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Twenty-three Years of Sea Turtle Stranding/ bycatch Research in Taiwan

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Coastal sea turtle stranding and bycatch are common phenomena worldwide and have received more attention in recent years. They are caused by both natural and anthropogenic factors. One thousand and seventy-two turtles were reported to be victims of these phenomena from March 1997 to November 2019 in Taiwan. Number of stranding/bycatch were variable and infrequent for the first 14 years, but increased each year after 2012 and peaked in 2019 with 217 cases. Most turtles were juveniles to subadults. All five of Taiwan's species were reported in stranding and bycatch records, and the green turtle was reported the most common. The main reported seasons lasted from winter to spring, when the weather changes dramatically. The sex ratio (female: male) ranged from 7 in the hawksbill turtle to 0.7 in the olive ridley, with an average of 2.4 for all species. Green turtles were the dominant stranded species, and more loggerhead turtles were by-caught. The hotspots were the towns of Dougou and Tochen in Yilan County, and Gongliao District in New Taipei City, located in NE coast of Taiwan respectively. Stranding was the more common of the two phenomena reported, and 80% of all stranded turtles were subadult green turtles. Eighty percent of all stranded/bycaught turtles were dead. Pond-nets were the fishing gear that accounted for the most bycatch, and captured mainly living young and subadult green turtles as well as subadult loggerhead turtles. The hotspots for bycatch were the towns of Dongou and Tochen in Yilan County. The Coast Guard and concerned citizen were the main sources of reports. This is the first study to analyze the long-term stranding/bycatch of sea turtles in Taiwan.

Key words: Stranding and bycatch, Green turtle, Temporal and spatial distribution, Report type, Bycatch type, Gender, Juvenile to subadult turtles.

BACKGROUND

Coastal sea turtle stranding/bycatch is a common phenomenon worldwide and a burning issue in marine conservation (Hamann et al. 2010). It can be caused by anthropogenic activities such as debris ingestion (Schuyler et al. 2014 2015; Stacy et al. 2018), coastal pollution (Barbieri 2009; Clucky et al. 2017; Gardner et al. 2006), boat strike (Denkinger et al. 2013; Lester et al. 2013), fishery bycatch (Koch et al. 2013; Moriya 2010; Nicolau et al. 2016; Tomás et al. 2008), and ghost net entanglement (Wilcox et al. 2013 2014). It can also be caused by natural occurrences such as disease (Orós et al. 2005), weather conditions (*e.g.*, cold stunned, extreme weather) (Flint et al. 2017; Innis et al. 2007; Witherington and Ehrhart 1989), and shark bite (Bornatowski et al. 2012; Poli et al. 2014; Chaloupka et al. 2008). Both factors can result in the turtle either being stranded ashore or drifting in the oceans (Flint et al. 2015; Poli et al. 2014). Stranded and bycaught turtles will die unless they are rescue and rehabilitated. In order to improve the viability of live turtles and determine the possible causes of death, it is necessary to strengthen the sea turtle stranding/bycatch network (Baker et al. 2015; Ullmann and Stachowitsch 2015).

The stranding/bycatch network can provide

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information such as species and size compositions, temporal and spatial distribution, stranding hotspots, gender, and stranding types. Long-term records thus provide important demography information on sea turtles in the nearshore waters, and help develop management strategies and assess the impact of global climate change (Flint et al. 2017; Still et al. 2005; Stacy et al. 2018).

There are five species of sea turtles in Taiwan: green, loggerhead, hawksbill, olive ridley, and leatherback (Chen and Cheng 1995). All can be found stranded or by-caught along the coast. The purpose of this study was to analyze the data collected from stranding and bycatch in Taiwan from March 1997 to November 2019 to determine the trends and possible causes of stranding/bycatch.

MATERIALS AND METHODS

Sample collection and data processing

Upon received a phone call from Coast Guards, concerned citizens or county official regarding turtle stranding or by-catchment, photos of the turtle were collected for species identification and body condition assessment. The curved carapace length (CCL) was also used as an indication for size. Furthermore, the stranding and bycatch site and type of stranding (drift, stranded ashore, fisheries bycatch, etc.) were also requested. Case reports were separated into fisheries by-catch, drift, stranded and miscellaneous. Drift is defined as a turtle, dead or alive, floating on the surface water and drifting passively. Stranded is defined as a turtle found on the seaside, and if alive, motionless. Fisheries bycatch is defined as a turtle caught unintentionally by a fishing gear. Miscellaneous was defined here by other methods, such as coastal fish ponds, seized during illegal trading, etc. Due to the fact that sea turtles can be bycaught by more than one gear type, fisheries by-catch is further separated into pond-net, drift net, trawl, hooks/longlines, and undetermined gear types, based on the major coastal fishing gears in Taiwan. The hook/longline is used for both sport fishing and commercial longline fishing, and represented here as line. The unidentified type includes those that failed to report the type of fishing gear. For turtles that died or starting decomposing (*e.g.*, lost its head or flipper, swollen, or remains of carapace and bone), the person who reported the case, the Coast Guard in most cases, was asked to take photos, measure the body length (curved carapace length), and bury the body at the scene. When the carcass appeared intact, even with minor injuries, a team from the corresponding author's laboratory was sent to perform necropsy at the scene to determine the possible causes of death. We also measured the CCL and determined the gender using the gross morphology of the sex organ with trained personnel. The maturity status was determined by the external morphology of the tail and overall size described in Eckert (1993). For live turtles, when the animal was in good health and had excellent body conditions – such as good gross morphology, minor injuries, vigorous responses (such as flippers beating, crawling, diving, response to eye poke, etc.), photos from whole body, front, rear, and both sides were taken, body length was measured, and a biopsy of the skin tissue was sampled, stored in an ethanol preserve solution for a population genetic study. The turtle was released back to the sea at the same location where it was found under the supervision of the county authorities. When a turtle was determined to not be in excellent condition, i.e., it was injured and did not respond to body contact, it was sent to veterinarians for clinical inspection. Turtle rehabilitation was carried out under the cooperation of the research team and veterinarians. If the turtle died during the rehabilitation, a necropsy was carried out by the veterinarians. Turtles that were rehabilitated were released back into the sea under the supervision of the same county authorities.

