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Spatial analysis of habitat loss for the endangered marine otter *Lontra felina* (Molina, 1782) in Peru

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Abstract

Urban development in coastal cities is highly threatening for marine coastal wildlife, especially endangered species like the marine otter *Lontra felina*, whose habitat is restricted to coastal rocky areas along the coast of Peru and Chile. In this work, we determine the habitat loss through the use of remote sensors along the coast of Lima, the capital of Peru with a high number of inhabitants and a nearly uncontrolled urban growth. We evaluated three localities: Punta Corrientes, Pucusana, and Ancón using satellite images for two different years: 2016 vs. 2023. The analysis of potential habitat and habitat loss followed the CORINE Land Cover technical guide adapted to Peru. Two algorithms for land classification were tested, SVM and Random Forest. Both had Kappa values over 0.60; however, SVM had the best precision on pixel classification. Among the categories analyzed, "rocky outcrops" showed a reduction in all the three areas but in Ancón and Pucusana there was over 20% of loss. On the contrary, the category "continuous urban fabric" increased over 23% in Ancón and 13.55% in Pucusana. The change in land cover and use was statistically significant in Ancón ($p < 0.005$; $\chi^2 = 8.0302$, df = 3). The loss of "rocky outcrops" has a statistically significant change for all the localities ($p < 0.005$; $\chi^2 = 6.229$, df = 2). Our results provide evidence that the coastline is changing in Ancón and Pucusana. The physical reduction of coastline is critical for marine otters, since their activity is limited to the rocky shoreline, both marine and terrestrial. Marine otters inhabit all of the three locations, however, the main modification occurs in Ancón and Pucusana; the loss of the available habitat would involve both habitat loss and reduction of habitat quality.

Keywords:
coast, land cover and land use, marine mammals, remote sensing, urban development

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Introduction

The marine otter *Lontra felina* is a mustelid inhabitant of the western coast of South America, from Huanchaco Port in the north of Peru (Alfaro-Shigueto et al., 2011) to Comuna de Quellón in Chile (Delgado et al., 2022). The marine otter is a predator from the intertidal zone (Córdova et al., 2009) that inhabits exposed rocky coasts (Sielfeld et al., 2025) where natural galleries exist and become proper habitat for the species for reproduction and shelter (Ostfeld et al., 1989; Sielfeld & Castilla, 1999; Apaza & Romero, 2012; Valqui, 2012). This kind of habitat in Peru is located almost homogeneously from the Santa River (08°58'S) to the border with Chile, with an extension of ~1,600 km (Valqui, 2012). Within that extension is located the region of Lima, the capital of Peru, where marine otters have been reported in 19 localities among coastal areas and islands with a range of 1 to 5 individuals (Valqui, 2012).

The marine otter can be classified as a meso-predator due to its predominantly predatory foraging behavior (Smith et al., 2021). Its diet consists mainly of fish such as hake (*Merluccius* spp.), frogfish (Batrachoididae), and croaker (*Cilus gilberti*), as well as invertebrates including decapods, shrimp, crustaceans, and mollusks (Valqui, 2012; Córdova & Rau, 2016). It is considered the smallest species within its genus, with a maximum weight of 5.8 kg (Valqui, 2012).

The ecological importance of the marine otter arises from its role as a key species within South American coastal and marine ecosystems, where it helps to maintain the balance of the trophic chain (Hostos-Olivera & Valqui, 2024); furthermore, its presence also serves as a reliable indicator of healthy and well-functioning habitats (Castilla & Bahamondes, 1979; Sielfeld & Castilla, 1999).

The population of marine otter has experienced a significant decline, primarily during the 20th century due to exploitation by the pelt industry. Currently, its main threats are associated with human activities such as urbanization, environmental pollution, and the increasing industrialization of coastal areas (Valqui, 2012); these threats also include incidental captures, the use of explosives in artisanal fishing (Valqui, 2012; Valqui et al., 2018; Santillán et al., 2020), and the increment of the extraction of brown macroalgae and fishery resources (Sielfeld et al., 2025). In addition, the expansion of urban areas has increased interactions with domestic animals such as cats and dogs, which pose risks of disease transmission to otters (Valqui et al., 2018).

