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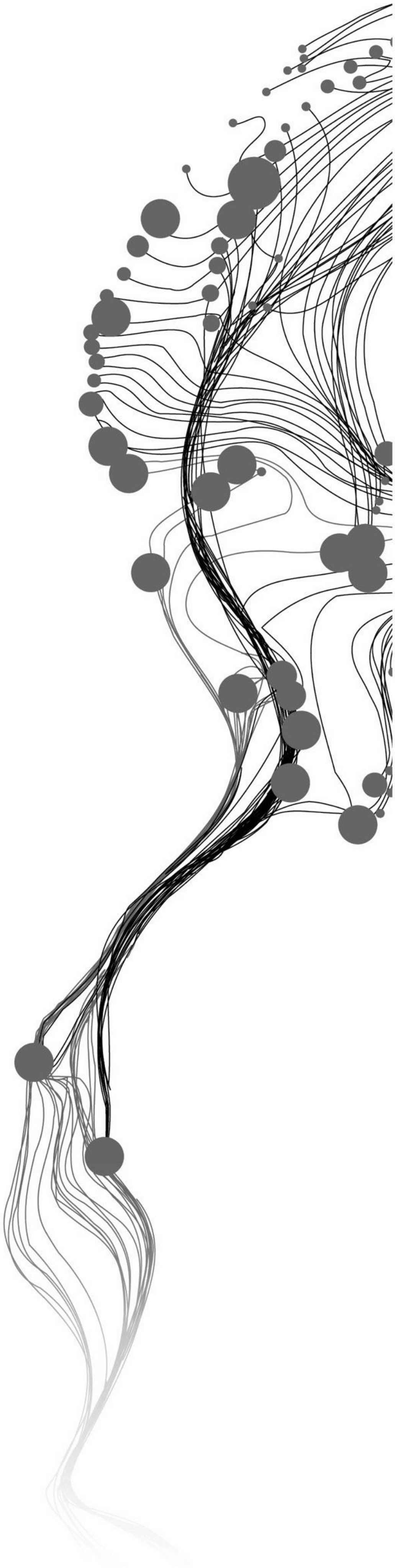

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Enschede, The Netherlands, May, 2016

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Geographic Information and Earth Observation for Environmental Modelling and Management (GEM)

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ABSTRACT

Crete, one of the most popular tourist destinations in the Mediterranean region is also home to three major loggerhead turtle nesting sites. The increase in the annual visitors in the island has generated improved economy for the local stakeholders in the past decades. Unfortunately, the annual nest number in those three primary nesting sites of the island has since then observed a declining trend, which may have a relationship to the increased human activities in those sectors. Considering the natal homing characteristics of loggerhead turtles as well as the high level of beach use by visitors during the nesting period (summer months), it is assumed that the disturbed female turtles may move to other beaches which may have less anthropogenic disturbances and were previously not known for hosting large number of turtle nests (so called secondary beaches). Two Machine Learning Algortithms were used in this study, each of them trained once with only primary beach nest points and another time with all beach nest points, in order to understand the effect of incorporating training points of relatively lesser known sites to correctly identify the potential nesting beaches.

The beach sectors not known for hosting large number of turtle nests or the so called secondary beaches have seen an increase in hosting loggerhead nests as the result of the paired t-test could confirm it with 95% confidence level. Furthermore, Sitia, one of the sectors in the eastern part of Crete, has been established during the recent years as an important nesting site hosting between 20 and 40 loggerhead nests annually.

The study also managed to reveal that training the SDMs with only nest locations from primary sites completely failed to identify the secondary nesting beaches. Incorporation of nest locations from secondary beaches to train the model also showed a very low accuracy, but it managed to identify some of the secondary beaches. As the accuracy of the models relied on correctly recording all the nesting events in reality, such poor results may still be accepted. Furthermore, considering the conservation status of loggerhead turtle, it may be acceptable to expand a future monitoring system in to beaches which were incorrectly predicted as nesting beaches by the models than not to monitor them at all.

The study expected to find a strong correlation between the distance of a beach sector from primary beaches and selection of beach for nesting. However, the relationship was found to have very poor agreement with a correlation coefficient of 0.06. Nonetheless, it was observed that only 26% of the beach sectors located at more than 50 km from a primary nesting beaches, were selected by the turtles for nesting as oppose to approximately 44.5% beach sectors which are located at a closer distance.

Despite the obvious increase in the annual loggerhead nest count in the secondary beaches of Crete, total nest count has seen steep decline. Considering the relatively steady annual nest number in the Mediterranean region, it is highly probable that there is not only a small scale local shift in their nesting ground, but also a shift covering greater distance and moving to other Mediterranean nesting grounds.

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LIST OF ABBREVIATION

ARCHELON	Sea Turtle Protection Society
BODC	British Oceanographic Data Centre
BRT	Boosted Regression Tree
DEM	Digital Elevation Model
GIS	Geographic Information System
ITC	Faculty of Geo-information Science and Earth Observation
IUCN	International Union for Conservation of Nature
MAXENT	Maximum Entropy
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
SDM	Species Distribution Model
SST	Sea Surface Temperature
TSS	True Skills Statistics
USGS	United State Geological Society
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund

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1. INTRODUCTION

1.1. Background: sea turtles and loggerhead turtle

Sea turtles or marine turtles are oceanic reptiles, generally found throughout the world, except the Polar regions. At present, seven species of marine turtles are found globally which belong to two scientific families; Cheloniidae and Dermochelyidae. The family Dermochelyidae only contains the species leatherback sea turtle (*Dermochelys coriacea*), while the family Cheloniidae contains the remaining six species; green turtle (*Chelonia mydas*), loggerhead turtle (*Caretta caretta*), hawksbill turtle (*Eretmochelys imbricata*), flat back turtle (*Natator depressus*), kemp ridley turtle (*Lepidochelys kempii*) and olive ridley turtle (*Lepidochelys olivacea*).

The loggerhead turtle, *Caretta caretta*, is a large oceanic turtle, found throughout the world within a certain latitude range. Due to the large head and the powerful jaws of this species, it is called "Loggerhead" (WWF, 2015a). Adult Loggerhead turtles normally have length of 70-100 cm and can weigh up to 200 kg.

1.2. Current status and threats

Decline in several species of marine turtle population has been observed in the recent past due to different human induced causes, with bycatch mortality being one of the major contributors (Lewison, Freeman, & Crowder, 2004; Limpus & Limpus, 2003; Spotila, Reina, Steyermark, Plotkin, & Paladino, 2000; Troëng, Chacón, & Dick, 2004). Due to this global decline of marine turtle population, six of the seven species are currently categorized as threatened (IUCN, 2015). Table 1 shows the current status of the marine turtles worldwide.

Table 1: Summary of marine turtle species present status (IUCN, 2015)

Species	IUCN Red List Status	Year Assessed
Leatherback sea turtle (*Dermochelys coriacea*)	Vulnerable	2013
Green turtle (*Chelonia mydas*)	Endangered	2004
Loggerhead turtle (*Caretta caretta*)	Endangered	1996
Hawksbill turtle (*Eretmochelys imbricata*)	Critically Endangered	2008
Kemp ridley turtle (*Lepidochelys kempii*)	Critically Endangered	1996
Olive ridley turtle (*Lepidochelys olivacea*)	Vulnerable	2008
Flatback turtle (*Natator depressus*)	Data Deficient	1996

The effect of bycatch mortality on marine turtles has been observed through the decline in their annual nest numbers globally. Researches has revealed the necessity of implementing a proper management plan in the Pacific Ocean in order to restrict loggerhead and leatherback sea turtles from extinction as the region has exhibited a declining trend in their annual nesting (Lewison et al., 2004; Spotila et al., 2000). The decrease in the turtle population has been observed most prominently in Colombia where the annual loggerhead turtle nest number dropped from approximately 2,000 nests in the 80's (Marquez, 1990) to a drastic low of 46 (Amorocho, 2003). Although, such drastic decrease in the loggerhead turtle nesting has not been observed in parts of USA, a study spanning for more than 15 years in South Carolina showed that the number of nests in the region dropped from 5,412 in 1980-82 to 2,887 nests in 1995-97 (Hopkins-Murphy, Murphy, Hope, Coker, & Hoyle, 2001), which still exhibits an alarming decline of 46% in nest count. Negative trend in nesting density in some major nesting sites of Greece has also been observed (Margaritoulis, Panagopoulou, & Rees, 2009).

However, bycatch mortality is not the only threat faced by the marine turtles. Several other terrestrial threats have also been identified that effect the nesting of oceanic turtles adversely (Casale & Margaritoulis, 2010; SWOT, 2006). Almost all the countries in the Mediterranean, known for hosting loggerhead turtle nests, are facing some terrestrial threats (Table 2).

Table 2: Threats to loggerhead turtle nesting in the Mediterranean (Casale & Margaritoulis, 2010)

Country	Coastal development	Beach restructuring	Non human predation	Human exploitation	Other threats
Cyprus	√	√	√	X	√
Egypt	√	X	√	√	X
France	√	√	X	X	√
Greece	√	√	√	X	√
Israel	√	X	√	X	X
Italy	√	√	√	X	√
Lebanon	√	√	√	X	√
Libya	√	√	√	√	X
Spain	√	√	X	X	X
Syria	X	X	√	√	√
Tunisia	√	X	√	X	√
Turkey	√	√	√	X	√

1.3. Loggerhead turtle: nesting behaviour

Loggerhead turtles are known to reach their sexual maturity between 10-30 years (WWF, 2015b). The species has been studied extensively in Northern Cyprus and it was observed that the median interval between two nesting seasons for the female turtles is approximately 2 years (Broderick, Glen, Godley, & Hays, 2002). The main nesting season for this species of turtle in the Mediterranean is between May and September with most nesting activities taking place during the night time. The female loggerhead turtles are known to nest multiple time in a season with the range of clutch frequency varying between 1.8-2.2 clutches/season (Broderick et al., 2002), while some study simplified it and considered 3 clutches per female per season (Marquez, 1990). Study conducted in Zakynthos, Greece has revealed that a clutch of loggerhead turtle can contain between 90 to 110 eggs (Margaritoulis, 1982).

1.4. Loggerhead turtle: nesting environment

Factors influencing the selection of a site for nesting, had already been studied for several years (Foley, Peck, Harman, & Richardson, 2000; Karavas, Georghiou, Arianoutsou, & Dimopoulos, 2005; Kikukawa, Kamezaki, & Ota, 1999; Mortimer, 1982; Wood & Bjorndal, 2000). Studies, in the form of comprehensive Master's thesis, had been carried out during the recent years in Crete, Greece, to understand the nesting site selection based on physical characteristics of beach, aquatic environment, presence of certain elements in water etc. (Li, 2009; Louhenapessy, 2010; Moetasim, 2011). Based on those studies, it was established that the nesting density is often dependant on parameters such as beach length, slope, temperature, sand grain size, sand conductivity, pH, presence of sea grass etc.

1.5. Loggerhead turtle: nesting distribution

Global nesting distribution of Loggerhead turtle shows that approximately 88% of all the nests of this species occur in Oman, USA and Australia with the beaches in Oman and South Florida being the only beaches with more than 10,000 nesting females per year (Marquez, 1990; NOAA-FISHERIES, 2014). This species is also known for nesting in the Mediterranean coasts and one of the earlier study revealed that approximately 2,000 female turtles of this species annually nest in this region (Groombridge, 1990). Relatively recent study showed that the total number of loggerhead turtle in the Mediterranean can be between 2,280-2,787 (Broderick et al., 2002), with an annual nest count of approximately 7,200 (Casale & Margaritoulis, 2010). Studies have revealed that approximately 44% of the total Loggerhead nests in the Mediterranean coasts are found in three main nesting locations in Greece (Margaritoulis et al., 2009; Margaritoulis & Rees, 2001; Margaritoulis, 2005). These areas are; 5.5 km beach along Laganas Bay, 9.5 km beach along Kyparissia Bay and around 10.8 km beach in Rethymno in Crete. The other known major nesting site of this species in the Mediterranean includes, Turkey, Libya, Cyprus (Margaritoulis et al., 2003), with few other countries such as Tunisia, Syria, Israel and Italy hosting relatively fewer nests. However, the lack of proper monitoring and management system in some Mediterranean countries might have led to an underestimation of loggerhead nests, as the estimation of approximately 10 nests annually in Italy (Casale & Margaritoulis, 2010), has been suggested to be underestimating the total nest number in Italy which could be few folds greater than the estimated 10 (Casale et al., 2012; Mingozzi et al., 2007).

1.6. Species distribution model (SDM)

Distribution of a species is closely related to its preference of the environmental and climatic conditions. Classification of plant formation in the world based on precipitation and evapotranspiration had been done almost 50 years ago (Holdridge, 1967). The development in the field of statistical analysis, geographic information as well as with the increased availability of powerful computers has led to the development of several algorithms or models in the recent years to predict the distribution of a species using the environmental parameters (Crisci, Ghattas, & Perera, 2012; Guisan & Thuiller, 2005; Guisan & Zimmermann, 2000).

Based on the availability of data for a species, different distribution models such as data-based or algorithm-based can be used. In case the species data consist both "presence" and "absence" information, generalized linear models (e.g. GLM, GAM, BRT etc.) can be used in order to extract the suitability of the species presence based on the selected environmental parameters. However, in the field of ecology it is often very common to have only "presence" information. In order to utilize those "presence" only information, several machine learning algorithms have been developed which can predict habitat suitability using the available "presence" information through generating some "pseudo-absent" points (e.g. ENFA, DOMAIN, MAXENT etc.). Hegel, Cushman, Evans, & Huettmann, (2010) has explained in detail about the different statistical models being used for species distribution modelling at present.

In case of loggerhead turtle nesting, it is relatively more difficult to categorize a beach as non-nesting due to the absence of continuous monitoring system in most beaches. Thus, using a model which requires both "presence" and "absence" information will probably not be the best solution. This has led to the selection of machine learning algorithm that use presence and some form of pseudo absence for modelling. Considering that both Boosted Regression Tree (BRT) and MAXENT have already been proved to exhibit a robust performance throughout a wide geographic range and over several species (Elith et al., 2006), the study used both these models.

1.7. Research problem

Beaches in the Mediterranean regions are one of the most popular tourist destinations at present. Tourism in this region has increased significantly in the past decades with approximately 306 million tourists visiting Mediterranean countries in 2011, which is around 100% increase from 1990. The scenario in Greece has not been any different in compare to the other Mediterranean countries. Tourism presently plays an important role in their economy with more than 16% of the total Gross Domestic Product (GDP) coming from this industry (World Travel and Tourism Council, 2014).

Direct economic gain through tourism is often not the only benefit for a country, as infrastructural developments as well as preservation of historic sites are ensured to maintain touristic attraction of the area. However, unless the main touristic attraction of the area is a forest, preservation of natural resources or the related floral or faunal species is often overlooked during these developments. Increased tourism in Crete has triggered the development of infrastructures such as hotels, bars, restaurants, taverns etc. to support the additional visitors. This had led to light pollution, sound pollution and increased use of the beaches. In case of loggerhead turtles, their nesting activity was found to be inversely related to the beach use intensity (Arianoutsou, 1988).

Figure 1: Photo showing the extent of beach use close to Chania

As of 2002, Greece hosts seven major loggerhead turtle nesting sites with the island of Crete representing three of those sites (Margaritoulis & Rees, 2003). The same study revealed that those three nesting sites in Crete received a total of 486 nests in 2002 (Table 3). Considering the large number of tourists visiting Crete annually, the effect of tourism or the increased beach use (example of one beach section shown in Figure 1) on loggerhead nests was studied (Lima, 2008). The same study found that the nesting females in Rethymno avoided nesting in areas exposed to high level of disturbance caused by shops or parking lots. The same study has also observed a proportionate relationship between nest counts and distance from the town. Threat from light pollution was not proved in Greece, but experience from other parts of the world on other marine turtles reveal that the increased amount of illumination can also act as a threat to the nesting turtles (Tripathy & Rajasekhar, 2009). Continuation of the monitoring in Rethymno even beyond 2002 has revealed that in 2004 the beach received only 256 loggerhead nests (Margaritoulis et al., 2009).

Loggerhead turtle, similar to all other marine turtles, exhibit natal homing characteristics, meaning that the adult females return to the beaches where they were born (Brothers & Lohmann, 2015; Lohmann, Witherington, Lohmann, & Salmon, 1997). Due to the lengthy period it takes for the species to reach sexual maturity, the probability of the natal beach being degraded is relatively high. This is much more prominent in case of Crete which has experienced more than 100% growth in tourist arrival in last 25 years. Female turtles, if disturbed upon their return to the natal beach, may not be able to delay the nesting process beyond a certain period. Thus, the selection of other beaches by them for nesting, cannot be overlooked. However, the only time the whole island of Crete was surveyed to compile loggerhead nest information was in 1990-1991, and yielded in the discovery of three main turtle nesting sites in the island (Margaritoulis & Dretakis, 1991). Despite those three main nesting beaches in Crete (known as primary beaches from hence forward) exhibiting declining trend in annual nest count during past decades, the complete island has not been re-surveyed to investigate the development of any new important nesting site since 1990-1991. Thus, the necessity of a study investigating the current situation of loggerhead turtle nests in Crete, especially in beaches which were not known to host large number of turtle nests (secondary nesting beaches), cannot be discarded. Considering the intensity of human activity in the primary nesting beaches between May-August, this study expects to find an increase in nest count in the beaches which traditionally had very low or no nest count.

Table 3: Major loggerhead nesting sites in Greece (Margaritoulis & Rees, 2003)

Name of site	Beach length (km)	Number of nests	Nest density (nests/km)
Zakynthos	5.5	1175	213.6
Kyparissia	9.5	593	62.4
Rethymno, Crete	10.8	325	30.1
Lokonikos	23.5	187	8.0
Chania, Crete	13.1	100	7.6
Messara, Crete	8.1	61	7.5
Koroni	2.7	55	20.4

As species distribution modelling, especially for faunal species, often derive the "presence" data from area which are easily accessible or from known locations with high abundance of the species (Dennis & Thomas, 2000), the results may exhibit geographic biases. The detection of beaches that differ from the primary beaches in physical characteristics may not be possible with such biased models. However, sporadic nesting in non-primary nesting sites has been recorded in several places of the Mediterranean (Casale & Margaritoulis, 2010), which may only be detected through inclusion of secondary beach nest points during model training. Moreover, as the process of nesting is related to time and cannot be delayed indefinitely, it is probable that the beaches that are in close proximity to the primary nesting beaches may be preferred by the female turtles over the beaches located at a further distance.

1.8. Research objective

1.8.1. General objective

The general objective of this study was to investigate whether an increased trend has been observed in the selection of relatively unknown beaches by the loggerhead turtles for nesting in the island of Crete. In order to do this, the annual nest count in the secondary beaches were recorded and was compared with the information from 1990-1991. Considering the overall decrease in loggerhead nest count in Crete, identification of other suitable beach sectors, with a potential to host loggerhead nests, is of great importance. Thus, the study also investigates if training a model with both primary and secondary beach nest information enables better identification of those secondary beaches. In other words, compares the accuracy of the results obtained through training the model with only primary beach nests and with both primary and secondary beach nests. Considering the inability to delay the nesting indefinitely, it is assumed here that the female turtles may tend to select beaches close to the primary nesting site to lay their eggs.

1.8.2. Specific objective

1. Compare the present loggerhead nest count in the secondary nesting beaches with data from 1990-1991.
2. To investigate if the accuracy of modelling loggerhead nesting habitat suitability increase when the model is trained using both primary and secondary beach nest points.
3. Investigate the relationship between distance from primary nesting beaches and selection of a beach by the loggerhead turtles for nesting.

1.9. Research question

1. Is there any difference in the nest count of loggerhead turtles in the secondary nesting beaches of Crete in compare to the count from 1990-1991?
2. Does the SDM's accuracy to identify secondary nesting beaches improve when the model is trained with both primary and secondary beach nest information?
3. Does distance from primary nesting beaches show a strong relationship with that beach being selected by the turtles for nesting?

1.10. Research hypotheses

H_0 1: Current loggerhead nest count in the secondary nesting beaches of Crete is not different to that of 1990-1991.
H_1 1: Current loggerhead nest count in the secondary nesting beaches of Crete is significantly higher to that of 1990-1991.

H_0 2: Inclusion of presence information from secondary beaches has no difference on the accuracy of the models result.
H_1 2: Inclusion of presence information from secondary beaches improves the accuracy of the models result.

H_0 3: Selection of a beach for nesting has no relationship with the distance of that beach from the nearest primary nesting site.
H_1 3: Selection of a beach is strongly correlated to the distance it is located from the primary nesting beaches.

2. MATERIALS AND METHODS

2.1. Study area

Crete, one of the largest islands in the Mediterranean Sea, is also the largest island in Greece. Geographically the island is located between 23°31' E to 26°18' E and 34°55' N to 35°41' N (Figure 2). The island encompasses an area of larger than 8,000 km² with a coastline which is longer than 1,000 km ("Explore Crete," 2015). The island of Crete supports approximately 623,065 inhabitants with Iraklio being the largest city with a population of 173,993 (Hellenic Statistical Authority, 2014).

The development of tourism has already impacted on loggerhead nesting in the island of Crete and the annual nest count has exhibited a downward trend. However, the present monitoring for loggerhead nests only focuses on the three primary nesting beaches in Crete, discovered during the 1990-1991 study. Thus, it is of great importance to investigate the existence of other potential nesting beaches and ensure (if any present) a better management or development plan to restrict any deterioration of those sites.

Figure 2: Map showing the island of Crete

2.2. Nesting and non-nesting beaches

Based on Margaritoulis & Dretakis (1991), 294 discrete beach sections were surveyed during the study which totalled to approximately 179 km in length. Out of the surveyed beaches (several sections were often merged to one name/sector), 105 beach sectors were in the main island of Crete. The absence of any other survey covering the whole island made the results of this study to be used as a baseline and the data collected during the field work were compared to this.