The treatment for reported stranding in Taiwan was divided in the northern and southern regions. The northern region ranged Hualien County in eastern Taiwan to Miaoli or even Taichung County in western Taiwan, and the southern region ranged from Taitung County in eastern Taiwan to Changhua County in western Taiwan (Fig. 1). The corresponding authors' laboratory – Marine Ecology and Conservation laboratory of the National Taiwan Ocean University – is responsible for the stranding/bycatch in northern Taiwan, and the National Museum of Marine Biology and Aquarium in Kenting region, Pintung County, Taiwan is responsible for the reports in southern Taiwan. In northern Taiwan, the research team carried out both necropsy and rehabilitation works. We cooperated with veterinarians from the School of Veterinary Medicine, National Taiwan University to rehabilitate the sea turtles. In southern Taiwan, only the living turtles are accepted for rehabilitation. Dead turtles were buried at the scene. However, when analyzing the reported data for the whole of Taiwan, the reports from southern region were also included.

Statistical analysis

Two-way ANOVA was used to determine the differences in gear or report type for each species on a yearly basis. One-way ANOVA was used to determine the yearly differences in gear or report type among five

species (Sokal and Rholf 1982).

RESULTS

Reports

A total of 1072 turtles from all around Taiwan were reported from March 1997 to November 2019. The yearly variation showed that (Fig. 2) the number of reports were variable and low over the first 14 years (*i.e.*, from 0 to fewer than 5 reports in some years), then increased sharply after 2012 until peaking in 2019 at 217 cases. All five species were reported. The most common species was the green turtle (83%), followed by the hawksbills (7%), loggerheads (7%), olive ridleys (2%) and leatherbacks (0.6%; Fig. 3).

Size

The majority of turtles ranged from 35 to 55 cm CCL, representing juveniles to subadults (Fig. 4). The majority of green turtles were also 35 to 55 cm CCL, representing juveniles to subadults. There was no shift in range between the first 10 years (1997 to 2007) and the last 10 years (2009 to 2019), except the size range was wider for the last 10 years (25.5 to 110 cm for the first 10 years, 4.5 to 125 cm for the last 10 years). The majority of hawksbill turtles were 20-35 cm CCL and all were young juveniles. There was also no shift in range between the first 10 years (1997 to 2007) and the last 10 years (2009 to 2019), except the size range was wider for the last 10 years (28 to 54 cm for the first 10 years, 8.8 to 84 cm for the last 10 years). The loggerhead turtles, on the other hand, ranged from 65-85 cm CCL, and included only subadults. Again, there was also no shift in range between the first 10 years (1997 to 2007) and the last 10 years (2009 to 2019), except the size range was wider for the last 10 years (69 to 86 cm for the first 10 years, 51.5 to 110 cm for the last 10 years). The numbers of olive ridley and leatherback individuals were too low to determine major size ranges (Fig. 4).

Sex ratio

Due to the fact that no necropsy was carried out in southern region of Taiwan, the sex ratio of sea turtles was determined only based on the data from northern Taiwan. The results showed that the sex ratio (female: male) ranged from 7 in hawksbills to 0.7 in

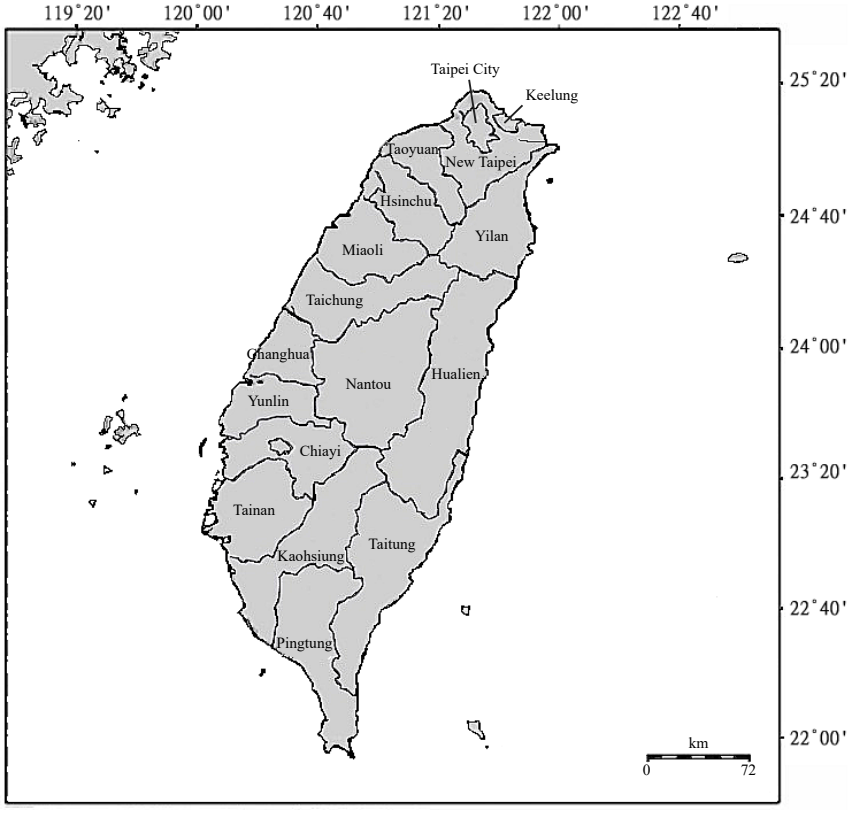

Fig. 1. Map of Taiwan marked with the location of each county. The two thick lines shows the separate between the surveys of northern from southern Taiwan. See text for explanation.

olive ridleys (Table 1). The sex ratio was not available for the leatherback turtle because only one individual was collected. The very high and very low ratios might relate to the low sample size ($n < 7$).

