Identifying Similar Biophysical Characteristics among Nesting Beaches of Green Turtles of Turkey Using Remote Sensing Techniques

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***Abstract*-We introduce the use of remote sensing analysis in providing new insight in characterizing green turtle nesting habitat. A maximum likelihood classification (MLC) and a multiple endmember spectral mixture analysis (MESMA) were conducted on a Landsat image that contained six nesting beaches in Turkey that represent varying degrees of importance. Both techniques highlighted similarities of the vegetative cover as a function of distance from the shoreline for beaches of similar importance. These similarities in percentage and change of vegetative cover allow for categorization of nesting beaches which may be applied to other nesting areas throughout the green turtle's range.**

Keywords-Cheloniamydas; classification; green turtle; Landsat 7 ETM+; remote sensing

I. INTRODUCTION

The future of green turtles, *Cheloniamydas*, is precarious. Despite intensive research efforts focused on individual nesting beaches, relatively little is known regarding the preferences turtles may have for some beaches over others. Sand grain studies have remained inconclusive at best, and the rising sea level may decimate entire populations at once. In order to successfully draft conservation implementation plans that will be the most effective in conserving the populations that remain, it is imperative to identify trends amongst the nesting beaches of the highest importance.

Characteristics of the entire nesting beach and of specific areas within a beach can affect species success. A balance between distance from the ocean and distance from vegetation appears to be the preference of *C. mydas*. Nesting above the high tide line is a commonality amongst sea turtle species, as nesting too close to the ocean would cause egg death by drowning [1]. However, nesting too far from the water adds additional threats; nesting efforts are energy-consuming and may result in adult female turtle death from heart attacks[2], and hatchling turtles face predators, mis-orientation from the water, and possible entanglement or entrapment in debris once leaving the nest[3].

Female green turtles prefer to nest among or near vegetation[1,2,4,5]. Nesting near vegetation allows the nests to benefit from the additional substrate moisture that would prevent egg desiccation, and the rootlets provide cohesion in the sandbank to prevent nest collapse, which could result in egg death[1]. However, there does appear to be a range in the amount of vegetation suitable for the nesting females. A study from Wan-An Island, Peng-Hu Archipelago, Taiwan found that green turtles preferred to nest in areas with 10-30% vegetation cover [5]. Areas with vegetation cover less than 10% lack appropriate root support, causing more nest chamber cave-ins, and areas with vegetation cover greater than 40% contain root systems that are too dense to allow the females to construct nests [5].

Extensive sand grain studies have only concluded that sand grain size may not be a factor in nest site selection for *C. mydas*[6]. Green turtles from Ascension Island, for example, nest in substrate whose texture varies from that of dust to that of gravel [7]. A study from Ascension Island showed that nest success is not correlated to organic, water, or calcium carbonate content, pH, color, or grain size distribution [8]. A study of sand grains from 34 nesting beaches worldwide found a wide range of sand characteristics [6].

Although all marine turtle species return to the general region of their natal beach, green turtles in particular show a high degree of natal beach fidelity [9,10]. This preference to return to the beach of their birth, in addition to geographic limitations, has shaped the matriarchal phylogeny of the species and has resulted in certain green turtle populations becoming genetically separate [11,12]. Female green turtles never nest in consecutive years [13], but rather breed every two or more years, laying approximately two to three clutches a season, with each clutch consisting of more than 100 eggs [14]. Occasionally female green turtles can stray from their natal beach, laying eggs in a new location, thus establishing a new breeding subset; however, this does not seem to be common [10].

Home to a genetically distinct population of green turtles [11]the Mediterranean Sea has become a focus of study by chelonian researchers. Within the Sea, the annual number of nesting females has been estimated to be 115-580 [15].The majority of nests are found on beaches in Turkey and on Cyprus, with two-thirds of nests located in Turkey [15]. Turkey's nesting beaches have been ranked as a 1st, 2nd, or 3rd degree of importance based on annual nesting values, with Akyatan and Kazanlı beaches both assigned to the 1st degree, comprising nearly 80% of all nest sites [16]. Although *C. mydas* surveys have been regularly conducted at many of Turkey's important nesting beaches [16], to date no published research has attempted to identify common features of these beaches, beyond their location in eastern Mediterranean [15].

