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Modelling the spatial distribution of the striped dolphin (*Stenella coeruleoalba)* and common bottlenose dolphin *(Tursiops truncates)* in the Gulf of Taranto (Northern Ionian Sea, Central-eastern Mediterranean Sea)

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Abstract:

Introduction

The Marine Strategy Framework Directive (MSFD), the Maritime Spatial Planning Directive (MSPD) and the Common Fisheries Policy (CFP) are the main EU policies incorporating the ecosystem-based management (EBM) framework to human activities as a significant contribution to achieving the goals of the Biodiversity Strategy for the EU marine environments (European Environment Agency, 2015). The main issue for the EU policy is to embank the loss of biodiversity in a holistic pathway, maintaining marine habitats as a whole in a healthy, clean, productive and resilient condition. Such an approach will allow supporting habitats' functioning and, consequently, to benefit by the delivery of ecosystem services. In particular, the implementation of any management action aimed at marine biodiversity conservation, has to be founded on: 1) the knowledge of the spatial distribution of target species and extension of critical habitats as well as 2) their overlapping with human activities, pressure and impacts.

In fact, a key insight of ecosystem-based management is that human activities often affect the marine environment in complex ways. This is highly relevant in the Mediterranean Sea, the largest and deepest enclosed sea on earth, defined as a sort of ocean in miniature acting as a marine biodiversity hot spot hosting the 7% to the world's marine biodiversity (Coll et al., 2012). Mediterranean sea diversity has been severely altered by different anthropic pressures through time then resulting particularly vulnerable. Anthropogenic pressures include, for example, increasing use of the coastal areas, eutrophication, pollution and dumping, marine traffic, alien species, global warming and they are expected to increase in the future (CIESM, 1997; Bianchi and Morri, 2000; Myers et al., 2000; Coll et al., 2010 and 2012). The presence of different environmental and human drivers of change generates cumulative impacts at different spatial and temporal scales (Coll et al., 2012). This condition represents the main obstacle when striving to protect marine mammals. In Mediterranean coastal areasdolphins and whales, suffering habitats fragmentation and loss (Simmonds and Nunny, 2002) or the alterations in distribution and availability of resources (Learmonth et al., 2006; Gambaiani et al., 2009; MacLeod, 2009), could also be exposed to high levels of local anthropogenic impact, such as fishing, shipping collision, noise from military sonar or seismic surveys (Bearzi, 2002; Roussel, 2002; Hildebrand, 2005; Nowacek et al., 2007; Fossi and Lauriano, 2008; Dolman et al., 2010), chemical pollution including marine litter (Kannan et al., 2002; Fossi et al., 2003; Petterson et al., 2004; Aguillar and Borrel, 2005; Triantafillou, 2008). Up to date, the knowledge about the presence and the distribution of cetaceans in the Mediterranean Sea, as well as their conservation status, is still rather heterogeneous and defective. In particular large areas of the central-eastern regions are still scarcely or totally not surveyed (Notarbartolo di Sciara and Birkun, 2010). Concerning the Ionian Sea (Central-eastern Mediterranean Sea), the available information reported the presence of eight different species of cetaceans (Notarbartolo di Sciara et al., 1993; Reeves and Notarbartolo di Sciara, 2006; Notarbartolo di Sciara and Birkun, 2010). Specifically, more recent observations collected in the framework of a monitoring vessel survey confirmed that the striped dolphin *Stenella coeruleoalba* regularly inhabits the Northern Ionian Sea, together with the common bottlenose dolphin *Tursiops truncatus* (Dimatteo et al., 2011; Fanizza et al., 2014; Carlucci et al., *in press*). Despite the presence of adult, juveniles and calves of *S. coeruleoalba*, no conservation measures to ensure a favorable status and long-term survival of the species, are currently enforced in the area, mostly due to shortcomings in the basic scientific information (Fanizza et al., 2014). Conversely, both species could be exposed to high levels of anthropogenic threats such as strikes from merchant traffic, disturbance from high intensity military sonar and exposition to chemical pollution due to the presence of a commercial harbor (Taranto harbor) (Marsili and Focardi, 1997; Cardellicchio et al., 2000). In addition, recently seismic surveys were permitted in order to detect possible offshore gas/oil deposits in the Northern Ionian Sea. These activities were allowed without taking into account that the striped dolphin and common bottlenose dolphin were both assessed as vulnerable species with evidence of suspected decline in subpopulation within the ACCOBAMS regions (Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area) (Reeves and Notarbartolo di Sciara, 2006). Hence, the need for identifying the critical habitats for *S. coeruleoalba* and *T. truncatus* in the Northern Ionian Sea become even more urgent. The habitats characterization should be matched with the identification of the distribution of the main anthropogenic threats in order to better support potential alternative management strategies (Ahmadi-Nedushan et al.,2006; Halpern et al., 2008).

In the last thirty years, the advances in the regression analyzes provided by generalized linear models (GLMs) and generalized additive models (GAMs) allowed the development of ecological models increasing our understanding of ecological systems (Guisan et al., 2002). Lastly, Random Forest technique (Breiman et al.,1984), based on an automatic combination of decision trees was also applied in comparison with other regression techniques, resulting more reliable and accurate in predicting habitat uses (Qui serve PER FORZA un riferimento/citazione). In particular, recent developments in spatial modeling have allowed predicting the presence/absence or the abundance of a species by means of a set of predictor variables, highlighting the relative importance of habitats (Baumgartner, 1997; Moses and Finn, 1997; Tynan, 2004; Phillips et al., 2006; Redfern et al., 2006; Thorne et al., 2012). In particular, such approaches are increasingly becoming essential to identify critical habitats enhancing the protection of threatened species, mostly in coastal areas where the potential for conflicts is high (Edren et al., 2010; Best et al., 2012; Thorne et al., 2012).