Season

Over the 23 years the study was conduct, 9-12% of the total records were made from December to April and 4-8% were made from May to November, suggesting the majority of stranded/bycatch turtles were reported during the seasons when the weather changes dramatically (Fig. 5). The average air temperature for the time period ranged from 18°C in January to 21°C in March. Air temperature was 20°C in December and 23°C in April. Average air temperature ranged from 23 to 28°C from May to November (Central Weather Bureau 1997 to 2019). Green, hawksbill, and loggerhead turtle stranding/bycatch were most prevalent from December to April, which is close to the peak months of

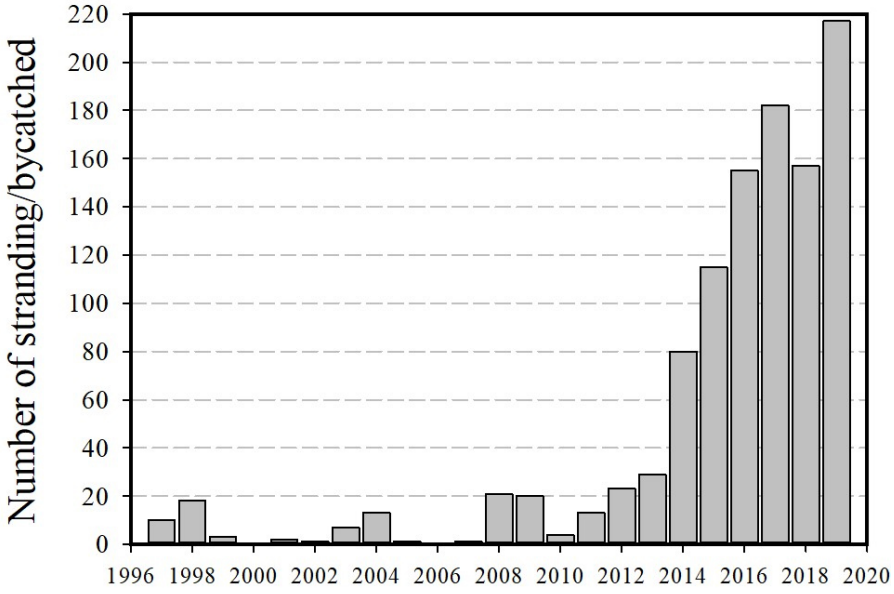

Fig. 2 Number of yearly stranded/bycaught turtles from 1997 to 2019 in Taiwan.

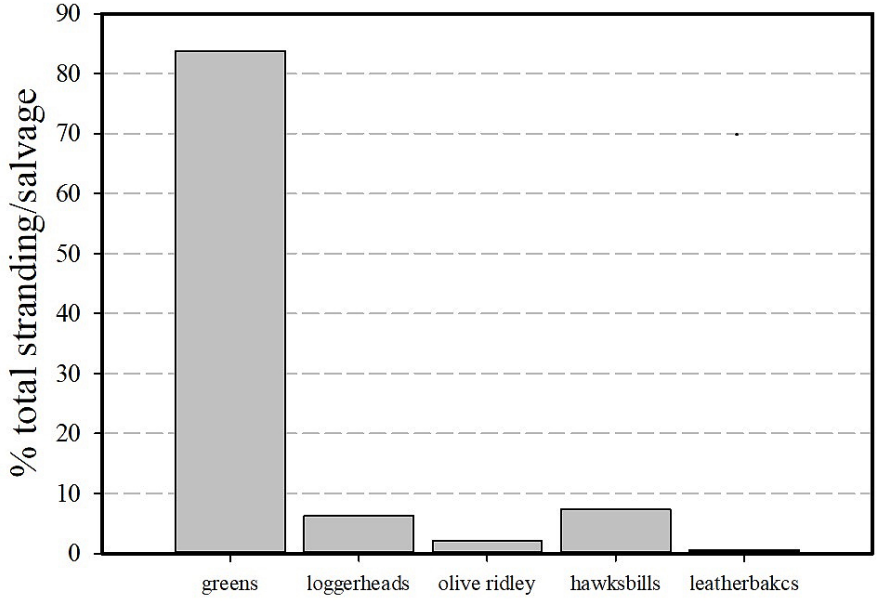

Fig. 3 Percentage of each species of sea turtle in the total stranding/bycatch records.

stranding/bycatch for these turtles. The number of olive ridley and leatherback turtles was too low to determine their major stranding seasons.

Spatial distribution

Sea turtles were found stranded/bycaught in every coastal county in Taiwan. The Northern coast includes Keelung City, New Taipei City, Taoyuan County, Hsinchu County, Miaoli County. The northeast coast includes Yilan County. The eastern coast includes Hualien County and Taitung County. The west coast includes Taichung County, Yunlin County, Chiayi County. The southern coast includes Tainan County, Kaohsiung City and Pingtung County. The outlying island in the Taiwan Strait includes Penghu County, Kinmen County and Lianjang County. Of all the counties, New Taipei City and Yilan County had the highest records (Fig. 6). Green turtles were most abundant in New Taipei City, Yilan County and Penghu County. The most loggerhead turtles were found in Yilan County. Most hawksbill turtles were found in Penghu County, while the records of the olive ridleys and leatherbacks were too low to determine the highest record sites (Fig. 6).

Strandings, drift and by-catch in fishrey activities

This study identified four major types of reports: bycatch, drift, stranding, and miscellaneous. Among four types, stranding was the most abundant (57%), followed by bycatch (28%), then drift (13%), and miscellaneous (6%, Fig. 7). One-way ANOVA showed that more reports were from green than from olive ridley turtles (p = 0.007). Eighty percent of all reports were carcasses. Ninety-three percent of the stranded individuals were immature (35 to 55 cm CCL) female green turtles. The main stranding season was from winter to spring (December to April). The highest record

