Bycatch reduction technology for marine turtle bycatch in eastern Mediterranean Small-Scale fisheries.

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Cover images: A selection of images captured during this project by fishermen onboard commercial fishing vessel Eminem, Famagusta.

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Executive Summary

Hosting 30% and 10% of all green and loggerhead turtle (respectively) nesting in the Mediterranean, North Cyprus is of great importance for marine turtles. A long-term conservation and research project established in 1992 by university of Exeter's Marine Turtle Research Group (MTRG) and North Cyprus Society for Protection of Turtles (SPOT) has produced a large proportion of the marine turtle research in the Mediterranean and nesting numbers in North Cyprus are starting to respond positively to conservation efforts implemented at nesting beaches. As well as migrating to North Cyprus to nest, marine turtles also use the North Cyprus coast for foraging, but far less is known about these foraging populations. Recent work by MTRG has detailed concerning rates of marine turtle bycatch and mortality in the local small-scale fishery, in particular in bottom-set trammel nets that target rabbitfish (*Siganidae*), where there appears to be a large degree of overlap between the setting of nets and the habitat use of resident foraging and migrant nesting marine turtles. The main aim of the current project was to use well established links between MTRG, SPOT and Turkish Cypriot small-scale fishermen in order to trial LED lights, which in other areas of the world have proved a useful tool in reducing the bycatch of marine turtles. LED lights were provided to fishermen who agreed to record their sets and landings, to be tracked for the duration of the study by GPS and to photograph any turtles they caught using a compact waterproof camera we provided. Fishermen were trained in deploying the LED lights at 10m intervals on their siganid trammel nets. Fishermen were also trained to flipper tag and to record carapace measurements of caught turtles and to note the depth at catch sites from their existing echo-sounder. The vessel mounted GPS and the on board camera were regularly downloaded and serviced during contact meetings. Photographs of marine turtles were linked to GPS data according to their time stamp metadata in order to estimate the point of capture of individual turtles. All vessel GPS data were filtered and mapped to provide a useful summary of the fishing activities of this vessel. Some useful data on fish catch rates of LED and non-LED trammel nets was also obtained and at the end of field work an interview was held with fishermen primarily to determine the effect of the LED lights. The fishermen reacted very positively to the lights and thought that they were useful in deterring marine turtles. Design faults were found that will be important in the development of similar LEDs that are better tailored to this application. Bycatch data for marine turtles recorded during this project are the best and most detailed available for the island. All of these data will be of use in conservation planning. In particular in regulating small-scale fisheries operating in Famagusta Bay where significant aggregations of foraging turtles are known to occur but where national and international conservation networks are yet to establish protective legislation or develop MPAs. The methodologies developed here are repeatable and will provide a tool for further research in similar fisheries.

Contents

Introduction

The global and local significance of small-scale fisheries

Small-scale fisheries produce over half of the world's fish catch and support more than 90% of its fishers (FAO, 2010) yet research on industrialised fisheries has far outweighed research into small-scale fisheries. Small-scale fisheries are comparatively more challenging to study and more difficult to control than industrial fisheries because of their diversity, vast distribution, the number of people and vessels involved and their strong ties to local communities (Soykan et al., 2008; Moore et al., 2010; Stewart et al., 2010). Clustered in rural areas, fishing communities represent some of the most marginalised social groups in North Cyprus.

The small-scale fisheries threat to marine turtles and other species of conservation concern

It is speculated that the contribution of small-scale fisheries to global bycatch of large threatened marine vertebrates could equal or exceed the contribution of industrialised fisheries (Gilman et al., 2010). The greatest threat to endangered loggerhead and green turtles in the Mediterranean is bycatch in small-scale fisheries (Casale, 2011). Snape et al (2013) found that bottom-set trammel nets are responsible for the death of thousands of sea turtles in North Cyprus. There are currently no viable mitigation strategies in fisheries to reduce the impact of gillnets or trammel nets on marine turtles (Gilman et al., 2010) and in North Cyprus there are no Marine Protected Areas (MPAs) to protect resident marine turtles and their habitats.

Current research into marine turtle bycatch mitigation in gillnet/trammel net fisheries

Research into net illumination using specific light spectra as a method to reduce sea turtle bycatch in similar fisheries in Mexico (Wang et al., 2010, 2013) and in Peru (Marine Turtle Research Group in prep) has shown promising results with over 50 percent reduction in bycatch and insignificant impact on target catch where glow sticks and LED lights are attached to nets. However, glow stick technology is extremely wasteful and LED technology is too expensive even for subsidised use and its design needs to be better tailored to gillnets and trammel nets.