Previous remote sensing studies focusing on marine turtle nesting beaches have noted that the geographic location of nesting beaches can change when located in a highly dynamic environment (e.g. prone to cyclonic activity or erosion [17]), and that some marine turtle populations can switch preferences to neighboring beaches if a preferred beach has been drastically altered [18]. However, neither of these studies investigated which characteristics make a nesting beach suitable to marine turtles.In this study, we test two methods of analyzing moderate spatial resolution imagery:maximum likelihood classification (MLC), and multiple endmember spectral mixture analysis (MESMA) to identify trends amongst the nesting beaches. Maximum Likelihood Classification (MLC) which uses an algorithm that uses Mahalanobis distance between pixel and classes to assign each pixel to the class in which it has the highest probability of belonging.In addition, MLC uses prior probabilities for each class. In this case we set these probabilities equal to one another which in essence classifies each pixel based primarily on Mahalnobisdistance[19,20]. MLC is often used for biological-based research and has been utilized to map habitat types [21-23]. The use of MESMAin wildlife research is still relatively novel.

A pixel within a satellite image covers a geographic area that varies by sensor. Regardless of the spatial resolution of the sensor, few pixels are entirely composed of one surface material; rather, two or more land-cover types generally comprise any given pixel. An assumption often made in remote sensing analysis is that the reflectance measured at each pixel is the average of the reflectance of each "pure" material present, weighted by the area each material covers [24,25]. As a result, measured reflectance is a mixture that may not represent any of the distinct land-cover types present. In a beach environment, for example, a 30-m Landsat pixel might be expected to contain a combination of water, wet sand, dry sand, and/or vegetation. Spectral mixture analysis (SMA) is a method that models each pixel as a linear combination of the "pure components" (i.e., endmembers) in the image (e.g., [24-26]. Endmember spectra can be selected directly from the image, or spectra can be collected in a laboratory or field setting.Generally, an endmember representing shade is included in each model to account for spectral variability of materials due to variations in illumination [27,28].The output of SMA is per-pixel assignment of the fractional contribution of each endmember to the measured spectrum.

Multiple endmember spectral mixture analysis (MESMA) is an extension of SMA that allows the number and type of endmembers to vary on a per-pixel basis [29].This reduces overall error by accounting for a wider range of spectral variation of materials present in the scene, as well as accounting for the spatial variability of materials on the ground [28]. In a beach environment, the reflectance of sand may vary as a function of wetness or parent material, and the reflectance of vegetation may vary as a function of species and/or soil moisture availability, among other factors.The distribution of these materials is not expected to be uniform across an image, and therefore, combinations of all appropriate endmembers are tested to model each pixel.The best-fit model is determined based on two principal criteria:(1) physically realistic endmember fractions (e.g., all fractions are non-negative, and fractions for each pixel sum to one), and (2) a measure of overall model fit.The latter is generally assessed based on root mean square error of the residuals (RMSE) (i.e., the difference between modeled and measured reflectance) across all wavelengths [24,28].

II. METHODS

A. Study Area

Six beaches located on the southern Turkish Mediterranean coast were chosen for the study, ranked by their relative importance. Beach importance degrees were determined by dividing the average number of nests per beach by the total number of nests for all surveyed nesting sites in Turkey, and then ranking the beaches by percentages. Beaches with higher percentages are assigned to higher degree of importance tiers. The study beaches were two 1st degree C. mydas nesting sites, Akyatan (54.4%) and Kazanlı (24.1%); one 2nd degree nesting site, Samandağ (13.0%); and three 3rd degree nesting sites: Tuzla (0.9%), Karataş (0.5%), and Agyatan (0.5%), as identified by earlier ranking [16]. All six study beaches are located within 140 km of each other (Figure 1), andAkyatan, Kazanlı, Tuzla, Karataş, and Agyatan are located within 75 km from one another. The beaches all contain some amount of vegetation cover.