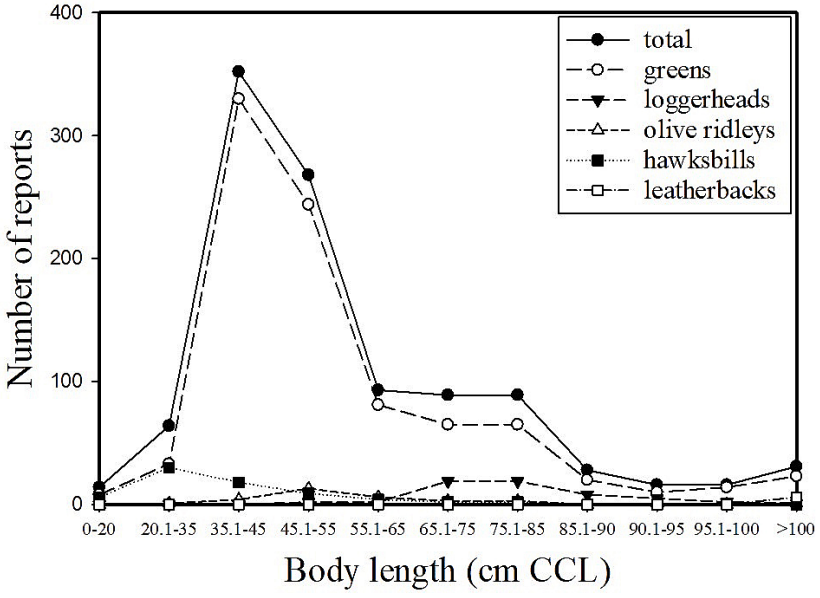

Fig. 4 Number of stranded/salvaged turtles of different size range of the total and of each species from 1997 to 2019 in Taiwan.

Table 1. Sex ratio (female: male) of the five species of sea turtle

Species	Sex ratio
Green	2.3
Loggerheads	4
Olive ridleys	0.7
Hawksbills	7
Leatherbacks	NA*
Total	2.4

*: No data available.

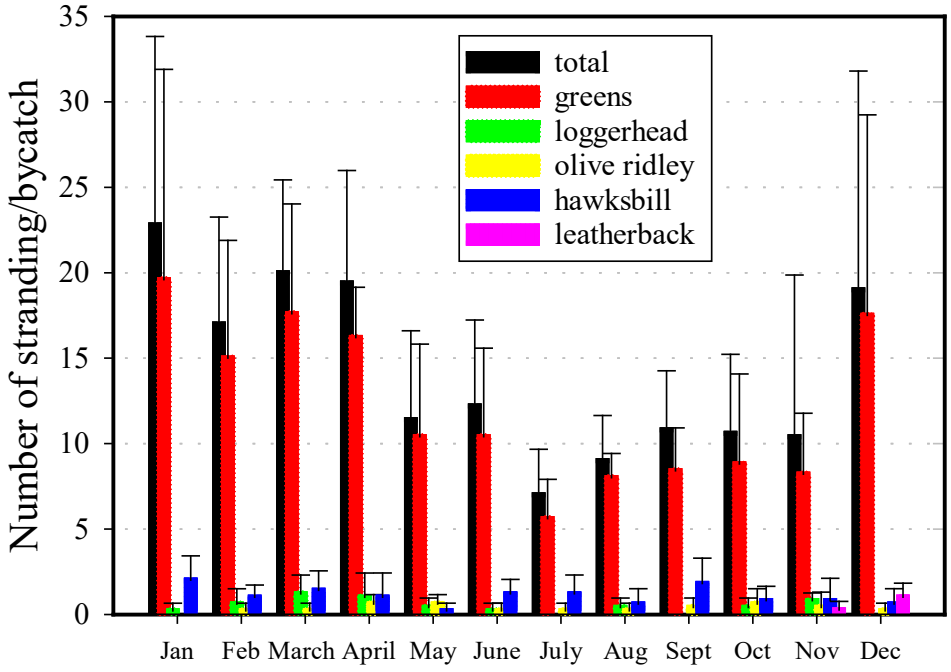

Fig. 5 Monthly changes in stranding/bycatch turtles from 2015 to 2019 in Taiwan. Data of total and each species showed in mean and standard deviation, and $n = 60$.

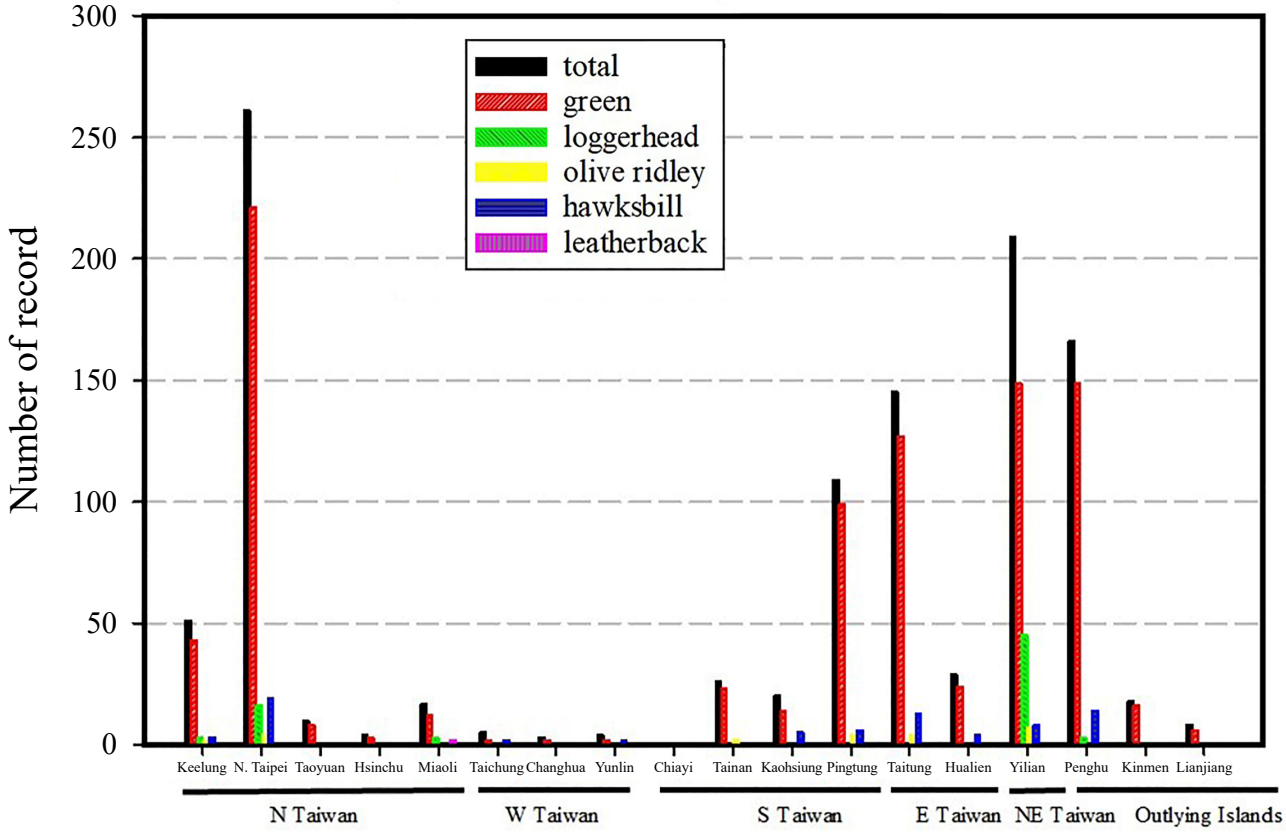

Fig. 6. Number of stranded/bycaught turtles in different counties of the total and of each species from 1997 to 2019 in Taiwan. The region of each county belongs are underlined with thick line.