The ongoing growth of cities and human populations along the coast further intensifies pressure for anthropogenic impacts like habitat loss and pollution in coastal and marine ecosystems (de Andrés & Barragán, 2016). Overpopulation has a significant role in the biodiversity decline because human populations increase their resources consumption, also increase their waste material production, and displace other species in the ecosystem (Cafaro et al., 2022). Although some marine otter populations have shown a degree of adaptation to areas with marine infrastructure development, this also exposes the species to additional risks (Cursach et al., 2012). Conflicts arise between natural populations of otters and humans not only in terms of a direct perturbation, like habitat loss, but also through indirect effects. Marine otter's main prey are invertebrates; however, it was also recognized as an opportunistic predator, feeding mainly on the most abundant subtidal prey species, responding to seasonal variations in prey availability (Medina-Vogel et al., 2004). The loss of subtidal habitat due to urban development impacts the subtidal organism community; as a consequence, marine otters are affected with the loss of prey in amount and quality. For these reasons, *L. felina* is listed on the Red List of Threatened Species (Valqui & Rheingantz, 2021) and has been classified as "Endangered" under Peruvian legislation outlined in Supreme Decree 004-2014-MINAGRI (Valqui et al., 2018).

Along the Lima coast, rocky cliff zones provide suitable habitat characteristics for the marine otter with its presence reported in 19 different localities along the coast and nearby islands (Valqui, 2012). In some areas, such as Ancón, Pachacamac Islands, Pucusana, and Punta Corrientes, unusually high concentrations of four to five individuals have been observed (Valqui, 2012). Such group sizes are rare for this species in Peru, as its population is generally small and fragmented (Larivière, 1998).

There is a significant concern regarding the increasing pressure on marine otter, as its habitat is further impacted by the expansion of urbanization along the coast of Lima. This region, which is one of the mapped habitats for the species, has one of the largest human populations in the country, with approximately 10.15 million people (30.1% of the country population) in 2023 (INEI, 2023). Such a large population generates intense demand for urban development, housing, seasonal private beach houses, and coastal recreation areas (Ludeña, 2004; Castillo-García, 2020).

To map land use and land cover changes in the localities along the coast of Lima, remote sensing was employed because of the practical advantages for monitoring large-scale alterations along the coastlines and quantitatively analyzing the potential drivers of these changes (Sui et al., 2020), which is critical for assessing biophysical interactions and habitat changes.

Currently, land modification can be effectively monitored using remote sensors, which provide a wide range of image scales and extensive historical data (Rogan & Chen, 2004). Some authors have additionally integrated artificial intelligence with remote sensing technologies to enhance spatial planning and biodiversity conservation in marine ecosystems (Simmons et al., 2025). The availability of such data has increased noticeably, making this technology more applicable across different spatial scales and at lower costs (Rogan & Chen, 2004), particularly for terrestrial surfaces (Martínez & Mollicone, 2012).

Moreover, remote sensing enables the mapping and tracking of changes in coastal habitats such as rock formations and coastlines, all of which are essential variables for marine otter habitat-suitability models. An example supporting this technology as a tool for studying wildlife ecology and monitoring species with low occurrence is the study by Strang et al. (2025), who conducted ground-truthing of satellite imagery to estimate the size of Adélie penguin colonies. The authors highlighted that very high-resolution (VHR) imagery represents a significant technological advancement in wildlife research, offering key benefits such as improved efficiency and safety, as well as reduced costs.

This paper evaluates the loss and modification of marine otter habitat along the coast of Lima between 2016 and 2023 by analyzing changes in land cover and land use driven by urban expansion. The main objectives were to identify and quantify habitat loss within the species distribution in the mapped localities, and to assess how land-use and land-cover dynamics have transformed the ecological conditions of marine otters' coastal environment.