Project scope

Using the platform that MTRG researchers have created amongst Turkish Cypriot artisanal fishing communities our project aimed to introduce the concept of and to trial LED lights. Using participatory methods we wanted to test their effectiveness on Mediterranean populations of green and loggerhead turtles. We also aimed to gather practical experience from which to advise developers on the better design of tailor-made lights. We tracked a fishing vessel for two fishing seasons and recorded all of their marine turtle bycatch during this period in great detail using novel techniques that could be implemented to gather data for the design and management of MPAs. These added value elements will be useful in determining fisheries legislation in Famagusta Bay which is considered to be an important loggerhead turtle foraging site for the region (Godley et al., 2003; Broderick et al., 2007; Snape et al., 2013; Snape et al., in prep), but is currently overlooked as such in any local or international (eg. EU Natura 2000) conservation schemes.

Project Methods

Choosing our boat, setting of led lights, recording sets, catch and bycatch

Our participatory and anthropological studies to date suggests that the siganid fishery in Famagusta Bay would be the best arena for our study. This fishery sector is already associated with marine turtle bycatch (Snape et al., 2013), due to shallow setting and long soak times. The siganid fishery was thus likely to produce the largest sample sizes of caught turtles and thus the most significant results.

Prior to the project the chosen fishermen had been particularly responsive to our outreach and workshops where the aims and results of other turtle related work was presented (Snape et al., 2013) and where training was provided in handling of marine turtles in order to optimise their likelihood of post-release survival (Gerosa & Aureggi, 2001).

Left. A loggerhead and two green turtles returned to port by fishermen using the vessel Eminem in August 2012. Eminem is a 10 metre wooden fishing boat with an inboard diesel engine typical of this fishery.

The fishermen had regularly contacted us by phone to register their bycatch and provided dead turtles to us for sampling and necropsy and live turtles to be tagged and released. Their rates of bycatch - when compared to other fishermen who were similarly helpful – were high and we associated this high bycatch rate with their mostly targeting siganids through information gathered during island-wide interviews.

Right. The first nets to be set with the LEDS. Summer 2013.

The first 150 lights (LP-Electrolume green) were received in June 2013 and in July a field trip was held with fishermen onboard the vessel Eminem to establish a protocol for setting lights and recording data. LEDs were set at 10m intervals along 1500m of bottom set trammel net. A handheld GPS was used to measure 10m intervals between LED attachment points and the fishermen practiced estimating 10m intervals and clipping the lights onto the float line of the nets as the boat moved along with the trammel nets running out behind the boat and sinking onto the sea bed. After this field trip the fishermen were asked to record in their note books every set made with LEDs and every set made without LEDs using the designated 1500m 32mm^2 mesh trammel net targeting siganids. Fishermen were asked to make one experimental set with LEDs followed by one control set without LEDs and to record for each set the approximate weight in kilograms of their catch of class 1, class 2 and class 3 fish, according to the locally used classification system for commercial fish where class 1 is low value and class 3 is high value. They were asked to record any turtles caught and to photograph, measure and record any turtles caught. They were provided with a waterproof compact camera, tape measure, notebook, pencils and other basic kit in a kit bag that was stored in their cabin. They were later provided with flipper tags and trained to tag turtles that they released alive. All equipment was maintained and images, data and GPS files downloaded during contact meetings every two months. The fishermen were also provided with a new model Furuno eco-sounder/fish-finder device to incentivise their participation.

Left. Captain Ali Gür and the fish-finder we provided as an incentive through the project (blue screen on right hand side).

Later in the project it became clear that the fishermen were having difficulties in keeping accurate records of their sets during hot and busy summer periods when the fishermen were tired. This was concerning because it was these during these periods that they were most likely to be catching turtles. However, they continued to record with their camera and notebook all of the turtles that they caught. The fishermen were then asked to use their camera to log all of their sets and hauls rather than to take daily notes. Experimental sets were to be photographed on setting or hauling with the LEDs visible on the nets and images of sets with no LEDs would indicate control sets. They were asked to photograph all catches from experimental and control nets in standard Styrofoam boxes in order for us to estimate catches associated with control and experimental sets. This led to problems with battery failure in the camera and the project coordinator not being able to make regular enough maintenance checks. The specific lithium batteries were exhausted by April 2014 at which point the decision was made to use remaining funds to bring in 105 more lights and enough batteries to equip all of the remaining lights and these were passed on in May 2014 during a field trip. The original lights were inspected and serviced and batteries replaced during this field trip leaving the fishermen with 230 functional lights with which to carry out the rest of the study. Finally an interview was held in January 2015 to gauge the affect of the LEDs from the opinion of the fishermen.

Turtle bycatch - Kit and training

The fishermen were provided with kit including a compact waterproof camera with which to report their catch and marine turtle bycatch. They also received marine turtle flipper tags and a flexible tape measure. The fishermen were trained to measure minimum curved carapace length (minCCL), to fit flipper tags and how to record these details in a log book during a field trip when they called the project coordinator to a live turtle they had caught. During regular port visits when GPS loggers were replaced, cameras were serviced and memory cards downloaded. All kit was stored in an unlocked cabin which allowed our inspection during port visits if the fishermen were not available to attend. We had aimed to assign turtle bycatch to control and experimental LED sets but this became impossible as set details were not properly logged by the fishermen after winter 2013-2014 (see above).