B. Field Data

During the summer nesting season of 2007, the first author, Kristina Yamamoto, conducted fieldwork at Akyatan beach in conjunction with the WWF-Turkey turtle project directed by Dr. OguzTurkozan of the AdnanMenderesUniversity, and a team of field assistants. AkyatanBeach was mapped using a global positioning system, GPS, receiver and mobile geographic information systems, GIS, software. The high and low tide lines and the vegetated areas of the nesting area of Akyatan were all represented by polylines. Green turtle nests from the 2007 nesting season were mapped using the GPS receiver. The data collected from this nesting season aided in identifying locations of green turtle nests in relation to the vegetation and served as the basis accuracy assessment in this study.

Figure 1. Study Area

C. Landsat Data

One cloud-free Landsat ETM+ data scene acquired on 13 June 2000 (Path 175 Row 35) was used for this study. The scene covered all beaches of interest. No atmospheric correction was applied, as the surface radiance was not of interest for this study. As nesting by C. mydas is conducted in the summer in the area, the acquisition date of the image was appropriate for this study. An additional Normalized Difference Vegetation Index (NDVI) layer, which uses the near infrared (NIR) and the red bands to highlight vegetation, was generated to enhance the ability to effectively classify vegetated areas.

D. Maximum Likelihood Classifier

The image was classified using the maximum likelihood classifier (MLC) (Figure 2). The MLC is based on mean, variance/covariance and a Bayesian Probability function derived from the image. These statistics are used to assign each pixel to a class. MLC, a parametric classifier, assigns the pixel to the class to which it has the maximum likelihood of belonging. Four classes were chosen: water;pure sand, defined as beach area with no to very limited vegetation visible in the image; sand and vegetation, defined as sand with vegetation present; and heavy vegetation, used to distinguish areas of heavy forest and agricultural lands from more sparsely vegetated areas adjacent to the beach. Classes were assigned based on visual interpretation of the scene, spectral signatures, and knowledge of the area from previous fieldwork.

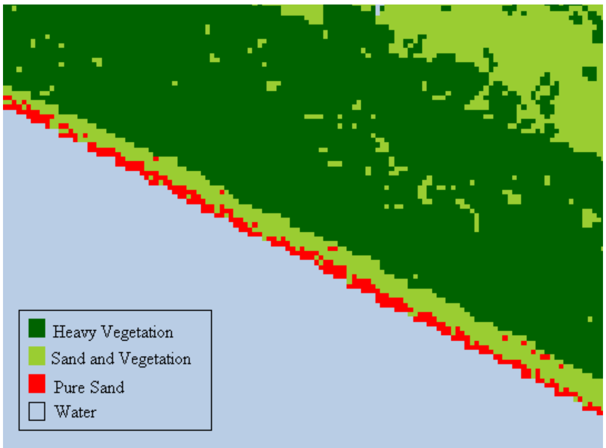

Figure 2. Subset of Classified Landsat Image showing Akyatan

After the supervised classification was applied, polygons that enclosed each of the beaches were converted to rasters, and map algebra was used to multiply the beach polygon raster by the image raster to obtain a count of the number of pixels per class per beach. The number of pure sand pixels was converted to area (m2) to represent the area of pure sand between the shoreline and the vegetation. The total length of each beach was also measured. The pure sand area was then divided by beach length to normalize the data based on beach length (Sand Area/Beach Length, referred to as SA/BL in the context of this study). Beaches were ordered according to their degree of nesting importance.

