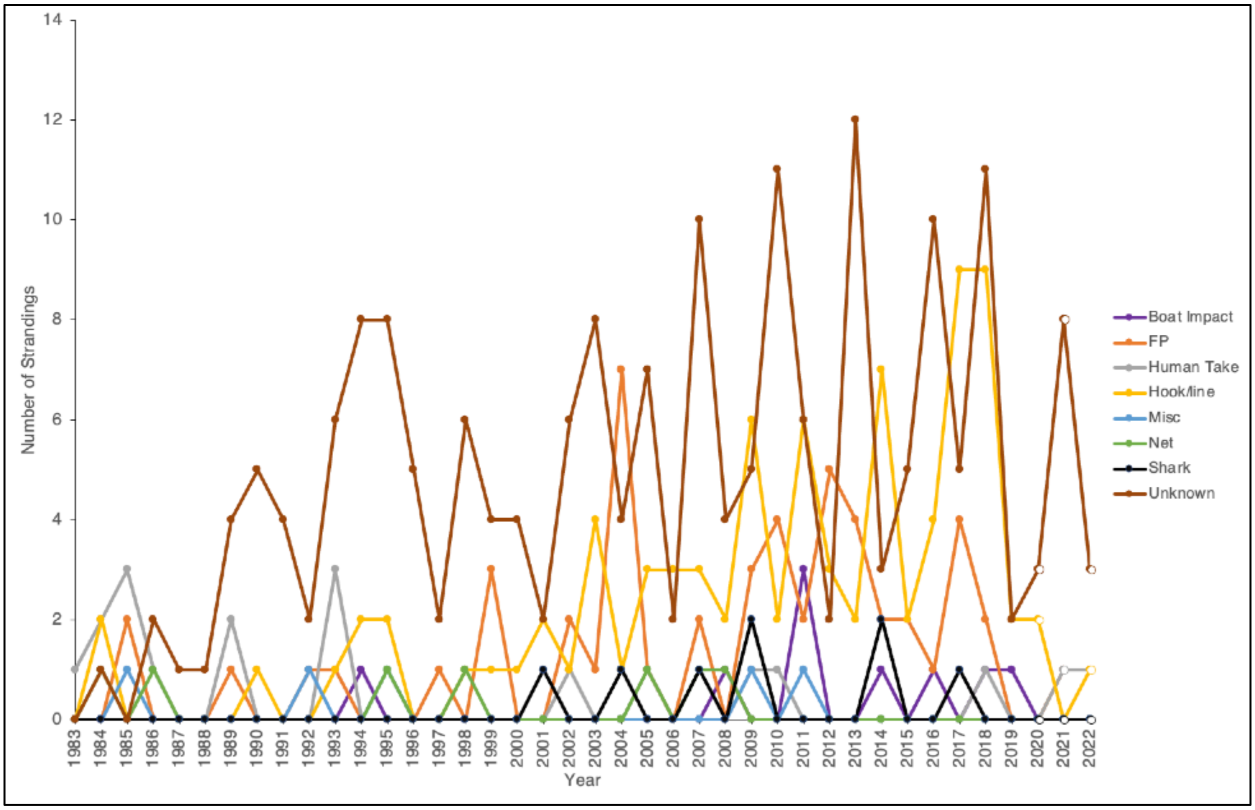


Figure 9. Number of strandings on east Hawai'i Island for each cause from 1983-2022. Open circles from 2020-2022 indicate years stranding reports may have been interrupted by COVID-19.

Size and gender

Stranded turtles on Hawai'i island ranged from 19.8 cm to 99 cm SCL, with an average of 54.8 cm SCL. Stranded turtles comprised of 381 juveniles, 88 subadults, and 19 adults. No size class could be determined in 266 turtles, as size was not always included in the stranding report. Turtles stranding in east Hawai'i (mean 58.5 cm SCL, range 19.8 cm – 99 cm) were significantly larger ($W = 37557$, $p = 3.1 \times 10^{-7}$) than those in west Hawai'i (mean 51.3 cm SCL, range 19.8 cm – 83 cm) (Fig. 10). Three main causes of stranding consisted of larger turtles: FP, boat impact, and shark attack (Fig. 11). Turtles stranded because of shark attacks had the highest average SCL value, 66 cm, among the eight causes. Gender ratio was found to be very even among the stranded turtles. 154 (20.42%) stranded turtles were female, 145 (19.23 %) were male, and 455 (60.35%) turtles could not have gender determined.