In this study, the spatial pattern of *S. coeruleoalba* and *T. truncatus* in the Gulf of Taranto (Northern Ionian Sea, Central-eastern Mediterranean Sea) was modeled aiming at: 1) assessing the distribution of *S. coeruleoalba* and *T. truncatus* in the gulf of Taranto2) identifying the driving forces influencing the distribution of these top predators and, in turn, 3) suggesting suggestions and practices for their conservation and management. At these purposes, different predictive variables were considered. Physiographic features, reckoned as important for cetaceans' distribution both in the Atlantic oceans (Watts and Gaskin, 1986; Selzer and Payne, 1988; Gowans and Whitehead, 1995; Baumgartner, 1997; Bailey and Thompson, 2006) and more recently in the Mediterranean Sea (Azzellino et al., 2008; Blasi and Boitani, 2012, Marini et al., 2015), were taken into account together with the human activities existing in the basin, suggesting an innovative approach to habitat modeling. Thus, eight predictive indirect variables were identified for modeling the spatial distribution of both striped and common bottlenose dolphins in the Gulf of Taranto: depth, slope, distance from coast, canyon, areas of navy exercises, routes of merchant traffic, fishing areas, industrial activities. In particular, these predictive variables were employed to determine the presence/absence probability by means of generalized additive model (GAM) and Random Forest (RF).

Materials and methods

Study area

The Gulf of Taranto in the Northern Ionian Sea (Central Mediterranean Sea) stretches from Punta Alice to Punta Mèliso (Figure 1). In particular, the basin is the extension of a Southern-Apenninic orogenic system characterized by very complex bottom topography. In fact, the western sector is characterized by a narrow continental shelf with a steep slope and several channels, while the eastern showed terraces declining toward the "Taranto Valley", a NW-SE submarine canyon with no clear bathymetric connection to a major river system (Rossi and Gabbianelli, 1978; Pescatore and Senatore, 1986; Harris and Whiteway, 2011). This singular morphology involves a complex distribution of water masses with a mixing of surface and dense bottom waters (Sellschopp and Álvarez, 2003) and occurrence of upwelling currents with high seasonal variability (Bakun and Agostini, 2001; Milligan and Cattaneo, 2007).

The coastal area in the Gulf of Taranto is characterized by a high level of urbanization (Ladisa et al., 2010). In addition, the coastal zone nearby the harbor of Taranto is devoted to many different activities among which an intense commercial shipping throughout main defined commercial routes stands out (https://www.marinetraffic.com/it/) together with the presence of heavy industries (Ben Meftah et al., 2008). Different areas are employed to the execution of navy exercises such as naval, submarine and shooting ones. Their geographical coordinates and characteristics were gathered by consulting the decree provided by National Coast Guards and "Notice to Skippers" from 2009 to 2014 (http://www.guardiacostiera.gov.it/taranto/Pages/ordinanze.aspx).

An intense fishing activity is also recorded in the basin with trawlers, long-liners, gillnetters and purse seiners distributed in different fishing harbors along the coasts (Carlucci et al., in press).

Distribution of fishing activities

Different fishing activities are present in the basin since trawlers, long-liners, gillnetters and purse seiners are distributed in different fishing harbours along the coasts (Carlucci et al., in press). The data provided by the Vessel Monitoring System (VMS) were used, in this study, to assess the amount and the distribution of fishing effort for all the fishing vessels with length over all (LOA) larger than 12 m. The original VMS data were provided by by the Italian Ministry for Agricultural, Food and Forestry Policies (MAFFP) within the activities planned for the Data Collection Framework Program in Fisheries Sector (DCF) and were processed within the R-environment using the standard procedures provided by the VMSbase platform (Russo et al., 2014a). In summary, VMS data for each fishing vessel operating in the area were cleaned, interpolated (Russo et al., 2011a) and linked to external database (i.e. Logbook and the Community Fishing Fleet Register available at: http://ec.europa.eu/fisheries/fleet/index.cfm) to assess the fishing gear (Russo et al., 2011b). Then, after complete reconstruction and classification of the fishing activity for each vessel, the fishing set positions for each vessel/day of activity were finally inferred using speed and depth filters (Russo et al., 2014a). These fishing set positions were finally used to compute the spatial distribution of the fishing effort, for the different gears, on a XxX Km square grid, for each year of the temporal range 2006-2014. Given that VMS data for the current year (2015) were not already available, the expected distribution of the fishing effort for the year 2015 was estimated from the previous years. Namely, for each cell, one-year ahead forecasts of the effort have been obtained from the estimates of an ARMA model (see Box et al., 2015) fitted on the available observations. Estimates have been obtained using the R package “forecast” (Hyndman, 2015).

Investigated cetaceans species

Striped dolphin (Stenella coeruleoalba, Meyen, 1833)

The striped dolphin is a cosmopolitan species, preferentially inhabiting highly productive waters off the continental shelf (Perrin at al., 1994a; Notarbartolo di Sciara et al., 1993; Forcada et al., 1994; Frantzis et al., 2003; Gannier, 2005). In the Mediterranean Sea, *S. coeruleoalba* is distributed both inshore and offshore (Aguilar, 2000; Gaspari et al., 2007). The striped dolphin (*S. coeruleoalba)* is the most abundant cetacean species in the western Mediterranean with a decreasing W-E gradient in the abundance observed, probably reflecting the reducing in the productivity of the easternmost basins (Notarbartolo di Sciara and Birkun, 2010).

The Red List of the IUCN classifies Mediterranean striped dolphin Mediterranenan subpopulation as vulnerable since it is suspected a 30% reduction in population size occurred over the last three generations due to a decline in quality of habitat, affecting food availability, incidental mortality in fisheries and the effects of pathogens and pollutants (Aguilar and Gaspari, 2012; Notarbartolo di Sciara et al., 2007).