E. Accuracy Assessment of MLC

As the vegetation near the shore at Akyatan beach is sparse, we expected that not all the pixels that fell within the vegetation polygon delineated during field work would be classified as "sand and vegetation,"and it is possible that many of the pixels that fall along this border will be classified as pure sand, and many as sand and vegetation. Due to the nature of an MLC, each 900 m2 (30 m by 30 m) image pixel was assigned to one, and only one, class, and a pixel that contained a combination of two classes (i.e. a mixed pixel) could not be fully accommodated. An overlay of the vegetation polygon delineated during field work onto the classified image found that 48.5% of the pixels within the polygon were classified as pure sand, and 51.5% were classified as sand with vegetation.

A satellite image of the area from Google Earth was used as reference data to conduct an accuracy assessment of the classified image. Google Earth imagery has been successfully used to validate classified Landsat images [30]. Although Google Earth imagery does have limitations as a reference data set, we deemed it a useful source, due in part to its high spatial resolution. At least fifty randomly assigned points from each class were used as reference points for the accuracy assessment. Accuracy levels were high (Table 1). Both the producer's accuracy (error of omission), which indicates the probability that a sample of a class from the image was correctly mapped, and the user's accuracy (error of commission), which is the probability that a sample from the classified image matches the reference image, were above 80% for most classes. The temporal differences between the Landsat image and some Google Earth images accounts for some of the discrepancies, as a fertile producing field in the Landsat image may correspond to a fallow field in the Google Earth image. Urban areas account for the remainder of the differences, as "urban" was not a class used in the classification.

The kappa statistic [31], which is used to compare the classified map and the reference data [32], accounts for agreement and disagreement between the classified map and reference data simply due to chance. The closer the kappa statistic to one, the more likely the agreement is not due to chance, while the closer the kappa statistic to zero, the more likely the agreement is due solely to chance. Negative values reflect a poor classification [31]. The kappa statistic of 0.88 for this study is high enough to warrant acceptance of the overall classification (Table 2).

TABLE I. ACCURACY ASSESSMENT ERROR MATRIX.

	Reference Data					
Classified Data	**Sand and Vegetation**	**Pure Sand**	**Heavy Vegetation**	**Water**	**Total**	**User's Accuracy**
Sand and Vegetation	47	1	2	0	50	94.0%
Pure Sand	5	45	0	0	50	90.0%
Heavy Vegetation	11	0	41	0	52	78.9%
Water	0	0	0	55	55	100.0%
Total	63	46	43	55	207	
Producer's Accuracy	74.6%	97.8%	95.4%	100.0%		
						Overall Classification Accuracy = 90.8%

TABLE II. KAPPA STATISTIC.

Conditional Kappa for Each Category	
Class Name	**Kappa**
Sand	0.885
Sand and Vegetation	0.8467
Heavy Vegetation	0.733
Water	0.9751
Overall Kappa Statistics: 0.8583	

F. MESMA

The beaches in the study area are predominantly characterized by a combination of sand and vegetation.The per-pixel fractional composition of each material, in addition to shade, was modeled using MESMA, as implemented in the VIPER Tools add-in to ENVI image processing software [33]. Multiple image endmembers were selected for each material component by identifying extreme pixels—assumed to be most "pure"—in scatter plots of different image band combinations.The final endmember library consisted of 17 sand endmembers, 18 vegetation endmembers, and a single non-zero shade endmember.Allowed MESMA models included three endmembers; each model included the shade endmember, a sand endmember and a vegetation endmember.All possible permutations of a sand plus vegetation endmember were evaluated, resulting in 306 models that were applied to each pixel.

Candidate models were selected based on three constraints:(1) sand and vegetation fractions were constrained between -0.05 and 1.05; (2) the maximum shade fraction was not allowed to exceed 0.80; and (3) the root mean square error (RMSE) of the model was not allowed to exceed a value of 8 digital numbers (DNs), equivalent to 3% reflectance.The fraction constraints are those commonly accepted in the literature (e.g., [33]), and the RMSE constraint was empirically determined in the context of this study.If no model fit a pixel within these constraints, the pixel remained unmodeled.If multiple models fit a pixel, the best model was identified based on lowest RMSE - the assumed best-fit - as all models being compared had the same number of endmembers [28,34].Nearly 100% of all beach areas were modeled, with the exception of a few pixels in the Samandağ area that were excluded from the analysis as they fell outside the analysis area.Of the entire image, 46.6% of the pixels remained unmodeled; however, this percentage accounts for areas outside of study area—much of it open water—and was therefore not of concern for this analysis.

