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Cover images: *Catanthera keris* Veldk. (1. Inflorescences; 2. Close up flower; 3. Flower bud), *Medinilla squillula* Veldk. (4. Habit; 5. Branches; 6. Fascicle of uniflorous Infructescences), *Medinilla uninervis* Veldk. (7. Habit. Note 1-nerved leaves; 8. infructescence; 9. Immature and mature fruits), *Medinilla zoster* Veldk. (10. Habit; 11. Inflorescences; 12. Flower). Photo credits: Bangun 223, Lowry & Phillipson 7287, Mahroji, Fabanyo & Soleman 69, Callmander, *et al*. 1067.

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PREDICTING HABITAT DISTRIBUTION OF ENDEMIC AND CRITICALLY ENDANGERED *DIPTEROCARPUS LITTORALIS* IN NUSAKAMBANGAN, INDONESIA

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ABSTRACT
ROBIANSYAH, I. 2017. Predicting habitat distribution of endemic and critically endangered *Dipterocarpus littoralis* in Nusakambangan, Indonesia. *Reinwardtia* 16(1): 11 – 18. —The tree species *Dipterocarpus littoralis* (Blume) Kurz. is endemic to Nusakambangan and categorized as critically endangered. In the present study, the habitat suitability of the species in Nusakambangan was predicted using logistic regression analysis and Maxent model. Three topographic variables (elevation, slope, and aspect), distance from river and coastline, and one vegetation index (Normalized Difference Vegetation Index (NDVI)) as well as two water content indexes (Normalized Difference Water Index (NDWI) and Normalized Difference Moisture Index (NDMI)) were used as predictors of the models. Employing initial number of 82 presence and 250 absence data of *D. littoralis*, both models were able to predict the suitable areas for the species with fairly high success rate. The AUC and Kappa value for logistic regression were 0.77 ± 0.027 and 0.34 ± 0.058, respectively, while the respected values for Maxent were 0.91 ± 0.062 and 0.37 ± 0.025. Logistic regression analysis identified a total area of 26.13 km^2 to be suitable for *D. littoralis,* while a smaller suitable area (7.85 km^2) was predicted by Maxent model. Coastal areas in the west part of the island were predicted by both models as areas with high suitability for *D. littoralis*. Furthermore, distance from coastline and river, elevation, NDVI, NDWI and NDMI were suggested to be very important for the species ecology and distribution. The results of this study may serve as a basis for population reinforcement and reintroduction programs of *D. littoralis* and guide for ecosystem management of Nusakambangan Island as a whole.

Key words: Critically endangered, *Dipterocarpus littoralis*, endemic species, logistic regression, Maxent, Nusakambangan.

ABSTRAK
ROBIANSYAH, I. 2017. Prediksi distribusi habitat jenis endemik dan genting *Dipterocarpus littoralis* di Nusakambangan, Indonesia. *Reinwardtia* 16(1): 11 – 18. — *Dipterocarpus littoralis* (Blume) Kurz. adalah jenis endemik Nusakambangan dan termasuk ke dalam kategori genting. Pada penelitian ini kesesuaian habitat dari tumbuhan ini diprediksi menggunakan analisis regresi logistik dan model Maxent. Tiga variabel topografi (ketinggian, kelerengan dan arah lereng), jarak terhadap pantai dan sungai, serta satu index vegetasi Normalized Difference Vegetation Index (NDVI)) dan dua index kandungan air (Normalized Difference Water Index (NDWI) dan Normalized Difference Moisture Index (NDMI)) digunakan sebagai penduga untuk kedua model. Dengan menggunakan data awal berupa 82 titik keberadaan dan 250 titik ketidakhadiran jenis, kedua model ini dapat memprediksi kesesuaian habitat *D. littoralis* dengan tingkat kesuksesan yang cukup tinggi. Nilai AUC dan Kappa dari model regresi logistik secara berurutan adalah 0.77 ± 0.027 dan 0.34 ± 0.058, sedangkan bagi Maxent adalah 0.91 ± 0.062 dan 0.37 ± 0.025. Analisis regresi logistik memperkirakan total area yang sesuai bagi jenis ini adalah 26.13 km^2 sedangkan model Maxent hanya seluas 7.85 km^2. Kedua model ini memperlihatkan bahwa zona pesisir di daerah sebelah barat Nusakambangan adalah area dengan kesesuaian habitat yang sangat tinggi bagi *D. littoralis*. Selain itu, kedua model berhasil mengidentifikasi faktor lingkungan yang berpengaruh bagi ekologi dan persebaran spesies ini, yaitu jarak terhadap pantai dan sungai, ketinggian, NDVI, NDWI dan NDMI. Hasil dari penelitian ini dapat dijadikan dasar bagi program penguatan populasi alami dan reintroduksi *D. littoralis* dan sebagai panduan bagi pengelolaan ekosistem kawasan Nusakambangan secara keseluruhan.