Turtle bycatch - identification and assessment of status

Photographs taken by fishermen using the provided camera were inspected for those containing images of turtles. Individual turtles were separated by their appearance and by the time stamps on photos. Where more than one turtle was caught at the same time fishermen were asked to photograph them all individually and as well as all together in one photo. For each image or group of images of an individual turtle the species, size class and (where possible) sex were determined. Size classes were demarcated as >40cm=Juvenile, 40-60cm=Sub-adult and >60cm=Adult. As nearly all of the identified turtles were juveniles, sub-adults or small adults, we did not attempt to sex any as female but if an elongated tail was showing then we sexed as male. We also attempted to estimate the state of the turtle when it was returned to the water according signs of life such as whether the eyes were open or whether the head and flippers were raised.

Left above. An example of a turtle that was released alive but in poor condition. Such individuals most likely died subsequently. **Left below.** An example of a turtle that was released in good condition. Able to contract its muscles, respond to stimuli and with its eyes open.

In many cases fishermen recorded images and/or videos of each other trying to revive turtles (in particular loggerheads), by holding them upside down by the hind flippers or the carapace in order to offload water from the airways. These activities were recorded.

Turtle Bycatch – Assigning capture locations, gears and soak times

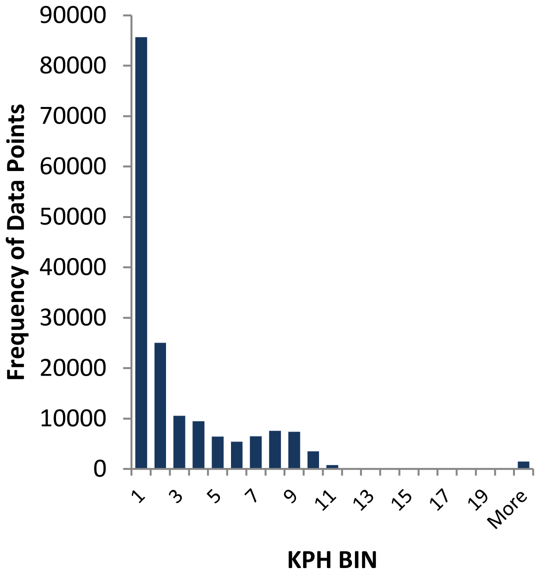
In order to find the geographical location of a gear-set temporally closest to the time when the image was taken, time stamps in turtle bycatch image file metadata were compared against GPS tracking data within which coordinates are assigned a date and time stamp. Although fishermen had been instructed to always take the images at the point of hauling, this was not always the case and probably was not always possible. Often turtles were photographed en route back to port after a haul or in the port itself. In these cases the GPS track was viewed, the set was located and the coordinates at the mid-point of the set were attributed to the point of capture. The time at which each set that caught a turtle was set and hauled were also recorded through the GPS data to estimate a soak time for each set. Gear types responsible were established from photographs which usually included the gear on the boat. It was also possible to elucidate the gear type according to soak time and depth according to the findings of Snape et al. (2013). Additionally, fishermen recorded the gear type, time of hauling, depth measurement on their eco-sounder and a shore-based landmark, all of which helped in our pinpointing the exact point of capture when turtles were photographed after having moved away from the haul site or if photos were not taken at all. Where images were not available, turtles over 60cm were considered to be loggerhead turtles and those under 60cm were considered to be green turtles as per the stranded turtles and bycatch reported by Snape et al. (2013).

GPS settings and deployment protocol

I GOT U GT-600 (i-gotu.com) GPS loggers provided by MTRG were programmed to collect data points every 2-4 minutes with a motion detector enabled to switch the GPS off in order to conserve battery when the vessel is stationary in port. The GPS devices were wrapped in layers of electrical insulating tape and were taped above steel or aluminium beams of the vessel canopy and beneath a canvas or thin plastic canopy where available. Many I GOT U devices were used with varying histories of previous use. Generally their batteries lasted for between 3 and 8 weeks. Our chosen vessel Eminem was tracked between June 2012 and November 2014.

Tracking data analysis - Plotting speed between subsequent points and removing taxi data

Coordinates (data points) from GPS devices deployed onboard Eminem during the study were collated from many files into one large file which contained over 170,000 data points. The majority of these points were not representative of fishing effort and required filtering.



Speed was deemed to be the best parameter for identifying and removing taxi data. A common pattern among results retrieved from this and other vessels was for speed frequencies when plotted in a histogram, to peak at zero when the vessel is in port and between 5 and 10 km per hour when taxiing to and from fishing sites at full throttle. Data with speeds below the speed at the trough between these two speed peaks is deemed to be representative of gear sets, hauls and time spent in port. Data above this speed threshold is deemed to be taxi data and is therefore removed from subsequent analysis. For Eminem, any data points carrying a speed of 5km/h or more were deleted.