Bottlenose dolphin (Tursiops truncatus)

The bottlenose dolphin consists of two ecotypes, one coastal and the other pelagic with different morphological and ecological characteristics (Mead and Potter, 1995; Notarbartolo di Sciara and Demma, 2004; Reeves and Notarbartolo di Sciara, 2006). In the Mediterranean Sea, *T. truncatus* is preferentially distributed within the limits of the continental shelf, also inhabiting estuaries, bays and lagoons and generally show a residential attitude (Reynolds et al. 2000, Wells and Scott, 2002; Bearzi et al., 2008). However, the bottlenose dolphin can be also found in deeper waters above the shelf-break in the western Mediterranean (Forcada et al., 2004; Cañadas and Hammond, 2006). The bottlenose dolphin generally constitutes small groups, which tends to be wider passing from coastal to offshore waters (Bearzi et al., 1997; Cañadas and Hammond, 2006). The shallow water preference of the bottlenose dolphin could be related to the feeding habits of the species, preying mostly on benthic and demersal fishes. Due to these attitude *T. truncatus* is subjected to various anthropogenic threats and then it has been included in the IUCN red list of threatened species being listed among species under the "least concern" category and classified as Vulnerable in the last IUCN report on the Status of Cetaceans in the Mediterranean and Black Sea (Marini et al., 2015; Reeves and Notarbartolo di Sciara, 2006).

Data collection

Commentato [TR1]: E' il posto giusto per questo titolo?

Data employed for the development of the prediction models were collected in a specific sector of the Gulf of Taranto (hereinafter named "survey area", Figure 1) 640 km^2 wide. The survey area was selected both for the heterogeneity of forcing factors acting in this specific sector of the Gulf of Taranto and for logistics reasons since it is comprised between the harbors of Taranto and Policoro allowing daily trips of the area. Further sightings (validation dataset), beyond those collected in the survey area and collected in other, independent research campaigns, have been employed for the validation of the presence/absence prediction when projected on the whole study area.

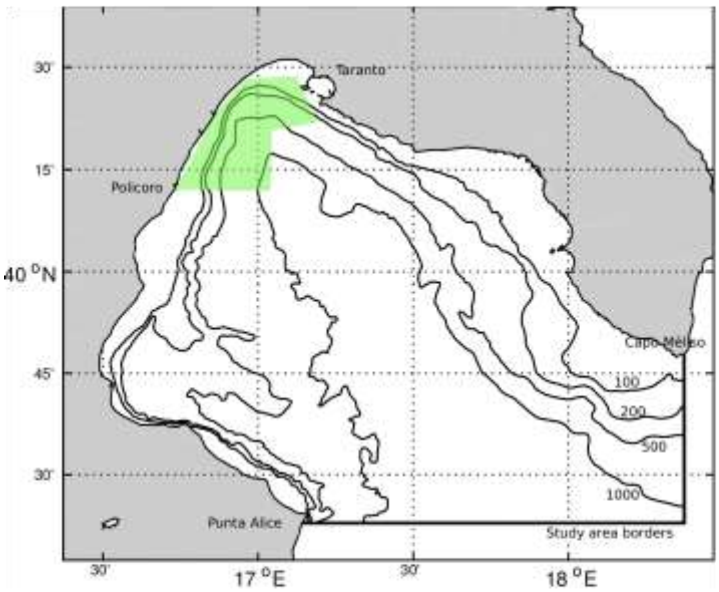

Figure 1 – Map of the study area located in the Gulf of Taranto (Northern Ionian Sea, Central Mediterranean Sea) with main isobaths. The survey area is marked in green.

Sightings of both *S. coeruleoalba* and *T. truncatus* were collected according to a standardized vessel-based survey carried out from 2009 to 2015. In particular, until 2012 surveys were carried out with a rib boat, replaced by means of a 12 m catamaran in the following years. The sampling effort was set to about 5 h/days along 35 nautical miles. Speed was maintained between 7 and 8 knots and trips occurred only in favorable weather conditions (Douglas scale ≤ 3 and Beaufort scale ≤4). Sightings data for both *S. coeruleoalba* and *T. truncatus* were collected following the line transect distance sampling according to the methodology proposed in Buckland et al. (2001). In particular, the random transect was adopted using the software Distance 6.0 (Thomas et al., 2010), with an equal coverage probability design in each sampling area. The observation team on board consisted at least of three people with specific experience in the recognition of marine mammals. One was an independent observer searching for targets around 180°, while the others searched in a sector from the track-line to 90°. Observer teams rotated each 90 minutes. Once a target was sighted, 7×50 binoculars were used to identify species and in the meanwhile during sightings, observers were recommended to adopt responsible behavior in order to prevent collisions and possible injuries to dolphins. Observers had to maintain a minimum safe distance of 5–10 m from dolphins lowering speed or interrupting navigation. In order to verify identification of the species, video-photo records were gathered. Documents were focused on body markers. Date, daytime, sea weather conditions, geographic coordinates, depth (m), group size, perpendicular distance (in NM) of the target to the track-line and behavior were recorded.

Data processing

The entire Gulf of Taranto area was divided into a regular grid composed by 109720 square cells (422 horizontal and 260 vertical cells)) of about 450 x 450 m. A dependent variable (response) is assigned to each cell identifying the cell as a presence cell if at least a sighting occurred (absence cell otherwise). Moreover, a set of 8 explanatory variables were calculated as reported in Table 1.