The results of this work underscore the urgent need to complete the Economic and Ecological Zoning (ZEE) for the department of Lima, as the absence of this instrument makes it difficult to delineate, manage, and implement action plans aimed at the sustainable use of coastal lands. Furthermore, the study aimed to highlight the importance of strengthening urban planning with an emphasis on sustainability, improving beach-management practices, and ensuring the conservation of marine and coastal ecosystems within the study area.

Methods

Study area description

Within the 19 localities with populations of marine otters in Lima, we selected three with the following characteristics: (1) a high number of individuals reported by Valqui (2012) and (2) anthropogenic pressure. The three localities were Punta Corrientes (12°57′ S, 76°30′ W), Pucusana (12°28′ S, 76°47′ W), and Ancón (11°45′ S, 77°11′ W).

Ethical statement

The study adhered to Peruvian national regulations for research in wildlife. The authorization code Nº AUT-IFS-2022-091 in Directorial Resolution RD N° D000156-2022-MIDAGRI-SERFOR-DGGSPFFFS-DGSPFS provides the required research permission.

Data collection

Potential habitat loss

The study focuses specifically on quantifying habitat loss for the endangered species *L. felina* within three specific coastal localities in Lima, Peru: Ancón, Pucusana, and Playa Punta Corrientes. The analysis of potential habitat and habitat loss used the MaxEnt Model with a CORINE Land Cover (CLC) Classification adapted to Peru (Bossard et al., 2000) (See Table 1).

Satellite imagery was sourced from the European Space Agency's (ESA) Sentinel-2 mission through Google Earth Engine (GEE), and the comparative analysis was done between two different years: 2016 vs. 2023. The obtained imagery was preprocessed to mee,t specific requirements to ensure the algorithm could accurately classify pixels for land cover and land use analysis. Some of the specifications consist of the following:

Atmospheric Correction

Sentinel-2 Level 2A (L2A) Surface Reflectance pre-corrected product was utilized to ensure that pixel values represented actual surface reflectance, as it includes corrections for aerosols and water vapor that could otherwise reduce imagery accuracy.

Spectral Bands

Our analysis utilized the Sentinel-2 bands at their optimal resolutions: the 10-meter visible and near-infrared bands B2 (Blue), B3 (Green), B4 (Red), and B8 (NIR), alongside the 20-meter Short-Wave Infrared bands B11 (SWIR-1) and B12 (SWIR-2). These bands were selected for their sensitivity to built-up areas, vegetation, and moisture content.

Cloud Filtering

The cloud cover threshold was applied to each image from the data set, ensuring the median composite provides the minimum optimal visibility and represents the true surface reflectance for an accurate pixel classification.

Table 1. Categories of CORINE Land Cover classification adapted to Peru and the study area

MaxEnt Class	Level I	Level II	Level III
Class 0 - *L. felina* potential habitat	3. Forests and natural areas	3.4 Areas without or with poor vegetation	3.4.1 Sandy Natural Areas
			3.4.2 Rocky Cliffs / Rocky Outcrops
	5. Water surface	5.2 Coastal waters	5.2.2 Seas and Oceans
Class 1 - Urbanized Areas	1. Artificial areas	1.1 Urbanized areas	1.1.1 Continuous Urban Fabric
			1.1.2 Discontinuous Urban Fabric

Median Composite Generation

A median composite of each image was generated by taking the median pixel value across the filtered collection, which resulted in a representative image from the locality and year with reduced noise and cloud effects.

Marine otter occurrence

Counts of individuals were implemented in the three localities for the period October-November 2022 (warm season) and May-June 2023 (cold season). In Punta Corrientes and Ancón, the survey was terrestrial, while in Pucusana the survey was onboard a small boat. The counts were implemented to complement the sensor analysis, in order to know if the localities were in use by marine otters at the time, more than to obtain an accurate population abundance. Additionally, the survey included searching for indirect evidence of the occurrence of otters, like scats and food remains.