Above. Speed frequency histogram for Eminem, Famagusta. n=170137 data points between June 2012-November 2014.

Tracking data analysis - Harmonising data

As field work progressed different GPS fix rates were used experimentally within a range of 2-4 minutes in order to get the best battery life from the devices, with 4 minutes providing longer battery life. In order to account for this variation, which could ultimately bias certain tracks, an integer time interval of 6 minutes was assigned to each data point and where more than one data point existed within a given 6 minute time integer, the mean latitude and longitude was calculated for that integer and the values used to determine this mean were deleted and replaced with the mean value.

Tracking data analysis - Removing terrestrial and in-port data

The resulting file was uploaded to ArcGIS and exported as a point shape file for subsequent editing. In order to remove terrestrial data acquired during transfer of devices between the office and the vessel, the “select by location” tool of Arc GIS was used to select those points that overlapped with a map of Cyprus polygon. Those overlapping points were selected and deleted. This operation also removed many of the points aquired in Famagusta Port but not all of them. A satellite image was used to trace a polygon feature for Famagusta port in ArcGIS. This polygon was used in the same way as above for selecting and deleting points lying within the port area.

Hexagonal utilisation plot of fishing intensity

The remaining filtered data were viewed in ArcGIS and a “fished area” polygon shapefile was drawn covering the greatest extent of all data points. This fished area polygon shapefile was used in the “genhexagoninpolys” function Geospatial Modelling Environment (GME; spatialecology.com/gme) to create an array of tessellating hexagon polygons. The number of filtered vessel tracking data points each hexagon was counted through the "countpntsinpolys" function of GME. The resulting hexagon polygon was viewed in ArcGIS where the percentage of total data points falling within each hexagon was viewed with 7 intensity levels (yellow to red) that were calculated by the Jenks natural breaks classification method.

Results of Project Activities

The effect of LED lights on bycatch and catch rates – Quantatative results

LEDs did not have a significant affect on catch rates for any of the categories of fish landings that were assessed. No differences between landings from control and experimental sets were found to be significant (T test p=<0.1). On average though fishermen caught >55% more class 3 fish by mass which may have proved significant had the sample size been larger with more repeats.

Below. Haul composition for those control and experimental sets where a quantative assessment of landings was made by fishermen and recorded in their notebooks November 2013-February 2014. Non-com=Non commercial (either dicarded, used as bait or consumed by the fishermen). Cl=Class. L. sceleratus=*Lagocephalus sceleratus* a non-native invasive lessepsian migrant pufferfish which is poisonous, has no value, depredates catch and damages gear.

Net set up	Stat	Soak (h)	Mesh Size (mm)	Cl 1 fish (kg)	Cl 2 fish (kg)	Cl 3 fish (kg)	Octopus (kg)	Cuttlefish (kg)	Non-Com (kg)	L. sceleratus	Total haul
LEDs (Exp)	Mean	5.9	26.6	1.6	1.3	2.8	0.4	1.1	3.2	0.9	11.4
	SE	0.8	1.7	0.4	0.3	0.5	0.3	0.4	0.6	0.8	1.1
	Max	14.7	32.0	6.0	3.5	8.0	5.0	4.0	10.0	14.0	21.0
	Min	2.7	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
	n	17	18	18	18	18	18	18	18	18	18.0
No LEDs (Cont)	Mean	7.1	27.5	1.5	1.3	1.8	0.4	1.1	2.9	1.5	10.5
	SE	1.1	1.4	0.4	0.2	0.4	0.2	0.4	0.6	1.4	1.7
	Max	18.8	32.0	6.0	3.0	6.0	3.5	6.0	8.0	30.0	38.0
	Min	2.7	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
	n	22	22	22	22	22	22	22	22	22	22.0
T-Test (independent samples)		0.41	0.65	0.89	0.81	0.14	0.94	0.97	0.73	0.72	0.67

No marine turtles were caught during the period within which fishermen propperly recorded data on control and experimental sets.

The effect of LED lights on bycatch and catch rates – Qualatative results.

See Appendix I. Fishermen said that they used the LEDs 50-55 times in total during the study from September 2013 to January 2015. Overall they believe that the lights are good at reducing marine turtle bycatch in their trammel nets when the nets are set at night. The main commercial target siganid fish that they catch are targeted during dusk and dawn. Turtles may come to the nets to eat these fish when they are caught in the net during those transition periods during which there is some ambient sun light and the LEDs may not be affective at these important times. Neither species were affected more than the other.

The fishermen feel that he LEDs have no influence on fish catches.

Regarding the design of the LEDs

A swivel that links the spring attachment clip to the LED was made from a poor quality metal and corroded during the study. The rusting was so bad that some lights snapped off from their fixing. We thus removed and bypassed the swivels on all of our LEDs and we suggest that in any further studies that the swivels be bypassed.