Table 1: Description of the explanatory variables applied for the determination of striped and bottlenose dolphins' distributions

Variable	Calculation method	Acronym
Depth	Depth values are derived from EMODnet Bathymetry dataset provided by the European Marine Observation and Data	Depth

	Network (http://www.emodnet.eu/bathymetry)	
Slope	Maximum rate of depth variation between adjacent cells	Slope
Distance from coast	Minimum distance of the cell center from the coastline	Coast
Distance from canyon	Minimum distance of the cell center from the main axes of the “Taranto Canyon” (Figure 2)	Canyon
Distance from navy exercise area	Minimum distance of the cell center from the areas of navy exercises (Figure 2)	Navy
Distance from the merchant shipping routes	Minimum distance of the cell center from the main merchant routes recorded towards the Taranto harbor (Figure 2)	Commercial
Distance from fisheries	Minimum distance of the cell center from the areas with recorded trawl fishing effort	Fishery
Distance from the industrial area	Minimum distance of the cell center from the areas identified as specifically addressed to heavy industrial activities (Figure 2)	Industry

Some of the adopted explanatory variables were already applied in many studies on the distribution of dolphins and whales (Bailey and Thompson, 2006; Torres et al. 2008; Marini et al., 2015; Panigada et al., 2008; Azzellino et al., 2008; Fiori et al., 2014). A few explanatory variables have been specifically introduced in this study due to the peculiarity of the area and the strong anthropic features of the Gulf of Taranto (i.e. navy, commercial, fishery and industry). These latter are here considered as proxies of impacts and disturbances that may have an influence on shaping the distribution of cetaceans. In particular, distance from the industrial area is intended as a proxy of the pollution effect on cetaceans' distribution, distance from the commercial routes and from areas of navy exercises are employed as measures of the effect of noise disturbance and, finally, distance from fisheries as a measure of the competition or synergies for the food resources.

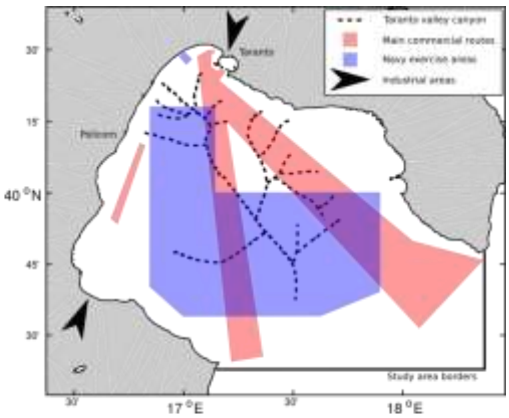

Figure 2 – Location of canyon main axes as identified by Senatore (1987) and anthropic variables identified in the study area.

Spatial analyzes

Usually, techniques applied for modeling the spatial distribution of dolphin and whales are based on the collection of presence-absence data. But, obtaining reliable and accurate absence data for cetaceans is problematic due to their mobility and ability to spend underwater time being undetectable to observers. Thus, although recurrent samplings may reduce this uncertainty, the separation of true from false absences is difficult and leads to uncertainty when interpreting results (Hall, 2000; Martin et al., 2005). In fact, the inclusion of false absences in predictive modeling could substantially bias analysis (Hirzel et al. 2002), indicating the need of the use of alternative approaches to modeling spatial distribution of species when there is no reliable absence data (zero inflated). Statistical adjustment to face this intrinsic uncertainty have been developed and, to this aim, in this study we applied a zero inflated correction recently proposed and applied in similar studies (Azzellino et al., 2012; Fiori et al., 2014; Marini et al., 2015). It consists in the selection of random sets of cells where the number of absence cells was equal to the number of presence cells. This approach is reported to satisfactorily cope with zero-inflated data avoiding the application of more sophisticated methods such as the hurdle-Negative Binomial and zero-inflated mixture-Negative Binomial models (Hall, 2000). In fact, the adopted procedure has the advantage to carry into the analysis a unique zero inflated correction that could be applied to both GAM and RF modeling, avoiding the introduction of further differentiations among methodologies.

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Generalized additive model

A statistical approach based on additive model (GAM) was applied to determine if the selected variables affect the distribution of *S. coeruleoalba* and *T. truncatus* in the study area. When data are related to certain variables but the relationships fall to be simply linear, additive modeling may be a useful tool to improve predictive accuracy. GAM relates the dependent variable to a combination of functions of explanatory variables. The coefficients of the combination are identified in order to generate the best fit (maximum likelihood) between the model outputs and the calibration data set (Hastie and Tibshirani, 1990). GAM technique was recently employed to model cetaceans distribution (Forney et al., 2012; Tardin et al., 2013) and in some cases also at Mediterranean level (i.e. Tepsich et al., 2014, Marini et al., 2015).

The dependent variable in this study was spatial distribution of the presence of striped and bottlenose dolphins in each cell Y_i (binominal variable, i.e. presence or absence) where 1 is the presence and 0 is the absence. As a consequence, the presence/absence of dolphins in each spatial cell (Y_i) follows a Bernoulli distribution with P_i (probability of presence/absence) and can be specified as:

$$Y_i = B\ (1, P_i)$$

where $P_i = P_i = e^{g(x_i)} / \left(1 - e^{g(x_i)}\right)$ being P_i comprised between 0 and 1 and where $g(x_i) = \alpha + f_j(x_j) + \ldots + f_n(x_n)$ is a combination of smoothing functions (splines) $f_j(x_j)$ of explanatory variables (smoothers). x_j are the explanatory variables, that in our case are: depth, slope and distance from coast, canyon, industry, fisheries, commercial routes and navy exercise areas. f_j are the best smoothing functions, that were estimated by maximum likelihood and that are a fit of data most representative than a straight line.

Generalized additive models (GAM) allow a data driven approach by fitting smoothed non-linear functions of explanatory variables without imposing parametric constraints (Hastie and

Tibshirani, 1990). The greatest benefit of using GAMs resides in their flexibility in capturing non-linear species-habitat relationships. In GAM, there is a link function used to establish a relationship between the mean of response variable and the smooth function of explanatory variable. As a consequence, the association between response and explanatory variables derives from data itself and not from the model, because it does not assume any kind of parametric assumption (Yee and Mitchel, 1991).

In this study GAM regression and smoother terms were derived using penalized regression splines using the MGCV library for freeware R (Wood, 2006) with a binomial distribution (family=binomial, link function=logit) of dependent variable (presence/absence of cetaceans in each spatial cell). Smoothness selection was based on an Un-Biased Risk Estimator (UBRE).

The numerical output of the model show significant variables, selected by means of a chi-squared test with a significance level for the selection of the explanatory variable fixed at 5%. Significant explanatory variables were selected by means of a Backward Elimination method that starts from a model of size p (being p the total number of variables) and eliminates not significant variables in a step by step procedure.When a variables is selected a significant non-linear relationship exists within this variable and the presence/absence of cetaceans.