Kata kunci: *Dipterocarpus littoralis*, genting, jenis endemik, Maxent, Nusakambangan, regresi logistik.

INTRODUCTION

Small islands have very important role in the conservation of global plant biodiversity. Although they share only 5% of land surface of the earth, about one quarter of all known vascular plant species are endemic to islands (Kreft *et al*., 2008). As elsewhere, plant diversity of islands is under increasing pressure from habitat loss and conversion, population increase, introduction of invasive alien species, unsustainable use of native species, and climate change. Due to small geographic area, however, plant species in small islands are more sensitive to rapid environmental changes compared to other ecosystems. This eminent sensitivity of island plants is reflected in the high number of the island endemic extinction in the last 400 years (Sax & Gaines, 2008).

The tree species *Dipterocarpus littoralis* (Blume) Kurz. is endemic to Nusakambangan, a small island located in Central Java, Indonesia. According to IUCN Red List 2015, the tree is categorized as

Critically Endangered (Ashton, 1998). It is also included on a national list of priority species for conservation action in Indonesia 2008-2018. The major threats for the species are illegal cutting and the expansion in distribution of the Langkap tree (*Arenga obtusifolia* Mart.) (Robiansyah & Davy, 2015). To conserve and protect the species from extinction, several conservation measures have been implemented by government, local communities, non government organization and/or university. These include information dissemination and public awareness program (USD, 2016), ecology and population status assessment (Robiansyah & Davy, 2015), population genetic research (Dwiyanti *et al*., 2014, Yulita & Partomihardjo, 2011), as well as propagation and reintroduction of *D. littoralis* (Holcim, 2013).

To be successful, population reinforcement and reintroduction programs need to take into account habitat suitability of the target species. In case of *D. littoralis*, there is no detailed study assessing and describing suitable areas of the species in Nusakambangan. Previous modeling study assessing habitat suitability of *D. litoralis* by Primajati (2015) was incomplete and only covered the area of West Nusakambangan Nature Reserve. Thus the present study aims to assess habitat distribution of *D. littoralis* in entire Nusakambangan Island. Using high resolution environmental variables and both presence-only and presence-absence modeling methods, the objectives of the present study are to: i) compare the ability of the two modeling methods in predicting habitat suitability of the species, ii) assess and describe suitable habitat areas of *D. littoralis* in Nusakambangan, and iii) identify environmental variables influencing the species distribution. The results of this study may serve as a basis for conservation programs of *D. littoralis* and the ecosystem management of Nusakambangan as a whole.

MATERIALS AND METHODS

Study site and occurrence data

Nusakambangan is located in Indian Ocean, separated by a narrow strait off the southern coast of Central Java Province, Indonesia. It has an area of 210 km^2 and the highest point at about 190 m above sea level. The climate is B type or Afa according to Koppen classification system. The ecosystem is generally classified as lowland rainforest, and provides habitats for several rare and endemic plant species, such as *Rafflesia patma* Blume, *Lithocarpus platycarpus* (Blume) Rehder, *Gonystylus macrophyllus* (Miq.) Airy Shaw, *Anisoptera costata* Korth., *Shorea javanica* Koord. & Valeton, *Hopea sangal* Korth., and *Amorphophallus decus-silvae* Backer & Alderw. as well as *Dipterocarpus littoralis* (Blume) Kurz (Partomihardjo *et al*., 2014).