At the shallow depths that the fishermen were fishing at, the pressure activated mechanism could not always be relied upon so the lights were always turned on manually before setting in waters of less than 10m. This increased handling times markedly. As this function uses moving parts, the lights need to be well maintained and re-greased regularly if they are to be relied upon to initiate at depth automatically, requiring additional work.

Right. Two buckets full of activated LED lights ready to be attached to a trammel net at 10m intervals. The image was taken by a fisherman in order to indicate an experimental set.

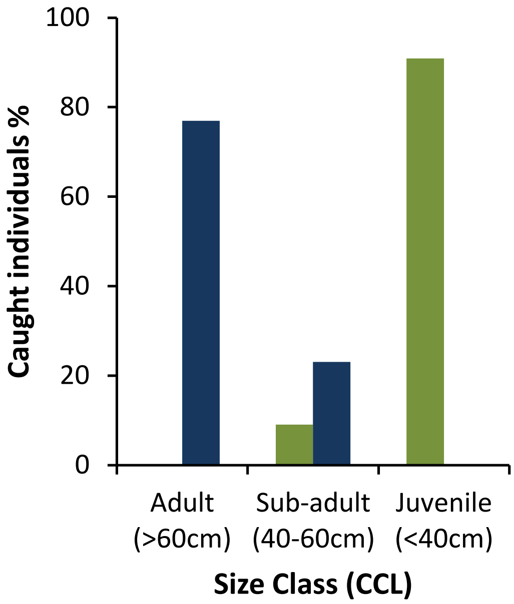
The LEDs, which were not designed specifically for use with nets, are not held tight to the attachment point on the float line and tend to tangle the net, potentially reducing its capturing capacity and often leading to tangles which again require significant additional handling time to resolve. Their dangly nature and sharp edges cause them to tangle the nets when stored in net bags. So the lights have to be removed after each set and deployed again on subsequent sets. Again, more handling time. So all LEDs were always removed from nets, dried out and stored between sets and were always turned on and off manually. Deploying the LEDs during setting takes practice and even then, requires the fishermen to reduce engine revs periodically to resolve tangles and to ensure each LED is properly attached and switched on.

Some LEDs broke loose of their clips due to corroded swivels, some were lost because the clip broke loose of the float line and some failed due to water ingress. The later losses perhaps could have been mitigated by more regular services and greasing of moving parts, which would further devalue the LEDs in the eyes of the fishermen.

If the lights were properly modified and freely available then the fishermen would certainly use them voluntarily (Appendix 1).

Turtle bycatch - The turtles and their condition

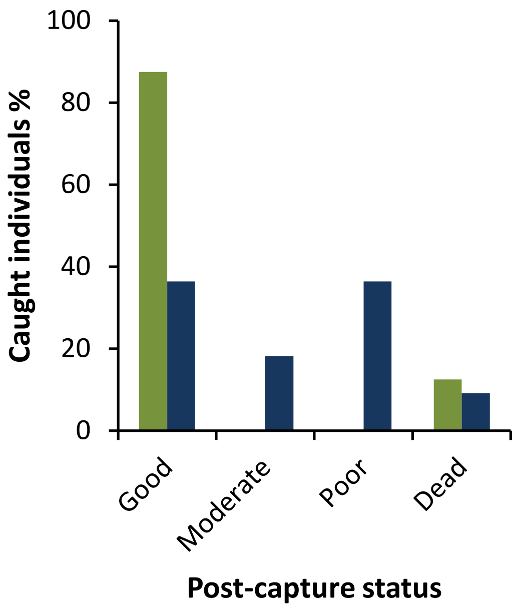
Between May 13th 2013 and November 11th 2014 twenty five marine turtles were caught by the fishermen using Eminem. Of these turtles thirteen were loggerhead turtles and 12 were green turtles. Mean curved carapace lengths were for loggerheads 65cm and for green turtles 32cm. These results are similar to those published for marine turtle bycatch in North Cyprus where loggerhead turtles averaged 70cm green turtles averaged 37cm (Snape et al., 2013).



Right. Frequency histogram of loggerhead (blue, n=13) and green (green, n=11) turtle bycatch by size class.

Four of the loggerheads were sexed as male based on tail morphology ascertained from photos and one individual which was returned to Marine Turtle Conservation Project in Alagadi where a necropsy confirmed the sex as male according to both tail morphology and gonad structure. We were not able to sex any of the green turtles.

Hauled green turtles tended to be in better condition than loggerheads of which over 60% were dead or in moderate to poor condition and likely died post-release.



Left. Frequency histogram of the status of loggerhead (blue, n=11) and green (green, n=8) turtles hauled on the vessel Eminem.

One loggerhead turtle bore an Israeli tag which the fishermen recorded. Yanif Vely, a marine turtle biologist working in Israel confirmed that the tag was applied after the turtle was caught there by a fisherman.