The study recorded information on turtle emergences on a beach as well as actual nesting in the sectors. Dividing the beach sectors according to turtle emergence or nesting showed a clear distinction between the mean length of the beaches from each category (Table 4).

Table 4: Nesting and non-nesting beaches in Crete (Margaritoulis & Dretakis, 1991)

Beach	Total no.	Average length of the beaches
Beaches with no emergence, no nest	59	1108.64 m
Beaches with emergence, but no nest	23	1817.39 m
Beaches with nests	23	2483.04 m

2.3. Method

The overall study consisted of three general segments; preparation for field visit, data collection during field visit and analyses of the collected data. The following sections discuss briefly about the activities that were undertaken during each segments of the study.

2.3.1. Pre field work

Limited availability of time during the field work restricted the study from visiting every beach sectors that were covered by Margaritoulis & Dretakis (1991). Thus, the beaches categorized as improbable for nesting by the 1990-1991 study were not visited. Beach sectors that have not been visited by previous ITC students were provided with a relatively higher priority due to the lack of information regarding turtle nests in those sectors from recent past. Moreover, the primary nesting beaches were kept for the last as the actual numbers of turtle nests in those beaches could be obtained from the researchers or volunteers working with ARCHELON. Based on these, a tentative list was made with the names of the beaches to be visited as well as their coordinates before the field work started.

The coordinates given in the report from 1990-1991 were added to a GIS software and inspected for errors. Incorrect coordinates were edited with the use of accompanying information (i.e. name of location) and were corrected. Figure 3 shows one such area where four points had incorrect coordinates, and also the probable correct location of those points based on the name of the places.

Due to the timing of the field work, which was between September and October, the probability of all the laid eggs being already hatched was very high. Moreover, other than the primary nesting beaches, only few areas are regularly monitored by ARCHELON, making it extremely difficult to identify a nest. Thus, the study focused on collecting information about nesting through interview of local people.

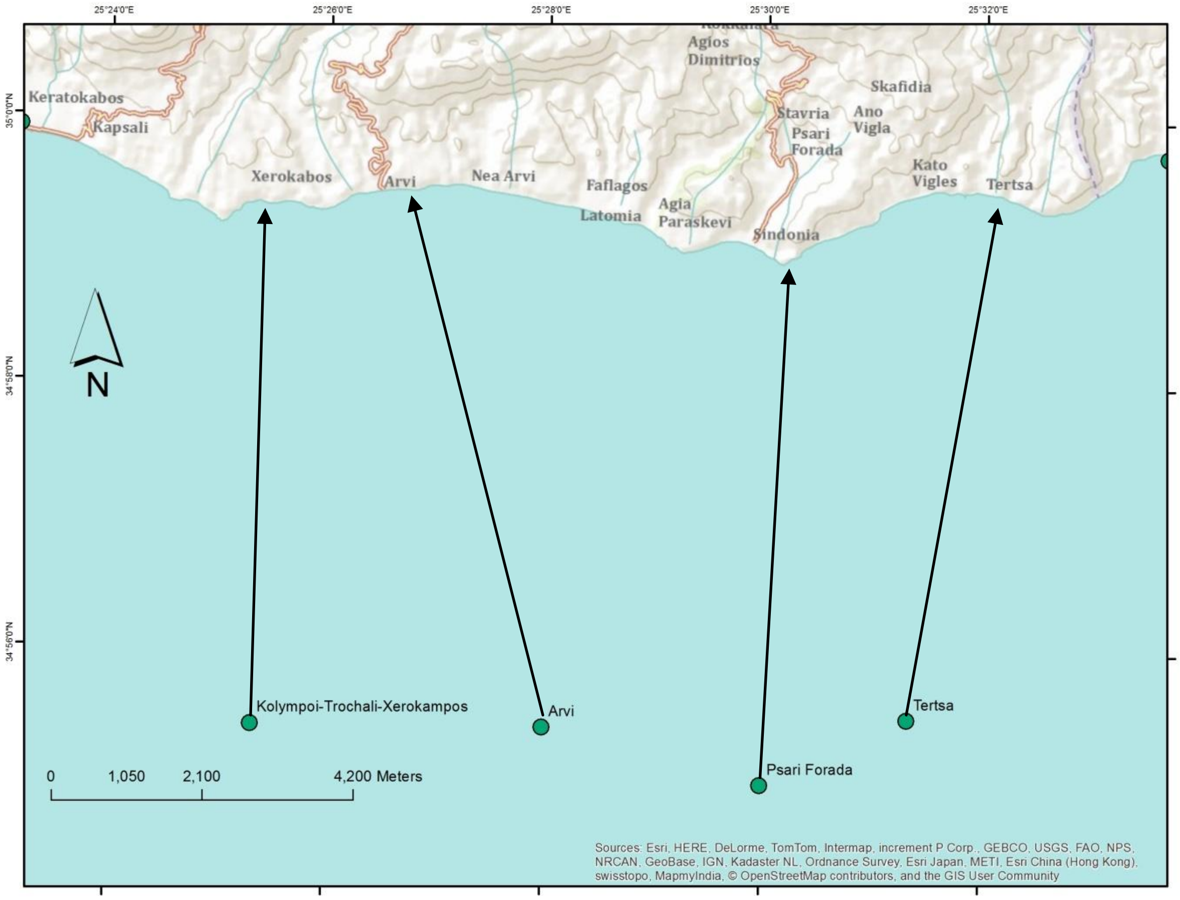
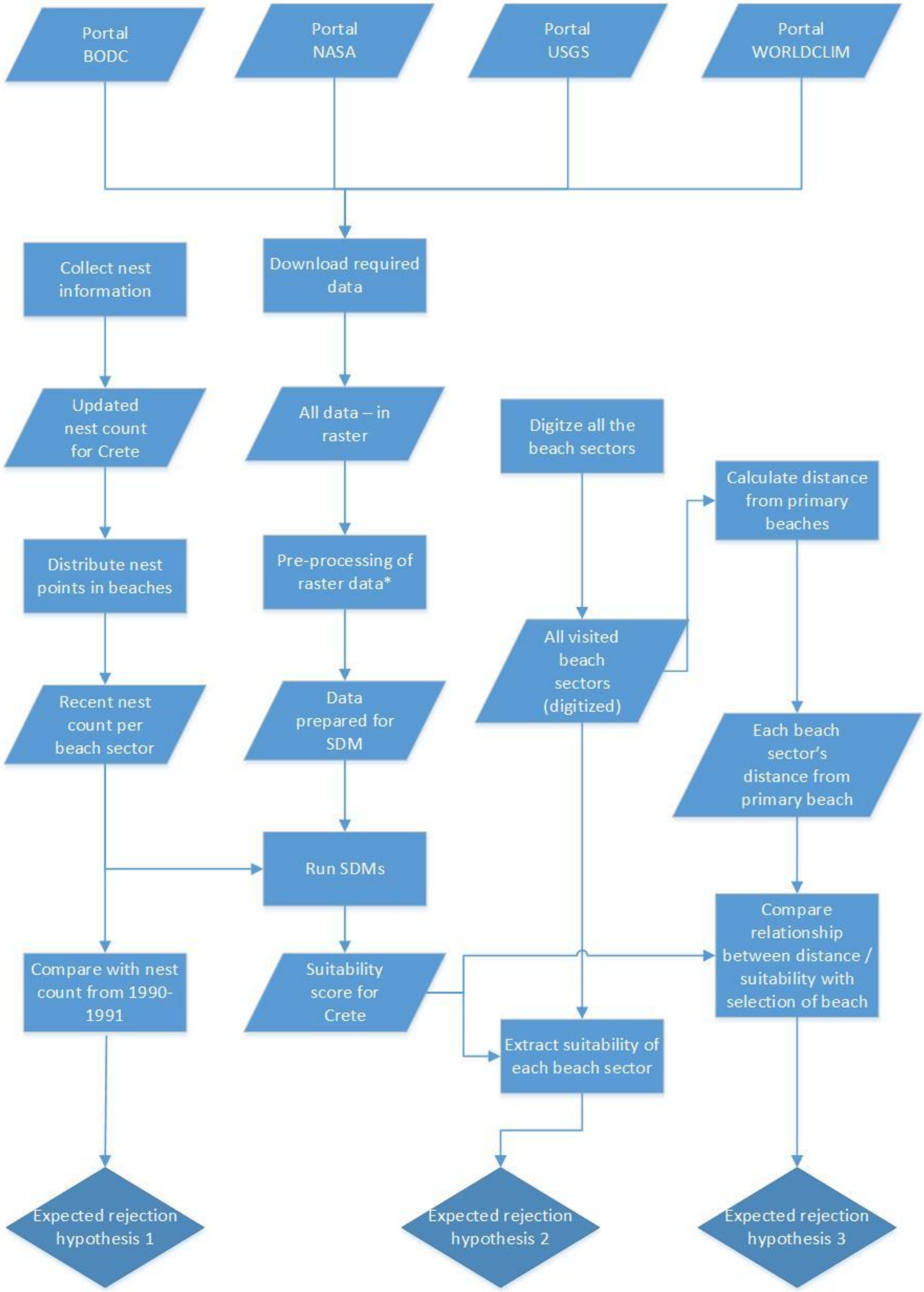


Figure 3: Incorrect beach locations and probable correct location

2.3.2. Field work

During the field work, the selected beaches were visited in order to investigate the loggerhead nest count of the ongoing season. In addition to that, questions were also asked to obtain information regarding turtle nesting during previous years. In order to understand nature of the nesting locations, the interviewees were requested to show the exact location of the nests (if they remembered). Moreover, an attempt to understand the attitude of local people towards loggerhead turtle nesting was undertaken through inquiring about measures taken by the local people once a nest was identified. Questions were also asked in order to understand the extent of human use in each visited beach during the peak of the tourist season. An approximate quantification (rank based) of human use on each beach sector was done based on the opinion of the interviewees as well as the visual confirmation of existing facilities (bars, cafes, sun chairs etc) on each sector at the time of visit. An example of the questions asked is provided in Appendix 7.4.

Researchers and experts from Natural History Museum of Crete and ARCHELON were also visited in order to understand their perspective of the present loggerhead nesting in Crete as well as to inquire about any other threats that should be taken into consideration. Moreover, their point of view on monitoring and management of turtle nests were also recorded in order to achieve an overview of probable steps that can be taken in future.



* Elaborated in next figure

Figure 4: Simplified flowchart of the study

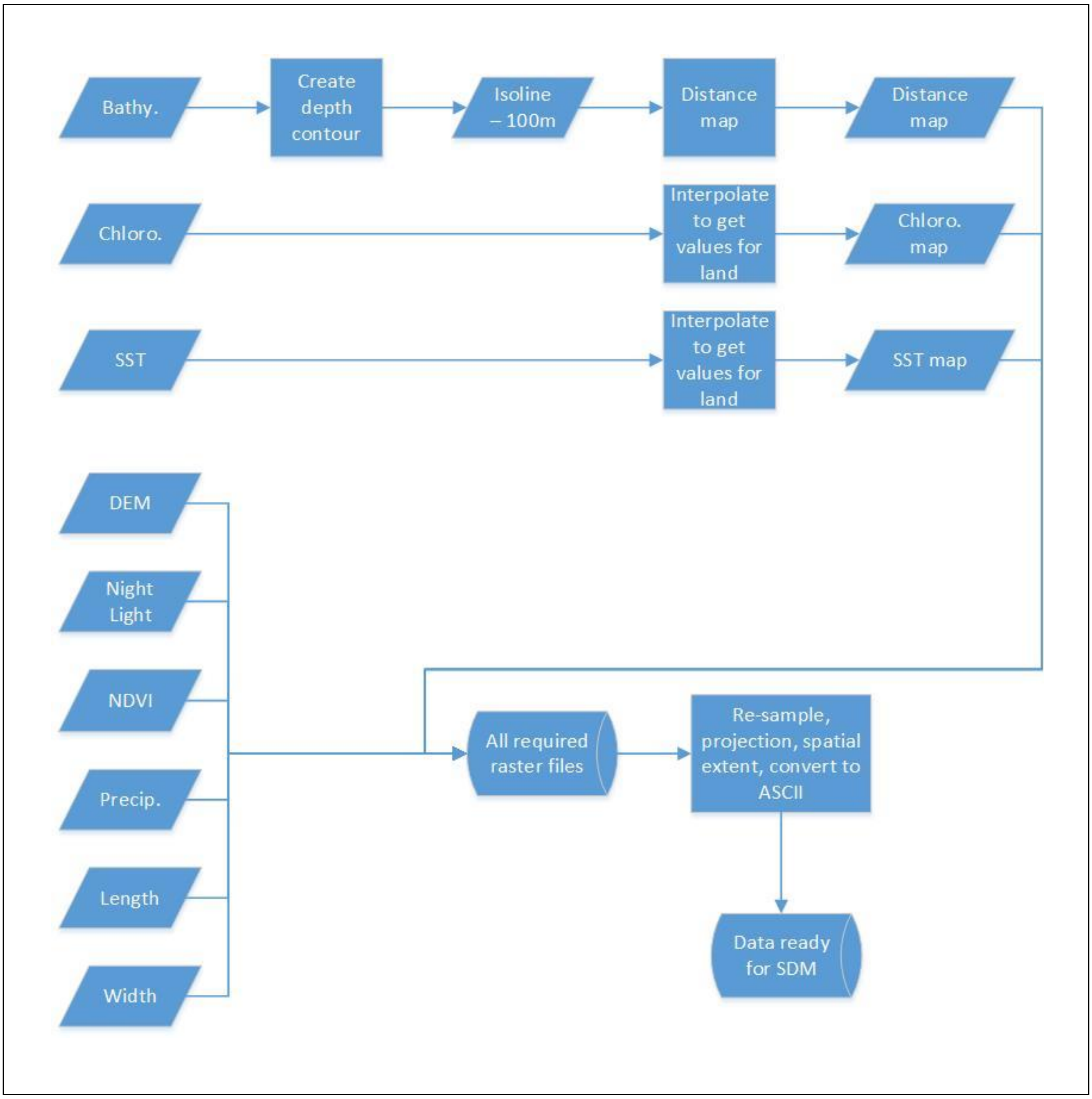


Figure 5: Flowchart explaining the steps taken for pre-processing of the raster data in order to run SDM

2.3.3. Data preparation and analyses

Erroneous data were eliminated through examination of the collected field data. In addition to that, information from nine beach sectors, collected by Guo (2014) were merged to the database, as those beaches were not visited during this visit. Loggerhead turtle nest numbers from the visited beaches were then compared to that from 1990-1991 and a paired-t test was carried out in order to justify the hypotheses mentioned earlier.

The identification of explanatory variables necessary for the SDMs were completed in this stage. In order to select the explanatory variables, several literatures were reviewed and the variables previously found to be significant for loggerhead turtle nesting were obtained and used for the SDM.

Successful execution of the SDM required several steps that includes; acquisition of relevant data, processing of the acquired data both in terms of extents as well as projection. The result of the distribution model was extracted for each visited beach section. An overview of the steps taken for data preparation and analyses are shown in Figure 4 and Figure 5. The following sub-chapters discuss the same steps in more detail;

2.3.3.1. Data acquisition

Remotely sensed images were obtained from several portals in order to acquire all the necessary data required to run the SDMs. Data were acquired from United States Geological Survey (USGS), National Aeronautics and Space Administration (NASA), British Oceanographic Data Centre (BODC), WORLDCLIM/BIOCLIM portals (Table 5). In order to reduce the load on memory space of the work station, data were only obtained for either the plates (satellite image) which represented the island of Crete or with the use of bounding coordinates.

Table 5: Table displaying the different data used as input for the model and their sources

Data	Resolution	Unit	Format	Source
Chlorophyll	0.1 degree	mg/m3	GeoTiff	NASA
DEM	30 m	m	GeoTiff	USGS
Bathymetry	30 arc seconds	m	ESRI ASCII	BODC
Night light	30 arc seconds	Range (0-63)	GeoTiff	NASA
NDVI	30 m	Range (-1 to 1)	GeoTiff	Landsat/USGS
Precipitation	1 km	mm	GeoTiff	Worldclim
Sea surface temperature (SST)	0.1 degree	degree Celsius	GeoTiff	NASA
Length	30 m	m	GeoTiff	From 1990-1991 report
Width	30 m	m	GeoTiff	Calculated through digitization of beaches

2.3.3.2. Delineation of beach section boundary

In order to delineate the boundary of each beach sections, they were digitized from Google Earth and were converted to polygon layers. As some of the beach sectors were fragmented into several sections, they were merged together to represent the same sector. The boundary layer of Crete, obtained from DIVA-GIS, was probably generated from a relatively coarser resolution (exact metadata was unknown), as it was observed at some cases that the boundary of the island was unable to cover the beach sector polygons completely. In order to contain all the beach sections inside the boundary of Crete, the boundary line was extended outwardly by 20 meters.

2.3.3.3. Identification of explanatory variables

Majority of the explanatory variables were selected based on expert knowledge and through review of similar studies. For example, literature reviews revealed the importance of SST during nesting period for loggerhead turtles (Hays et al., 2002), thus the variable was included in the model. Similarly, mean precipitation during the nesting period was also added to the model as sand moisture can play a potential role on selection of a site by turtles for nesting (Wood & Bjorndal, 2000). Studies have shown that turtles prefer long sandy beaches for nesting as the relationship between beach length and clutch number was robust (Mortimer, 1982), thus the length of the visited beaches were calculated as well as their width and were added to the model to represent the physical characteristics of the beaches. In order to have an approximate width of the beach sectors, the area of the beach was divided by the length and the resulting value was considered as the average width of each section. Literatures also suggested that the nesting females prefer to spend time in the shallower water regions during the day time (Mortimer, 1982), thus bathymetric data were also added in the model. In order to add the bathymetric data, a distance map was produced from the 100 m depth isoline as the distance can represent the availability of shallow water area in front of the beach. As an indicator of the presence of algae in the water, chlorophyll content was also chosen as an input to the model. In order to incorporate the anthropogenic disturbances, night light data were added to the model as night light represent the number of people who are in the proximity of the beach and can cause disturbance to nesting of loggerhead turtles (Arianoutsou, 1988; Berry, Booth, & Limpus, 2013).

2.3.3.4. Processing of the raster data

Species distribution modelling through machine learning algorithm requires certain pre-processing of input data. This include; i) ensuring that all the necessary explanatory variables are in the same coordinate system, ii) maintain the same spatial extent as well as resolution for the selected variables, iii) ensure that all the raster layers are coincident (every explanatory variable has to align perfectly), iv) ensure that all the variables have cell values inside the boundary of Crete. As the coordinates of the nests are in the beach, some additional processing was required in order to incorporate variables such as sea surface temperature and chlorophyll. As the raster layers of sea surface temperature and chlorophyll content had NoData values for the terrestrial part of the island, a three step process was adopted to address this issue. Firstly, the two raster layers were converted to a vector point layer, secondly, the points that represented cells on terrestrial Crete were removed, and thirdly, using the edited vector layer, the missing points were then interpolated and were converted back to a new raster layers. Considering that the study area for turtle nesting is in the beaches (close proximity to the sea), it was assumed that the value of the nearest sea surface temperature or chlorophyll content can represent the value at the point of the nest. Upon ensuring all the above mentioned criteria, the raster layers were converted to ASCII format in order to perform the SDMs.

2.3.3.5. Resolution of explanatory variables

Identical spatial resolution for all the explanatory variables is required to be ensured for running SDM. In order to extract maximum information from the finer resolution variables, all the remaining variables were re-sampled to that finer spatial resolution of 30m. This decision was also motivated by the fact that the study area consisted of a relatively small region representing approximately 250 km in East-West direction, and a coarse resolution of 4 km might have led to loss of information.

2.3.3.6. Nest locations and SDM

The study focused on the importance of the inclusion of training data from relatively lesser known sites and the the accuracy of each SDM using different training data. Thus, the compiled nest count information was divided according to beach type (primary vs secondary). Inability to collect exact geographic position of each nest led to generate random points inside each sector representing the number of nests hosted in that sector. For example; as Rethymno in 2015 received 173 nests, a total of 173 random points were generated inside the polygon that represents the beach sections of Rethymno. Those points were then used in order to run the model, once using only primary beach nest information, and another time with both primary and secondary beach nests to train the model.

2.3.3.7. Accuracy of the model

As the second hypothesis of this report focuses on the accuracy of the models, mean suitability for each beach section was extracted. For comparing the accuracy, Cohen's Kappa coefficient and True Skill

Statistics (TSS) were used. Delineation of the threshold value was made through investigating the minimum - mean suitability score of the primary beaches from all the model runs (two models, each having two runs). It was assumed that the primary beaches are considered as suitable beaches, disregard to their mean suitability score. Thus, the minimum - mean suitability score of the primary nesting beaches was used to create the threshold value (shown in Table 6), which in return was used to calculate a confusion matrix and also to calculate the Kappa coefficient and TSS (the equations for these are provided in Table 7).