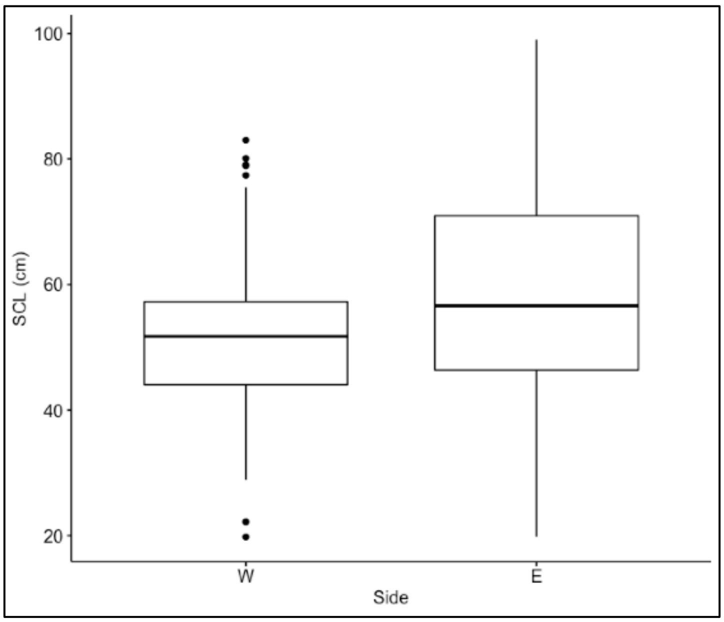


Figure 10. SCL values for turtles stranding in west (W) and east (E) Hawai‘i.