Output presents also the degrees of freedom of a smoother, sometimes called effective number of parameters, is an indication of the amount of smoothing. The smoothers are calibrated so that a smoother with one degree of freedom gives an approximate straight line. The default value in R is for four degrees of freedom, which approximately coincides with the smoothing of a third-order polynomial (Zuur et al., 2007; Liu, 2008).

The model also gives information about the deviance, that is the explained variance or the residual sum of squares. This is equivalent to the R^2 in linear regression.

To help visual interpretation smoothing curves, graphically representing the relationship between the response variable and the explanatory variables, are shown: the y-axis show the influence predicted by GAM on presence/absence of cetaceans in function of each smoother, whose range of variability is displayed on the x-axis. The higher is the y value in the smoothing curve, the more it is probable the presence of cetaceans in the corresponding value of the explanatory variable considered.

Models' performances verification

Models performances were evaluated within the survey area for the verification of the model reliability. Performances were tested comparing predicted to observed values and reporting the true and false presences (a and b respectively in Table Tabella) and the true and false absences (c and d respectively in Table Tabella) at different cut-off values (Allouche et al., 2006).

Table 3: An error matrix used to evaluate the predictive accuracy of presence-absence models. a, number of cells for which presence was correctly predicted by the model; b, number of cells for which the species was not found but the model predicted presence; c, number of cells for which the species was found but the model predicted absence; d, number of cells for which absence was correctly predicted by the model.

		Observed	
		Presence	Absence
Predicted	Presence	a	b
	Absence	c	d

Values in **Errore. L'origine riferimento non è stata trovata.** allow the calculation of a set of model accuracy metrics among which sensitivity and specificity. Sensitivity is calculated as the ratio among true presences and total presences (a/(a+c)) and thus counting for the probability that the model will correctly classify a presence. Specificity is computed as the ratio among true absences and total absences (b/(b+d)) measuring the probability that the model will correctly classify an absence (Allouche et al., 2006).

Despite commonly adopted, sensitivity and specificity have been also reported as often dependent upon prevalence (the overall proportion of presences). Recently, the true skill statistic (TSS=sensitivity+specificity-1), a new measure for the performance of presence–absence distribution models, have been proposed and is expected to correct for this dependency (Allouche et al., 2006).

To select the optimal cut-off probability value, we applied the Youden Index method (Fluss et al., 2005) applied to the receiver operating characteristic (ROC) curve (Fielding and Bell, 1997). ROC curve is obtained plotting false-positive rate (1-specificity) on the horizontal axis and the true-positive rate (sensitivity) on the vertical axis for various cut-off values. The Youden Index method allows the determination of the optimal cut-off point using the maximum vertical distance of ROC curve from the chance line (where false positive rate = true positive rate). In fact, Youden index maximizes the difference between sensitivity and 1-specificity. Thus, by maximizing Sensitivity + Specificity across various cut-off points, the optimal cut-off point is calculated (Hajian-Tilaki, 2013). Once the optimal cutoff was identified, the model is projected to the entire study area, the suitable habitat areas are plotted and validated with an independent set of data collected outside the survey area borders (validation dataset).

Random forest

Random Forest (RF) is based on regression tree methodology, able to model a response variable from a number of explanatory variables by subdividing a dataset in subgroups. Subgroups originate from recursive partitions based on decision rules that allow dividing successively each part into smaller data portions.

This can be represented as a binary tree, a hierarchical structure formed by nodes and edges, the latter representing some sort of information flow between adjacent nodes (Figure 3).

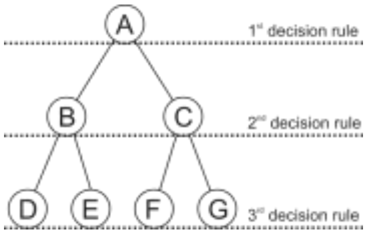

Figure 3: A complete binary tree with a set of three decision rules.

The random forests (RF) are a classification technique of neural networks (Breiman, 2001) based on regression tree methodology. It differs, as it does not only grow a single tree, but a whole forest of trees.

This is achieved by two means: (1) a random selection of explanatory variables is chosen to grow each tree and (2) each tree is based on a different random data subset, created by bootstrapping (Efron, 1979). Finally the “splitting” optimal in comparison with real data is identified and selected as predictor.

The data portion used as training subset is known as the “in-bag” data, whereas the rest is called the “out-of-bag” data. The latter are not used to build the tree, but provide estimates of generalization errors (Breiman, 2001). The mean square error calculated from prediction with the test dataset averaged over all trees is called the out-of-bag error. As forest size increases, this generalization error always converges (Breiman, 2001). The number of trees therefore needs to be set sufficiently high (800 in this case). In particular, RF implicitly deals with over fitting issue as decision trees are fitted to random samples of the data. In addition, RF performs splits in random subsets of the variable space, allowing to predict distribution on the whole dataset (Kehoe et al., 2012).

The rank importance of each explanatory variable is accounted as the changes in mean square error estimated by leaving a variable out of the model. After the most relevant variables were identified, the following step is consisted in studying the nature of the dependence between the response variable and each explanatory variable. Partial dependence plots were used to graphically characterize relationships between individual explanatory variables and predicted probabilities of presence obtained from RF (Hastie et al. 2001).

Results

A total of 334 daily trips for about 1670 hours of observations and 11690 nautical miles were carried out actively searching for *S. coeruleoalba* and *T. truncatus* in the Gulf of Taranto from 2009 to 2014. In particular, a total of 287 and 37 sightings of striped dolphin and bottlenose dolphin were recorded, respectively (Table 4).

Commentato [P2]: Da rivederere a seguito dell'introduzione dei dati 2015

Table 4: Sampling period, daily trips, survey effort, range of depth investigated and number of sightings of *T. truncatus* and *S. coeruleoalba* in the study area.