The goal of this study was to determine the abundance of material classes, and shade is not a land-cover component; therefore, the fractions of each optimal model were shade-normalized [26]so that the sum of the sand and the vegetation fractions for each pixel was 100%. For each beach, four transects parallel to the shore 35 m apart were created (Figure 3). A beach width of 140 m was chosen based on a previous study from Akyatan beachthat showed that 67% of all nesting occurred 30-60 m from the tide line, and that all but one of the nests were located within 140 m from the high tide line [4]. The tidal range for the Mediterranean is low (0.3-1 m) due to it being nearly landlocked from the ocean [35,36]. In addition, an overlay of the field-collected nest sites onto the Landsat image showed that 100% of the mapped nests were located within 100 m of the high tide line, with the majority being located inside the 70 m line.

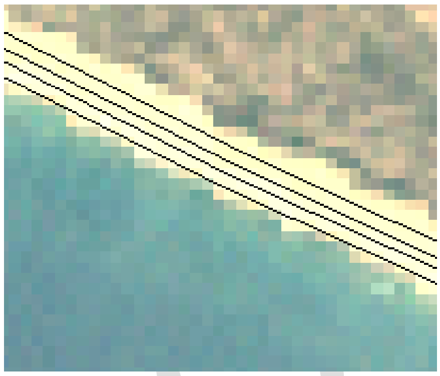

Figure 3. Subset of Classified Landsat Image showing Akyatan

Mean values for the sand fraction, vegetation fraction, and RMSE were calculated for each transect of each beach. The RMSE value is the measure of model fit, and no mean RMSE for any of the transects was higher than 3 DNs. The mean fraction values for each transect line by beach were plotted as a function of distance from water line to identify trends between the beaches of similar importance. Regression equations for the transects for each beach were calculated using the transect distance from the water line as the independent variable and the sand fraction as the dependent variable, in order to show the degree of change from sand to vegetation for each beach.

III. RESULTS AND DISCUSSION

MLC: The normalized values of Sand Area/Beach Lengthrepresent the distance a female green turtle must travel before reaching the vegetated area used for nesting. A beach with a large area of pure sand will have a higher SA/BL valuethan a beach of the same length but a small area of sand. Akyatan, Kazanlı, and Samandağ, which are beaches of the higher importance tiers, have intermediate SA/BL values (3.1-3.4 m2/m) (Table 3). C. mydas nesting beaches of lesser importance have SA/BL values that are at the extremes of the range. Agyatan and Tuzla, with SA/BL values of 9.5 and 5.1 mm2/m respectively, represent beaches with a greater distance for the females to travel to reach the vegetated area, which may lead to female exhaustion and failure to nest.Karataş, with its SA/BL value of 1.1 m2/m, represents a beach with a vegetated area much closer to the water than the others.

TABLE III. MAXIMUM LIKELIHOOD CLASSIFICATION RESULTS.

Tier	Beach Name	Number of Pure Sand Pixels	Area (m^2)	Length (m)	Sand Area/Beach Length (m^2/m)
1	Akyatan	578	52020	16804	3.1
1	Kazanli	161	14490	4366	3.3
2	Samandağ	156	14040	4161	3.4
3	Tuzla	986	88740	17505	5.1
3	Agyatan	1026	92340	9747	9.5
3	Karataş	34	3060	2796	1.1

MESMA: The fractions of vegetative cover and sand that compose the beach pixels generally show an overall trend: a gradual increase in vegetation as one moves inland. However, it is the amount of vegetative cover and the rate of change from sand to vegetative cover that differs among the beaches. Akyatan and Kazanlı, the two 1st degree nesting beaches, show similar results: vegetation cover ranges between 9.0% to 34.3% for the transects from 35–140 m from the water line (Table 4, Figure 4). These results are similar to those obtained by an earlier study which illustrated that the preferred nesting range for C. mydas beaches is 10 to 30% vegetation cover [5].