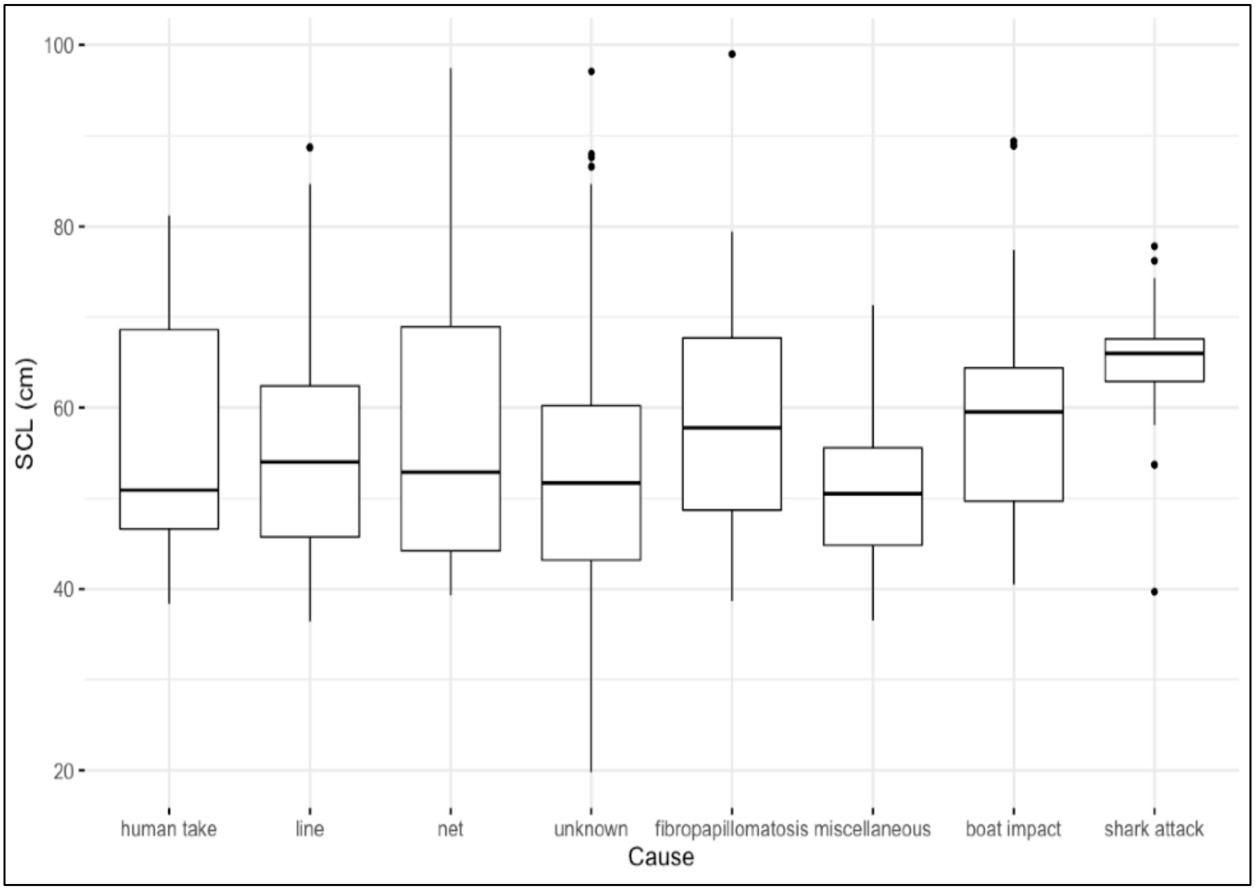


Figure 11. Causes of stranding by turtle size.

FP tumor presence/absence

Tumor presence/absence was found to not be proportional, with far more stranded turtles having no tumors present ($X^2 = 259.9$, $p = < 2.2 \times 10^{-16}$). FP mentioned in this section is strictly presence/absence, compared to the FP mentioned in the causes section where it was the chief cause of stranding. On Hawai‘i Island as a whole, 460 (61%) turtles had no tumors present, while 150 (19.9 %) turtles had tumors, and 144 (19.1 %) turtles lacked data on tumor presence or absence. Tumor presence/absence was found to be significantly associated with location of stranding, and turtles that stranded on east Hawai‘i were more likely to have tumors than turtles that stranded on west Hawai‘i ($X^2 = 198.2$, $p = < 2.2 \times 10^{-16}$) (Fig. 12).