Table 6: Threshold values used for the different model runs

Model	Training points	Threshold
MAXENT	Only primary beach nest points	0.455
	All beach nest points	0.476
BRT	Only primary beach nest points	0.752
	All beach nest points	0.773

Table 7: Description of confusion matrix and the methods by which Kappa coefficient and TSS were calculated

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Ground Truth</td></tr>
<tr><td>Presence</td><td>Absence</td></tr>
<tr><td rowspan="2">Model</td><td>Presence</td><td>a</td><td>b</td></tr>
<tr><td>Absence</td><td>c</td><td>d</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="2">Sensitivity</td><td colspan="2">$\frac{a}{a+c}$</td></tr>
<tr><td colspan="2">Specificity</td><td colspan="2">$\frac{d}{b+d}$</td></tr>
<tr><td colspan="2">Kappa</td><td colspan="2">$\frac{\left(\frac{a+d}{n}\right)-\frac{(a+b)(a+c)+(c+d)(d+b)}{n^2}}{1-\frac{(a+b)(a+c)+(c+d)(d+b)}{n^2}}$</td></tr>
<tr><td colspan="2">TSS</td><td colspan="2">Sensitivity + Specificity - 1</td></tr>
</table>

3. RESULTS

3.1. Present loggerhead nest count

Compilation of present field work as well as data from Guo (2014), provided nest count information of more than 90 beach sectors. Considering the higher popularity of the Northern beaches of Crete in compare to the Southern, an imaginary line was drawn in East-West direction, dissecting Crete into two halves and the beaches were classified based on their location on either Northern or Southern Greece. As several beach sectors were neither used by the loggerhead turtles during 1990-1991, nor in recent years, those sectors were not shown in the tables that follow in the next sections.

3.1.1. Beaches in northern part of Crete (secondary)

More than 50 beach sectors were visited in the Northern coast of Crete including two of the three main turtle nesting sites in Crete. However, only 16 of the visited secondary beaches had nest records either during 1990-1991 study or during this study (Table 8).

Table 8: Change in loggerhead nest counts in Northern beaches of Crete

No.	Name	Code (based on 1990-1991 study)	Nest no. (1990-1991 study)	Nest no. (this study)
1	Phalasarna	CR 1-8	0	1
2	Kissamos	CR 30-32	1	1
3	Kera	CR 115	1	0
4	Georgioupouli	CR 130-133	10	2
5	Latzimas-Mylopotamos	CR 169-170	4	9
6	Panormos	CR 175	1	3
7	Bali Beaches	CR 186-189	0	1
8	Paralia Fodele	CR 215-216	0	1
9	Ligaria	-	0	3
10	Ammoudara	CR 244-247	0	1
11	Aghia Pelagia (Aposelmis river mouth)	CR 277-278	0	10
12	Malia (Archaeological site)	CR 302	0	10
13	Pacheia Ammos	CR 344-347	4	4
14	Sitia	CR 370-372	3	30
15	Vai	CR 414-416	4	0
16	Kouremenos	CR 422	1	2
	TOTAL		**29**	**78**

Among the 16 secondary beaches mentioned above, only Georgioupouli and Vai has seen a decline in turtle nest number, where as Sitia has turned out to be an important nesting site hosting between 20 to 40 loggerhead nests annually.

3.1.2. Beaches in southern part of Crete (secondary)

Similar to the Northern coast of the island, the Southern coast beaches were also visited during the field work and more than 45 beach sectors were covered during the period, including the major nesting site in

Messara. However, similar to the Northern beaches, only 19 of the visited secondary beaches had turtle nest record either in 1990-1991 or during this study (Table 9).

Table 9: Change in loggerhead nest counts in Northern beaches of Crete

No.	Name	Code (based on 1990-1991 study)	Nest no. (1990-1991 study)	Nest no. (this study)
1	Xerokampos	CR 437-441	0	1
2	Diskari	CR 470	1	1
3	Achila	CR 487	0	3
4	East Ierapetra	CR 513	1	0
5	Myrtos	CR 538-543	0	2
6	Vatos	CR 550-551	3	0
7	Tertsa	CR 562-565	0	6
8	Arvi	CR 573-576	0	1
9	Kastri	CR 587	0	1
10	Tsoutsouras	CR 597	2	0
11	Lentas	CR 644	0	1
12	Diskos	CR 655	0	1
13	Hrissostomos	CR 664-670	2	0
14	Matala	CR 700	0	1
15	Melissa Beaches	CR 745-746	0	1
16	Schinaria	CR 774	0	1
17	Damnoni	CR 777	1	1
18	Plakias	CR 781	0	2
19	Korakas	CR 787	1	1
	TOTAL		**11**	**24**

The secondary beaches in the Southern Crete have not observed any significant increase in turtle nest numbers. However, unlike Rethymno and Chania, the primary nesting site of Southern part of Crete, Messara, has observed an increase in turtle nest number (Table 10).

3.1.3. Primary nesting beaches in Crete

Two of the three primary loggerhead nesting sites of Crete has exhibited steep decline in annual nest count (Table 10). Rethymno has observed 57% decline in nest number while Chania has observed 55% decline since the study in 1990-1991.

Table 10: Change in loggerhead nest count in the three main nesting beaches of Crete

No.	Name	Code (based on 1990-1991 study)	Nest no. (1990-1991 study)	Nest no. (this study)
1	Rethymno	CR 155-165	403	173
2	Chania	CR 55-65	100	45
3	Messara	CR 710-713	28	40
	TOTAL		**531**	**258**

In general, the surveyed beaches of Crete in 1990-1991, hosted approximately 570 nests and it was estimated that the total turtle nesting in Crete during that period was around 800. Considering the

approach adopted by Marquez (1990), with one female turtle nesting 3 times in a nesting season, that number would reflect a nesting female population of approximately 265 loggerhead turtles. Interviews of local people from those same beaches have revealed that the present nest count for loggerhead turtle in those beaches is approximately 360. Volunteers of ARCHELON had confirmed that the present nest count for the island of Crete is around 400 which is a decline of 50% from the earlier study. Figure 6 and shows the beach sectors that have observed a change in nesting number with a brief overview of the nest number differences in Crete with few sections of the island being zoomed in
Figure 7 and Figure 8. Based on the figures, it can be observed that majority of the secondary nesting beaches located east of Rethymno has observed some increase in loggerhead nest count since 1990-1991.

3.2. Increase of nest count in secondary beaches

Based on the recent development of infrastructure and the increased arrival of tourists in Crete (Lima, 2008), the study expected to find an increase of nest count in the secondary nesting beaches. In order to compare the difference in nest number on the secondary nesting beaches, paired-t test was carried out.
Analysing the nest number differences between the 1991 report and recently gathered information, it was observed that the visited beaches has observed an increase in the nest numbers with an average increase of 0.63 nests per visited beach section. It should be mentioned here that only 35 of the visited 98 beach sections had hosted turtle nests either during 1990-1991 or now. The remaining beaches had not hosted any nests during either period. The standard deviation of the nest number difference was calculated to be 3.36. The P value obtained from performing the t-test was 0.033. Considering a 95% confidence interval or significance level of 5% ($\alpha = 0.05$), the null hypothesis of having no difference between nest count of 1991 and recent years in secondary beaches can be rejected. The results of the different steps of the paired t-test are provided in the Table 11.

Table 11: Results obtained from performing paired t-test between nest numbers of secondary nesting beaches

H0: There is no difference in recent nest numbers and nest numbers from 1990-1991 in secondary nesting beaches of Crete.		
	Variable 1 (Recent nest numbers)	Variable 2 (1990-1991 nest numbers)
Mean	1.0408	0.4082
Variance	12.225	1.708
Observation	98	
df	97	
t Stat	1.866	
t critical (one tail)	1.661	
P (one tail)	0.033	

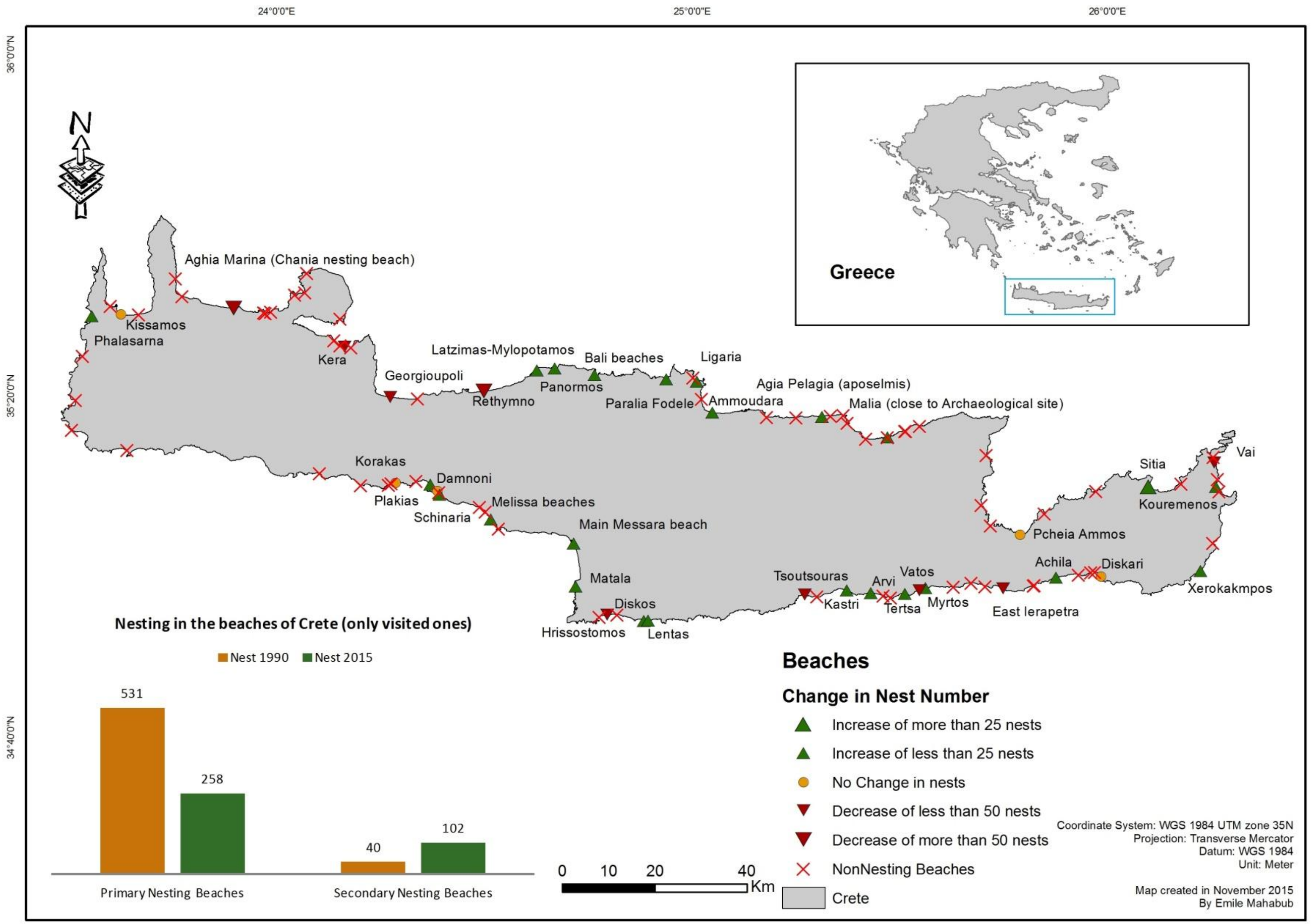


Figure 6: Change in nest number in primary and secondary nesting beaches of Crete

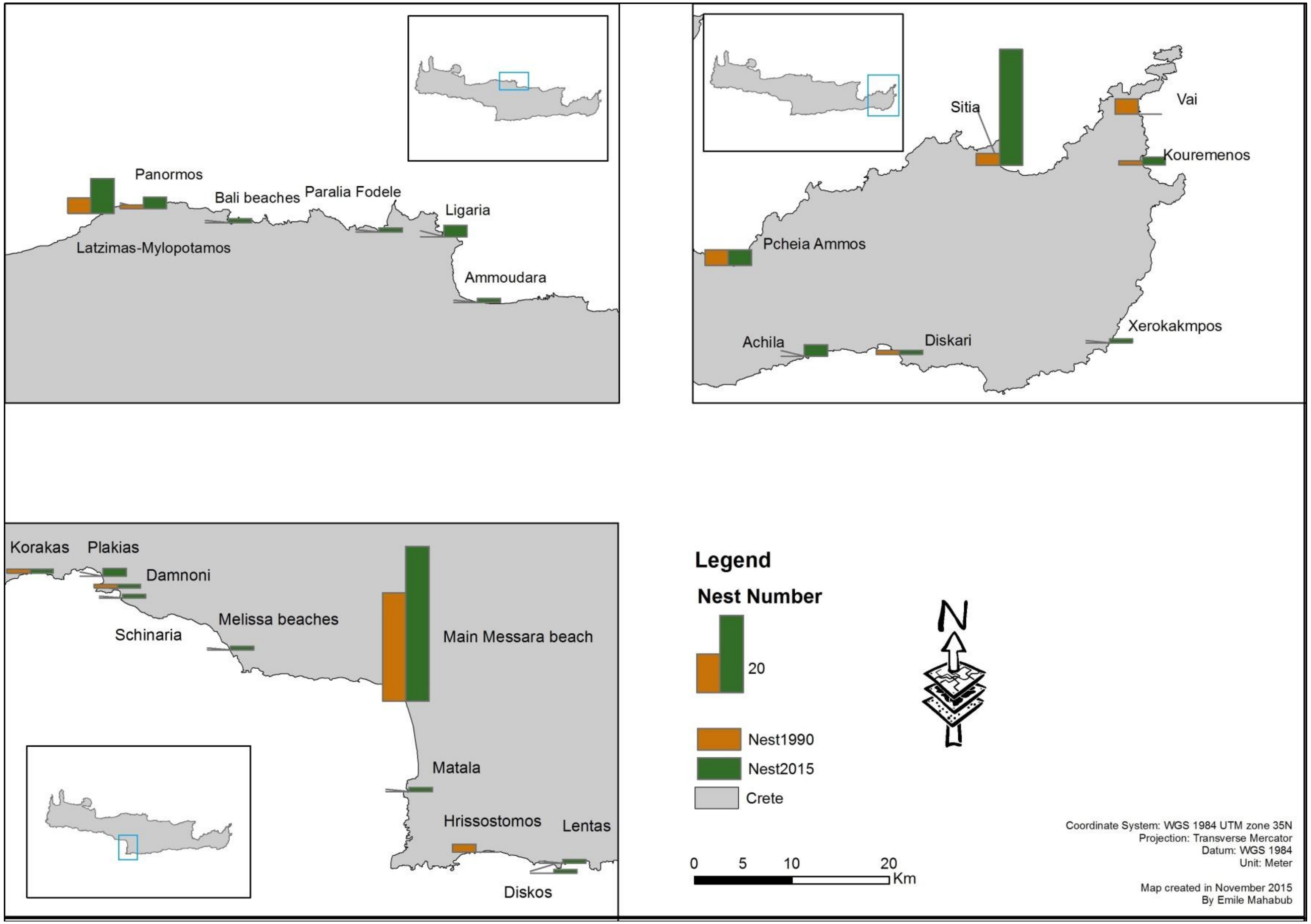


Figure 7: Changes in nest number of Crete with few sections of the island being zoomed in for increased clarity

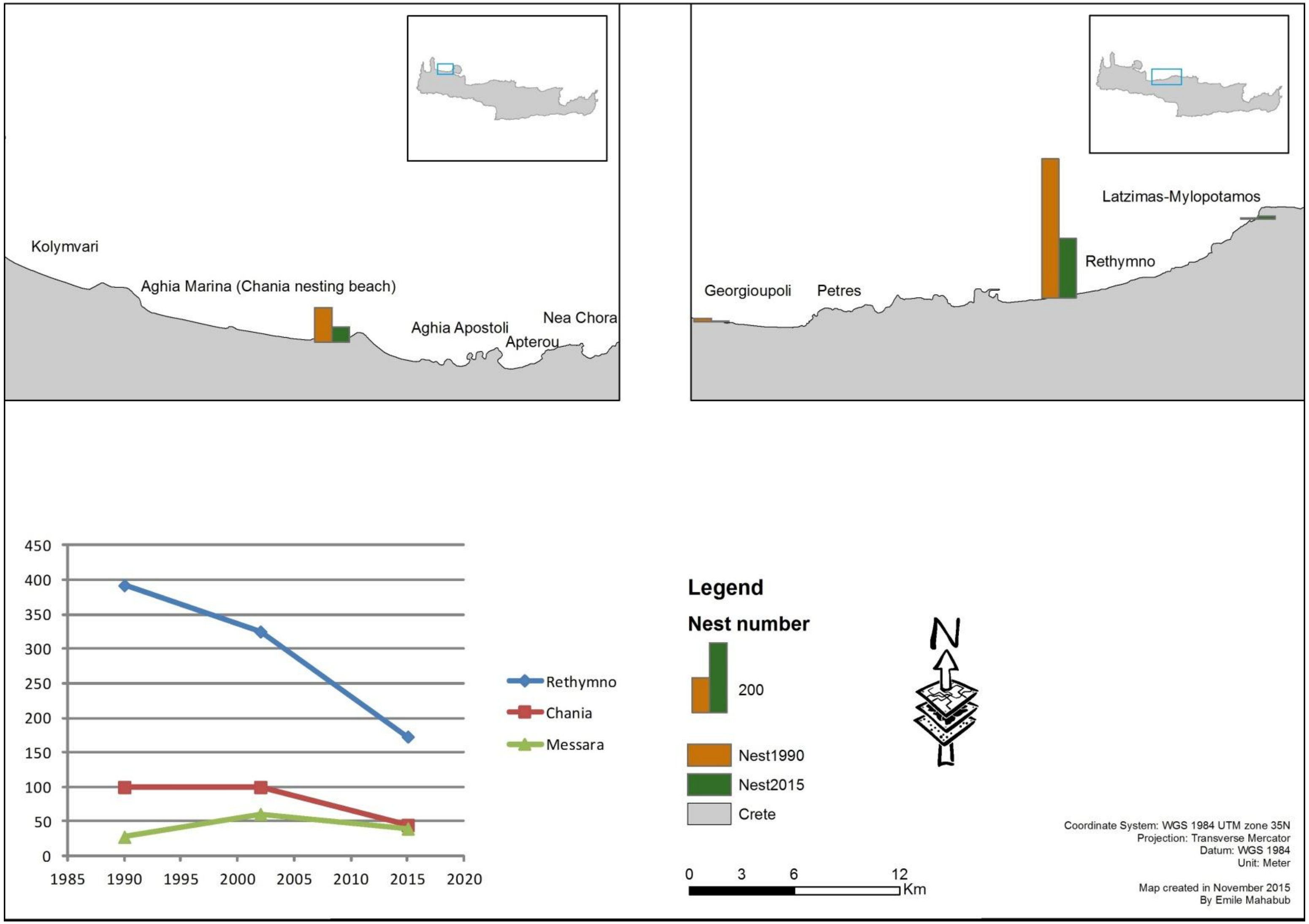


Figure 8: Changes in nest number of Crete with the primary beaches being zoomed in for increased clarity (Messara is shown in earlier figure). The nest number graph is generated based on Margaritoulis & Dretakis (1991), Margaritoulis & Rees (2003) and the present field work.

3.2.1.1. Variation of environmental variables on different beaches

Boxplots were generated to depict the variation in the different explanatory variables on different beach types (primary, secondary and non-nesting). Considering that Sitia, Malia and Aghia Pelagia were the only secondary beaches which host more than 10 nests regularly (according to the interviews), those beaches were separated from the remaining secondary beaches.

As seen in Figure 9, the difference in the mean SST value among the beaches was relatively small. The SST was further divided in to the period when the nesting season starts (April-May) and the period when nesting season ends (August-September) and similar to the mean SST, the difference in those periods were also very small.

Similarly, it is also seen in Figure 10 that some variables, such as, precipitation, distance to 100 m depth isoline, night light, length of beaches, show clear difference between the primary beaches and the other beach sectors. Whereas, the difference is relatively smaller for elevation, width, NDVI and chlorophyll content. Furthermore, it should be mentioned that the night light has high values for both primary beaches as well as the three secondary beaches with more than 10 annual nest count, due to their popularity among the visitors as well as local tourists.

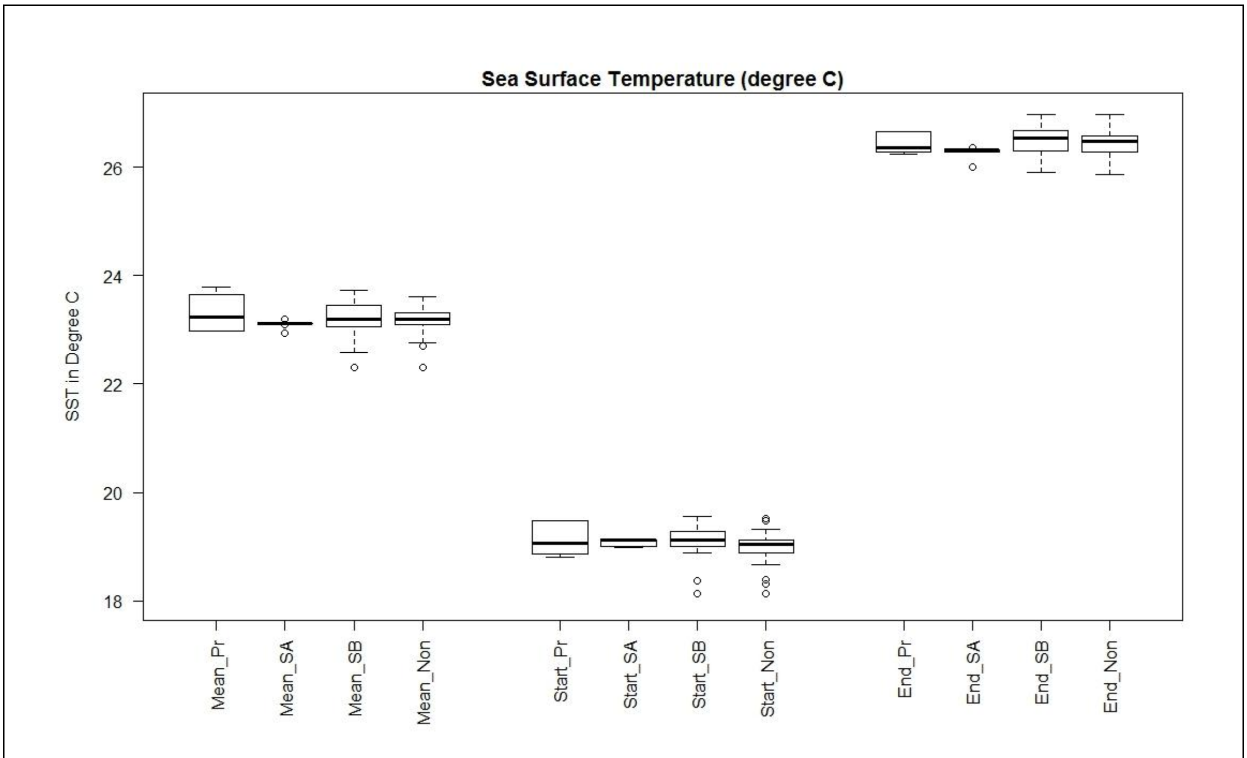


Figure 9: Boxplot showing the variation of Sea Surface Temperature in the different beaches. Here the code Pr represents primary beaches, SA represents the three secondary beaches that host more than 10 nests annually, SB represents the remaining secondary beaches and Non represents non-nesting beaches. The boxplot is divided in to mean SST, SST of start of nesting period (April-May) and SST of end of nesting period (August-September).