was in New Taipei City (25%), with the hotspot in Gongliao District (Fig. 8), located at the base of Mo-O Bay, northeast corner of Taiwan. For the drift report, 74% were immature (35 to 55 cm CCL) female green turtles and 57% were carcasses. The most reports were made in December and mainly occurred in New Taipei City, northern Taiwan and Penghu County, the outlying island in the Taiwan Strait.

Two-way ANOVA on different report types and different years (Table S1) showed that, for green turtles, the most reports were from stranding ($p < 0.01$), there were more reports from 2019 than from 1997 and 1999 to 2012 ($p < 0.01$). For loggerhead turtle, more reports were from by-catch than from drift and miscellaneous ($p < 0.001$), and more report from 2019 than from 1997, 1999, 2000, 2001, 2006 and 2007 ($p = 0.037$). For olive ridley turtles, there was no difference among report types ($p = 0.05$), there were more reports from 2019 than from 1997 to 2007, 2009 to 2013 and 2015 ($p < 0.001$). For hawksbill turtle, the most reports were from stranding ($p = 0.003$). Even though there was a significant difference among years ($p = 0.005$), there was no difference among report types or years. No difference in both report types and among years for leatherback turtles ($p = 0.265$ for report type, $p = 0.549$ for years). One-way ANOVA among different species on the same report type showed that, for fishery bycatch, except loggerhead turtle, reports from green turtle were highest, and the loggerhead turtle was higher than the leatherback turtle (H = 42.948, *d.f.* = 4, $p < 0.001$). For the drift type, the green turtle was higher than the leatherback turtle (H = 17.905, *d.f.* = 4, $p = 0.003$). For the stranded type, the green turtle was higher than the olive ridley and leatherback turtles (H = 21.935, *d.f.* = 4, $p < 0.001$). For the miscellaneous type, there were significant differences among species. However, no difference was detected between any two species (H = 14.552, *d.f.* = 4, $p = 0.006$).

Bycatch gear types

Five major coastal fishing gear types were identified: pond nets, driftnets, trawlers, line, and undetermined. Among them, pond nets were the most prevalent, accounting for 49% of gear types, followed by the gillnet (12%) (Fig. 9). The other two fishing gears accounted for 6% or less of the reports. Undetermined contributed 28% of fishery bycatchment.

Ninety-eight percent of pond net bycatch consisted of green (73%) and loggerhead (25%) turtles. All bycatch turtles were alive and most were immature. Two peak size ranges were identified: 35 to 45 cm CCL (juvenile) and 75 to 85 cm CCL (subadult). Eighty-five percent of driftnet bycatch consisted of green turtles, of which 70% were alive. All gillnet-caught turtles were immature (35 to 55 cm CCL).

Two-way ANOVA on different gear types and years showed that (Table S2), for green turtles, more

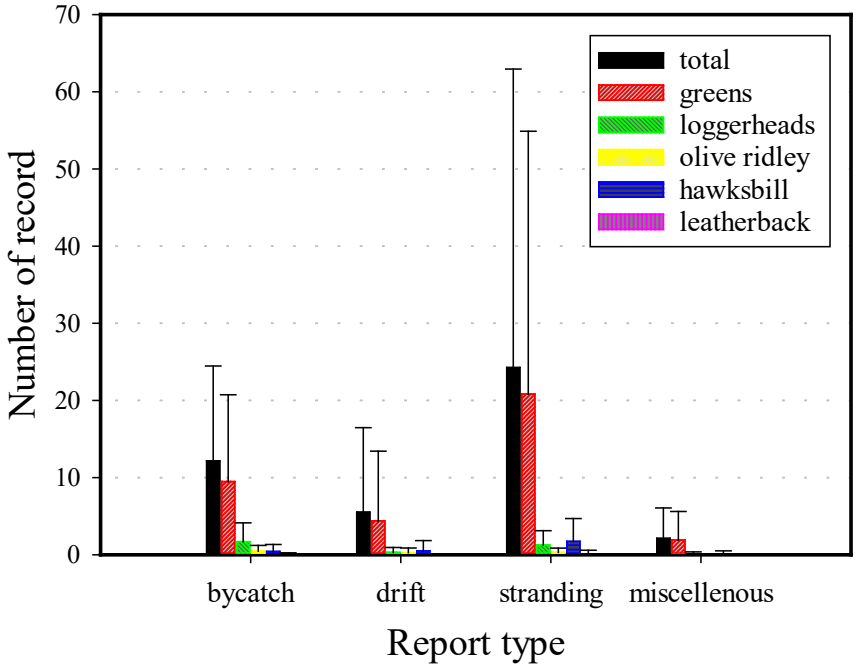

Fig. 7. Number of the total and each species of sea turtle for each report type in Taiwan from 1997 to 2019. Data on total and each species showed in mean and standard deviation, and $n = 23$.