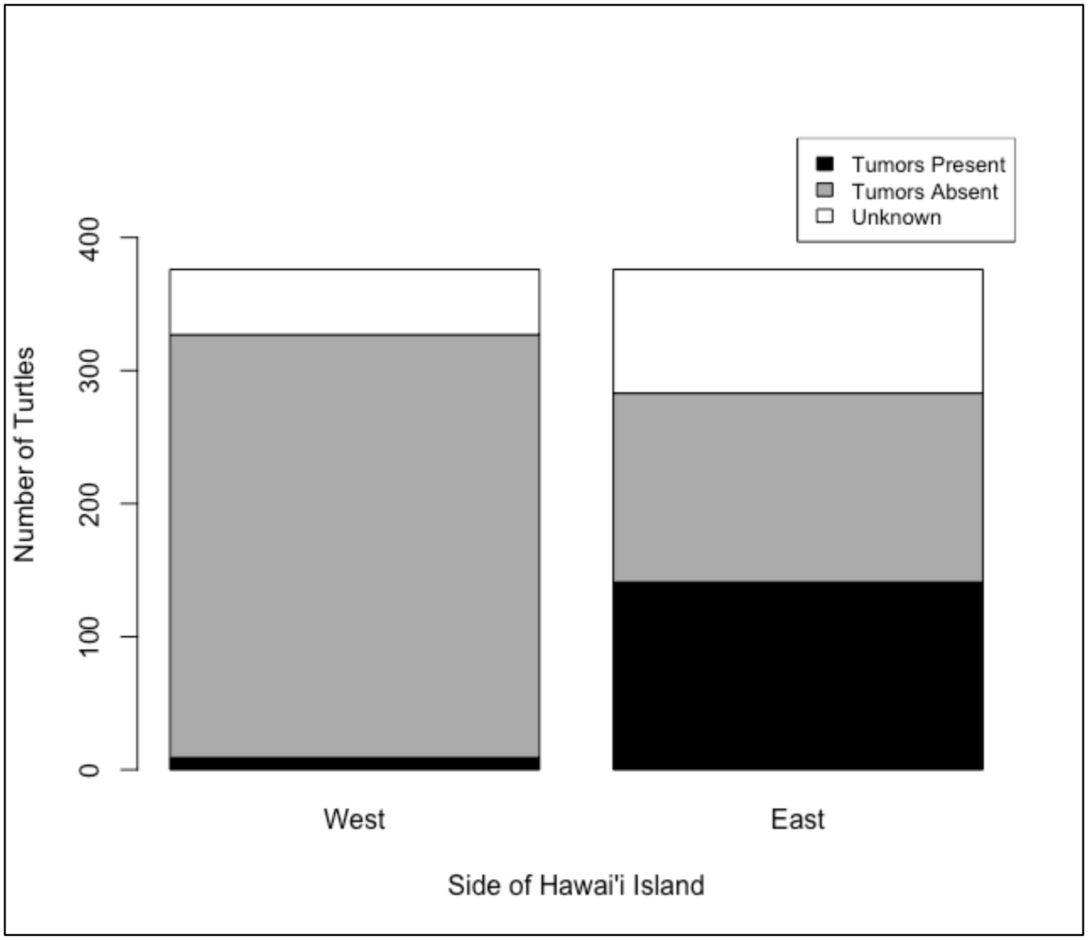


Figure 12. Number of stranded turtles with tumors present or absent for west and east Hawai‘i Island.

Stranding status

Of all the stranded turtles, 359 (47.6 %) stranded alive, 381 (50.5 %) stranded dead, and 14 (1.9 %) turtles had no stranding status reported. More turtles stranded alive than dead in the months of November – March, while more turtles stranded dead than alive in the months of April – October (Fig. 13). Stranding status was found to be significantly associated with cause (X^2 = 102.1, p = 1.9 x 10^{-15}) (Fig. 14). More turtles stranded alive than dead because of FP, hook-and-line, and miscellaneous, while boat impact, human take, shark attack, and unknown were causes more likely to result in dead stranded turtles. Net fishing gear strandings showed equal numbers of turtles that stranded alive and dead. Stranding status was also found to be significantly associated with stranding location (X^2 = 23.2, p = 9.2 x 10^{-6}). West Hawai'i had 146 (39.7 %) turtles strand alive and 222 (60.3%) strand dead, while east Hawai'i had 213 (57.3 %) turtles strand alive and 159 (42.7 %) strand dead.