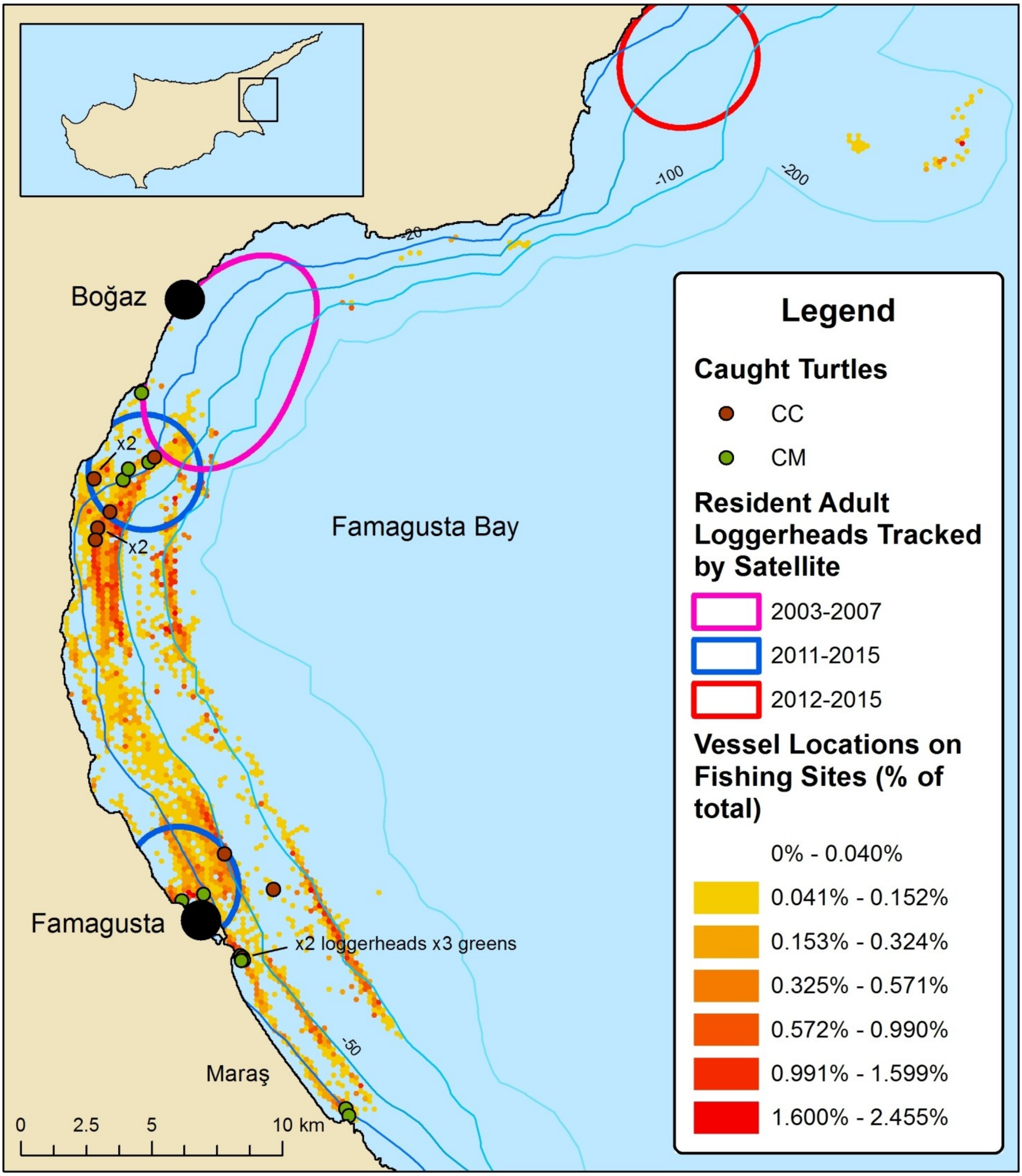
Bycatch locations and depth at capture

Eleven green turtle and eleven loggerhead turtle captures were assigned to GPS locations through relating photo time stamp or recorded time of capture to coordinate data points (see map below).

In general turtles were caught within areas that were regularly fished but tended to be caught in shallower depths. According to fishermen this was particularly so for the green turtles which were more likely to survive because they were caught in shallow water and so (even when entangled) were able to reach the surface to breathe (Appendix 1).

Soak times of nets

Sets for which turtle bycatch was recorded were set for on average 11 hours which is consistent with typical overnight setting of siganid nets previously reported (Snape et al., 2013).