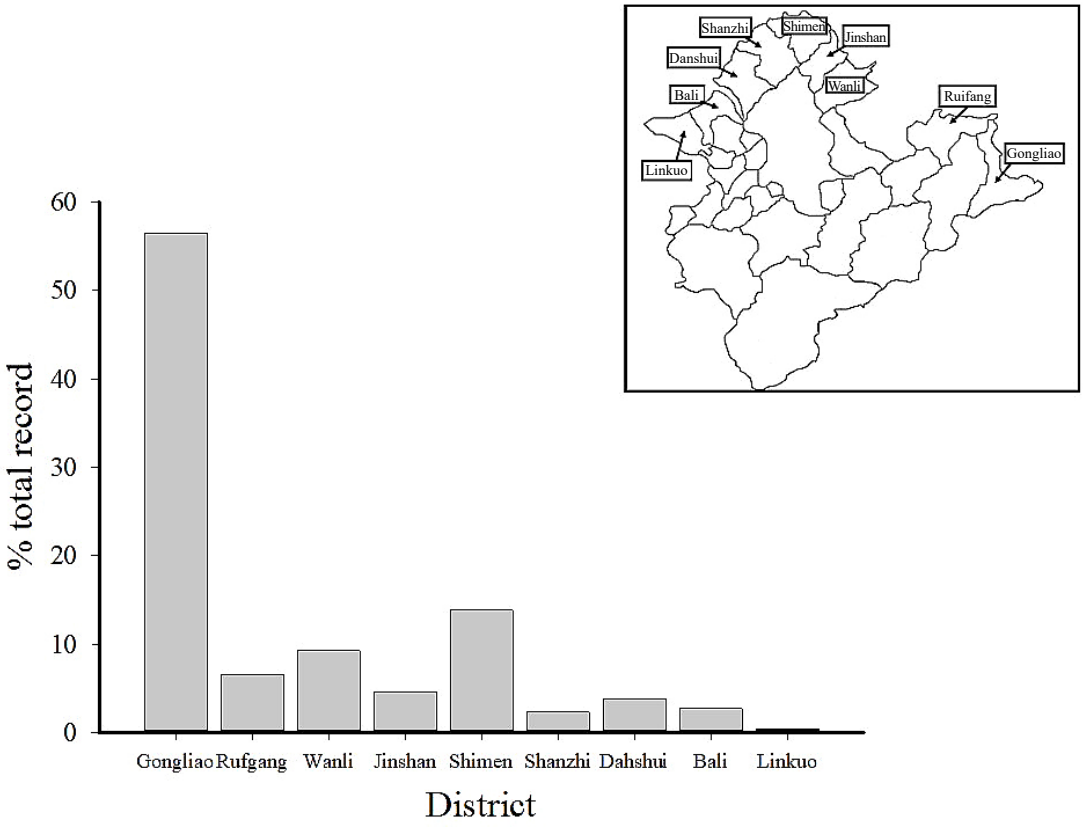

Fig. 8. Distribution of stranded/bycaught sea turtles in different districts in New Taipei City. Location of each coastal district in New Taipei City is showed in the upper right figure.

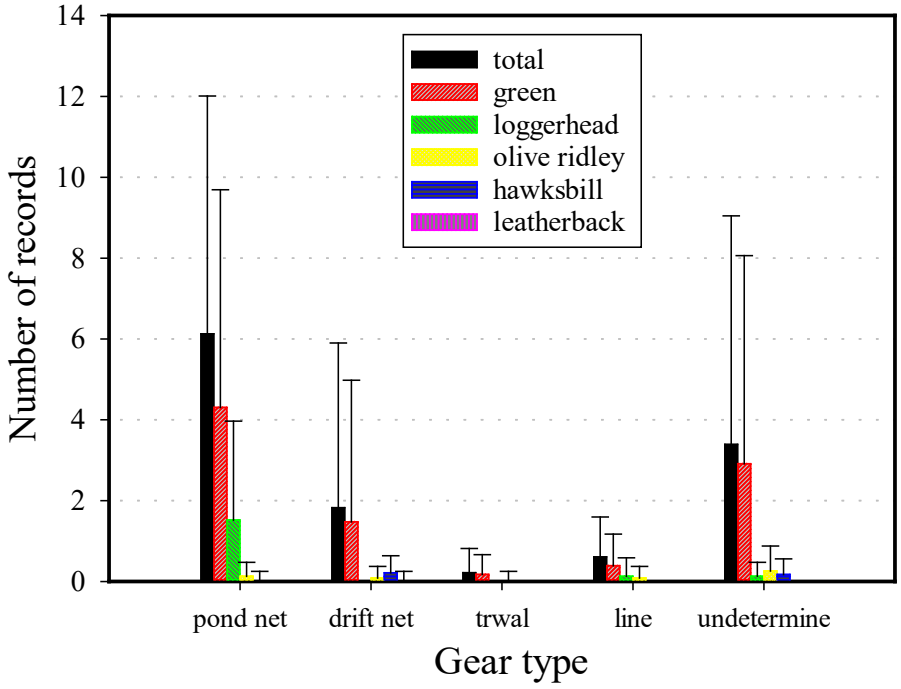

Fig. 9. Number of the total and each species of sea turtle from bycatch by coastal fishing gears from 1997 to 2019 in Taiwan. Data on total and each species showed in mean and standard deviation, and $n = 23$.

reports were from pond net than from line or trawl (p = 0.003). Even though a significant yearly difference was found (p = 0.005), no difference was detected between any two years. For loggerhead turtles, more reports were from pond net than from other gear type ($p < 0.001$). No yearly difference was found (p = 0.547). For olive ridley turtles, there were no difference across gear types or years (p = 0.198 for gear type and p = 0.11 for year). Although no difference was found among gear types in both hawksbill and leatherback turtles (p = 0.061 for hawksbill turtle, p = 0.156 for leatherback turtle), there was significant difference among years for hawksbill turtle (p = 0.017). However, no difference was detected between any two years. There was no yearly difference for leatherback turtles (p = 0.509). One-way ANOVA among different species for the same gear type showed that, for the pond net, except the loggerhead turtle, the green turtle had the most reports than the other species (H = 42.948, *d.f.* = 4, $p < 0.001$). For the drift net, line and undetermined gears, even though significant different was found (H = 19.64, *d.f.* = 4, $p < 0.001$ for drift net, H = 13.121, *d.f.* = 4, p = 0.011 for the line, H = 14.607, *d.f.* = 4, p = 0.006 for undetermined gear), no difference was detected between any two species. No difference was found among species for the trawl (H = 8.773, *d.f.* = 4, p = 0.067).