The endemic *D. littoralis* is a monoecious, emergent tree that grows up to 30 m tall. The wood is of good quality and is illegally harvested by local people for boat construction, timber, and firewood. In the present study, a total of 52 presence and 150 absence data of *D. littoralis* were obtained from the study conducted in West Nusakambangan Nature Reserve (WNNR) by Robiansyah and Davy (2015). The absence points were obtained by identifying all seemingly suitable habitats where the species was absent. In addition, 30 presence-only data were gathered from WNNR database and a total of 100 independent absence points were created randomly outside WNNR using ArcMap 10.1. Therefore, the present study initially used a total of 82 presence and 250 absence points for further modeling analysis.

Environmental variables selection

Elevation, slope and aspect were suggested to be very important for the ecology of *D. littoralis* (Robiansyah & Davy, 2015) and thus were selected as main predictors. Elevation data was obtained from Aster Global Digital Elevation Model V002 (http://earthexplorer.usgs.gov/) from which slope and aspect were derived using surface analysis extension in ArcMap10.1. Distance from river networks and coastline were also used as predictors to see the effect of these two geographical features on the species distribution. In addition, one vegetation index (Normalized Difference Vegetation Index) and two water content indexes (Normalized Difference Water Index and Normalized Difference Moisture Index) were used as a proxy of vegetation greenness and soil moisture, respectively. All these indexes were derived from Landsat 8 OLI/TIRS satellite image acquired in 6 May 2016 (http://earthexplorer.usgs.gov/) using the following formula (Sahu, 2014):

$$\text{Normalized Difference Vegetation Index (NDVI)} = \frac{(\text{Band 5 - Band 4})}{(\text{Band 5 + Band 4})}$$

$$\text{Normalized Difference Water Index (NDWI)} = \frac{(\text{Band 3 - Band 5})}{(\text{Band 3 + Band 5})}$$

$$\text{Normalized Difference Moisture Index (NDMI)} = \frac{(\text{Band 5 - Band 6})}{(\text{Band 5 + Band 6})}$$

All the environmental layers used in the models had 30 m resolution. These layers were clipped to Nusakambangan boundary to be used in the modeling procedures.

Modeling procedures

Binary logistic regression and Maxent method were used to predict habitat suitability of *D. littoralis* using presence-absence and presence-only data, respectively. In binary logistic regression, all environmental variables intersected with 82 presence and 250 absence points were extracted using ArcMap 10.1. The results were than analyzed using PASW Statistic 18 (SPSS Inc., 2009, www.spss.com) with aspect being converted into categorical variable to simplify the explanation of the results. Relative importance of each variable was estimated based on the absolute value of its standardized beta coefficient (Menard, 2011).

For presence-only data, Maxent has been shown to perform better than other models (Elith *et al*., 2006) and has the best predictive power even with very low sample size (Wisz *et al*., 2008). It predicts the geographical distribution of a species using maximum entropy theory. In the present study, the Maxent software was set to the "auto feature", logistic output format and ASCII output file type following the suggestion of Phillips and Dudík (2008). As Maxent automatically removes the duplicate records in the same cell, only 78 presence records were used in the modeling. Initially, a model was produced using Maxent that included all 8 environmental variables. Based on jackknife analysis provided by Maxent, variables contributing < 3% to the full model were excluded from the final model. To minimize the level of uncertainty and increase model accuracy, 10-fold cross-validation technique was used in which the final model was run 10 replicates and the results were then averaged. Furthermore, maximum training sensitivity plus specificity (MTSS) logistic threshold was used to convert the continuous suitability index into suitable and unsuitable areas of *D. littoralis*. This MTSS threshold is the best method for threshold selection when only presence data are available (Liu *et al*., 2013). The same threshold was also applied for the suitable areas distribution map resulted by logistic regression.

The performance of both models was evaluated using the area under the curve (AUC) of the receiver operating characteristic and Kappa value. AUC has been shown to be a highly effective threshold-independent measure of model performance (Thuiller *et al*., 2005) and its value varies from 0 (random prediction) to 1 (perfect prediction). For Kappa value, it is a robust statistic useful for model reliability testing, and its results can be range from -1 to +1 (McHugh, 2012).

RESULTS

Model performance

The AUC and Kappa value for logistic regression were 0.77 ± 0.027 and 0.34 ± 0.058, respectively, while the respected values for Maxent were 0.91 ± 0.062 and 0.37 ± 0.025. These values indicated the fairly high success rate of both models in predicting potential distribution of *D. littoralis*. Araújo *et al*. (2005) suggested the following standard for judging model performance based on AUC value: excellent (AUC>0.9), good (0.9>AUC>0.8), fair (0.8>AUC>0.7), poor (0.7>AUC>0.6), and failed (0.6>AUC>0.5). For Kappa statistic, its values can be interpreted as follows: values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement (McHugh, 2012).