Sampling period	Daily trips	Survey Effort (NM)	Survey Effort (hours)	Range Depth (m)	Number of sightings	
					Stenella coeruleoalba	*Tursiops truncatus*
April-August 2009	13	455	65	93-500	11	1
April-August 2010	24	840	120	180-636	27	3

January-November 2011	61	2135	305	15-665	54	9
January-August 2012	50	1750	250	20-694	42	6
June-December 2013	73	2555	365	6-882	64	5
May-December 2014	113	3955	565	5-1000	89	13
Total	**334**	**11690**	**1670**	**5-1000**	**287**	**37**

Commentato [P3]: 2015

An information summary about sightings of striped dolphin and bottlenose dolphin is shown in Table 5.

Stenella coeruleoalba resulted the most frequently sighted species (88.6% of total sightings) with a frequency occurrence between 0.84 to 1.13 from 2009 to 2014. Observations occurred with a mean aggregation number of 47±39 specimens, in a depth range between 15 and 1000 m with a mean depth of 428±163 m. Encounter rate varied between 0.023 and 0.032

Tursiops truncatus presented a percentage occurrence of total sightings of 11.4% and frequency occurrence between 0.07 to 0.15 from 2009 to 2014. Observations occurred with a mean aggregation number of 12±10 specimens, in a depth range between 5 m to 586 m with a mean depth recorded 141±157 m. Encounter rate varied from 0.002 to 0.004.

Table 5

Commentato [P4]: Da rivedere considerando 2015

Table 5: Sampling period, encounter rate (sightings per survey effort in nm), frequency of occurrence (number of sightings per daily trip), mean aggregation number (number of individuals per sighting)

standard deviation) and range of depth of sightings of *S. coeruleoalba* and *T. truncatus,* in the study area.

	Stenella coeruleoalba				*Tursiops truncatus*			
Sampling period	Encounter rate	Frequency of occurence	Mean aggregation number	Range depth (m)	Encounter rate	Frequency of occurence	Mean aggregation number	Range depth (m)
April-August 2009	0.024	0.85	46±68	200-500	0.002	0.08	10	93
April-August 2010	0.032	1.13	49±91	200-636	0.004	0.13	11±1	180-419
January-November 2011	0.025	0.89	43±38	15-665	0.004	0.15	16±61	36-586
January-August 2012	0.024	0.84	46±68	22-694	0.003	0.12	21[illegible]	20-500
June-December 2013	0.025	0.88	62±28	117-882	0.002	0.07	6[illegible]	6-421

May-December 2014	0.023	0.79	38□87	144-1000	0.003	0.12	8□□	5-401

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GAM results

GAMs developed for *S. coeruleoalba* and *T. truncatus* reached respectively 34.7% and 23.4% of explained deviance. *S. coeruleoalba* distribution resulted mainly affected by depth, distance from navy exercise area and distance from industrial areas; lower influence but still significant is shown by distance from fisheries (Table 6). Slope, distance from coast, distance from canyon, distance from the merchant shipping routes were not significant variables and then are not considered. The habitat identified by the GAM was characterized by depth over 250 m; distances from fishery areas exceeding 32 km; distances from navy exercise area greater than 6 km and distance from industrial areas ranging from 5 to 25 km (Figure 4).

Table 6: GAM numerical results, reported statistics include the estimated degrees of freedom (edf) and significant values of test based on model deviance.

S. coeruleoalba					***T. truncatus***			
	Estimate	**Std. err.**	**p-val**			**Estimate**	**Std. err.**	**p-val**
(Intercept)	-2.130	0.1285	<0.001		**(Intercept)**	-2.213	0.399	<0.001
Approximate significance of smooth terms:								
	edf	**Chi.sq**	**p-val**			**edf**	**Chi.sq**	**p-val**
f(fishery)	0.621	2.735	0.033		**f(fishery)**	0.887	7.501	0.036
f(depth)	2.716	70.252	<0.001		**f(depth)**	0.705	2.926	0.004
f(navy)	1.169	68.747	<0.001		**f(industry)**	2.658	10.839	0.001
f(industry)	2.329	15.178	<0.001					

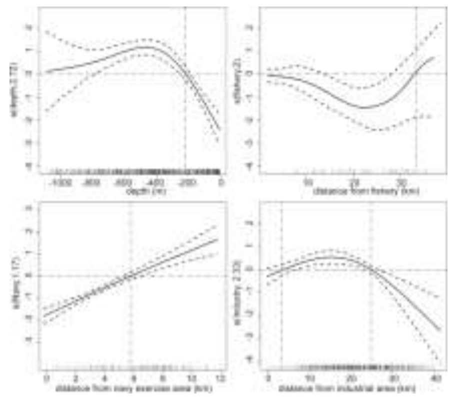

Figure 4: Generalized additive model (GAM) predicted smooth splines of the response variable presence/absence of striped dolphin as a function of the explanatory variables (see Table 6). The degrees of freedom for non-linear fits are in parentheses on the y-axis. Tick marks above the x-axis indicate the distribution of sightings. Dotted lines represent the 95% confidence intervals of the smooth spline functions.

T. truncatus distribution resulted mainly affected by distance from fishery, depth and distance from industry (Table 6). Slope, distance from coast, distance from canyon, distance from the merchant shipping routes, distance from navy exercise area were not significant variables and then are not considered. The GAM identified the *T. truncatus* habitat as characterized by depth lower than 300 m, distances from fishery areas lower than 10 km, and distance from industrial area ranging from 15 to 25 km with a second peak at distances higher than 40 km (Figure 5).