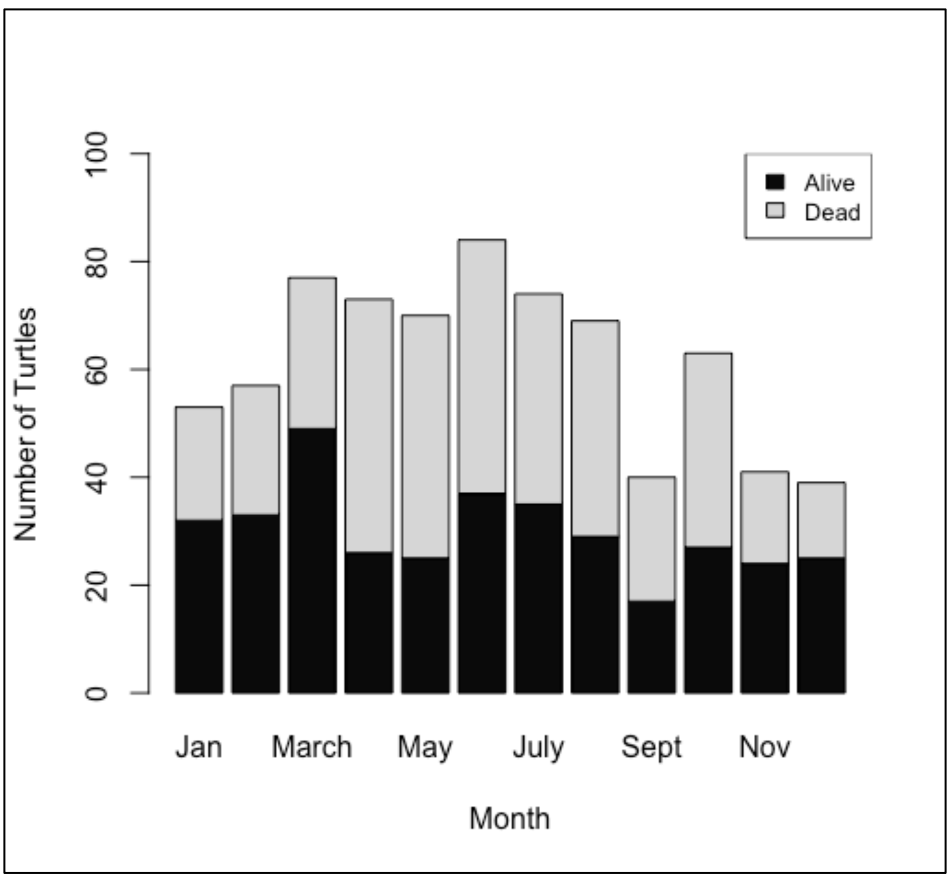


Figure 13. Stranding status by month for Hawai‘i Island.

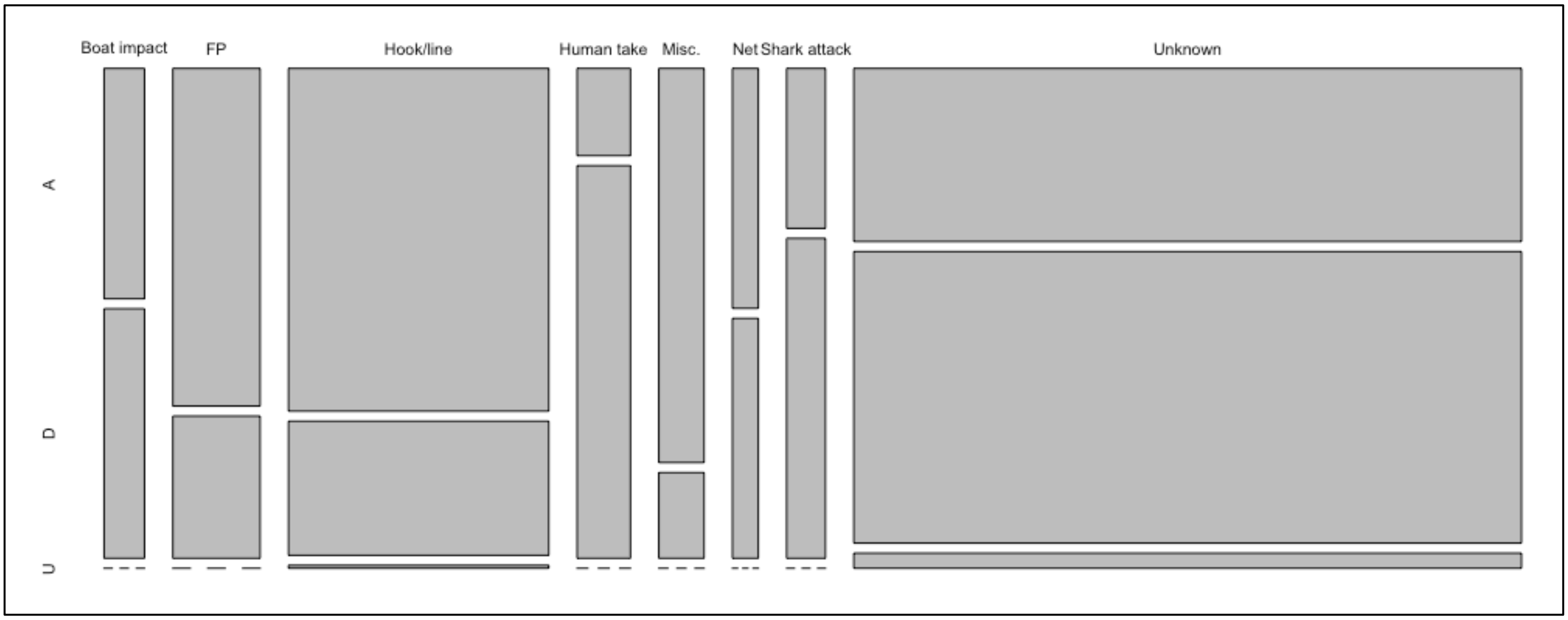


Figure 14. Stranding status (A = alive, D = dead, U = unknown) by cause for Hawai‘i Island.