DISCUSSION

In 1997, two green turtles with fibropapillomatosis were found in Tamsui District, New Taipei City, nothern coast of Taiwan. The turtles were then euthanized and necropsied by veterinarians. This case initiated the sea turtle stranding/bycatch works in Taiwan, and data have been collected ever since then. This study is the first long-term study of sea turtle stranding/bycatch conducted in Taiwan.

Reports

The variable and infrequent reports over the first 14 years was due to the long coastline, insufficient marine conservation awareness, lack of proper stranding/bycatch reporting system, and lack of proper coordination between the Coast Guard and local authorities. Flint et al. (2017) suggested that, in general, an increase in stranding reports indicates that the environment has changed. Corsini-Foka et al. (2013) suggested that this pattern can be explained by an increase in human activities. However, this do not seem to be the case in Taiwan. That the number of reports increased continuously and peaked in 2019 might be due to the increase in environmental awareness in recent years (*e.g.*, more beach cleaning). In addition, the Forestry Bureau, Council of Agriculture, Executive Yuan initiated a sea turtle stranding/bycatch network in 2014, and the Coast Guard has actively participated in the system since then. In 2016, the cell phone social media application "LINE" (similar to Facebook) establish a "Sea Turtle Stranding Report Line Group." This group allows members to edit and send photos, upload/download videos to/from YouTube, and invite people to join the group. It speeds up the reporting process and provides useful hints from experts on how to treat sick, wounded, and dead turtles at the scene. The percentage strand/bycatch reported for each species is similar to those found in East Queensland, Australia (Flint et al. 2015), Japan (Moriya 2010), Brazil (Mascarenhas et al. 2005; Poli et al. 2014), and Turkey (Sönmez 2018, also see Sönmez 2019). The high number of reports of green turtles may simply be due to the fact that this species is most abundant in the nearshore waters of Taiwan (Cheng et al. 2008). Similar results were found in stranding and pond net reports. The higher reports of the olive ridley than the leatherback turtles was simply due to the low number of leatherback turtles reported.

Size

The majority of size ranges were juvenile to subadult, which were similar to those reported from Japan (40 to 60 cm CCL, Moriya 2010), Turkey (40 to 45 cm CCL, Sönmez 2018), Texas, USA (32.8 to 57.5 cm CCL, Shaver 1995), and Brazil (56.5 cm mean CCL, Mascarenhas et al. 2005; 31.5 to 56 cm CCL, Tourinho et al. 2010). The major size ranges of hawksbill and loggerhead turtles were similar to those reported from Texas, USA (Shaver 1995) and the western Mediterranean (Domènech et al. 2009). The difference in the size range suggests that the different species recruit to the coastal waters of Taiwan at different ages. Green and hawksbill turtles are recruited as juveniles, hawksbills are recruited younger, and loggerheads are recruited as subadults. There was no shift in the size range between 1997 to 2007 and 2009 to 2019 for the green hawksbill and loggerhead turtles, except that the number of reports increased during the second 10 year (47 vs. 842 turtles for green turtle, 4 vs. 71 turtles for hawksbill turtle, and 19 vs. 50 turtles for the loggerhead turtle). The wider size range was mainly due to more reports from 2009 to 2019 (1048 reports) compared to 1997 to 2017 (76 reports).

Sex ratio

The female:male sex ratio of the green turtles was 2.3 and the average of all turtles was 2.4. This suggests

that the majority of stranded dead turtles are females. The primary sex ratio of hatchlings is female-biased, especially the green turtle in Taiwan (*e.g.*, King et al. 2013). James et al. (2007) caught nearly twice as many females as males in foraging waters in Canada. If one considers that the chances of mortality are similar for both sexes, then the high female mortality might simply be explained by more female turtles in nearshore waters.

Season

Seasonal variations in stranding were similar to those in northern Brazil from winter to spring (Poli et al. 2014). The weather in Taiwan changes dramatically from winter to spring; average air temperature dropped from 23℃ from November to 20℃ in December, and increased from 21℃ in March to 23℃ in April during the study period. Also, the major size group of stranded/bycatch turtles was juvenile to subadult. It is possible that turtles of these ages, especially juveniles, cannot deal with dramatic climate changes. Their lungs are not fully developed, and thus they cannot dive deep enough to escape the bad weather on the water's surface (Hochscheid et al. 2007) like adults do. Flint et al. (2015) suggested that immature turtles are "immunologically naive and susceptible to environmental stressors."

Spatial distribution

The hotspots for stranding/bycatch were the towns of Dougou and Tochen in Yilan County, northeast coast of Taiwan for both green and loggerhead turtles (Fig. 7) and Gongliao District in New Taipei City, northern coast of Taiwan for green turtles (Fig. 8). These three sites are small towns or fishing villages. The reason for the numerous records in these three locations are given in later sections. Most hawksbill turtles were found in Penghu County, which might be explained by extensive coral reefs in the nearshore waters of the Penghu Archipelago (Shih and Chiau 2009).

Strandings, drift and by-catch in fishrey activities

The highest stranding record occurred in New Taipei City, and the hotspot was in Gongliao District. This district is located at the base of Mo-O Bay. Coastal currents, especially the Kuroshio intrusion, are present mainly from autumn to winter (Chuang and Liang 1994) and may have brought carcasses from other sites and deposited them into this bay. Furthermore, embayment is also an area of concentrated discharge that will not dissipate into the other areas (Flint et al. 2017).

Different report types showed that green and hawksbill turtles were stranded than the other report types, and more loggerhead turtles were bycaught by fishing gears than drift and miscellaneous types during the study period. There were more reports from green, loggerhead and olive ridley turtles in 2019 than most of the first 14 years (1997 to 2014). This may simply be because more turtles were reported in 2019 than the other years. No difference was found for leatherback turtles simply because there were not enough turtles to determine significant differences. In spite of these results, except the miscellaneous type, more green turtles were reported from bycatch, stranded and drift than at least one other species, while the leatherback turtle had the lowest record among drift, stranded and bycatch types. These results were due mainly to the fact that the green turtle is the most highest abundant while leatherback is the least abundant species found in the nearshore waters of Taiwan.