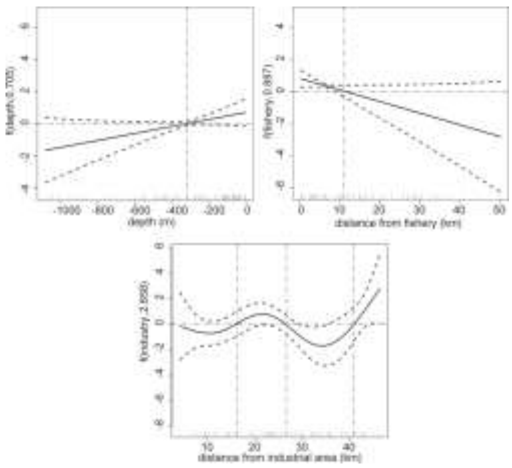

Figure 5: Generalized additive model (GAM) predicted smooth splines of the response variable presence/absence of bottlenose dolphin as a function of the explanatory variables (Table 6). The degrees of freedom for non-linear fits are in parentheses on the y-axis. Tick marks above the x-axis indicate the distribution of sightings. Dotted lines represent the 95% confidence intervals of the smooth spline functions.

RF results

Random forest identified the *S. coeruleoalba* distribution driven principally by depth, distance from industrial areas, distance from coast and distance from navy exercise areas (Figure 6A). On the contrary, slope and distance from fishery resulted poorly important for the determination of *S. coeruleoalba* distribution.

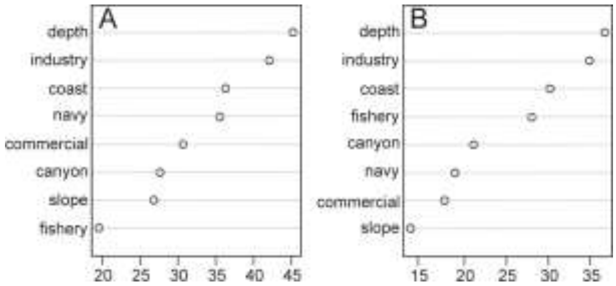

Figure 6: Importance scores of the explanatory variables used in the models (A) striped dolphin; (B) bottlenose dolphin. Importance is quantified as % increase in mean square error of the RF model when that explanatory variable is removed.

The univariate partial dependence plots are a tool to identify, for each considered variable, the range of optimal values expected to increase the presence probability (signature). The influence of depth values on the distribution of striped dolphin is shown in Figure 7A displaying an increasing presence probability at increasing depth reaching maximum values from 300 m depth. A threshold level is clearly detectable with very un-probable presence of striped dolphins at depth lower than 200m.

The second most important explicative variable influencing the striped dolphin distribution is distance from industrial zone (Figure 7B) displaying a single presence probability peak between 10 and 25 km from industrial zone and very low presence probability at distances higher than 28 km. Distance from coastline influenced the striped dolphin distribution with very low probabilities at distances lower than 5 km and a steep increase in probability toward 10 km where a plateau is reached and presence probability is maximized Figure 7C. Distance from navy exercise areas has again a relevant effect on striped dolphin distribution. In particular, a continuous increasing trend is detected with maximum presence probabilities detected at distances exceeding 18 km (Figure 7D).

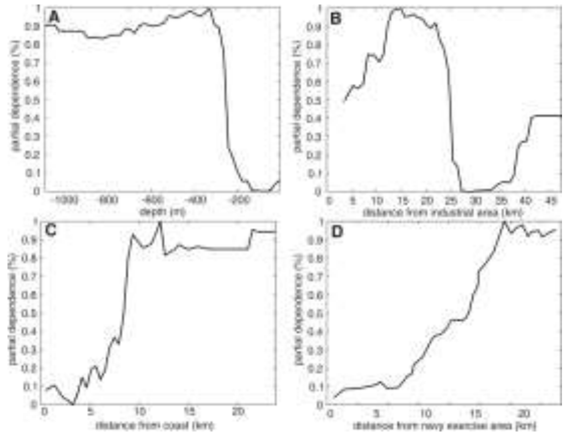

Figure 7: Univariate partial dependence plots of the depth (A), distance from the industrial area (B), distance from coast (C) and distance from navy exercise areas (D) for striped dolphin in the study area.

Also *T. truncatus* distribution is mainly shaped by depth followed by distance from industrial area, distance from coast and distance from fisheries. Once again slope resulted poorly important to discriminate the distribution also for *T. truncatus* (Figure 6B).

Depth resulted the most important explicative variable also for bottlenose dolphin and it revealed an increasing presence probability at depth lower than 300 m with the highest influence around the 100 m bathymetry (Figure 8A). Dependence from industrial areas revealed an increasing presence probability at increasing distance. Bottlenose dolphin revealed a trend with a clear threshold at 40 km and a sudden increase at higher distance (Figure 8B). Distance from coast has again a relevant effect on bottlenose dolphin distribution. Its influence displayed a clear presence probability increase at distance lower than 5 km (Figure 8C). Unlike striped dolphin, bottlenose dolphin resulted attracted by fisheries with a clear dependency from this variable and the tendency to stay in the close proximity to fishing areas. A threshold level is detectable with bottlenose dolphin, unlikely to be detected at distances higher than 5 km from fishery activity (Figure 8Figure 8D).

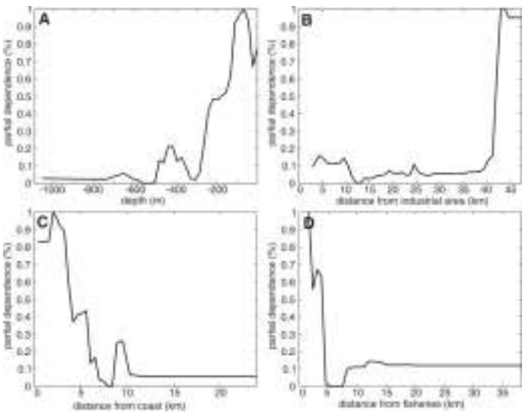

Figure 8: Univariate partial dependence plots of depth (A), distance from industrial areas (B), distance from coast (C) and distance from fishery area (D) for bottlenose dolphin in the study area.