DISCUSSION

Seven hundred fifty-four green turtles were recorded stranded on Hawai‘i Island from 1983-2022, which represents an unknown fraction of total strandings (Chaloupka et al. 2008). Stranding programs rely on reports from the public, thus many strandings may never be reported or may never be observed. However, strandings that are reported are probably an accurate reflection of the distribution, demographics, and causes of Hawai‘i Island strandings (Boulon 2000).

Strandings on Hawai‘i Island showed an overall increase from 1983 - 2022. Strandings since 1982 also increased for green turtles on the other main Hawaiian Islands (Chaloupka et al.

2008). Green turtle populations in the Hawaiian Islands have increased since their 1974 protection by the State of Hawaiʻi under Regulation 36 and their 1978 protection under the Endangered Species Act (Balazs & Chaloupka 2004, Bennett & Keuper-Bennett 2008), and the increase in number of individuals may explain the increase in number of strandings (Boulon 2000). Additionally, the increase in the human population on Hawaiʻi Island and more humans interacting with stranded sea turtles may influence the number of strandings reported. The increase in strandings over time may also be a result of increased awareness of strandings and response programs with more public participation occurring as the years progressed. Fluctuations in strandings occurred throughout the years but began to stabilize at about 25-30 turtles stranded per year on Hawaiʻi Island in the early 2000s. This trend was also noticed in green turtle strandings in the other main Hawaiian Islands (Chaloupka et al. 2008).

Strandings peaked in 2011 and 2018. The first peak may have been a result of the March 2011 magnitude 9.0 Tohoku earthquake off the coast of Japan that caused large waves and hazardous currents around Hawaiʻi Island (Cheung et al. 2013). The waves and currents associated with tsunamis bring marine life onshore with them and can lead to turtles washing inland. Two hawksbill turtles were reported stranded in Hawaiʻi as a result of the 2011 earthquake (Brunson et al. 2022), and a 2009 tsunami in Samoa led to 52 turtles stranding on land (Bell et al. 2011). The downward trend of strandings after 2018 is probably not because fewer turtles stranded, but because of the COVID-19 pandemic, which caused fewer people to be around Hawaiʻi Island to report strandings.

The highest green turtle strandings occurred during Hawaiʻi's spring and summer months, from March – August. This is similar to the findings on Oʻahu where green turtle strandings were highest from March – June (Chaloupka et al. 2008), and for adult hawksbills in the Hawaiian Archipelago where strandings were highest from June – September (Brunson et al. 2022). Strandings of loggerhead, green, and leatherback turtles in Brazil were highest during their austral spring and summer seasons (Monteiro et al. 2016). Strandings on Hawaiʻi Island were lowest during the months of September, November, and December, but peaked in the month of October. This same peak was seen in the 2022 green turtle strandings on Maui (Cutt et al. 2023). Oʻahu showed a similar secondary peak of strandings in September (Chaloupka et al. 2008). The trend of strandings seen in the Hawaiian Islands may indicate seasonal abundance of turtles, seasonal activity of humans, or seasonality of currents and winds (Chaloupka et al. 2008).

Hook-and-line fishing gear was the most common known cause of stranding of green turtles on Hawaiʻi Island as a whole. Fishing gear strandings have greatly increased on Hawaiʻi Island since the mid 2000s, often doubling the number of hook-and-line strandings per year that occurred in the 20 years prior. Chaloupka et al. (2008) similarly found a steady increase of hook-and-line fishing gear strandings since 1982, indicating a rise in exposure to fishing gear throughout the Hawaiian Islands. The increased population of Hawaiian green turtles since state and federal protections may also mean more interactions with fishing gear. Hawaiian green turtles are frequently reported with hooks intact and line entangled around their flippers and body. These interactions are often a result of lost and/or discarded fishing gear or fishers cutting the line when accidental hooking occurred, which illustrates the need for stronger management and preventatives (Nitta & Henderson 1993). Hook-and-line fishing gear strandings were also prevalent on Oʻahu, Maui, and Kauai, making up the second most common cause of stranding of green turtles (Chaloupka et al. 2008). Similar to the findings of the present study, fishing gear was the foremost cause of stranding for green turtles on Maui in 2022, with 81% of the total strandings showing interactions (Cutt et al. 2023). However, the number of hook-and-line strandings may be even greater than estimated. Work et al. (2015) performed necropsies (post-mortem autopsies) on stranded turtles throughout the Pacific and found that 48% of foreign body ingestion (mostly all associated with fishing gear) showed no external sign of fishing line interactions. Green turtle strandings that occurred as a result of fishing gear are prevalent around the world, including the U.S. Virgin Islands (Boulon 2000), Brazil (Guimaraes et al. 2016), Taiwan (Cheng et al. 2019), and Greece (Panagopoulos et al. 2003). Fibropapillomatosis was the second most common cause of stranding in this study, whereas Chaloupka et al. (2008) found FP to be the main cause of stranding in green turtles in O‘ahu, Maui, and Kauai.