Samandağ, the sole 2nd degree beach recognized in the ranking [16]has vegetation cover ranges from 18.4% to 54.4% cover. These values are well beyond the published preferred 10 to 30% values [5], except for the transect at 35 m (18.4%).

Two of the 3rd degree beaches, Tuzla and Agyatancontain vegetation fractions (4.5% and 3.6%) that are far below the low range (10%). In fact, all of Agyatan'svegetation fractions beyond the water line are below 10% (3.6 to 8.8%). In contrast, three of the four transects of Tuzla have vegetation fractions for vegetation within the acceptable range (12.0-20.8%). It is possible, however, that the sharp drop in vegetation fractions from the 35 m transect (16.5%) to the 70 m transect (4.5%) makes the beach less preferable to nesting females.The remaining 3rd degree beach, Karataş, has sand fraction results similar to Samandağ. Karataş' vegetation fraction for the 35 m line (21.72%) is also within the acceptable 10 to 30% range, but vegetation fractions for the remaining inland transects are 39.3 and 53.0%.

TABLE IV. MESMA FRACTIONS AND RMSE.

Akyatan - 1st Degree			
Transect	Sand	Veg	RMSE
35	87.9%	12.1%	1.85
70	91.0%	9.0%	1.39
105	82.8%	17.2%	1.17
140	72.9%	27.1%	1.20

Kazanlı - 1st Degree			
Transect	Sand	Veg	RMSE
35	88.7%	11.3%	2.76
70	84.0%	16.0%	2.14
105	73.3%	26.7%	1.79
140	65.7%	34.3%	1.79

Samandağ - 2nd Degree			
Transect	Sand	Veg	RMSE
35	81.6%	18.4%	2.95
70	60.5%	39.5%	2.10
105	47.7%	52.3%	2.00
140	45.6%	54.4%	2.06

Tuzla - 3rd Degree			
Transect	Sand	Veg	RMSE
35	83.5%	16.5%	2.29
70	95.5%	4.5%	1.46
105	88.0%	12.0%	1.35
140	79.2%	20.8%	1.38

Karataş - 3rd Degree			
Transect	Sand	Veg	RMSE
35	78.3%	21.7%	1.99
70	60.8%	39.2%	2.24
105	56.6%	43.4%	2.43
140	47.0%	53.0%	2.16

Agyatan - 3rd Degree			
Transect	Sand	Veg	RMSE
35	91.2%	8.8%	1.81
70	96.2%	3.8%	1.46
105	96.4%	3.6%	1.37
140	95.5%	4.5%	1.24

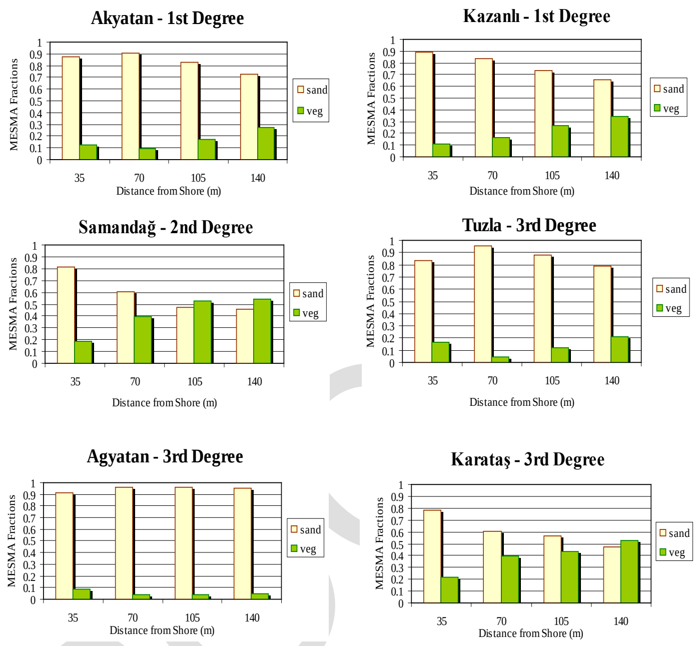

Figure 4. Graphs of MESMA fractions of sand and vegetation along transects for each beach