Contribution of environmental variables

Logistic regression analysis identified four environmental variables being significantly influential (χ^2=46.45, df= 4, P<0.000) for *D. littoralis* distribution (Table 1). These factors include NDWI, NDMI, distance from coastline and elevation. The first factor had the highest influence to the model as indicated by its high absolute standardized beta value. In addition to these four factors, Maxent predicted that distance from river networks and NDVI were also important for the species (Table 2). The model also revealed that distance from coastline was the main determinant factor of *D. littoralis* distribution in Nusa-

Table 1. Environmental variables significantly contribute to the presence of *Dipterocarpus littoralis* in Nusakambangan based on logistic regression analysis.

Variable	Absolute standardized beta	*P*
Normalized Difference Water Index	0.31	0.000
Normalized Difference Moisture Index	0.17	0.027
Distance from coastline	0.10	0.017
Elevation	0.09	0.000

Table 2. Relative contribution (%) of the environmental variables to the Maxent model of *Dipterocarpus littoralis*

Variable	Percent contribution
Distance from coastline	36.4
Elevation	21.8
Normalized Difference Vegetation Index	17
Distance from river networks	16.4
Normalized Difference Moisture Index	8.4

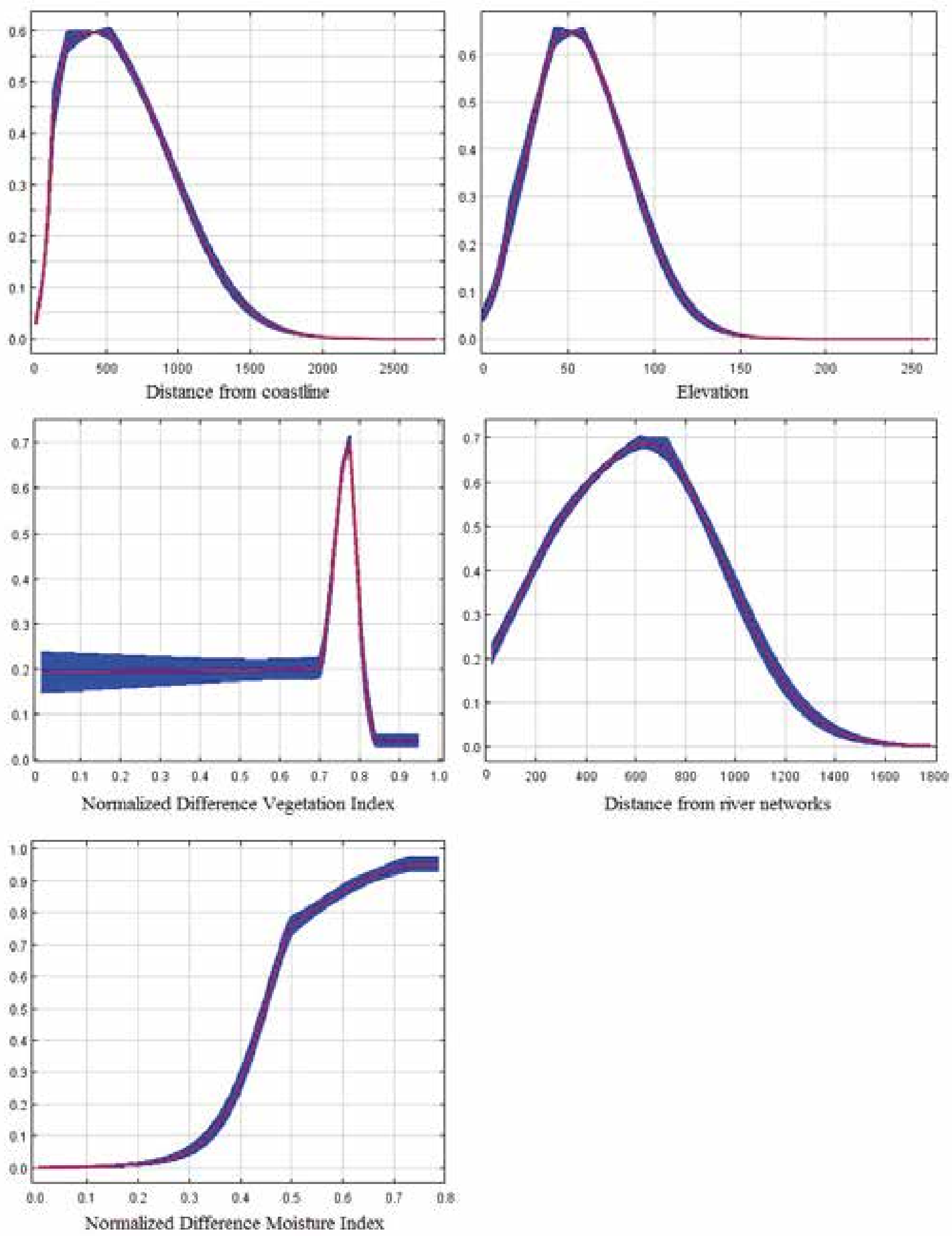

Fig. 1. Response curves showing the relationship between the probability of presence of *Dipterocarpus littoralis* and the significant environmental variables. Values shown are average over 10 replicate runs; blue margins show ±1 SD calculated over 10 replicates.