The current study found that different sides of Hawai‘i Island had different rankings for causes of stranding. West Hawai‘i Island had a higher proportion of shark attack and boat impact strandings, while east Hawai‘i had more FP and human take strandings. Increased shark attack strandings on west Hawai‘i may be because of the larger population of tiger sharks found along the west coast (Meyer et al. 2009). Tiger sharks are well-known predators of sea turtles, and green turtles are often found in their stomach contents (Witzell 1987, Lowe et al. 1996). West Hawai‘i also has a large tourism industry, with many snorkel, manta ray, and marine mammal watching tours operating in the same coastal waters that green turtles occupy. These tours, as well as commercial vessels, frequent the many shallow bays located in west Hawai‘i that are important foraging habitats for green turtles (Fuentes et al. 2021). Increased boat presence accompanied with high vessel speeds, varying water depth, and poor water visibility can all factor into a higher proportion of boat impact strandings on the west side of the island (Fuentes et al. 2021).

The majority of green turtles that stranded on Hawaiʻi Island were juveniles. Similarly, juveniles predominated the stranded green and hawksbill turtles throughout the Hawaiian Islands (Chaloupka et al. 2008, Brunson et al. 2022). Juvenile green turtles were also the most common size class stranded in New Caledonia (Read et al. 2023), Australia (Flint et al. 2015), and Brazil (Monteiro et al. 2016). The high proportion of juveniles stranding may be a result of increased nesting populations at French Frigate Shoals leading to an increase in juveniles moving from nesting to foraging areas (Balazs & Chaloupka 2004). Juvenile turtles may be more immunologically naïve and susceptible to environmental stressors that could contribute to stranding (Flint et al. 2015).

Larger turtles stranded on east Hawaiʻi Island than west Hawaiʻi. A spatial trend in size-classes was also reported by Chaloupka et al. (2008): larger turtles stranded on Maui and Kauai than on Oʻahu. An explanation for the size-class differences in stranded turtles on Hawaiʻi Island is that stranded turtles with the highest SCL values were the result of shark attacks. Bornatowski et al. (2012) found that the probability that a green turtle in Brazil stranded with a shark bite increased with size, and Chaloupka et al. (2008) reported the same trend for green turtles in the main Hawaiian Islands. Smaller green turtles are also frequently attacked by sharks but may be completely consumed and thus do not wash ashore after such event.

There was no gender-bias of stranded green turtles on Hawaiʻi Island: male and female strandings occurred with a 1:1.06 ratio. The lack of a gender-bias for green turtles was also shown in the main Hawaiian Islands (Work et al. 2004, Chaloupka et al. 2008). The present and prior studies are consistent with the 1:1 sex ratio of Hawaiian green turtles found by Wibbels et al. (1993). Unlike in the Hawaiian Islands, many green turtle populations around the world appear to have more females than males (Flint et al. 2010, Cheng et al. 2019, Read et al. 2023). Clutches of sea turtles are sensitive to temperature change, and an increase in the temperature during incubation can drastically change sex ratios of nests, leading to clutches of all females. As temperatures continue to rise as a result of climate change, the Hawaiian population of green turtles may eventually see the same skew seen in other locations around the world (Hawkes et al. 2009).