The regression equations derived from the MESMA show that both Akyatan and Kazanlı have an intermediate slope (0.053 and 0.080) and the lowest intercept values (0.031 and 0.021), compared to the other beaches of lesser nesting importance. Thus, the change from areas of high sand to areas of high vegetation beyond the water line occurs at an intermediate value, starting from areas with the lowest amount of vegetation.

Samandağ and Karataş have the highest slopes of the MESMA regression lines (0.121 and 0.098) and the highest intercepts (0.109 and 0.148) of the study area's beaches.Thus, the change from areas of high sand to high vegetation occurs at a faster rate than all the other beaches, and in this analysis, the portion of beach immediately beyond the water line has a relatively high vegetation fraction.

The regression slopes for Tuzla and Agyatan are the lowest (0.021 and -0.013), and their intercepts are in the intermediate range for the study set (0.083 and 0.085), so the gradient from areas of high sand to high vegetation for these beaches occurs at a much slower rate than the other beaches. The R2values of both regression equations are low (0.144 and 0.486) due to the decrease, and then increase, of vegetation as one moves inland.

Not all areas within the nesting beaches are used equally. As the majority of nests reported by Brown and Macdonald [4] were located in the 30-70 m area from the high tide line, special consideration should be given to this range. For the two 1st degree beaches, the vegetation fractions at the 35 m and 70 m transects were 9.0 and 12.1% for Akyatan, and 11.3 and 16.0% for Kazanlı, all of which are near or within the ideal 10 to 30% range, but just barely [5]. At the 2nd degree beach, Samandağ, the vegetation fractions for the same transects were 18.4 and 39.5%, on the upper end of the ideal 10-30% range [5]. For the three 3rd degree beaches, the vegetation cover at the 35 m and

70 m transects varied; for Tuzla, the values were 16.5 and 4.5%, for Agyatan, the values were 8.8 and 3.8%, and for Karataş, the values were 21.7 and 39.2%. The three 3rd degree beaches all contain at least one value for the 35-70 m transects from the shore that is either at least 5% lower or nearly 10% higher from the ideal 10 to 30% range [5].

TABLE V. MESMA FRACTIONS AND RMSE

Beach	Slope	Intercept	R^2
Akyatan	0.053	0.031	0.749
Kazanlı	0.080	0.021	0.982
Samandağ	0.121	0.109	0.889
Tuzla	0.021	0.083	0.144
Agyatan	-0.013	0.085	0.486
Karataş	0.098	0.148	0.935

The similarities between the two 1st degree beaches,Akyatan and Kazanlı are apparent. Both have intermediateSA/BL values, and both have vegetation cover fractions that coincide closely with the reported 10-30% preferred vegetation percentage [5]. In addition, the gradients from high sand fractions to high vegetation fractions are moderate for the study beaches. As Akyatan and Kazanlı host 78.5% of all C. mydas nests in Turkey [16], and are not located directly next to one another, it may be more than coincidence that their characteristics are so similar.

Likewise, as Samandağ does share some characteristics with the two 1st degree nesting beaches, it seems logical that it would also be relatively highly used by green turtles. Karataş also shares trends with Samandağ. Despite these similarities, however, it may be that Karataş' slightly higher vegetation fraction at the 35 m transect (21.7%) is beyond the threshold preferred by C. mydas in this region for the area closest to the shore. Additionally, throughout the summer months, which coincide with the turtle nesting period, Karataş is frequently used by beachgoers. Such traffic may either discourage nesting females altogether or damage eggs once laid, or previous generations may have been so adversely affected by humans that there is no longer a sufficient nesting population located at this beach.