kambangan with more than 36% contribution to the model. Response curves of environmental variables produced by Maxent model (Fig. 1) showed the specific environmental preferences of *D. littoralis*. The species had high probability of being presence at areas with distance of 200-750 m from coastline and 300-900 m from rivers, elevation of 30-75 m above sea level, NDVI of 0.75-0.79 and NDMI above 0.45.

Habitat distribution of *D. littoralis*

A total area of 26.13 km^2 was predicted by logistic regression analysis to be suitable for *D. littoralis* . These areas were distributed mainly in the west and north part of the island (Fig. 2). A smaller suitable area (7.85 km^2) was predicted by Maxent model and found mainly in West Nusakambangan coastal areas. Furthermore, as it was agreed by both logistic and Maxent, the intersection areas of both models were predicted to have very high suitability for the species. These areas had an area of 3.82 km^2 and were located mainly in the west part of the island.

DISCUSSION

Using logistic regression and Maxent model, the present study was able to predict the distribution of suitable areas for *D. littorralis* with high success rate. The Maxent model, however, outperformed the logistic regression method as showed by its

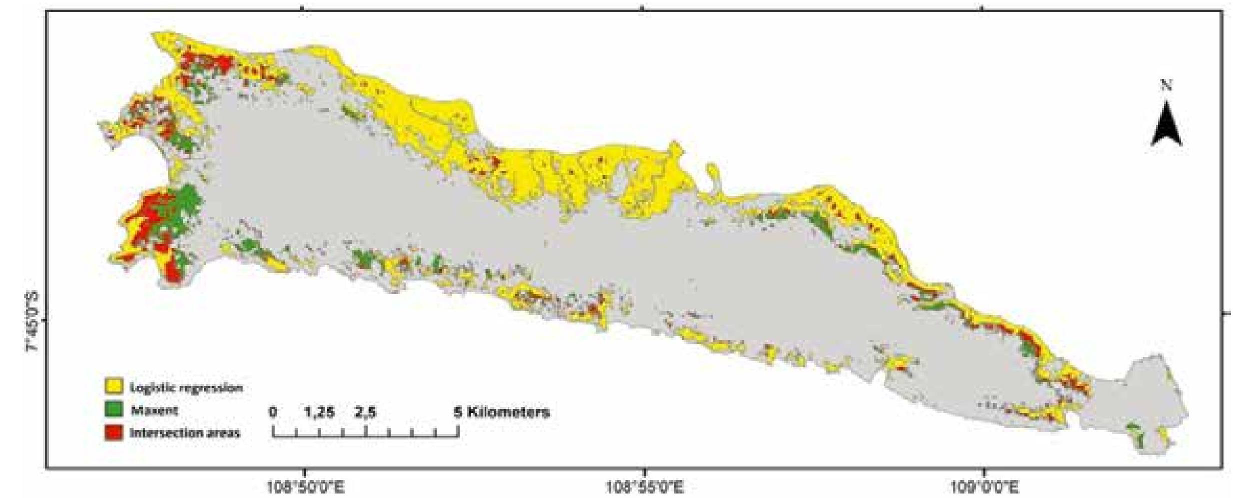

Fig. 2. Predicted distribution of *Dipterocarpus littoralis* in Nusakambangan Island based on logistic regression analysis (yellow), Maxent model (green) and intersection areas of the two models (red).