The terrestrial survey followed a point count since we already knew the regular areas of occurrence of individuals. Terrestrial counts were obtained from a fixed point with two observers doing permanent scanning along the shoreline and the marine area within 30 m from shore for one hour. The marine survey was implemented in Pucusana because the group of otters used to inhabit an island located 800 m from the shore of Pucusana. The boat sailed around the island at a constant speed of 4 km for one hour.

Data analysis

Analysis of potential habitat loss

For the classification and analysis of the satellite imagery, the process followed a two-step approach, consisting of cloud-based Maximum Entropy (MaxEnt) modeling and field validation.

Cloud-Based Maximum Entropy Classification (MaxEnt)

The acquisition and analysis of the satellite data from Sentinel-2 was done through Google Earth Engine (GEE). After the images were pre-processed, derived indices were calculated and included as environmental predictor variables for the MaxEnt model:

- Normalized Difference Vegetation Index (NDVI): Crucial for delineating vegetated areas
- Normalized Difference Built-up Index (NDBI): Key for identifying human-made, urbanized areas

For the modeling and classification of Land Use and Land Cover (LULC), the MaxEnt model was selected. MaxEnt is an algorithmic model that employs machine learning to predict presence-only data of species ecological niches, and has been previously used for predicting the extension of protection areas of high value (Li et al., 2022). This means that for the study Urbanized Areas (1.1) were called "urbanized areas" within the algorithm, whereas potential habitat for marine otter such as Areas without or with poor vegetation (3.4) and Coastal Waters (5.2) were clumped into "background".

For the classification of the imagery, the following process was applied:

1. Model Training: A MaxEnt model was trained by defining the target class (Urbanized Areas) as "presence" (1) and all other points as "background" (0). This created six independent MaxEnt probability models.
2. LULC Classification: Each MaxEnt model was applied to the image, generating six probability maps. The final map for the year was derived using a Max-Probability assignment, where each pixel was assigned to the class for which it showed the highest predicted MaxEnt probability.
3. Accuracy Assessment: The accuracy of the model was calculated using ROC Curve (Receiver Operating Characteristics) and AUC (Area under the Curve) on the final Max-Probability map, as these tools for validation are considered useful for binary classifiers because they measure the performance of the model (Zhang et al., 2015). For the calculation of the AUC, and preparation of the ROC table and ROC graph, the NDBI values were used as the predicted probability scores (thresholds). These scores, and the training data points obtained from GEE, were used to calculate the True Positive Rate (TPR) (the proportion of actual positives correctly predicted) and the False Positive Rate (FPR) (the proportion of actual negatives incorrectly predicted) across all possible thresholds.
4. Results Validation: In addition, because the MaxEnt model provided only a binary classification (habitat features = background (0); urbanized areas = presence (1)), the LULC change analysis involved only two categories. Therefore, a single chi-square test was conducted per locality to compare the 2016 and 2023 land cover area results.

Field Validation and Statistical Analysis

For the second step, a site visit was conducted to perform field validation on the land cover and land use change analysis in the study area. This step also assisted in the verification of the classification of LULC types and accurately defined the boundaries and extent of the affected marine otter habitat.

Later, for the detection of LULC a Post-Classification Comparison (PCC) was done between the baseline LULC map - initial year of the study - and the current LULC map - final year of the study. The resulting change matrix quantified the transformation of area (hectares and percent) between all categories.

The significance of the LULC change (ha) for each locality was statistically compared using Chi-squared contingency tables with a significance level of $\alpha = 0.05$. In the context of marine otter habitat, the analysis focused on changes within the background area compounded by the following categories: Rocky Areas Without Vegetation (RAWV), the primary and preferred habitat; Sandy Areas Without Vegetation (SAWV), secondary or buffer habitat; and Urbanized Areas (UA), the main driver of habitat loss and degradation. The final cartographic products and visualizations were generated using QGIS software.

Results

Accuracy of the Model

The habitat suitability models for marine otters demonstrated consistently high predictive accuracy across all three study localities and both study years (Fig. 1). The AUC ranged from 0.7813 to 0.8750, confirming the efficacy of the environmental covariates (such as the NDBI, used in the threshold) in delineating suitable habitat. Ancón had one of the best model performances with an AUC of 0.8750 in 2023. This stability suggests that because of its extension, the imagery had a better-quality resolution that allowed a better level of accuracy and performance.