Fishery bycatchment

No leatherback turtle were collect as bycatch in Taiwan. This may have related to scarce abundance of jellyfish in the nearshore waters of Taiwan. Pond net caught more green turtles than line and trawl. Pond net caught more loggerhead turtles than the other fishing gears. These suggest that pond net caught more green and loggerhead turtles than the other gear types. Even though the green turtle composed 85% drift net bycatch, high yearly variation (0 to 5 reports per year from 1997 to 2016) might contribute to no different among species statistically. No difference in the by-caught turtles among gear types for olive ridley and hawksbill turtles. These might be due to the low by-catch turtles of these two species. Pond net bycaught more green turtles than olive ridley, hawksbill and leatherback turtles. This suggests that green turtle is the major species bycaught by the pond net. Even though there were significant difference among species in drift, line and undetermined gears, no difference can be detected between any two species. These might have related to high variable of each species bycaught.

There were 28% fishery bycatches belonged to undetermined fishing gear. Further examine the spatial distribution found that, the major sites were Penghu and Taitung Counties. Penghu County occurred mainly from 2014 to 2019. Taitung County occurred mainly in 2017. Thus, more efforts are needed from these two counties, especially Penghu County to improve the report system of the fishery bycatchment.

Pond net bycatch

Pond nets are the major bycatch fishing gear, for

which two major size groups were reported. A detailed examination showed that the juveniles were composed exclusively of green turtles and the subadults were composed of 56% green and 44% loggerhead turtle. Yilan County was the major site, and the hotspots in this county were the townships of Nanao and Tochen (Fig. 10). The coastline is straight and the major fishing gear is the pond net.

Conservation implications

Sixty-one percent of reports were carried out by the Coast Guard and 37% by concerned citizens. Even in drift cases, 58% were reported by the Coast Guard and 42% by concerned citizens. Marine environmental awareness, especially of anthropogenic pollution such as debris ingestion, has become an important issue in recent years. Beach cleaning, recycling of usable wastes, coastal watches, etc. have increased substantially. The Coast Guard also conducts an environment protection program by actively participating in the stranding/bycatch reporting system. The increase in marine environment awareness has led to more detailed information on the population of sea turtles in the nearshore waters of Taiwan. With the help of government officials, the stranding/bycatch system is more efficient and allows for more data collection. Long-term data collection can identify species, stock size, and temporal and spatial distribution, including juveniles, subadults, etc., which are important for the demographic study of sea turtles (Bjorndal 1997). Stranding and mortality data can also provide information on anthropogenic threats, trends, and potential issues in the nearshore waters (Koch et al. 2013; Peltier et al. 2012). These are important for the long-term conservation and management of sea turtles.

CONCLUSIONS

This is the first long-term sea turtle stranding/bycatch study ever done in Taiwan. One thousand and seventy-two turtles were reported from 1997 to 2019. The green turtle was the most abundant species and occurred mainly from winter to spring. Most stranded turtles were immature females. The hotspots were the towns of Dougou and Tochen in Yilan County, and Gongliao District in New Taipei City. Stranding was the most common report type, and pond net was the main bycatch fishing gear. The Coast Guard and concerned

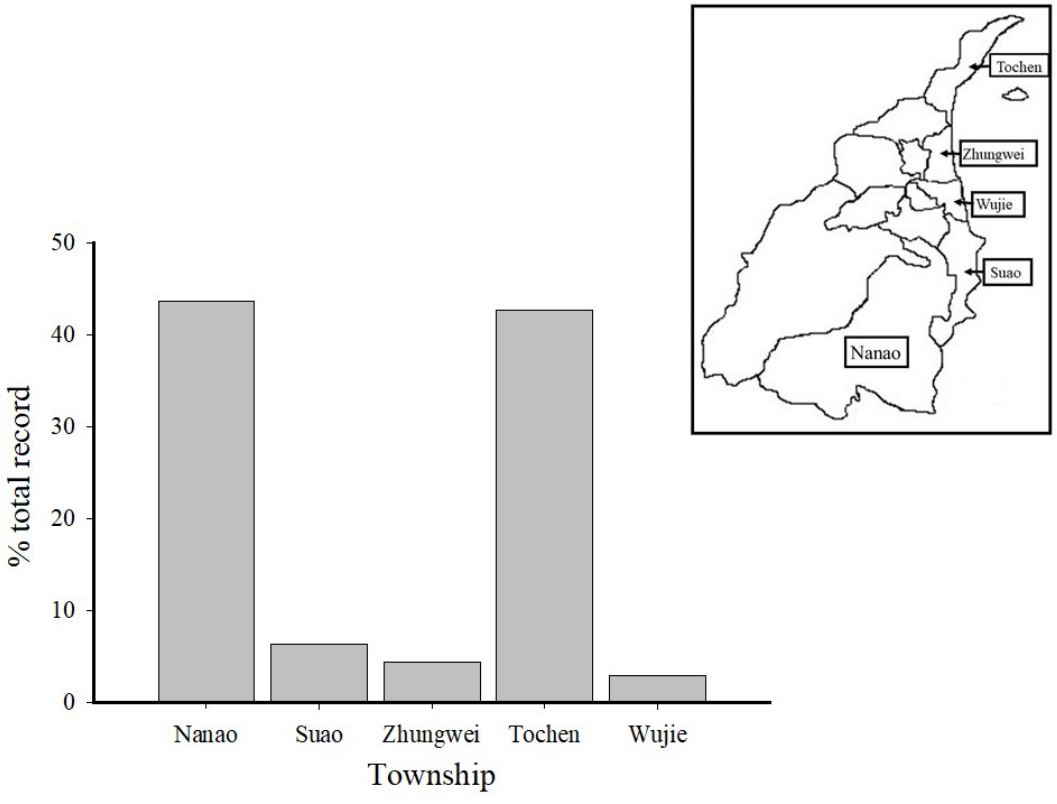

Fig. 10. Distribution of stranded/bycaught sea turtles in different towns in Yilan County. Location of each coastal township in Yilan County is showed in the upper right figure.

citizen were the main sources of these reports.

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Supplementary materials

Table S1. Two-way ANOVA table of report types and yearly effect on different species. (download)

Table S2. Two-way ANOVA table of gear types and yearly effect on different species. (download)