More than 60% of the stranded turtles on Hawaiʻi Island had no tumors indicative of FP. This percentage may vary slightly as not every turtle in this study underwent a necropsy and some might have had internal tumors with no visible external tumors. The reduction of incidence of FP has been documented previously in Hawaiian green turtles. Twenty-one of 66 turtles observed with tumors in one summer were then seen later with no tumors (Bennett et al. 1999). The low population of turtles with FP on Hawaiʻi Island is consistent with the 2022 stranding report for green turtles on Maui, in which only one case of FP was reported (Cutt et al. 2023).

Turtles were more likely to have FP on east Hawaiʻi Island, whereas FP was very rare on green turtles that stranded on west Hawaiʻi Island. The west (Kona) coast of Hawaiʻi Island had no diagnosed cases of FP for many of the years that FP was prevalent in the other Hawaiian Islands (Balazs 1991, Aguirre & Balazs 2000, Work et al. 2001). In Florida, turtles with tumors are more likely to become entangled in fishing line, thus the higher percentage of hook-and-line strandings that occurred on east Hawaiʻi may be a result of higher FP presence (Foley et al. 2005). However, Chaloupka et al. (2008) found no correlation between FP and fishing gear strandings in the other main Hawaiian Islands. Similar to the spatial variation in FP infection on Hawai'i Island, FP was more often found in Oahu and Maui than on Kauai (Chaloupka et al. 2008). Green turtles that stranded on the western (Gulf) coast of Florida (51.9%) were more likely to have tumors than turtles that stranded on the eastern (Atlantic) coast (11.9%) (Foley et al. 2005). In Australia, FP varied in prevalence from 0 to 11.6% in 15 sites all along the Queensland coast (Jones et al. 2022). A variety of factors have been hypothesized for the varying prevalence of FP in different locations and may be the reason for the contrasting FP abundance on west and east Hawaiʻi Island. For example, FP in Florida was greatest in areas with the greatest habitat degradation and pollution, most shallow water areas, and lowest wave-energy level, indicating that one or more of these conditions may affect FP (Foley et al. 2005). In Brazil, highly urbanized areas have a higher FP prevalence than lightly urbanized areas (Bastos et al. 2022). Additionally, FP may be related to water temperature, with higher water temperatures correlated with greater FP prevalence (Manes et al. 2022). Perhaps the greatest factor that could contribute to the absence of FP on west Hawai'i Island is the precipitation pattern on the leeward side of the island. The windward (east) side, experiences abundant, consistent rainfall and has large rivers and many streams (Juvik & Juvik 1998). Heavy rain may bring more land-based pollutants to rivers, and the discharge from these rivers located in urbanized areas may disrupt the immune system of green turtles, making them more susceptible to FP (Manes et al. 2022).

The number of turtles that stranded alive (359) vs dead (381) on Hawaiʻi Island showed little difference, which stands out from the Oʻahu, Maui, and Kauai data that showed 75% of green turtles stranded dead (Chaloupka et al. 2008). In the present study, stranding status was found to vary temporally, by cause, and spatially. Green turtles were more likely to strand alive in the winter months (November – March), and dead in the summer months (April – October). Additionally, more turtles stranded dead than alive because of boat impacts, human take, and shark attacks, similar to other Hawaiian Islands, where boat impact and shark attack were the hazards most likely to result in a dead turtle (Chaloupka et al. 2008). Shark attacks often cause the loss of appendages and boat impacts usually cause damage to the head, appendages, and/or the carapace, which would lower survival rate. The present study found that turtles that stranded as a result of FP were more likely to strand alive than dead, in contrast to the findings of Chaloupka et al. (2008). More turtles stranded dead than alive on west Hawaiʻi Island and more turtles stranded alive than dead on east Hawaiʻi Island, probably because shark attacks and boat impacts are more common on west Hawaiʻi Island. Chaloupka et al. (2008) found that the probability of a dead turtle stranding decreased with increasing turtle size, which supports the findings of larger turtles and more turtles stranding alive than dead on east Hawaiʻi Island.

Despite the large percentage of unknown causes of stranding, this long-term data set provides important information on Hawaiʻi Island green turtle strandings. The increasing incidence of hook-and-line fishing gear contributing to strandings highlights the need for mitigation to be focused on green turtle interactions with fisheries.

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