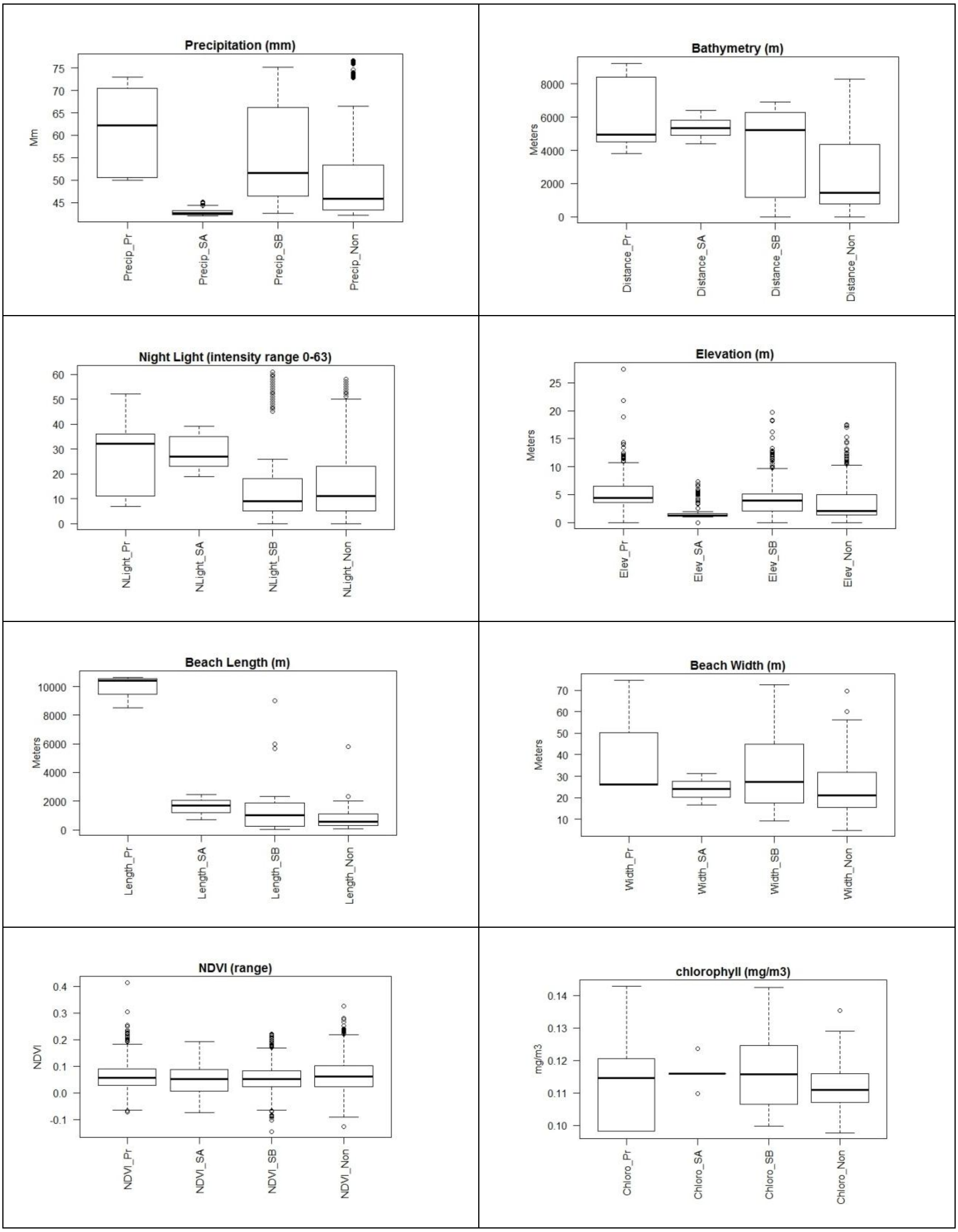


Figure 10: Boxplots showing the variation of explanatory variables in the different visited beaches. The codes for the beaches remain same as previous figure.

3.3. Delineation of nesting beaches from SDM results

Both the models used in this study displayed the necessity to use both primary and secondary beach nest points for training in order to identify other potential nesting beaches in Crete. Training MAXENT with only nest information from primary beaches exhibited only four beach sectors in the island of Crete as suitable for hosting loggerhead nests. Despite the large percentage of turtle nests (60% of total nests) hosted in those four beach sectors, the result can be considered as poor because it failed to identify sectors such a Sitia, Aghia Pelagia, Malia or Mylopotamos which together represent approximately 50 annual nests. Similar to MAXENT, BRT also, when trained with only primary beach nests displayed a poor performance. Despite, it classifying nine beaches altogether as "nesting", only two of those beaches hosted nests in reality.

However, training the models with both primary and secondary beach nest information improved the suitability scores and enabled identification of other beach sectors with similar suitability score of the primary nesting beaches. The inclusion didn't result in a major improvement of suitability scores in the primary beach sectors, nonetheless, several other areas in Crete received a relatively higher suitability.

Boxplots of each beach sectors mean suitability value were generated with the results from each model. The beaches were separated based on their type (primary, secondary or non-nesting). During both the models, the boxplots showed significant increase in mean suitability value for both secondary and non-nesting beaches when the models were trained with both primary and secondary beach nest information (Figure 11). However, the inclusion of information from both type of beaches in the model also reduced the difference between secondary and non-nesting beaches. Two tables are provided in the appendix (Appendix 7.2 and Appendix 7.3) with mean suitability values of each of the visited beaches obtained from the different models and their actual nesting status (beach section used for nesting by loggerhead turtles or not). Appendix 7.3 also contains an additional column showing the mean distance to the nearest primary nesting beach.

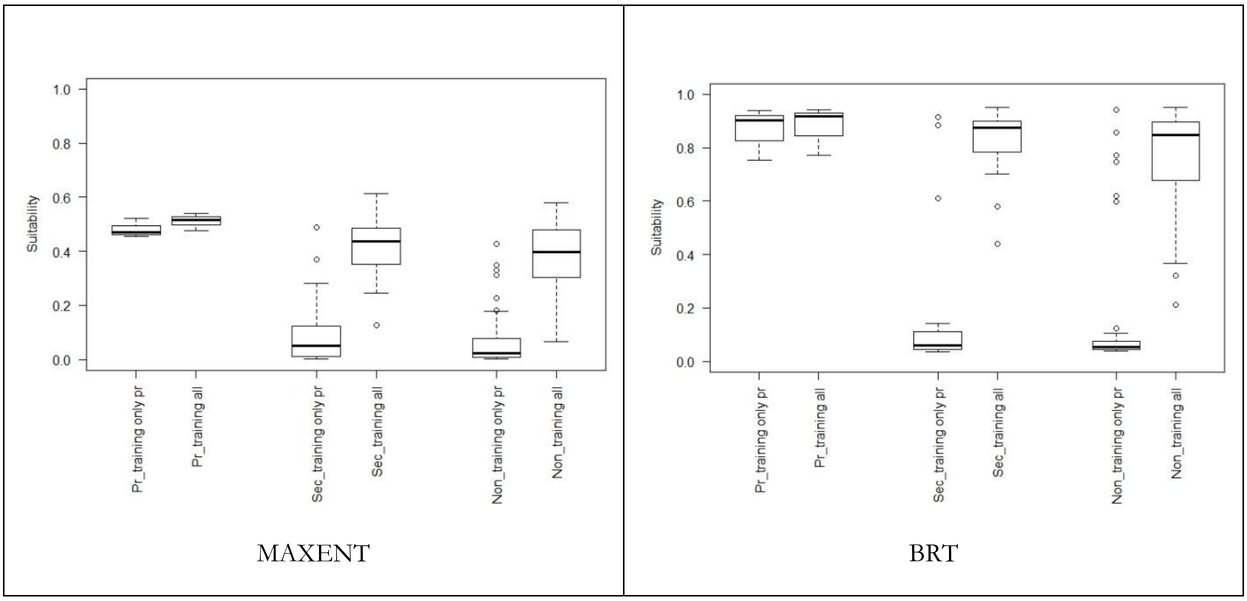


Figure 11: Boxplots displaying the difference in the mean suitability values in the different types of beaches in Crete. The plot in the left represents the results derived from MAXENT, with the model being trained with only primary beach nest points once and with all beaches nest points the other time. The plot in the right represents results from BRT, with the model being trained with only primary beach nest points once and with all beaches nest points the other time. when all the nest information collected in Crete were used.

3.4. Accuracy of the results

The results obtained from the two models were assessed for their accuracy to predict both nesting and non-nesting beaches in the island of Crete. In order to have a detailed assessment of the model results all the accuracy results are discussed here.

3.4.1. Accuracy of MAXENT

As observed in Table 12, training the model with only primary beach nest points made the model under predict the nesting beaches and it failed to identify the secondary nesting beaches almost completely. Despite the table exhibiting a total accuracy of approximately 66%, close inspection of the other components of the table displays the flaws of the model. Beach sectors receiving loggerhead turtle nests in recent years (between 2013 and 2015) have been considered as a nesting beach in this study, and based on that assumption, Crete had 30 nesting beaches. As the three primary nesting beaches are not the focus of the study, the accuracy analyses were made with secondary nesting beaches only. Out of the 27 secondary beaches, the model only managed to identify one beach sector as nesting. This extreme underestimation of nesting beaches in Crete is also reflected in the column of "Areal difference", which stated that the model made an approximately 96% under estimation of nesting beaches. However, these assessments do not consider the agreement by chance, and to eliminate the agreement by chance from the results, Kappa statistics was calculated. Based on that, it is observed that the generated result has only approximately 5% better agreement than the agreement by chance, which according to the rule of thumb is a poor agreement between ground truth and the modelled result. Similarly, the result from True Skill Statistics or TSS, is also observed at a poor score of 0.037 which does not reflect a model which performs much better than random prediction.

Table 12: Table with accuracy assessment results derived from training MAXENT with only nest information from primary nesting beaches in Crete

	User or object accuracy	Producer or classification accuracy	Total accuracy	Mean accuracy	Areal difference	Kappa statistics	TSS
Nesting	1	0.0370	0.6579	0.0714	-0.963	0.0473	0.0370
Non nesting	0.6533	1		0.7903	0.5306		

It could be observed in Table 13 that inclusion of nest points from secondary nesting beaches improved the model's capacity to identify those beaches, which is reflected in the relatively increased producer's accuracy. However, it also decreased the producer's accuracy for identifying non-nesting beaches. Comparing the different accuracy measures with Table 12, it didn't show any significant overall improvement, however, the inaccuracy to identify non-nesting beaches can be overlooked as the model managed to identify some of the secondary beaches which have the potential to host loggerhead nests regularly. Moreover, one of the main reasons to run the model was to properly identify the secondary nesting beaches due to the assumption that the decrease of nest number in the primary beaches will be compensated by more turtles nesting in the secondary beaches. Thus, even with a Kappa value of 0.0326, the second model could be considered as an improvement to the first one.

Table 13: Table with accuracy assessment results derived from training MAXENT with nest information from both primary and secondary nesting beaches in Crete

	User or object accuracy	Producer or classification accuracy	Total accuracy	Mean accuracy	Areal difference	Kappa statistics	TSS
Nesting	0.381	0.2963	0.5789	0.3333	-0.2222	0.0326	0.031
Non nesting	0.6545	0.7347		0.6923	0.1224		

3.4.2. Accuracy of BRT

Similar to the previous section, the results derived from the BRT were also assessed to check the accuracy of the model. As observed in Table 14, training BRT with nest points from only primary beaches also under predicted the nesting beaches. Despite the total accuracy of almost 62% the model provided very low Kappa statistics and TSS with the values being -0.009 and -0.008 respectively showing a performance which is worse than the agreement by chance.

Table 14: Table with accuracy assessment results derived from training BRT with only nest information from primary nesting beaches in Crete

	User or object accuracy	Producer or classification accuracy	Total accuracy	Mean accuracy	Areal difference	Kappa statistics	TSS
Nesting	0.3333	0.0741	0.6184	0.1212	-0.7778	-0.0092	-0.0076
Non nesting	0.7222	0.5306		0.6118	-0.2653		

Inclusion of secondary beaches to train BRT clearly improved the model to identify the secondary nesting beaches which can be observed in the field of producer's accuracy of Table 15. However, as the model failed to identify the non-nesting beaches equally well, the total accuracy for this model drops below that of previous one. Nonetheless, it could be said that the model performed better as both Kappa statistics and TSS were improved and showed a value of 12% and 14.5% respectively.

Table 15: Table with accuracy assessment results derived from training BRT with nest information from both primary and secondary nesting beaches in Crete

	User or object accuracy	Producer or classification accuracy	Total accuracy	Mean accuracy	Areal difference	Kappa statistics	TSS
Nesting	0.4038	0.7778	0.5132	0.5316	0.9259	0.1202	0.1451
Non nesting	0.75	0.3673		0.4932	-0.5102		

3.4.3. Delineation of nesting beach with a different threshold and accuracy

The previous two sections considered the mean suitability of beach sector and then used the threshold to delineate a beach sector as nesting or non-nesting. The drawback of this approach can be observed in some beaches when the mean suitability value goes below the threshold level despite certain percentage of the beach receiving relatively higher suitability score. Experience from field work showed that the turtles sometimes nested in beaches even when majority of the beach looked very disturbed and unsuitable (due to physical properties like stones or pebbles). Thus, the method of using mean suitability to distinguish a beach sector as nesting or non-nesting, may not be the most efficient method. For that reason, a different approach was adopted here. In this part the results from training the two models with all the nests were used and the delineation was done if at least 10% of a beach sector was above the threshold value. As in this case the whole beach is not considered, the threshold was put to the value approximately 5% higher than the minimum - mean suitability of the primary beaches. Thus, for the MAXENT result, the threshold was put at 0.5 and for the BRT result, the threshold was put at 0.8. Afterwards, the percentage of each beach sector with suitability score of above the related threshold was calculated. A beach sector was considered as suitable for hosting turtle nests if at least 10% of the beach had suitability score of above the threshold. The information was then used to generate another confusion matrix and the accuracy was calculated.

Table 16: Table with accuracy assessment results derived from running MAXENT with nest information from both primary and secondary nesting beaches in Crete with threshold of 0.5 on at least 10% of the beach area

	User or object accuracy	Producer or classification accuracy	Total accuracy	Mean accuracy	Areal difference	Kappa statistics	TSS
Nesting	0.4146	0.6296	0.5526	0.5	0.5185	0.1253	0.1398
Non nesting	0.7143	0.5102		0.5952	-0.2857		

As it can be observed in Table 16, this approach improved the accuracy of the model and provided a greater chance of identifying the secondary beaches as it received a producer accuracy of almost 63% for identifying nesting beaches. Similarly, the approach also received a relatively higher Kappa value and TSS which were 0.1253 and 0.1398 respectively. Results derived from this approach are also shown in Figure 13 where the performance of the model can also be observed in terms of correct and incorrect prediction.

Table 17: Table with accuracy assessment results derived from running BRT with nest information from both primary and secondary nesting beaches in Crete with threshold of 0.8 on at least 10% of the beach area

	User or object accuracy	Producer or classification accuracy	Total accuracy	Mean accuracy	Areal difference	Kappa statistics	TSS
Nesting	0.3387	0.7778	0.3816	0.4719	1.2963	-0.0457	-0.059
Non nesting	0.5714	0.1633		0.254	-0.7143		

Delineation of threshold in such way improved the results from MAXENT, however, similar method with the result from BRT did not improve the findings any further. Instead, considering a beach as nesting when at least 10% of the beach had suitability of 0.8, decreased the model's accuracy significantly as too many of the beaches were then identified as nesting. Table 17 shows the different accuracy assessments of creating threshold in this way for the BRT model.

3.5. Distance from primary beaches in nesting ground selection

In order to investigate the relationship between selection of a beach for nesting and the distance of that beach section from a primary nesting beach, the sectors were divided into classes based on the distance. The mean distance from the primary beaches for the nesting beaches and the non-nesting beaches were notably different (approximately 39,941 meters and 61,640 meters respectively), but investigating Figure 12 shows that the proximity only plays an important role when the beach sectors are more than 50 km away from a primary beach. Below that distance, the percentage of beach sectors used for nesting or not used for nesting has very little difference. Due to this high portion of non-nesting beaches in close proximity of the primary beaches, the correlation coefficient was found to be 0.06, which would mean that there is no relationship between a beach being used for nesting and the proximity of that beach to a primary nesting beach. However, it could be clearly seen that the selection of a beach for nesting significantly decreases if it is more than 50 km away from a primary nesting beach. It could also be seen in Figure 12 that only 26% of the beaches, that are more than 50 km away from a primary nesting beaches, are used by the loggerhead turtles for nesting, as oppose to 44.5% beaches that are located at lesser distance.

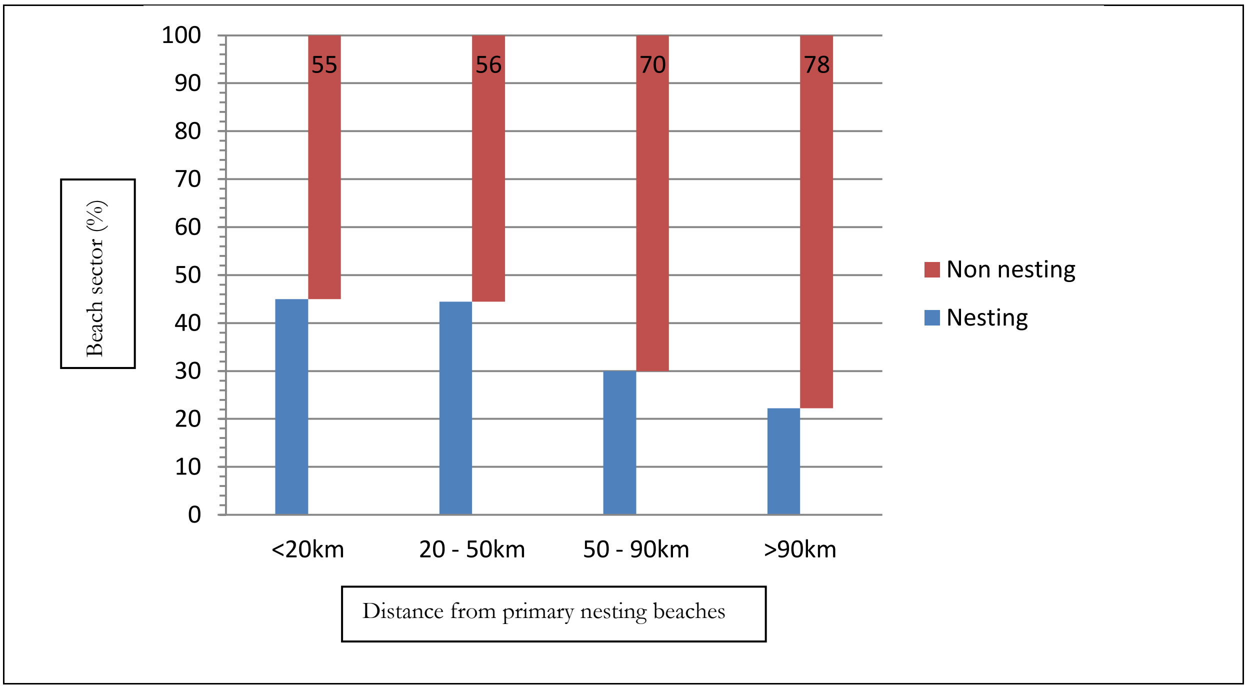


Figure 12: Percentage of beach sectors used as nesting or non-nesting beaches based on their distance from primary nesting beaches

4. DISCUSSION

4.1. Use of secondary nesting beaches in Crete

Excluding the three primary nesting beaches in Crete, the only beach sector hosting more than 20 nests annually is Sitia. However, the beach in Sitia, on visual assessment, didn't provide the impression of a very suitable beach for nesting due to the relatively narrow width and the number of visitors present in the beach during the summer months. Despite the facts, information comprehended from ARCHELON researchers revealed that the sector has hosted 20-40 nests annually for approximately last 5-10 years (conversation with ARCHELON researchers in Rethymno). Although marine turtles exhibit natal homing characteristics, an exception to this has also been observed (Hilterman & Goverse, 2007; Shanker, Ramadevi, Choudhury, Singh, & Aggarwal, 2004). Deterioration or development of certain nesting sites have resulted in abandonment or reappearance in such sectors. In either case the main reason for this movement was based on the suitability of the location to host turtle nests. However, considering human activity in a beach as a parameter which reduces the physical suitability of the beach to attract turtles to nest, Sitia does not appear as a major improvement to either Rethymno or Chania.