Punta Corrientes also had a very stable result for both years despite being a very small area; however, there were no significant changes within the study years in terms of LULC. In contrast, Pucusana had the lowest model accuracy over the seven-year period. This reduction in discriminatory power may have occurred because of the climate implications of the locality and the presence of clouds in the satellite imagery.

Potential loss and significance of the LULC changes

The results of the MaxEnt model showed that there was a decrease in the potential habitat for marine otter across all three localities, which can be correlated to the expansion of the Urbanized Areas in the period of this study (Tables 2 and 3; Figs 2 - 4). The correlation of the LULC changes in the study area caused by urbanization (increase of Urbanized Areas) and loss of potential habitat for marine otter are described in further detail in the following sections.

Ancón

Ancón had an increase of the Urbanized Areas of 1,208.4 ha, and after calculating the association of the LULC between the study years ($\chi^2 = 114.41$, $p < 0.001$), it was found there was a strong correlation between the expansion of Urbanized Areas and the simultaneous reduction of the potential habitat for marine otter in the seven-year period.

Pucusana

For Pucusana, the analysis found no statistically significant association between the study year and the land cover category ($\chi^2 = 0.18$, $p = 0.67$). Although slight changes were observed, with a minor decrease in potential habitat for marine otter, these variations were not large enough to be considered statistically

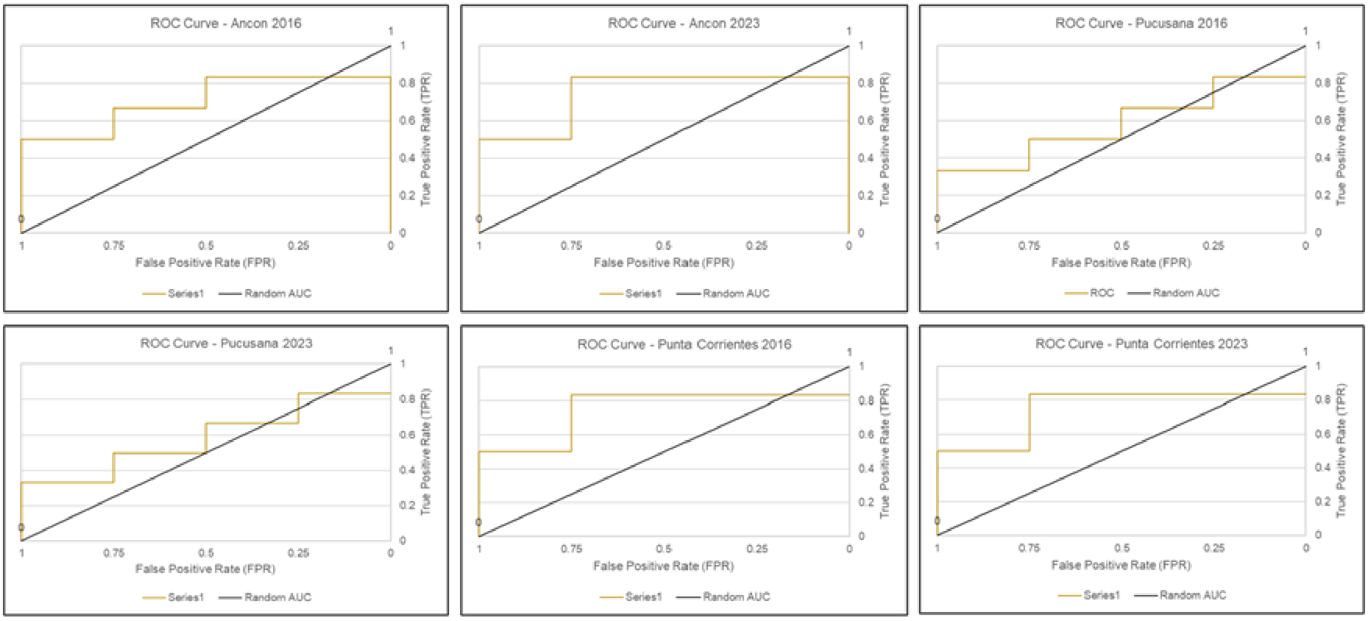
Table 2. Change of land coverage and use in the study area (ha)