The results indicate that both methods of analysis for remotely sensed images can highlight the similarities and differences between the beaches of different importance levels. Supervised classification provides more of a "cut-and-dry" description to determine the differences, whileMESMA provides a more nuanced view, focusing on gradients in relative composition of sand and vegetation as a function of distance from the water line. Both methods highlight similarities between the two 1st degree beaches. However, relying on MESMA alone fails to emphasize key similarities shared by the 1st and 2nd degree beaches, and sole reliance on MLC fails to highlight commonalities between Samandağ and Karataş. To use only one of the methods independently may not result in an accurate representation of the beaches.

The results from our study, however, do not imply causality. A beach outside of the study area that has qualities similar to Akyatan and Kazanlı may not be suitable as a nesting beach for the species, and we do not advocate moving green turtle nests to beaches that fit the pattern of the most important nesting beaches but are currently unused. This study focused on the ratio between sand and vegetation present on a beach and the distance from the shore to the vegetation. Other factors may be of equal, if not greater, importance to sea turtle nesting preferences. For example, offshore ocean floor morphology has not been intensely studied to date. In addition, as sea turtles return to nest at their natal beach [9, 10], a beach population that was completely or nearly completely decimated in the recent past will not appear to be using a beach of formally high importance. It is possible that Agyatan, for example, was the most important green turtle nesting beach in the Mediterranean in earlier generations, but due to unknown events, the nesting population has decreased to much lower levels today. Interviews with locals may shed additional insight to historic population trends.

The results show that Akyatan and Kazanlı, the most important nesting beaches to C. mydas, share similar biophysical characteristics. Beaches of lesser importance share some of these characteristics, such as supporting vegetation below the 140 m line from the shore, and almost all contain vegetation fractions that fall within the presumed optimum range [5]. However,beaches of lower degree of importance contain extreme values for several factors, such as vegetation fractions and amount of pure sand area. Based on our results, it is possible that additional beaches similar to Akyatan and Kazanlı that are currently used by C. mydas may have the potential, with additional protections in place, to support increased turtle populations.

IV. CONCLUSIONS

A main threat to endangered species is loss of habitat. The nesting beaches used by the green turtles in the Mediterranean Sea face numerous dangers, any of which could degrade the areas so heavily as to render them nearly useless. Identifying common characteristics between Akyatan, Kazanlı, Samandağ, Tuzla, Agyatan, and Karataş beaches could contribute to determining how best to conserve and preserve C. mydasnesting habitat.

It is predicted that a 0.5 m increase in sea level would cause a loss of 32% of sea turtle nesting beaches in the Caribbean, with lower, narrower beaches being most in peril [36]. Although similar models for the Mediterranean sea turtle population have not been published to date, it is likely that a rise in the sea level would have similar effects. Akyatan, Kazanlı, Tuzla, Karataş, and Agyatan are all located in a high-risk area of Turkey for inundation due to sea level rise of 1 m, and Samandağ is located in a medium to low risk area with a sea level rise of 1 to 3 m [38]. As sea level rise continues, the race to identify commonalities amongst nesting beaches for marine turtles becomes increasingly important. Previous attempts to pinpoint trademark attributes of beaches used by green turtles have proved inconclusive. This study offers insight to the intricacies of green turtle nesting sites as a much-needed addition to the current research, as well as provides the possibility of switchingthe focus on the micro-scale, such as individual sand grains, to a more global scale of analyses of beaches.

Beyond the Mediterranean green turtle population, sea turtle species globally are imperiled, and a greater understanding of sea turtle requirements for their nesting beaches is needed. All aspects of sea turtle biogeography should be explored, including examining beach biophysical characteristics using remotely sensed data. Many satellite images are free and available for public use, and the ability to compare large regions nearly simultaneously is a cost and time effective way to investigate habitat throughout a species' range.

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