In light of the increased human activity as well as infrastructural development in the vicinity of both Rethymno and Chania, it may be possible that female loggerhead turtles, that have experienced the anthropogenic disturbances in previous nesting seasons, migrate to sites with less disturbances or more suitability. The steep decline of loggerhead nesting in Rethymno and Chania can be explained if this probable migration of relatively older female loggerhead turtles is present in Crete. Yet, that does not completely explain the development of Sitia as an important nesting ground. The inability to delay the process of laying eggs indefinitely may have caused the selection of Sitia for nesting despite the sector having almost as much human activities as the northern primary nesting beaches. However, unavailability of remigration information of the nesting loggerhead turtles of Crete, restrict the ability to prove this explanation.

The three sites, Sitia, Aghia Pelagia and Malia, according to local interviewees have hosted more than 10 nests annually for approximately last 10 years. Considering their direction from the nearest primary nesting beach (all the sites located East of Rethymno), it is probable that sea current direction may have some role in this new site being selected. However, the inability to obtain sea current direction base map for different months of the nesting period has hindered the study to focus more on this.

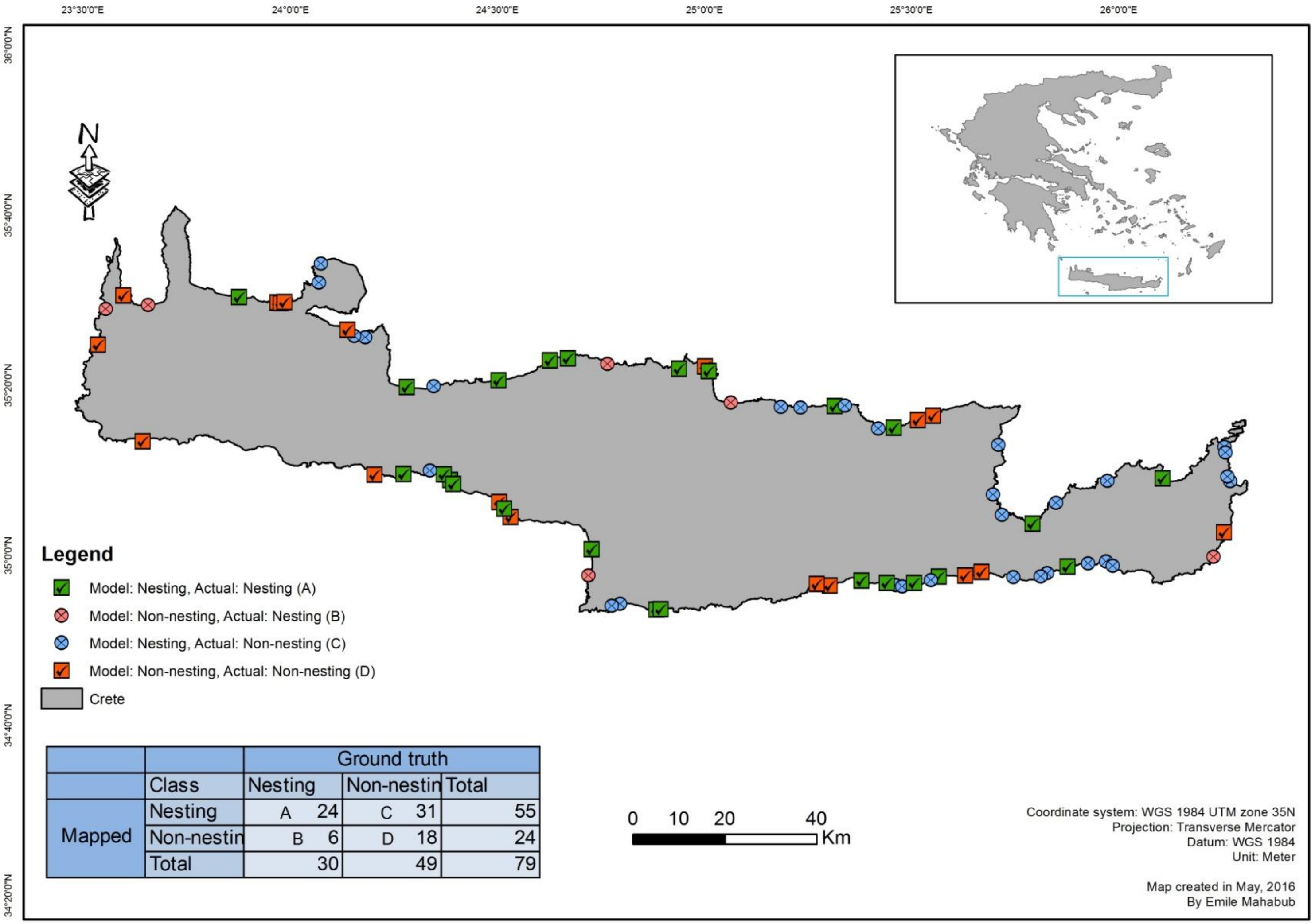
In addition to that, field work in Crete revealed that the beaches in the Northern part of Crete are relatively more popular among the visitors than the Southern beaches. Moreover, a large part of the main nesting beach in Messara is restricted for people to use due to the military base in the vicinity. This difference in the intensity of beach use between the Northern and Southern primary nesting beaches, is probably the reason behind the development of the three new nest sites which are all in the Northern part of Crete. This may also be the reason for Messara to have exhibited a steady nest count over the years.

4.2. Detectability of nests in secondary nesting beaches of Crete

The current monitoring scheme of loggerhead turtle nests in Crete focus primarily on the Rethymno, Chania and Messara, with recent addition of Sitia. Considering the limited resources available to the existing turtle conservation group in Greece, it is understandable that the current monitoring scheme only focuses on primary nesting beaches. The organization's inability to expand their monitoring work in remaining part of Crete restricts the turtle nest database to have continuous information from beaches which host sporadic nesting. Also, this creates a dependency on local reports of nests from those beaches, which at present is mostly accidental or coincidental discovery. Thus, reports of nests from beaches with comparatively less human use may not be as frequent as those of beaches that are more popular among local stakeholders and visitors.

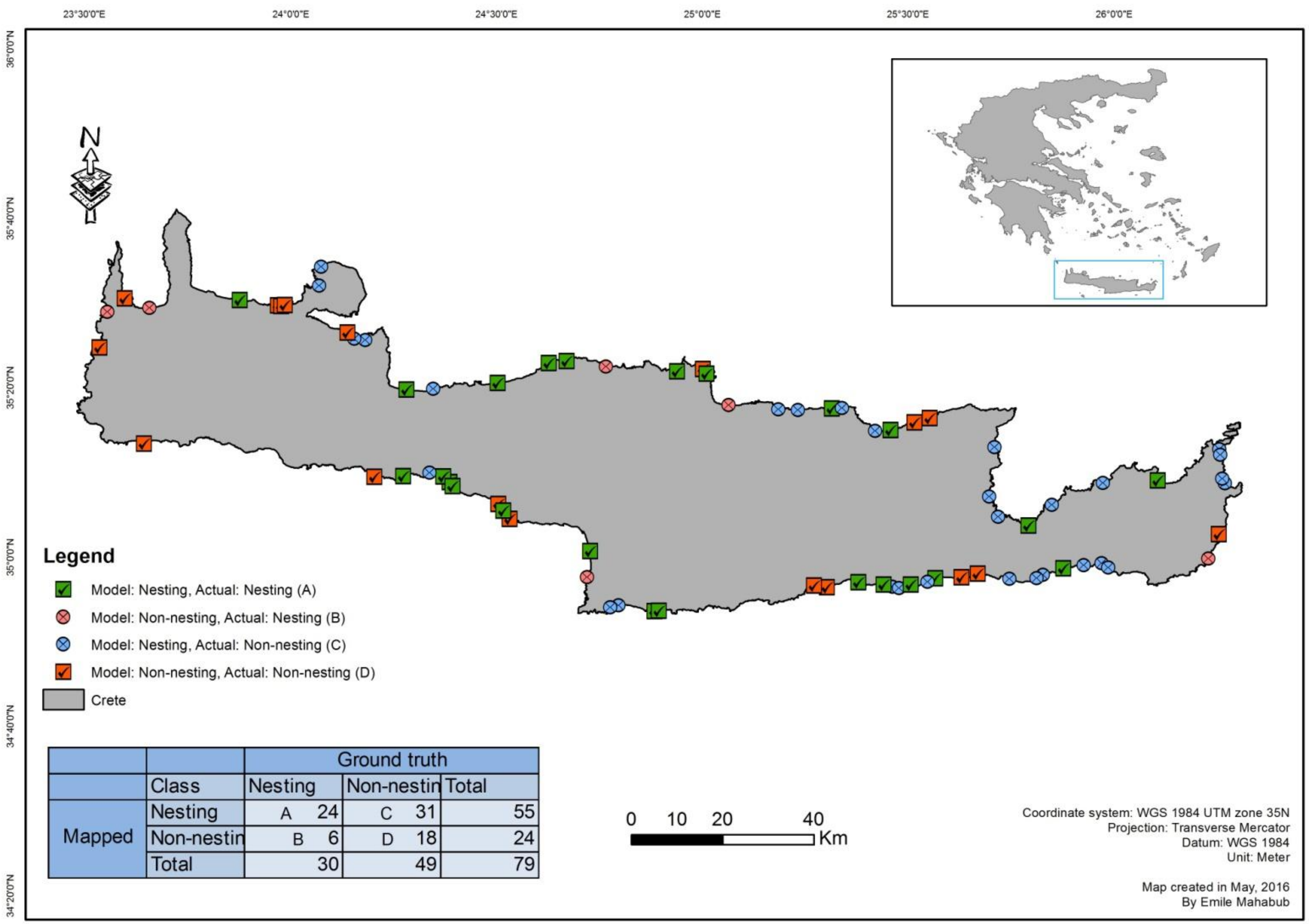
This scenario can be explained with some examples. Vai, a beach sector located in the North-Eastern corner of Crete, has three distinct beach sections. The field visit has revealed that only one of the sections in Vai is popular among the visitors, and that is the only section with physical infrastructure in the form of bar/cafe, leading to constant presence of people in the beach. During interviews it was revealed that no loggerhead nests were recorded in that section of Vai. Considering the physical attributes of the other beach sectors in Vai, it is probable that they may still host some scattered loggerhead nests, but due to the limited use of those beaches and the absence of any permanent (daily) local stakeholder in the vicinity, will remain unrecorded. Similar scenario was observed in some of the beach sectors in the South-Eastern part of Crete (around the town of Ierapetra). It was observed in Figure 13 and Figure 14, that both the models (MAXENT with modified threshold and BRT) predicted several beaches in that region (around Ierapetra) as "nesting", but the interviews couldn't confirm the record of turtle nests in recent years. Considering that the beaches in that area attracting comparatively less visitors as well as the absence of permanent infrastructure near the beaches, it is highly probable that sporadic nesting in those beaches will remain undetected or unrecorded. This inability to correctly identify the beaches which hosts turtle nests (regular or sporadic) in reality was probably one of the main reasons for the low accuracy scores for both the models.

The results of the two above mentioned models were merged to identify the beaches that were correctly predicted by both the models. The result showed that less than 50% of the beaches were correctly predicted (both nesting and non-nesting) in both the models (Figure 15) which is worse than the prediction by chance.



		Ground truth		
	Class	Nesting	Non-nestin	Total
Mapped	Nesting	A 24	C 31	55
	Non-nestin	B 6	D 18	24
	Total	30	49	79

Figure 13: Map of Crete showing the result from training MAXENT with all nest points, but using a different threshold option. Beach section was considered as "nesting" if at least 10% of the beach area had a suitability of 0.5 or more. The confusion matrix obtained from that run is also provided here.



		Ground truth		
	Class	Nesting	Non-nestin	Total
Mapped	Nesting	A 24	C 31	55
	Non-nestin	B 6	D 18	24
	Total	30	49	79

Figure 14: Map of Crete with result obtained from training BRT with all nest points and the threshold set at 0.773, with the confusion matrix obtained from that run

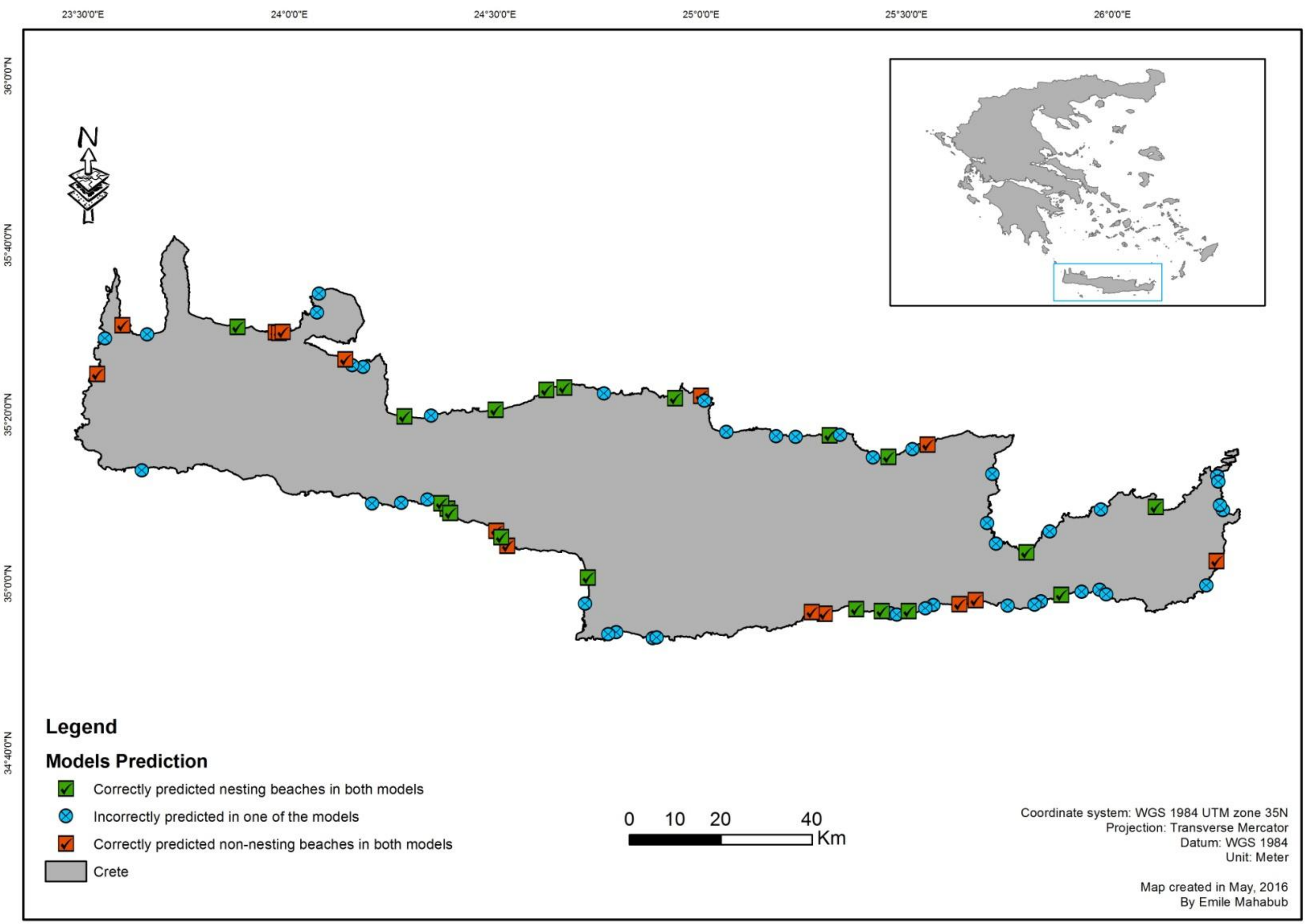


Figure 15: Map showing the correctly predicted beaches based on both the model results illustrated earlier, and the incorrect prediction in at least one of the models

4.3. **Trend in loggerhead turtle nesting in the Mediterranean region**

Published reports related to loggerhead nesting in the Mediterranean region, reflecting both past (Groombridge, 1990) and relatively more recent (Casale & Margaritoulis, 2010) nest numbers, do not display any decline despite the threats still being present in some regions. Considering the development of technology as well as the increased focus provided towards threatened faunal species in past decades, it is understandable that the present Mediterranean nesting (female) loggerhead estimate is higher than that of 80s. The latest review of Mediterranean loggerhead population reveals that several countries in the Mediterranean region have observed an increase in loggerhead nesting. Figure 16 and Figure 17 gives an overview of loggerhead turtle nesting in different Mediterranean countries during the last couple of decades.

Moreover, it is possible that loggerhead nesting in some parts of the Mediterranean had been underestimated. For example, Casale & Margaritoulis (2010) suggested that around 10 loggerhead nests are recorded in Italy annually. This number was estimated based on study between 2000 and 2004. However, Mingozzi et al., (2007) suggested that the nest number in Italy could be few folds higher than the numbers estimated from that study and could be as high as 30-40 nests/year in the Italian coasts. Successful awareness raising campaigns have resulted in an increased reporting of loggerhead nests by tourists. Improved management system with monitoring scheme may allow detection of scattered nests and may increase the annual nest count to an even higher value. Furthermore, volunteers from ARCHELON had also informed about an increase in nest number in Kyparissia. Possibility of a shift of greater distance in loggerhead nesting sites is hard to reject considering increased nesting number recorded in certain areas of the Mediterranean. Hilterman & Goverse (2007) found leatherback turtles in Suriname which had been tagged in Trinidad, which reveals a nesting migration of more than 900 km (Euclidean). Despite this evidence is from a different species of marine turtle, and report of such large migration being negligible, the possibility of such migration for the Mediterranean population of loggerhead turtles cannot be overlooked.

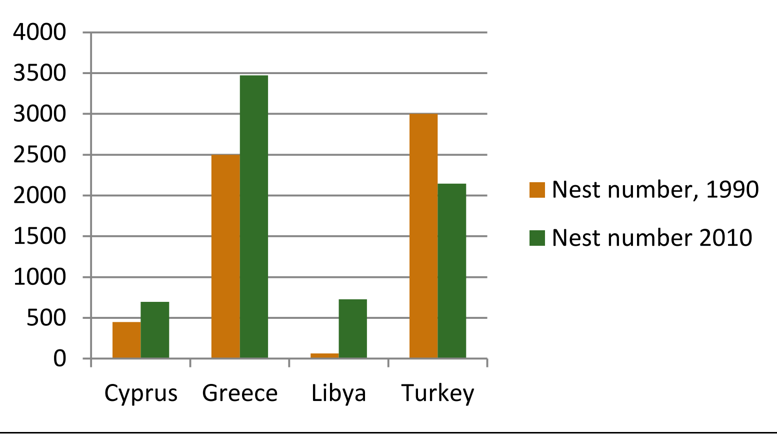


Figure 16: Change in nest number between 1990 and 2010 in the major Mediterranean loggerhead nesting grounds

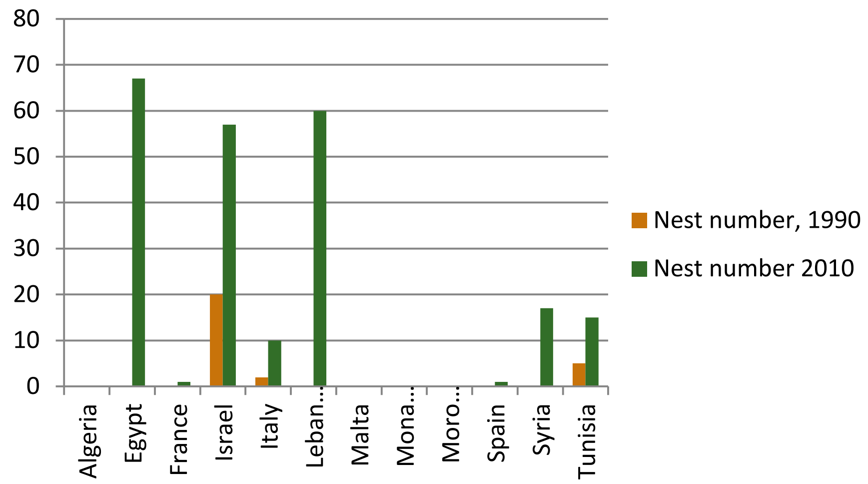


Figure 17: Change in nest number between 1990 and 2010 in other Mediterranean loggerhead nesting grounds

Decline in loggerhead nest count in Crete cannot be proved wrong as the beaches that were visited during the field work represented 360 nests in compare to the nest count of 571 during 1990-1991. Even though the secondary beaches in Crete has seen an overall increase of hosting loggerhead nests, it still failed to compensate the decline in the three main nesting beaches. However, confirmation of female loggerhead turtles from Crete, migrating to other nesting grounds (beyond the island of Crete) would require further studies, preferably with GPS trackers to monitor their movements.

4.4. Performance of the models

Considering the accuracy obtained by the two models, none of them has performed extremely well. However, in case of both the algorithms, inclusion of nest information from secondary beaches improved the detectability of beaches that are suitable for nesting. Moreover, for MAXENT, delineating the threshold value to the point when at least 10% of the beach has suitability of 0.5 or more, relatively improved the model accuracy, despite still having a very low Kappa and TSS values. As mentioned in earlier section, this accuracy assessment is highly dependent on the information received from local interviews and their ability to detect sporadic nests. Result from MAXENT, using this modified threshold, identified some areas in Crete as suitable for loggerhead nesting; however, the actual nesting information couldn't be confirmed in the field. One such example is Elounda, located between Iraklio and Sitia, which was mentioned by interviewees of other location to have hosted loggerhead nests. However, the stakeholders in Elounda couldn't confirm that claim thus, is not mentioned in the report as a nesting beach. Further to that, some beach sectors were identified by the model as "non-nesting", despite hosting sporadic turtle nests. Phalasarna, a sector located in the north-western part of Crete, had observed a very low mean suitability of 0.38 in the model. Despite the relatively low beach use in the sandy beaches of Phalasarna, 2015 was probably the first time the beach sector hosted a loggerhead turtle nest. Considering the relatively low elevation for majority of the beach sector, more than 70% of the beach with less than 0.4m elevation (Asaad, 2009), it is probable that the nesting over there was coincidental. In case of the BRT results, the issue of the detectability of nests was even more prominent, as the model categorized 31 beaches as nesting, but the interview survey provided no evidence of nesting in those beaches.