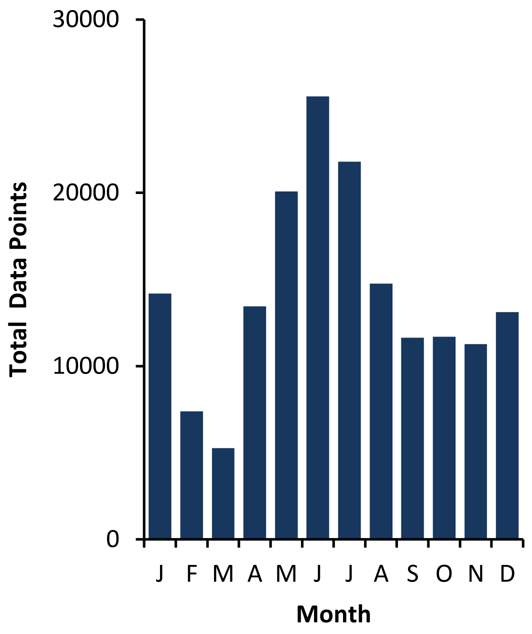
Above. Map showing the locations of marine turtle captures by our fishermen during the project, the currently available satellite data for three loggerhead turtles we tracked from nesting beaches around North Cyprus into Famagusta Bay where they each resided for more than 3 years and a hexagonal utilisation plot showing levels of fishing intensity for Eminem during the study.

Fishermen did not always log the depth (displayed on their eco-sounder) at which turtles were caught but for the 2 loggerheads and the 5 green turtles for which they did note down this information the average depths were 10.5 and 9.4m. Bathymetry data in the above map are downloaded from gebco.net (General Bathymetric Chart of the Oceans) and are not thought to be very reliable, however, they suggest that green turtles were more likely to be caught in waters under 20m and that loggerheads could be caught in deeper waters, but usually less than 50m deep which is consistent with the testimony of the fishermen (Appendix 1).

Three main areas of concern were an area around 5-10km south of Boğaz harbour, fishing areas in the immediate vicinity of Famagusta Harbour, particularly off Palm Beach Hotel and at the south end of Maraş beach (see above map). The former site we believe relates to the area described by the fishermen in their questionnaire responses as Istanbul Beach (Annex 1).

Vessel GPS tracking

Most intensive fishing occurred over 10km north of port (Famagusta) towards Boğaz/Iskele region. Other heavily used areas were directly in front of the harbour within a 5km radius and off Maraş beach. Fishing hotspots clearly followed bathymetric contours in shallow (>20m), medium (20-50m) and deep (~100m) waters. Some long trips were made to drop gear on an underwater sea mount over 30km north-east of port. Fishermen were particularly active during summer months. This was clear from our interactions with them and from the number of GPS locations recorded by their onboard GPS which were higher during busy periods when the vessel was in use and lower when the vessel was spending more time in port, during which the GPS motion detector would have turned the GPS off.



Left. Number of locations recorded per month by GPS onboard Eminem June 2012-November 2014.

Conclusions

During the last decade North Cyprus has been the target of biodiversity surveys in order to establish potential Natura 2000 areas which will - should North Cyprus be brought in line with EU aquis - become fully recognised Special Environmental Protection Areas (SEPAs). Within these areas marine turtle nesting sites are well protected but due to a lack of data on marine turtle habitat use, resident marine turtles will receive little targeted protection. As marine turtles tend to be aggregated in biodiversity rich marine habitats the sites with higher occurrence of resident marine turtles are also likely to be those sites of the greatest overall conservation value. Indeed, global analysis of satellite tracking data shows that marine turtles are significantly aggregated in Marine Protected Areas (Scott et al., 2012).

We present here some of the first data for the region on the distribution of resident marine turtles. We also demonstrate that based on relationships of trust and mutual understanding, small-scale fishermen can be effectively utilised to help to fill knowledge gaps towards establishing more affective protective mitigation. Combined with our ability to record and summarise fishing intensity data these tools could be of great value. The project has helped the author to develop participatory research methods which will be very useful to his continued studies, could be applied by other researchers in the region and globally to providing better data on similar fisheries.

Although we failed to categorically determine the precise effect of setting LED lights on marine turtle bycatch, target catch seemed to be positively influenced which merits more detailed study, as if target catches are indeed positively affected, then a finalised LEDs product would receive warmer acceptance by the fishery. It was very evident from the amount of wear endured by the LEDs that they were in continuous use through the project. The fact that the fishermen continued to use the LEDs and said themselves that the LEDs reduced turtle captures was encouraging. We also provide information on the positive and negative design elements of the LEDs that will be useful in developing better prototypes for further testing. In November 2013 we visited the director of Fishtek Ltd (www.fishtekmarine.com) at their offices in Devon UK. Fishtek Ltd would be interested to work towards the development of an affordable trammel-net tailored LED providing that some of the product research and development costs were met. The results of this project will be useful to such bycatch mitigation technology developers. What is required is a self contained, self activating LED light with no moving parts, contained in a slick silicon holster similar to that designed by FishTek Ltd for their banana pinger, that could be left to work on its own devices without regular manual operation.