higher AUC and Kappa value. This superiority of Maxent model compared to the logistic regression was also shown by previous studies (Gastón & García-Viñas, 2011; Marini *et al*., 2010; Tognelli *et al*., 2009; Roura-Pascual *et al*., 2009), and mainly due to its ability to ovoid overfitting by using regularization techniques (Gastón & García-Viñas, 2011). In addition, the AUC value of Maxent model from the present study was much higher compared to the AUC of 0.87 gained by Primajati (2015).

In general the results of the present study were in concordance with the study of Robiansyah and Davy (2015) and Primajati (2015), which highlighted the importance of elevation, distance from coastline and river networks, soil moisture and canopy cover for the ecology and distribution of *D. littoralis*. Interesting results were shown by logistic regression and Maxent model which identified NDWI and distance from coastline as the most important variable for *D. littoralis* distribution, respectively. NDWI has a strong positive correlation with fractional water index (Gu *et al*., 2008), thus is a very good proxy for soil moisture condition. In the present study, predicted suitable habitat for *D. littoralis* was associated with NDWI value above 0.35 (result was not shown), which corresponds to high soil moisture content. As previous study had shown that more than 60% of *D. littoralis* in WNNR were in 0-5 cm diameter class (Robiansyah & Davy, 2015), this high soil moisture content might be very important for seedling growth and establishment of *D. littoralis*. A study by Islam *et al*. (2016) found a positive association between sapling density of *D. turbinatus* and soil moisture content in Lawachara National Park, Bangladesh. The authors suggested that soil moisture content is a critical factor for the regeneration and a viable population of the species.

As indicated by its name, *D. littoralis* is an endemic tree found in littoral forest of Nusakambangan. A littoral forest is recognized by its close proximity to the ocean (generally < 2 km) (DECC, 2008). This might be the reason Maxent identified distance to coastline as the most important factor for the distribution of *D. littoralis*. Furthermore, inclusion of this variable as a significant predictor in the Maxent model restricted the distribution of these habitats mainly along the coastal areas of the island, and hence led to the prediction of smaller suitable habitats of the species compared to those predicted by logistic regression.

Most of the intersection areas between predicted suitable habitats of logistic regression and Maxent model were located inside WNNR. Since these intersection areas were predicted to have very high suitability for *D. littoralis*, this situation is good for the species in term of conservation strategies as these areas are already protected by the government. Furthermore, the undergoing and future population reinforcement and reintroduction of the species should be focused in these intersection areas in order to increase the successfulness of the programs. Hai *et al*. (2014) argued that site selection, habitat features and geographical location are among the most important factors affecting the success of plant reintroduction program.

Since there were some limitations in the present modeling study, care should be taken when implementing the results in the field-based conservation programs. Logistic regression and Maxent model did not consider other important factors for the distribution of a plant species such as dispersal process, anthropogenic influences, biotic interactions, or geographic barriers (Pearson, 2010; Soberón, 2007). In addition, microclimate variables were also not included in both models since there was no weather station in the island from which temperature and precipitation related variables can be collected. Furthermore, field surveys are required to validate the model predictions, especially outside WNNR where the presence and absence data of *D. littoralis* were absent.

CONCLUSION

The present study showed that Maxent model was better than logistic regression analysis in predicting the suitable habitats for *D. littoralis*. The AUC of the first model was much higher compared to the second one. Distance from coastline and river networks NDWI, NDVI and elevation were suggested to be very important for the species ecology and distribution. Coastal areas in the west part of the island were predicted by both models as areas with high suitability for *D. littoralis*. Although there were some limitations, the results of the present study can be used as a basis for conservation programs of *D. littoralis*. Population reinforcement and reintroduction programs can be focused at the areas with high suitability for the species, especially at the intersection areas predicted by both logistic regression and Maxent model. Furthermore, these predicted suitable areas should be protected as they may serve as *in situ* refugia for *D. littoralis* from ongoing climate change.

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