Regarding the overall low suitability scores from MAXENT, it is probable that modelling of loggerhead turtles nesting ground with this algorithm requires the full range of the distribution of this species as the study of Guo (2014) found the relationship to be much stronger in global scale than the regional scale.

Considering the poor accuracy received by both the models, it is necessary that further studies are carried out to identify the best explanatory variables that determine the selection of a beach by the turtles. Nevertheless, the results obtained from MAXENT with modified threshold or from BRT could still be used as a baseline to set up a management scheme, spread over the identified beaches, which would eventually ensure a system to record all the sporadic nesting incidents.

4.5. Role of earth's magnetic signature

Researches focusing on conservation of natural resources or threatened species mostly focus on the anthropogenic impacts on their distribution and their status. Species such as marine turtles and the distribution of their nesting grounds depend as much on natural components, and the variability or transition of the component can impact directly on the development or desertion of a site. Earth's magnetic imprint is one such component which has been proved to be used by the marine turtles in order to return to their natal beaches for nesting (Lohmann, 1991). However, the change in the magnetic field over time causes the turtles to shift their nesting sites (Brothers & Lohmann, 2015), furthermore, their nesting density has been found to increase in beaches where magnetic signatures converged over time. In addition to that, use of metal cages over the turtle nests, in order to protect them from being destroyed, also affect the magnetic imprint of the nearby fields (Irwin, Horner, & Lohmann, 2004). Considering the existence of slow but steady change in the earth's magnetic imprint, the probability of this decline in nest number being caused by natural phenomena cannot be discarded. However, modelling of the suitability with consideration of magnetic imprint of the beaches will require in depth study of the change of magnetic signature. Further to that, establishing a link between change in magnetic imprint of a specific beach sector and the decline of annual nest number requires the information on magnetic imprint of a beach over a certain period of years. Due to the absence of such data, this feature was not considered in the study.

4.6. Role of beach elevation

Depth at which a nest is laid, plays an important role on hatching success as well as sex ratio, with greater survival rate was found at nests laid at greater depth (Martins et al., 2008). Even though that study was carried out in a hatchery, it is probable that the turtles select beaches which allow sufficient sand depth in order to maximise the hatching success. The available DEM for this study had a resolution of 30 m and failed to record the subtle differences of elevation inside the beach sectors, as often the beach sectors were often very narrow. In order to understand the relationship of beach elevation and natural selection of nest locations, exact elevation of the location could be recorded and can be investigated. However, incorporating this high resolution DEM for modelling the nest distribution may not be economically the most feasible measure due to the high cost of acquiring it.

5. CONCLUSION AND RECOMMENDATION

5.1. Overall loggerhead nest count in Crete

Loggerhead turtle nest count has declined drastically in the island of Crete. Despite this significant decrease of annual nest count in Crete, the secondary beaches of the island have observed an increase in hosting turtle nests. Most importantly, the sector in Sitia has developed as an important site for loggerhead nesting with annual nest count being between 20 and 40. In addition to that specific sector, three other sites were found to have hosted approximately 10 nests annually. However, even this large increase in the secondary beaches failed to compensate for the decline that occurred in the three main nesting sites in the island. Thus, it can be concluded from this study that despite the increased selection of secondary nesting beaches of Crete by the turtles, overall nest count in the island has decreased. Considering the steady nest count in Zakynthos, and the increase in Kyparissia as well as other Mediterranean countries, it is difficult to reject the probability of loggerhead turtles from Crete are shifting to other grounds for nesting. Absence of the exact data regarding the movement of female loggerhead turtles and their revisit to the natal beach, restricted the study to confirm this probability.

5.2. Importance of secondary beach nests to train the model

The study showed the necessity of incorporating locations nest points from lesser known beaches in order to identify the beaches that can potentially host loggerhead nests. Training MAXENT with only primary beach nest locations failed completely to identify any of the secondary beaches as almost every other beach of Crete received a very low suitability score. Despite the low accuracy exhibited by the model, that used all nest information for training, it managed to identify some of the secondary beaches. Moreover, the present nest information used in the study was based on interview surveys, thus it is possible, that the number of nest had been underestimated, meaning that a regular monitoring in all those beaches may even record nests in some of the beaches that were categorized as non-nesting.

5.3. Selection of beaches based on their proximity to primary sites

The study has found no relationship between the selection of a beach for nesting and their proximity to the primary nesting beaches. Several of the beach sectors near the primary nesting beaches have remained non-nested despite their close proximity to the primary nesting beaches.

5.4. Selection of beaches based on their mean suitability

The study has also failed to observe any significant relationship between mean beach suitability and the beach being selected for nesting. Similar to the distance from primary beaches, this also provided a very low correlation coefficient.

5.5. Recommendation

5.5.1. Tagging nesting loggerhead turtles

As mentioned earlier, the annual loggerhead nest count in the Mediterranean region, during the past few decades, has remained relatively steady. On the other hand, the nest count in Greece has observed an increase of almost 40%, despite the number in Crete declining steadily. This has led to the assumption of migration of female loggerhead turtles from Crete to other nesting grounds. As mentioned earlier, it is also possible that the turtles only start to migrate after experiencing the disturbance in their natal beaches for some seasons. Required data for proving this possible behaviour can be acquired if female loggerhead turtles in Crete could be tagged. Methods to tag marine turtles with specific ID has been described by Dutton & McDonald (1994) and is probably one of the simplest approaches that allow to differentiate between nesting females from different sites. The method uses a microchip inside a cylindrical glass capsule that contains the ID of that specific turtle. This tag is then injected on the shoulder muscle of the nesting turtle during their nesting time. Even though this method is very simple, it has been adopted by Hilterman & Goverse (2007) and provided satisfactory results. Moreover, this approach can also shed information regarding the probable shift of nesting loggerhead turtles from Crete to other nesting sites. This method can also provide further information on Mediterranean loggerhead turtles' fidelity to their nesting site.

5.5.2. Incorporating local stakeholder to report nests

Moreover, in order to identify new beaches being used by loggerhead turtles for nesting, a proper management scheme is required. This will enable the responsible authority to identify the probable new nesting beaches correctly and avoid deterioration of the site. In order to address this issue, management schemes are developed differently throughout the world. Both literature reviews and field visits have revealed that the anthropogenic disturbances in the primary nesting beaches in Crete are very evident and the activities that result in disturbances are connected to the economy. Due to this reason, the current socio-economy has to be considered in any management scheme, as strategies that may lower the level of income among local stakeholders, have a higher probability to be unsuccessful.

Considering the abundance of infrastructures close to majority of the beaches in Crete, the local people working there can be included to develop a robust system of recording all nest incidents. As ARCHELON only monitors the primary nesting sites, this system will provide information on sporadic nesting also. However, a spontaneous participation of local stakeholders is only possible when the involvement provides some benefit to them.

Monetary incentives, in order to monitor turtle nests and protect them from being poached or damaged, had been provided in many countries for decades (Ferraro & Gjertsen, 2009). Such incentive scheme, together with awareness raising campaigns led to successful monitoring as well as drastic reduction of poaching of turtle eggs. Similar incentive based management plan can also be developed for Crete, which will motivate the local people to report turtle nests as well as protect them. However, the projects/management plans mentioned in the earlier mentioned paper are all located in countries where average monthly income is much lower than Greece (except for Malaysia and Indonesia), meaning that a successful incentive plan will require a greater monetary benefit for the local people to ensure their active participation.

Despite the success of incentive based turtle nest monitoring in parts of the world, this scheme requires continuous fund, which, considering the disparity in income between those project areas and Greece, might be significantly greater. As the local people in Crete, in general, has a positive attitude towards loggerhead turtle and the protection of this, a non-monetary approach may also become successful there.

As majority of the beaches has some sort of infrastructure (in the form of cafe or bar or restaurant) in the vicinity, these stakeholders could be motivated to monitor the beach segment in proximity to their facility. In order to do so, a number of stakeholders could be identified and trained from each sector/section to monitor and report turtle nests. The selection process may take the stakeholders general attitude towards the need of protection of turtles in to consideration. In return, the responsible authority could provide a certification system which can provide an added value to their establishment. Considering the large portion of European and North American tourists in Crete, it is possible that an establishment actively participating in conservation activity may offer an added value to those facilities and lead to a higher financial gain in the long run.

5.5.3. Educational outreach activity

Successful conservation plans are often coupled with proper implementation of an educational outreach activity. Several examples of successful educational outreach activities are present in the world and a selection of these activities are provided by Jacobson, McDuff, & Monroe (2015). Field visit in Crete has revealed that only the primary nesting beaches had representatives from ARCHELON exhibiting their work and raising awareness of visitors/local people. Responsible authorities from Crete can design an interactive exhibition which can move between different areas of Crete, thus can expand the coverage of the existing campaigns. Interactive exhibitions focusing on general awareness related to threat to specific endangered animals and probable behavioural change has been successfully implemented by globally recognized organization and has resulted in positive change in local people's behaviour and attitude (WCS-Bangladesh, 2015). At the same time all sort of print and electronic media can be used to inform both local people and visitors about the existing threats to the turtles as well as the importance of a proper monitoring scheme. Successful awareness raising as well as informing people, most importantly the visitors, about the stakeholders who are actively participating in the monitoring programme, can eventually motivate the visitors to take services from those stakeholders.

5.5.4. Incorporating interested local people or visitors

Considering the large number of tourists visiting Crete, and the attitude of some of the tourists or visitors comprehended during the field visit, developing a system to allow them to provide nest information may turn out to be a successful innovation. This can be achieved by building a platform or an app where local people or visitors can send photo of turtle nests and upload from year to year. One of the pre-requisite can be set that they are only allowed to upload photos that are geo-tagged so that the exact location of the nest can also be recorded in that platform. During the field visit, it was learned from interviewing a visitor in one of section that the person had spotted a nest before (few years ago; understood from the marks in the sand), but didn't know where to inform or how to mark it. Existence of such an application, connected to a database, can enable such enthusiast visitors to participate in an activity which can provide important information towards conservation of threatened species.

6. LIST OF REFERENCES

Amorocho, D. (2003). Monitoring nesting loggerhead turtles (Caretta caretta) in the Central Caribbean coast of Colombia. *Marine Turtle Newsletter*, *101*, 8–13.

Arianoutsou, M. (1988). Assessing the impacts of human activities on nesting of loggerhead sea-turtles (Caretta caretta) on Zakynthos Island, Western Greece. *Environmental Conservation*, *15*(4), 327–334.

Asaad, I. (2009). *Modelling the potential impact of Sea-Level Rise Modelling the Potential Impact of Sea-Level Rise*. University of Twente, Faculty of Geo-information Science and Earth Observation (ITC). MSc thesis.

Berry, M., Booth, D. T., & Limpus, C. J. (2013). Artificial lighting and disrupted sea-finding behaviour in hatchling loggerhead turtles (Caretta caretta) on the Woongarra coast, south-east Queensland, Australia. *Australian Journal of Zoology*, *61*(2), 137–145. http://doi.org/10.1071/ZO13028

Broderick, A. C., Glen, F., Godley, B. J., & Hays, G. C. (2002). Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean. *Oryx*, *36*(03), 227–235. http://doi.org/10.1017/S0030605302000431

Brothers, J. R., & Lohmann, K. J. (2015). Report evidence for geomagnetic imprinting and magnetic navigation in the natal homing of sea turtles. *Current Biology*, *25*(3), 392–396. http://doi.org/10.1016/j.cub.2014.12.035

Casale, P., & Margaritoulis, D. (2010). *Sea turtles in the Mediterranean: distribution, threats and conservation priorities*. Gland, Switzerland.

Casale, P., Palilla, G., Salemi, A., Napoli, A., Prinzi, M., Genco, L., … Lo Valvo, M. (2012). Exceptional sea turtle nest records in 2011 suggest an underestimated nesting potential in Sicily (Italy). *Acta Herpetologica*, *7*(1), 181–188.

Crisci, C., Ghattas, B., & Perera, G. (2012). A review of supervised machine learning algorithms and their applications to ecological data. *Ecological Modelling*, *240*, 113–122. http://doi.org/10.1016/j.ecolmodel.2012.03.001

Dennis, R. L. H., & Thomas, C. D. (2000). Bias in butterfly distribution maps: the influence of hot spots and recorder's home range. *Journal of Insect Conservation*, *4*, 73–77. http://doi.org/10.1023/A:1009690919835

Dutton, P., & McDonald, D. (1994). Use of pit tags to identify adult leatherbacks. *Marine Turtle Newsletter*, *67*, 13–14.

Elith, J., Graham, C., Anderson, R., Dudik, M., Ferrier, S., Guisan, A., … Zimmermann, N. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, *29*(2), 129–151. http://doi.org/10.1111/j.2006.0906-7590.04596.x

Explore Crete. (2015). Retrieved August 18, 2015, from http://www.explorecrete.com/

Ferraro, P. J., & Gjertsen, H. (2009). A global review of incentive payments for sea turtle conservation. *Chelonian Conservation and Biology*, *8*(1), 48–56. http://doi.org/10.2744/CCB-0731.1

Foley, A. M., Peck, S. A., Harman, G. R., & Richardson, L. W. (2000). Loggerhead turtle (Caretta caretta) nesting habitat on low-relief mangrove islands in southwest Florida and consequences to hatchling sex ratios. *Herpetologica*, *56*(4), 433–445.

Groombridge, B. (1990). *Marine turtles in the Mediterranean: Distribution, Population Status, Conservation. A Report to the Council of Europe*. Cambridge.

Guisan, A., & Thuiller, W. (2005). Predicting species distribution: Offering more than simple habitat models. *Ecology Letters*, *8*(9), 993–1009. http://doi.org/10.1111/j.1461-0248.2005.00792.x

Guisan, A., & Zimmermann, N. E. (2000). Predictive habitat distribution models in ecology. *Ecological Modelling*, *135*, 147–186. http://doi.org/10.1016/S0304-3800(00)00354-9

Guo, J. (2014). *Modelling loggerhead sea turtle (Caretta caretta) nesting habitat*. University of Twente, Faculty of Geo-information and Earth Observation (ITC). MSc thesis.

Hays, G. C., Broderick, A. C., Glen, F., Godley, B. J., Houghton, J. D. R., & Metcalfe, J. D. (2002). Water temperature and internesting intervals for loggerhead (Caretta caretta) and green (Chelonia mydas) sea turtles. *Journal of Thermal Biology*, *27*(5), 429–432. http://doi.org/10.1016/S0306-4565(02)00012-8

Hegel, T. M., Cushman, S. A., Evans, J., & Huettmann, F. (2010). Current state of the art for statistical modelling of species distribution. In S. A. Cushman & F. Huettmann (Eds.), *Spatial complexity, informatics and wildlife conservation* (pp. 273–311). Springer.

Hellenic Statistical Authority. (2014). *2011 Population and Housing Census*.
Hilterman, M. L., & Goverse, E. (2007). Nesting and nest success of the leatherback turtle (Dermochelys coriacea) in Suriname, 1999-2005. *Chelonian Conservation and Biology*, *6*(1), 87–100.
Holdridge, L. R. (1967). *Life zone ecology*. San Jose, Costa Rica: Tropical Science Centre.
Hopkins-Murphy, S. R., Murphy, T. M., Hope, C. P., Coker, J. W., & Hoyle, M. (2001). *Population trends and nesting distribution of the loggerhead turtle (Caretta caretta) in South Carolina 1980-1997*.
Irwin, W. P., Horner, A. J., & Lohmann, K. J. (2004). Magnetic field distortions produced by protective cages around sea turtle nests: Unintended consequences for orientation and navigation? *Biological Conservation*, *118*(1), 117–120. http://doi.org/10.1016/j.biocon.2003.07.014
IUCN. (2015). IUCN Red List. Retrieved August 3, 2015, from https://www.worldwildlife.org/species/loggerhead-turtle
Jacobson, S. K., McDuff, M. D., & Monroe, M. C. (2015). *Conservation education and outreach techniques* (2nd ed.). Oxford, UK: Oxford University, Press.
Karavas, N., Georghiou, K., Arianoutsou, M., & Dimopoulos, D. (2005). Vegetation and sand characteristics influencing nesting activity of Caretta caretta on Sekania beach. *Biological Conservation*, *121*(2), 177–188. http://doi.org/10.1016/j.biocon.2004.04.017
Kikukawa, A., Kamezaki, N., & Ota, H. (1999). Factors affecting nesting beach selection by loggerhead turtles (Caretta caretta): a multiple regression approach. *Journal of Zoology (London)*, *249*(4), 447–454. http://doi.org/10.1017/S0952836999009826
Lewison, R. L., Freeman, S. a., & Crowder, L. B. (2004). Quantifying the effects of fisheries on threatened species: The impact of pelagic longlines on loggerhead and leatherback sea turtles. *Ecology Letters*, *7*(3), 221–231. http://doi.org/10.1111/j.1461-0248.2004.00573.x
Li, R. (2009). *Influence of the aquatic environment on the nesting ecology of the Loggerhead Sea Turtle (Caretta caretta) in the Mediterranean Sea*. University of Twente, Faculty of Geo-information Science and Earth Observation (ITC). MSc thesis.
Lima, P. (2008). *Tourism impact on nesting habitat of loggerhead sea turtle in crete, Greece*. University of Twente, Faculty of Geo-information Science and Earth Observation (ITC). MSc thesis.
Limpus, C. J., & Limpus, D. J. (2003). The loggerhead turtle,Caretta caretta, in the Equatorial and Southern Pacific Ocean: a species in decline. In A. B. Bolten & B. Witherington (Eds.), *Loggerhead sea turtles* (pp. 199–209). Washington D.C.: Smithsonian Institution Press.
Lohmann, K. J. (1991). Magnetic orientation by hatchling loggerhead sea turtles (Caretta caretta). *The Journal of Experimental Biology*, *155*, 37–49.
Lohmann, K. J., Witherington, B. E., Lohmann, C. M. ., & Salmon, M. (1997). Orientation, navigation and natal beach homing in sea turtles. In P. L. Lutz & J. A. Musick (Eds.), *The Biology of Sea Turtles* (pp. 107–136). CRC Press.
Louhenapessy, D. G. (2010). *Study of the relationship between seagrass and sea turtle study of the relationship between seagrass and sea turtle*. University of Twente, Faculty of Geo-information Science and Earth Observation (ITC). MSc thesis.
Margaritoulis, D. (1982). Observations on loggerhead sea turtle Caretta caretta activity during three nesting seasons (1977–1979) in Zakynthos, Greece. *Biological Conservation*, *24*(3), 193–204. http://doi.org/10.1016/0006-3207(82)90057-X
Margaritoulis, D. (2005). Nesting activity and reproductive output of loggerhead sea turtles, Caretta caretta, over 19 seasons (1984-2002) at Laganas Bay, Zakynthos, Greece: the largest rookery in the Mediterranean. *Chelonian Conservation and Biology*, *4*(4), 916–929.
Margaritoulis, D., Argano, R., Baran, I., Bentivegna, F., Bradai, M. N., Caminas, J. A., … Lazar, B. (2003). Loggerhead turtles in the Mediterranean sea. In A. B. Bolten & B. E. Witherington (Eds.), *Loggerhead sea turtles* (pp. 175–198). Washington D.C.: Smithsonian Institution Press.
Margaritoulis, D., & Dretakis, M. (1991). *Determination of nesting habitats of Caretta caretta in Greece*.
Margaritoulis, D., Panagopoulou, A., & Rees, A. F. (2009). Loggerhead nesting in Rethymno island of Crete, Greece: fifteen-year nesting data (1990-2004) indicate a declining population. In *Proceedings of the Second Mediterranean Conference on Marine Turtles* (Vol. 109, pp. 116–119).
Margaritoulis, D., & Rees, A. F. (2001). The loggerhead turtle, Caretta caretta, population nesting in Kyparissia Bay, Peloponnesus, Greece: results of beach surveys over seventeen seasons and determination of the core nesting habitat. *Zoology in the Middle East*, *24*(1), 75–90. http://doi.org/10.1080/09397140.2001.10637886

Margaritoulis, D., & Rees, A. F. (2003). Loggerhead nesting effort and conservation initiatives at the monitored beaches of Greece during 2002. *Marine Turtle Newsletter*, *102*, 11–13.

Marquez, R. M. (1990). FAO species catalogue: Vol. 11. Sea turtles of the world. An annotated and ilustrated catalogue of sea turtle species known to date. *FAO Fisheries Synopsis*, *125*(11), 81p.

Martins, S., Abella, E., Lopez, O., Ikaran, M., Marco, Aa., & Lopez-Jurado, L. F. (2008). Influence of nest depth on incubation and emergence of loggerhead turtles. In *27th Annual Symposium on Sea Turtle Biology and Conservation* (pp. 241–242).

Mingozzi, T., Masciari, G., Paolillo, G., Pisani, B., Russo, M., & Massolo, A. (2007). Discovery of a regular nesting area of loggerhead turtle Caretta caretta in southern Italy: A new perspective for national conservation. *Biodiversity and Conservation*, *16*, 3519–3541. http://doi.org/10.1007/s10531-006-9098-6

Moetasim, A. M. I. (2011). *Investigating the nesting habitat selection of loggerhead sea turtle (Caretta caretta) in Crete island , Greece*. University of Twente, Faculty of Geo-information Science and Earth Observation (ITC). MSc thesis.