Models' performances verification

Models' reliabilities have been tested within the survey area considering the ability of the predicted distribution to correctly identify the habitat of the considered species. The Youden Index method applied to ROC curves was applied to recognize habitat versus non-habitat areas. The optimal cut-off values and a set of predictive accuracy metrics are reported in Table 7 for each model and for each species.

Table 7: Measures of predictive accuracy calculated as reported in **Errore. L'origine riferimento non è stata trovata.**.

		Cut-off	Sensitivity	Specificity	TSS
GAM	**SC**	0.30	0.74	0.78	0.52
	TT	0.26	0.72	0.77	0.49
RF	**SC**	0.51	0.97	0.95	0.92
	TT	0.52	0.95	0.94	0.89

The most reliable model is expected to show the highest values of sensitivity, specificity and TSS thus being able to correctly identify both presences and absences of considered species. RF resulted the most reliable model for both striped and bottlenose dolphin.

The information provided by RF prediction together with the selection of the cut-off values allowed the projection of the expected presence/absence pattern of striped and bottlenose dolphins in the entire study area and produced the identification of habitat versus non habitat map reported in Figure 9.

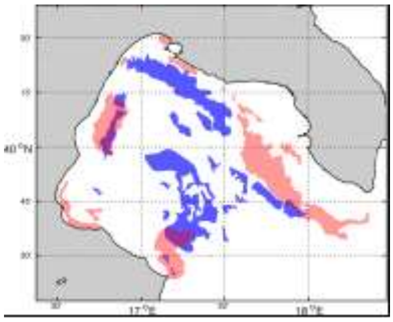

Figure 9: identification of habitat areas for striped dolphin (blue) and bottlenose dolphin (red).

RF predicted striped dolphin widely present in the central part of the Gulf of Taranto while bottlenose dolphin resulted mainly distributed along the coast with clear coastal hot spots in the western sector and favorable areas moved slightly offshore in the eastern sector, probably allowed by the wider platform present in this sector of the Gulf of Taranto. A clear separation of the habitat is showed with a couple of exception in front of the Policoro harbor and in the south-western sector.

The reliability of the projection on the entire study area has been tested considering the distribution of sightings collected as validation dataset and resulting in true presence rates of 0.73 and 0.77 for striped dolphin and bottlenose dolphin respectively.

Discussion

This study aimed at developing a reliable habitat modeling procedure suite for the characterization of striped and bottlenose dolphin distribution in the Gulf of Taranto. By means of the application of two different models (GAM and RF) three main results were obtained: 1) to identify most relevant explanatory variables among a set initially chosen 2) to test the reliability of different regression techniques, and 3) to identify areas to be considered as suitable habitat for dolphins in the Gulf.

Table 7

Human activities, and in turn impacts originating from them, are able to influence the cetaceans distribution both directly and indirectly. Among the eight considered variables some are able to directly influence the distribution (e.g. commercial routes with collision risk) or indirectly by acting upon other biotic (e.g. fishery activity with competition for feed resources) or abiotic factors (e.g. navy exercise, commercial routes and industrial zone generating noise and pollution).

Nonetheless variables employed, depth, distance from industry and distance from coast, turned out to significantly affect the distribution of both striped dolphin and bottlenose dolphin. On the contrary slope, which is commonly applied in other studies on cetaceans' distribution (Cañadas et al., 2002; Cañadas et al., 2005; Pirotta et al., 2011; Azzellino et al., 2012) never brought significant improvement to predicted distribution together with the distance from commercial routes.

For both species, two out of four among the most important variables identified during the analysis resulted dependent on human presence and activities. This finding highlighted how heavily human activities act as driving forces in shaping the habitat of marine species outclassing natural, geomorphological parameters that would normally shape the habitat of an undisturbed species.

Among anthropic variables, distance from industrial zones resulted the most important for the determination of the distribution of the considered species. Both species never showed the peak of probability values close to the industrial areas confirming the existence of these activity as disturbing the distribution of both striped and bottlenose dolphin.

Bottlenose dolphin distribution is also significantly affected by the distance from fishery activities, while striped dolphin resulted unaffected by this variable. In particular, bottlenose dolphin presence resulted particularly probable closer to fishery activity with a sudden increase in presence probability for distances lower than 5 km. This is in accord with what expected since only bottlenose dolphin have been reported as possibly attracted by fishery due to the ability of this species to prey on fish nets (Fertl and Leatherwood 1997; Corkeron et al. 1990; Pace et al. 2003; Chilvers and Corkeron 2001; Wells and Scott 2009; Lauriano et al. 2004; Diaz Lopez 2006; Brotons et al. 2008).

On the other hand striped dolphin showed a significant dependency on the distance from navy exercise areas displaying the tendency to be more present at increasing distance and thus to move away from this possible disturbance.

Depth and distance from coast resulted the only geomorphologic variables significantly affecting the distribution of both species. In the study area striped dolphin distribution is predicted mainly at depth higher than 350 m and distance from coast greater than 10 km while bottlenose dolphin distribution resulted concentrated near the 100 m isobath and rarely at depth higher than 200 m coupled with distances from coast unlikely to be greater than 5 km. This is in accord with other studies on *S. coeruleoalba* and *T. truncatus* habitat distribution in Mediterranean such as Cañadas et al. (2002) and Azzellino et al. (2012), who demonstrated that *T. truncatus* prefer coastal areas within 400 m while *S. coeruleoalba* presence probability is expected to increase around 1600-2000 m of depth and thus beyond the continental shelf.

Regarding the applied modeling techniques, RF displayed better ability to cope with the observed distribution of both striped dolphin and bottlenose dolphin (Table 7) confirming findings of other researches (Cutler et al., 2007; Virkkala et al., 2010). RF is based on multiple individual classification and regression trees: this technique has already been used successfully for environmental mapping and management (Pesch et al., 2011; Parravicini et al., 2012) and for characterizing bottlenose distribution (Marini et al., 2015) also because it is particularly appropriate in identifying and modeling complex interactions among multiple variables (Loh, 2008).

Conclusion

To do

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