Capture rates in Famagusta Bay are sufficient to implement research to investigate this technology further, but our findings show that this research requires onboard observers to be paid during summer months over multiple seasons. Unfortunately this was outside the scope and capabilities of our project. Fishermen would be happy to invite such observers (Appendix 1) providing that the relevant permissions were sought from the TRNC Animal Husbandry Department of the Ministry of Agriculture and Natural Resources. Providing reasonable incentives was sufficient to gain an exceptional level of participation and we have found the majority of Turkish Cypriot fishermen to be very positive and open to collaboration (with or without incentives) across all ports.

The fishermen do not lie and their estimates of their own activities we found to be very reliable. In our interview they said that they catch approximately 50% green and 50% loggerhead turtles and they say that they catch about 10-15 turtles per year (Appendix 1). These estimates are reflected quite accurately in the quantitative data we present above. This is reassuring and suggests that our anthropological survey derived estimates of marine turtle bycatch rates for North Cyprus of around 1000 individuals annually with a mortality rate of 60% are probably fairly accurate.

Our fishermen were genuinely concerned about their marine turtle bycatch and extremely open to addressing it, potentially in a way which might compromise their earnings or at least time. They gave up their time to help the turtles that they had caught and their own experiments with reviving caught turtles are commendable and are even meriting of further study. Their attitude bodes an air of hope for a bottom-up management approach which could potentially be used to address the marine turtle bycatch issue, in which the fishery would be self-managed via its unions, for example, to avoid certain areas at certain times of year. However, although a similar attitude has been encountered across all ports in North Cyprus, not all fishermen share these attitudes and some we encountered in Famagusta and elsewhere would routinely kill turtles that they caught in order to avoid catching them a second time in the same area. Clear cut laws and a zero tolerance enforcement policy will be necessary in order prevent such rotten apples from spoiling the whole bunch.

Left. Fisherman displaying a section of net destroyed by an entangled loggerhead turtle.

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Appendices

Appendix I. Final questionnaire with fishermen.

1. How many turtles do you catch in a year?

10-15

2. More loggerhead or more green?

50% each. Loggerheads tend to be caught in pairs during summer.

3. What is the economic cost of turtle bycatch for your fishing operation? How much money spent per year a on what and how many hours lost per year and why?

Fisher A. Turtles eat or chew high commercial value fish and cause damages to the nets this is the most significant economic impact. Fisher B. Of all gear and catch damages outlined by fisher A if turtles contribute about 30% then dolphins and pufferfish contribute about 70%, so turtles don't have the greatest impact here. But when turtles are caught in the nets they cause more significant economic losses as we have to cut the nets to get them free and as they wrap themselves up in many meters of net which is impossible to untangle.

4. What proportions are dead?

2-3 a year die. (of the above 10-15 individuals i.e. 20%).

5. Do greens or loggerheads tend to survive better?

Greens are caught in shallow water and so are more likely to survive. For greens 20% die and for loggerheads 40%. It is easier to resuscitate greens.

6. What are the main gear types and target catch with which bycatch is associated?

25, 28 and 30mm nets targeting red-mullet, siganids and parrotfish.

7. Is there anywhere that you tend to catch more turtles. Please indicate these areas and depths?

Off Istanbul Beach at 18-20m deep.

8. During what months do you catch most turtles?

June-August when we put nets at 18-20m targeting isgaro.

9. How many times did you use the lights?

50-55

10. During what months?

Nov-Feb 2013/2014 and Sep-Oct 2014

11. Do you think you caught fewer turtles when the lights were attached to your nets?

They worked well during night time sets but had no effect during day time sets. Siganids are mostly caught around dusk and dawn. Turtles come to the nets to eat the siganids and are not affected by the lights at dusk and dawn.

12. Were either loggerheads or greens more affected by the lights?

Equally affected. Neither came to the LED nets at night.

13. What was the influence on target catch? Did you catch more or fewer fish overall. What species did you catch more of, what species did you catch less of? Any influence on octopus, sepia? Discards?

The lights do not affect the fish catch. Octopus and cuttlefish numbers are low because of (recently colonising invasive non-native) pufferfish and because of illegal cage fishing.

14. What did you like about the design of the lights?

Great that they work automatically on pressure change but this didn't work at some of the shallower sets. For sets below 5m we turned them all on and off manually which was hard work and time consuming.

15. What did you not like about the design of the lights?

They break quite easily.

16. How could they be improved for your fishing operation?

They could turn on when they hit the water not when they get to a certain depth. They need to be smoother, flush with the float line and with no moving parts or jagged edges as they dangle about and tangle up the net which is annoying.

17. If the lights were freely available and could be modified to your suggestions would you chose to use them?

Yes of course.

18. For further research would you be happy to support onboard observers on your vessels to record data?

Of course no problems so long as you have the permission of the TRNC animal husbandry department for additional people to work on our boat.