Mortimer, J. A. (1982). Factors influencing beach selection by nesting turtles. In K. A. Bjorndal (Ed.), *Biology and conservation of sea turtles* (pp. 45–52). Washington D.C.: Smithsonian Institution Press.

NOAA-FISHERIES. (2014). Loggerhead turtle (Caretta caretta). Retrieved June 24, 2015, from http://www.nmfs.noaa.gov/pr/species/turtles/loggerhead.htm

Shanker, K., Ramadevi, J., Choudhury, B. C. ., Singh, L. ., & Aggarwal, R. K. (2004). Phylogeography of olive ridley turtles (Lepidochelys olivacea) on the east coast of India: implications for conservation theory. *Molecular Ecology*, *13*, 1899–1909. http://doi.org/10.1111/j.1365-294X.2004.02195.x

Spotila, J. R., Reina, R. D., Steyermark, A. C., Plotkin, P. T., & Paladino, F. V. (2000). Pacific leatherback turtles face extinction. *Nature*, *405*, 529–530. http://doi.org/10.1038/35014729

SWOT. (2006). *The state of the world's sea turtles* (Vol. I). Retrieved from http://seaturtlestatus.org/sites/swot/files/swot1.pdf

Tripathy, B., & Rajasekhar, P. S. (2009). Natural and anthropogenic threats to olive ridley sea turtles (Lepidochelys olivacea) at the rushikulya rookery of Orissa coast, India. *Indian Journal of Marine Sciences*, *38*(4), 439–443.

Troëng, S., Chacón, D., & Dick, B. (2004). Possible decline in leatherback turtle Dermochelys coriacea nesting along the coast of Caribbean Central America. *Oryx*, *38*(4), 395–403. http://doi.org/10.1017/S0030605304000766

WCS-Bangladesh. (2015). Shushuk Mela or Dolphin Festival. Retrieved May 19, 2016, from http://bangladesh.wcs.org/Initiatives/Shushuk-Mela-or-Dolphin-Festival

Wood, D. W., & Bjorndal, K. A. (2000). Relation of temperature, moisture, salinity, and slope to nest site selection in loggerhead sea turtles. *Copeia*, *2000*(1), 119–128. http://doi.org/10.1643/0045-8511(2000)2000[0119:ROTMSA]2.0.CO;2

World Travel and Tourism Council. (2014). *Travel & Tourism: Economic Impact 2014, Greece*.

WWF. (2015a). Loggerhead sea turtle overview. Retrieved June 18, 2015, from https://www.worldwildlife.org/species/loggerhead-turtle

WWF. (2015b). World Wildlife Fund. Retrieved June 26, 2015, from http://wwf.panda.org/what_we_do/endangered_species/marine_turtles/loggerhead_turtle/

7. APPENDICES

7.1. Appendix 1: Brief description of the visited beaches

Phalasarna (CR 1-8)
Date visited: 04/10/2015
Several beach sectors in Phalasarna with low-mid beach use. Most of the beach sectors are wide and are mostly sandy. Only few sections of the beaches have taverns and cafes.

Trachilos (CR 25-27)
Date visited: 04/10/2015
The beach is located close to Kaliviani and is small and consisting mostly sand. No taverns or cafes in the beach. Towards Kaliviani, there is another beach that consist a mix of sand and pebbles. The beaches were mostly empty during the time they were visited, however, from the number of cafe/tavern/bar in the area it seemed that the beach is not heavily used.

Nopigiya - Kissamos (CR 30-33)
Date visited: 04/10/2015
Close to Nopigiya, the beach is quite narrow with a lot of pebbles and with low-mid use. The beach close to Kissamos also consists a lot of pebbles but has a relatively higher beach use level.

Maleme - Aghia Marina (Part of Chania main turtle nesting site)(CR 55-65)
Date visited: 04/10/2015
These beach sectors get really crowded at places with mid-high level of beach use. Most of the sectors consist a mix of sand, some small pebbles and some areas with even larger stones. This whole stretch of beaches is part of one of the three main turtle nesting sites in Crete.

Aghia Apostoli (CR 76-77)
Date visited: 24/09/2015
Small beach just west of the Chania town consisting mostly sand. Being close to Chania town, the beach receives around mid level of use by people.

Apterou - Nea Hora (CR 78 -79)
Date visited: 24/09/2015
Apterou is located very close to Chania but is almost empty and consists of sand and some large pebbles at areas. The western end of the beach has more pebbles than the eastern end, however, the beach towards the eastern end is also relatively narrower. Nea Hora is almost inside the Chania town with heavy light pollution at night originated from the town and generally receiving mid-high level of beach use.

Kalathas - Stavros (West of Akrotiri) (CR 86-90) Agios Onoufrios (beach id not given)
Date visited: 02/10/2015
The beaches are mostly sandy with some parts in Stavros being covered with rocks. The beach use in these sectors varies from low-mid to mid.

Marathi (In Souda Bay)(CR 100-110)

Date visited: 02/10/2015
Some of the beaches visited in that region were very crowded (beach use: mid-high) and at places quite narrow. The beaches consist mostly of sand and some pebbles.

Kyani Akti (CR 112)
Date visited: 24/09/2015
The beach consisted mostly of sand with areas with some rocks with beach use of mid level.

Kalyves - Kera - Almyrida (CR 114-116)
Date visited: 24/09/2015
Kalyves and Almyrida beaches consist mostly sand. No beach was found in Kera, but the immediate back of sea-water line was abruptly high and felt like an area which could have been elevated from the natural state. Beach use in Kalyves and Almyrida ranged between mid and high.

Georgioupouli (CR 130-133)
Date visited: 23/09/2015
Most of the sectors had sandy beaches with parts with some pebbles and the beach in most places is quite wide. The beach use in the whole sector varies from low to high in some specific areas. The sectors were visited almost at the end of the tourist season and local people informed that parts of the beaches can get really crowded.

Petres (CR 140-142)
Date visited: 23/09/2015
Small beach with mid level beach use intensity. The beach consists mostly of sand and some pebbles in areas.

Rethymno (CR 155-165)
Date visited: 01/10/2015
A long beach stretching from just east of the Rethymno town for more than 10 km, consisting mostly of sand. The beach is segmented in smaller parts due to interruption caused by rocks. The section of the beach close to the Rethymno town has really high beach use with both during day and night. However, there are also areas which are relatively quiet and empty.

Mylopotamos (CR 170)
Date visited: 23/09/2015
A small beach at the mouth of a stream with low-mid beach use intensity. The beach has only one cafe and has normally no light pollution at night. The beach has a lot of pebble close to the edge of the water. However, the rear part of the beach after the first few meters consists of a mixture of sand and some pebbles.

Panormos (CR 175)
Date visited: 23/09/2015
The Panormos beach is very small with high beach use intensity. The beach consists of sand with very few pebbles.

Bali Beaches (CR 186-189)

Date visited: 30/09/2015
Several small beaches in Bali with some of them having mid level beach use intensity. The beaches in Bali consist of a mixture of sand and few pebbles. The sector close to the Bali village has light pollution at night from anthropogenic sources.

Paralia Fodele (CR 215-216)
Date visited: 30/09/2015
One section of the beach next to the road was completely empty with majority of the beach section being covered with sand with scattered pebbles and small stones. However, vehicle tyre tracks were observed in that section of the beach. The main beach section of Paralia Fodele had mostly sand in the beach and certain areas with high number of beach chairs and umbrellas.

Aghia Pelagia (CR 225-230)
Date visited: 30/09/2015
Several small sections of beach with almost all of them with mid-high beach use intensity. Several beach chairs and umbrellas were present in the beach and the beach consisted of mixture of sand and pebbles. One of the sections was really narrow with concrete wall behind the beach.

Ligaria (beach id not given)
Date visited: 30/09/2015
The beach section in Ligaria consists of sand and some parts being very pebbly. The sector gets mid level of crowd during the summer months mainly with tourists. The beach has several umbrellas and sun-chairs laid for the visitors and has several cafes, bars in the vicinity.

Palaikastro (CR 235-242)
Date visited: 30/09/2015
Series of beaches close to Palaikastro with some of the beaches being really small in length. One section, that was relatively longer, was closed and had restriction on entry. From distance, it seemed that the beach consisted of a mixture of sand and pebbles.

Ammoudara (CR 244-247)
Date visited: 29/09/2015
A long stretch of beach which gets highly crowded during the summer period. The beach consisted mostly of sands but at areas had some pebbles. The beach has numerous cafes, bars and taverns and some parts of the beach are covered with sun beds and umbrellas.

Aghios Ioannis (CR 259)
Date visited: 17/10/2015
The beach is just east of the Iraklio airport and is exposed to heavy sound pollution due to the landing and takeoff of aircrafts. The beach had low-mid use which may be due to the sound pollution from the proximity to the airport. The beach consisted mostly of sands.

Kokkini Hani (CR 264-270)
Date visited: 17/10/2015
Several small beaches with some of them being very narrow. Few of the beaches were sandy and had the beach use ranged from mid-high at some places to high at other.

Aghia Pelagia (Apposelmis) (CR 277-278)
Date visited: 16/10/2015
The beach close to Apposelmis river had very low use by people as the area is designated as a protected area. The beach consisted of a mixture of sand and pebbles. At the very western part of the beach is a hotel and a water sport centre, while the remaining part of the beach is empty.

Analipsi - Anissaras (CR 280)
Date visited: 16/10/2015
The beach stretch in Analipsi consisted mostly sand and is normally crowded in summer months (mid-high beach use). Several cafes and bars are located next to the beach. The beach close to Anissaras was relatively empty. A small part of the beach had beach rock while rest were sandy.

Stalida (CR 295-296)
Date visited: 16/10/2015
The beaches close to Stalida consisted mostly of sand; however, at areas the beach was highly crowded. In general, the beaches had mid-high beach use intensity. Several bars, cafes, hotels are present in the area with many of them with loud speakers which leads to the assumption of severe sound pollution in the area.

Malia (CR 298-302)
Date visited: 16/10/2015
A series of beaches mostly consisted of sand and some rocks at the splash zone at some areas. The western part of the beach stretch has mid level beach use intensity while the eastern most part of the stretch has very low beach use as the area is protected for an archaeological site.

Sissi Beaches (CR 306-307)
Date visited: 16/10/2015
Series of small beaches with beach use level ranging from low to mid level of intensity. The beaches consisted mostly of sand and in both beaches sun chairs and umbrellas were present.

Milatos (CR 310-311)
Date visited: 16/10/2015
The longer of the two beaches in Milatos consisted mostly of rocks and pebbles. The other beach is very small and next to the harbour and consisted of sand. The beach use was very low.

Elounda (beach id not given)
The Elounda beach consisted mostly of very compact sand and had a mid level beach use intensity. Several sun chairs and umbrellas were present in the beach.

Ammoudara (CR 334)
Date visited: 16/10/2015
A very small and narrow sandy beach next to the main road. The beach is crowded with people (beach use intensity of mid-high) and has several sun chairs and umbrellas.

Istro (CR 340)

Date visited: 28/09/2015
The Istro beach consisted mostly of sand with some areas with large pebbles and small stones. The beach had several sun chairs and umbrellas and it was assumed from the numbers of those objects and from local peoples' knowledge that the beach has low-mid level beach use intensity.

Pacheia Ammos (CR 344-347)
Date visited: 28/09/2015
A series of beaches in the village of Pacheia Ammos, with one of the sectors being heavily polluted with debris. Some sections of the beach consisted of sand and some pebbles. In general, the beach had low-mid level of use, except for the area close to the port.

Tholos (CR 351)
Date visited: 28/09/2015
The beach in Tholos is consisted of compact sand and lots of small and large pebbles as well as some stones. The area has very little development and has no bars or cafes near the beach and the beach has low use.

Sitia (CR 370-372)
Date visited: 13/10/2015
The beach next to Sitia town consisted mostly sand with some pebbles and small stones at places. The beach has mid level beach use intensity and has several sun chairs and umbrellas in the beach. The main road to Sitia town runs just behind the beach.

Itanos (CR 410-412)
Date visited: 27/09/2015
Three beaches are located close to the archaeological site of Itanos. The beach closest to the site is small and has lots of stone and pebbles in the beach. The beach furthest from the site, separated by rocky hill, is mostly sandy. All the beaches had very low beach use intensity.

Vai (CR 414-416)
Date visited: 27/09/2015
There are two beaches easily accessible in Vai; one of them is quite crowded with mid-high level of beach use, while the other beach, just south, has very little use. Both the beaches consisted of sand and shingles.

Kouremenos (CR 422)
Date visited: 11/10/2015
The beach in Kouremenos consisted of sand and some shingles in the splash zone. The beach had very little use during the time of the visit, however, it can be assumed based on the number of bars and cafes in the area, that the beach does not get very crowded during summer time either.

Chiona (CR 424-427)
Date visited: 11/10/2015
The beach in Chiona had sand and some small stones in places. There are only two taverns close to the beach and based on information from the local people it can be assumed that the beach has low use even in summer months.

Kato Zakros (CR 435)
Date visited: 11/10/2015
The beach in Kato Zakros consisted a lot of stones and pebbles with very few locations with sand. Several taverns and cafes are in close proximity to the beach. At places the beach has mid-high level of beach use intensity with several sun chairs and umbrellas in the beach.

Xerokampos (CR 437-441)
Date visited: 11/10/2015
Several small sections of beaches are located in Xerokampos, with most of them consisted of sands and small pebbles at areas. There is a salt marsh in the northern part of the beach which turns in to a wetland in winter. That area is designated as a NATURA site under the bird directive and due to that has very little development. The beach close to Xerokampos has low-mid level use while the part close to the salt marsh has low use.

Diskari (CR 470)
Date visited: 10/10/2015
The beach close to the village of Diskari consisted of sand with lots of large pebbles and small stones near the rear end. There are no cafes or taverns in the area and the beach had low use.

Analipsi - Makrygalos (CR 474-475)
Date visited: 10/10/2015
The beaches in Analipsi and Makrygalos consisted of sand. The Makrygalos beach also had some small stones in the beach. The beach use in these two beaches ranged from low-mid intensity in Analipsi to mid intensity in Makrygalos.

Koutsouras (CR 477-480)
Date visited: 10/10/2015
The beach in Koutsouras was covered with pebbles and stones and had no sandy part in the beach. The beach had several sun chairs and umbrellas and it was possible to assume that the beach get low-mid level of use during the summer months.

Achila (CR 487)
Date visited: 27/09/2015
The beach in Achila consisted of mostly sand and some shingles. There is only one cafe in the beach. The beach in general has mid level use with relatively more use close to the cafe in compare to the western end of the beach.

Kokkhos Bay (CR 494-496)
Date visited: 27/09/2015
Three small beaches in the Kokkos bay with high level of beach use. The beach had several sun chairs and umbrellas. The beach consisted mostly of shingles and some patches with sands.

Koutsounari (CR 498)
Date visited: 27/09/2015

A long stretch of beach consisting of a mixture of sand, shingles and small pebbles. In general the beach had low-mid level of use, however, part of the beach had relatively high use while some parts had almost no use at all.

East Ierapetra (CR 513)
Date visited: 27/09/2015
A long stretch of beach just east of the town of Ierapetra consisting of a mixture of sand, shingles and some small pebbles. The beach has a constant width and in general has low level of beach use.

Stomio (CR 522-524)
Date visited: 10/10/2015
The Stomio beach consisted of a mixture of sand, shingles, pebbles and at points small stones. Several houses and some cafes are just behind the beach towards the eastern side. Beach use was hard to estimate as most cafes/restaurants were closed during the visit.

Ammoudares (CR 531)
Date visited: 10/10/2015
The beach is Ammoudares consisted mostly of sand and some scattered pebbles at some parts. There is no cafe or taverns in the vicinity of the beach and at the time of visit, the beach was completely empty. However, there were tyre tracks visible in the beach.

Myrtos (CR 538-543)
Date visited: 10/10/2015
The beach in Myrtos had a mix of mainly pebbles and sand at places with the area close to the main market place of Myrtos being very crowded. Several cafes, bars, taverns are present in the eastern end of the beach.

Vatos (CR 550-551)
Date visited: 10/10/2015
The Vatos beach had a lot of pebbles and even large rocks on the eastern end. The road runs just behind the beach sectors, however, despite the vicinity to the road, the beach was empty at the time of visit. Considering the lack of restaurants and cafes in vicinity, it is assumed that the beach use in Vatos is very low.

Tertsa (CR 562-565)
Date visited: 10/10/2015
The beach sectors in Tertsa consist mostly of sand with mixture of some pebbles at places. Beach use close to the village of Tertsa is of mid level intensity, but towards the west is relatively low.

Sindonia (CR 570)
Date visited: 10/10/2015
The beach section close to Sindonia consists mostly of loose sand with few pebbles at areas. The western end of the beach has few cafes and houses and the eastern end consists of some rocks. At the time of visit, the beach was empty and based on the number of cafes and restaurants, it could be assumed that the beach receives low use by people.

Agias Parskevi
Date visited: 10/10/2015
A very small beach sector with only few houses on the western end. The beach consists mostly of scattered stones, pebbles and very compact sand. Very little use by visitors/local people.

Arvi (CR 573-576)
Date visited: 10/10/2015
Series of beaches mostly consisting sand with some small sections covered with pebbles and small stones. Beach use is relatively higher towards the eastern end with few cafes and restaurants located towards that part.

Kastri (CR 587)
Date visited: 10/10/2015
The beach sector in Kastri consists mostly of pebbles of various sizes with some patches with sand. The section close to the village of Kastri has low-mid level of beach use during the summer months. Beach use towards the eastern end is almost negligible.

Dermatos (CR 593)
Date visited: 09/10/2015
An empty beach consisting mostly of large pebbles and stones. Lack of cafes and restaurants hinders the beach use by visitors.

Tsoutsouras (CR 597)
Date visited: 09/10/2015
The beach sector in Tsoutsouras has relatively low use. The beach consists of pebbles and shingles towards the western end, but towards the eastern end has relatively more sandy patches. The section in eastern end is also relatively wider than that of the western section.

Lentas (CR 644)
Date visited: 09/10/2015
Small beach section in front of the village of Lentas with mid level of use by both local people and visitors. The beach consists of a mixture of pebbles, shingles and sand. The beach is very narrow towards the eastern end and also has number of beach rocks in that portion.

Diskos (CR 655)
Date visited: 09/10/2015
The beach sector in Diskos consists mainly of sand with a mixture of small pebbles and shingles. The beach has a low-mid level of use by visitors and has few cafes in the vicinity. The western end of the beach has relatively more pebbles and shingles than the eastern part.

Platania Permata (CR 660-661)
Date visited: 09/10/2015
Small beach consisting of rocks, stones and pebbles.

Hrissostomos (CR 664-670)
Date visited: 09/10/2015

The beach sector in Hrissostomos consists mostly of stones and pebbles with little sand in some small patches. There are no cafe or restaurants present in the vicinity of the beach section and it could be assumed that the beach use is generally very low.

Kaloi Limenes (CR 672-675)
Date visited: 26/09/2015
Series of beaches consisting mostly of sand with some pebbles and rocks on the beach. The beach is not heavily used and has no permanent cafe or restaurants in the vicinity. There is a fuelling station for ships just in front of the beach.

Matala (CR 700)
Date visited: 26/09/2015
A small but very busy beach close to the Matala village. There are several cafes, restaurants and bars in the vicinity which may cause both noise and light pollution. The beach consists mostly of sand.

Messara (CR 710-713)
Date visited: 26/09/2015
A long stretch of beach consisting mostly of sand with some areas with small pebbles and shingles. Some parts of the beach is very busy with several beach chairs and umbrellas and many cafes, restaurants in the vicinity. A portion of the beach sector is restricted due to the military use.

Aghia Pavlos (CR 735-737)
Date visited: 25/09/2015
A small sandy beach sector with mid level of use by people. The beach section has some beach chairs and umbrellas for visitors to use.

Melissa (CR 745-746)
Date visited: 25/09/2015
Sandy beach with few pebbles and stones in the section. The eastern end of the beach has few beach chairs and umbrellas for visitors to use.

Ligres (CR 752-757)
Date visited: 25/09/2015
Long stretch of beach mostly consisting of sand with some small pebbles and shingles in the splash zone. The western sectors have relatively more pebbles than the eastern sector.

Schinaria (CR 774)
Date visited: 08/10/2015
A small sandy beach with low-mid level of use by visitors. There is a small cafe close to the beach and some beach chairs and umbrellas towards the eastern end of the beach.

Ammoudi (CR 775)
Date visited: 08/10/2015
Small beach with a mixture of shingles and sand in the beach. The beach receives low level of use by both local people and visitors and has one small cafe in the vicinity.

Damnoni (CR 777)
Date visited: 08/10/2015
The beach section in Damnoni consists mostly of sand and the beach towards the western end is relatively more crowded due the presence of a cafe in that part.

Plakias (CR 781)
Date visited: 07/10/2015
The beach sector in Plakias consist mostly of sand and some pebbles at places. The beach is very crowded close to the main village of Plakias and also towards the eastern end. There are several cafes, restaurants and bars close to the beach but not on the beach directly.

Souda (CR 782)
Date visited: 08/10/2015
The beach sector in Souda consists motly of sand and shingles with a low-mid level of beach use by visitors as well as local people. There are only a few taverns in the vicinity of the beach.

Rodakino beaches (CR 787-790)
Date visited: 07/10/2015
Series of beaches with low to mid level of use by both local people and visitors. Most of the areas of the beaches are sandy but also has pebbles and stones on some sectors. The beach section in Polirizos is very narrow.

Frangokastello (CR 795-798)
Date visited: 07/10/2015
Series of beaches with some areas with lots of shingles and small pebbles with other areas with fine sand. The section of the beach close to the old castle has cafe and restaurant, thus has relatively higher beach use by visitors and local people.

Hora Sfakion (CR 850)
Date visited: 07/10/2015
A small beach mostly covered with pebbles and shingles with mid-high level of beach use by both local people and visitors.

Palaiohora (CR 900-901)
Date visited: 06/10/2015
The beach sectors in Palaiohora consist mostly of sand and some shingles in places. The section in front of the village of Palaiohora has mid level of use and has several cafes and restaurants in the vicinity. The beach is relatively more crowded towards the eastern end than the western part.

Sfinari (CR 980)
Date visited: 06/10/2015
The beach in Sfinari consists mostly of rocks and large pebbles. There are few cafes close to the beach but generally the beach use in that area is very low.

7.2. Appendix 2: Table displaying mean suitability values of the visited beaches (obtained from running the model with nest information only from primary nesting beaches)

Beach Name	Mean Suitability (MAXENT)	Mean Suitability (BRT)	Nesting in Reality
Achila	0.0052	0.0443	Yes
AghiaApostoli	0.3473	0.5993	No
AghiaPelagia	0.0298	0.0545	No
AghiaPelagia(Apposelmis)	0.0690	0.0586	Yes
AghiosIoanis	0.1043	0.0617	No
AgiosPavlos	0.0015	0.0464	No
AgParaskevi	0.0075	0.0412	No
Almyrida	0.4263	0.9416	No
Ammoudara	0.0491	0.0762	Yes
Ammoudares	0.0029	0.0460	No
Amoudara	0.0974	0.0738	No
Amoudi	0.0298	0.0528	No
Analipsi	0.0711	0.0607	No
AnaMakry	0.0083	0.0531	No
Aptera	0.2276	0.7478	No
Arvi	0.0173	0.0475	Yes
Bali	0.1696	0.6116	Yes
Chiona	0.0407	0.0401	No
Damnoni	0.0372	0.0856	Yes
Dermatos	0.0045	0.0437	No
Diskari	0.0074	0.0530	No
Diskos	0.0044	0.0483	Yes
EastIerapetra	0.0044	0.0482	No
Elounda	0.0779	0.0627	No
Frangokastello	0.0193	0.0371	No
Georgioupouli	0.4874	0.9129	Yes
Hrissostomos	0.0195	0.0475	No
Istro	0.0533	0.0505	No
Itanos	0.0115	0.0452	No
Kalathas	0.3301	0.9416	No
KaloiLimenes	0.0213	0.0470	No
Kalyves	0.3122	0.8566	No
Kastri	0.0172	0.0433	Yes
KatoZakros	0.0055	0.0402	No
KokkiniHani	0.0768	0.0608	No
KokkosBay	0.0044	0.0536	No
Kouremenos	0.0511	0.0427	No
Koutsonari	0.0035	0.0512	No
Koutsouras	0.0062	0.0520	No
KyaniAkti	0.0727	0.0962	No
Lentas	0.0017	0.0484	Yes

Ligaria	0.1715	0.1206	Yes
Ligres	0.0175	0.0475	No
MalemeAghiamarina	0.4688	0.9022	Yes
Malia	0.0729	0.0600	Yes
Matala	0.1612	0.1109	Yes
Melissa	0.0188	0.0475	Yes
Messara	0.4551	0.7520	Yes
Milatos	0.0149	0.0419	No
Mylopotamos	0.3684	0.1406	Yes
Myrtos	0.0055	0.0421	Yes
NeaHora	0.1780	0.7706	No
NopigiyaKissamos	0.0752	0.0749	Yes
PacheiaAmmos	0.0664	0.0554	Yes
Palaiohora	0.0226	0.1062	No
Panormos	0.2368	0.1258	Yes
ParaliaFodele	0.2821	0.8833	Yes
Petres	0.1825	0.6179	No
Plakias	0.0592	0.1143	Yes
Rethymno	0.5215	0.9398	Yes
Richtis	0.0284	0.0378	No
Rodakino	0.0043	0.0369	Yes
Schinaria	0.0134	0.0463	Yes
Sfinari	0.0065	0.0408	No
Sindonia	0.0048	0.0412	No
Sissi	0.0335	0.0521	No
Sitia	0.0867	0.0582	Yes
Souda	0.0469	0.0939	No
Phalasarna	0.0231	0.0429	Yes
Stalida	0.1303	0.0752	No
Stavros	0.1558	0.1244	No
Stomio	0.0044	0.0471	No
Tertsa	0.0010	0.0428	Yes
Tholos	0.0080	0.0391	No
Trachilos	0.0590	0.0563	No
Tsoutsouras	0.0240	0.0459	No
Vai	0.0191	0.0447	No
Vatos	0.0015	0.0405	No
Xerokampos	0.0034	0.0351	Yes

7.3. Appendix 3: Table displaying mean suitability values of the visited beaches (obtained from running the model with nest information from all beaches)

Beach Name	Mean Suitability (MAXENT)	Mean Suitability (BRT)	Nesting in Reality	Distance to nearest primary nesting beach
Achila	0.4399	0.8561	Yes	102986.1
AghiaApostoli	0.2642	0.3799	No	3217.323
AghiaPelagia	0.3373	0.7465	No	37084.81
AghiaPelagia(Apposelmis)	0.4963	0.9358	Yes	60601.81
AghiosIoanis	0.5446	0.9255	No	50339.33
AgiosPavlos	0.0663	0.2119	No	16573.23
AgParaskevi	0.4444	0.8882	No	65916.36
Almyrida	0.4793	0.9494	No	23528.59
Ammoudara	0.2566	0.5803	Yes	42191.85
Ammoudares	0.2988	0.6608	No	80869.47
Amoudara	0.2806	0.8882	No	87594.54
Amoudi	0.5790	0.8555	No	22561.14
Analipsi	0.4134	0.8955	No	62693.81
AnaMakry	0.3854	0.8364	No	111172.6
Aptera	0.2257	0.4371	No	3943.415
Arvi	0.4381	0.8563	Yes	64197.1
Bali	0.2524	0.7341	Yes	15876.22
Chiona	0.5198	0.8939	No	139145.1
Damnoni	0.5399	0.8996	Yes	22318.1
Dermatos	0.3315	0.6493	No	51651.88
Diskari	0.5401	0.8877	No	112726.9
Diskos	0.2908	0.8165	Yes	16411.72
EastIerapetra	0.4606	0.8372	No	91283.03
Elounda	0.5028	0.9357	No	90938.88
Frangokastello	0.4715	0.7010	No	30828.84
Georgioupouli	0.5361	0.9379	Yes	16394.2
Hrissostomos	0.3598	0.8947	No	9783.951
Istro	0.3360	0.8472	No	89062.63
Itanos	0.3185	0.9202	No	138996.9
Kalathas	0.4614	0.9474	No	12887.71
KaloiLimenes	0.4857	0.8956	No	9196.474
Kalyves	0.4207	0.8843	No	21188.2
Kastri	0.4589	0.9113	Yes	58420.7
KatoZakros	0.2198	0.4597	No	137005.5
KokkiniHani	0.4521	0.9082	No	53881.66
KokkosBay	0.3937	0.8206	No	98582
Kouremenos	0.5371	0.9161	No	138670
Koutsonari	0.5678	0.8271	No	97139.51
Koutsouras	0.4284	0.8474	No	107092.1
KyaniAkti	0.2685	0.6561	No	19334.34
Lentas	0.1279	0.7769	Yes	17303.71
Ligaria	0.3847	0.8846	Yes	37785.02
Ligres	0.2373	0.7320	No	19726.3

MalemeAghiamarina	0.5170	0.9184	Yes	1.6607
Malia	0.4591	0.8904	Yes	70610.82
Matala	0.4042	0.7560	Yes	1790.145
Melissa	0.5378	0.8934	Yes	18300.41
Messara	0.4763	0.7727	Yes	3.5843
Milatos	0.2529	0.6623	No	79408.62
Mylopotamos	0.6127	0.9500	Yes	3989.377
Myrtos	0.3549	0.7972	Yes	75131.92
NeaHora	0.1531	0.4158	No	4706.617
NopigiyaKissamos	0.2450	0.4411	Yes	15013.66
PacheiaAmmos	0.3982	0.8743	Yes	95512.86
Palaiohora	0.5491	0.6773	No	35950.16
Panormos	0.4581	0.8831	Yes	7665.814
ParaliaFodele	0.4936	0.9092	Yes	31412.47
Petres	0.3978	0.8942	No	10433.89
Plakias	0.4497	0.9016	Yes	21689.34
Rethymno	0.5390	0.9410	Yes	4.019849
Richtis	0.4302	0.9238	No	112680.4
Rodakino	0.3472	0.7912	Yes	26252.56
Schinaria	0.5299	0.8734	Yes	23019.71
Sfinari	0.1060	0.3661	No	27939.29
Sindonia	0.5461	0.8496	No	67349.07
Sissi	0.3839	0.7347	No	76008.16
Sitia	0.4786	0.9505	Yes	124691
Souda	0.4638	0.9098	No	22265.96
Phalasarna	0.3900	0.5786	Yes	24153.78
Stalida	0.5725	0.9289	No	67295.88
Stavros	0.4057	0.8789	No	15162.36
Stomio	0.3212	0.7638	No	84176.1
Tertsa	0.4317	0.8935	Yes	69877.85
Tholos	0.3701	0.7886	No	101047.1
Trachilos	0.3283	0.3219	No	20159.22
Tsoutsouras	0.2586	0.5671	No	48799.25
Vai	0.4812	0.9349	No	138991.3
Vatos	0.3023	0.8780	No	73393.57
Xerokampos	0.3197	0.7011	Yes	134635.8

7.4. Appendix 4: Standardized questionnaire developed to collect field data

Interviewee: Location:

Nest observed in 2015:

Nest observed in 2014 and/or 2013 and/or 2012:

Do you feel that more nests are being observed annually in the span of last 10 years in this area:

Are there more visitors during peak summer months than the current time?: a)same, b)more (double/tripple/..)

What did you do (local people) when you identify a nest?:

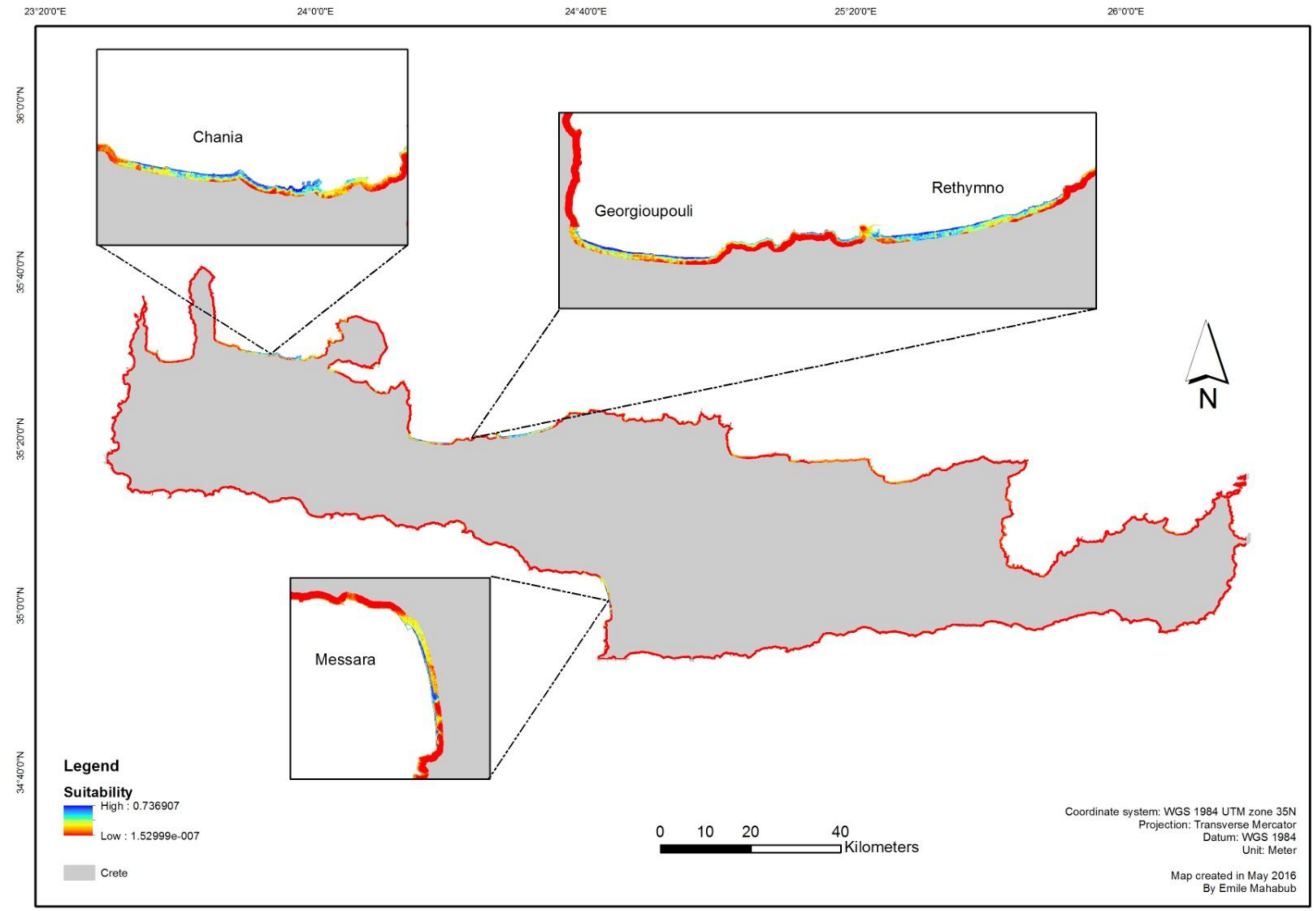
Did you inform any specific authority?:

Have there been any threat (natural/anthropogenic) to the nests?:

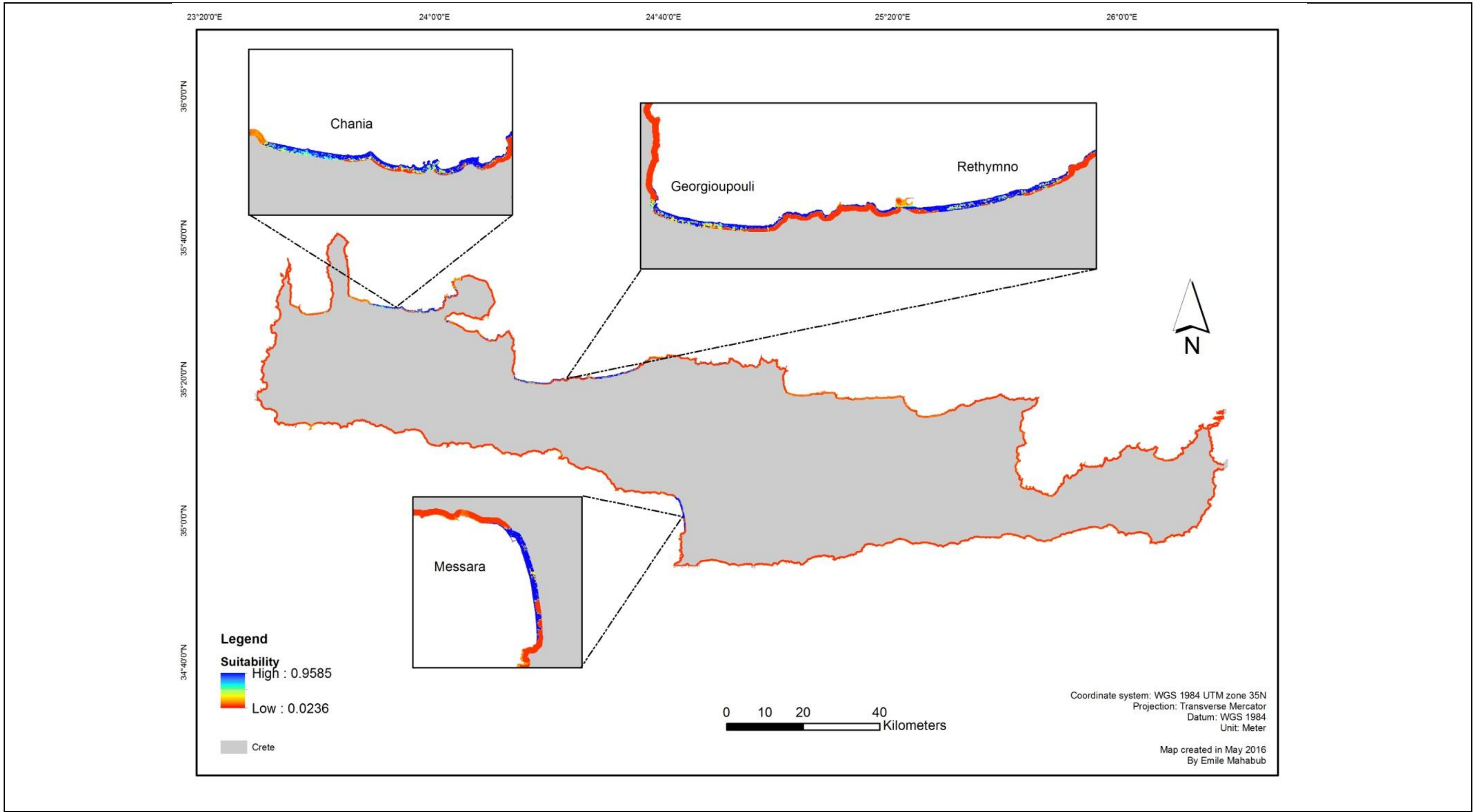
If nest observed in 2015, the interviewee will be requested to show the location of nest.

ID	Waypoint	Lat	Lon	Beach use by people (low - high; category)	Remarks

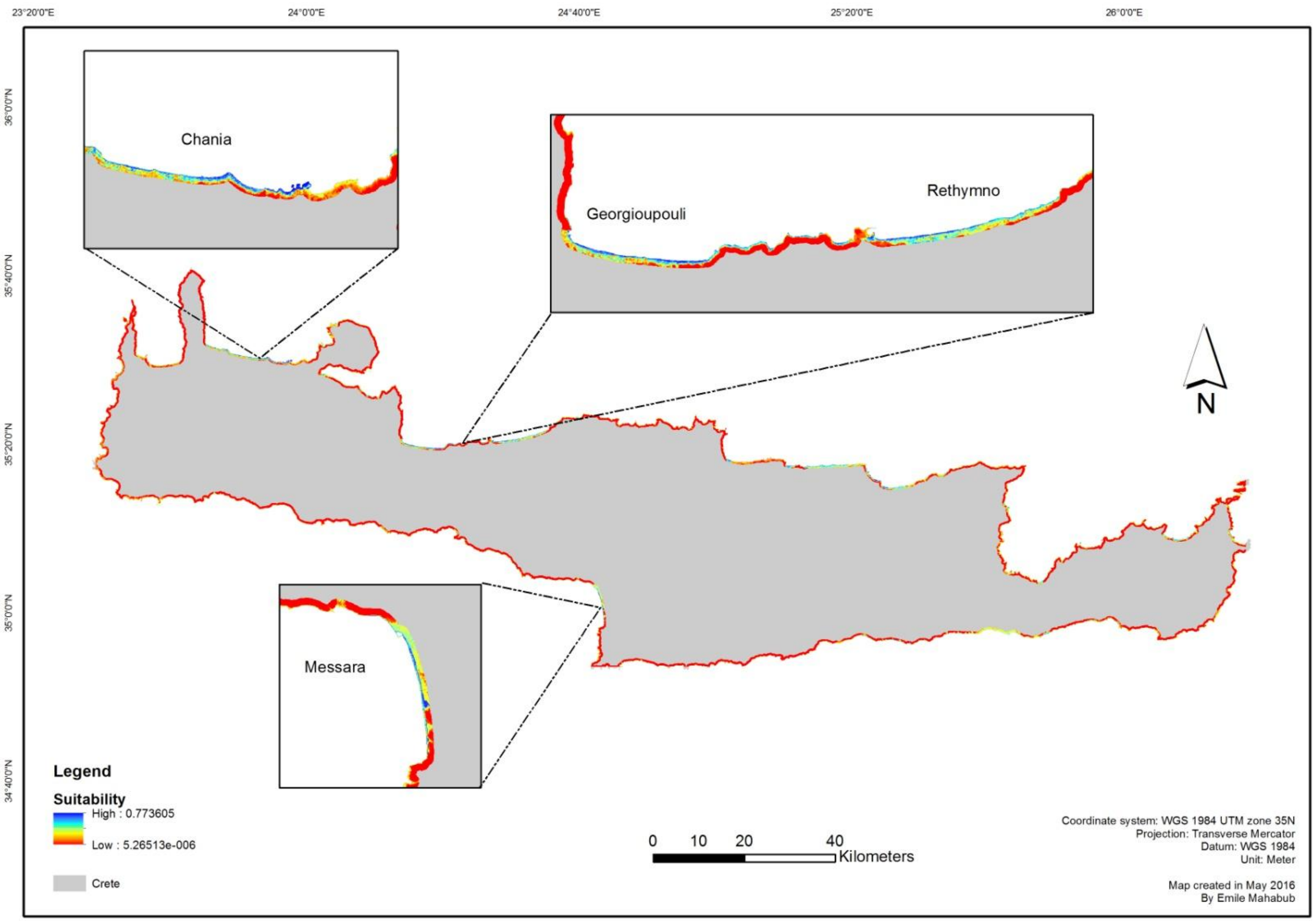
7.5. Appendix 5: Result obtained from training the MAXENT with only primary beach nest points



7.6. Appendix 6: Result obtained from training the BRT with only primary beach nest points



7.7. Appendix 7: Result obtained from training the MAXENT with both primary and secondary beach nest points



7.8. Appendix 8: Result obtained from training the BRT with both primary and secondary beach nest points