Locality	2016 - Class 0 (*L. felina* potential habitat)	2016 - Class 1 (Urbanized Areas)	2023 - Class 0 (*L. felina* potential habitat)	2023 - Class 1 (Urbanized Areas)
Ancón	63,670.3	6,482.6	62,461.9	7,691
Pucusana	1,361.3	270.5	1,351.1	280.6
Punta Corrientes	195.78	8	195.5	8.3

Table 3. Marine otter *Lontra felina* habitat loss in the study area

Locality	Total change in LULC *(ha)	Total loss of *L. felina* potential habitat (%)	Total increase of Urbanized Areas (%)
Ancón	1,208.4	1.90	18.64
Pucusana	10.2	0.75	3.77
Punta Corrientes	0.28	0.14	3.50

*Land Use and Land Cover



Localities	AUC - 2016	AUC - 2023
Ancon	0.7813	0.8750
Pucusana	0.8647	0.7813
Punta Corrientes	0.8646	0.8646

Figure 1. AUC (Areas Under the Curve) and ROC (Receiver Operating Characteristics) Performance of the MaxEnt Model for classification of Land Cover.

significant as the Urbanized Areas increased 3.77% in the 7-year period.

Punta Corrientes

Similar to Pucusana, Punta Corrientes showed no significant association between the study year and the land cover category ($\chi^2 = 0.00$, $p = 1.00$). Urbanized Areas showed slight to no increase; however, in the satellite imagery the enhancement of the beach condos that were developed in the area previous to the year 2016 are noticeable.

Marine otter occurrence

All the localities had evidence of otter occurrence both in the warm and cold seasons (Table 4). In Punta Corrientes, during the warm season survey, one specimen was observed with a crab in its mouth; additionally, scats and food remains were found in a burrow. Both scat and food remains were abundant and fresh. Local fishers reported the occurrence of at least two otters. In the cold season the situation was the opposite.

The occurrence of otters in Pucusana was mainly constant, however in the warm season there were no sightings, but local people informed the occurrence of at least two individuals, even minutes before our arrival. In Ancón marine otters seemed scarce in the warm season, while increasing their occurrence in the cold season.

Table 4. Occurrence of marine otter *(Lontra felina)* in the three assessed localities. For each locality it is indicated: the occurrence of scats and qualitative conditions, the occurrence of food remains, and oral information from locals.

Locality	Season	Count	Scats	Food remains	Oral information
Punta Corrientes	Warm	1	Yes (plenty, fresh)	Yes	At least 2 otters
	Cold	0	Yes (scarce, dry)	Yes	No
Pucusana	Warm	0	Yes (plenty, fresh)	Yes	At least 2 otters
	Cold	1	Yes (plenty, fresh)	Yes	At least 2 otters
Ancón	Warm	0	Yes (scarce, dry)	Yes	No

Discussion

The urban growth rate in Peru was on average 30% higher than in other countries in Latin America (Espinoza & Fort, 2020). Between 2007 and 2016, more than 4,700 urban ha were created per year, 27.66% more than in the previous period of 2001–2006 (Espinoza & Fort, 2020). That exponential growth has produced the deterioration of natural ecosystems, especially those in coastal areas, because the city has grown in the coastal direction (Ludeña, 2004; Castillo-García, 2020; Lizarbe-Palacios et al. 2022).

Ancón's human population has increased dramatically according to the national demographic census: the population in 1981 was 8,425 inhabitants, and in 2007 it reached 33,367 inhabitants (Municipalidad de Ancón, 2017); meanwhile, Pucusana has around 14,891 inhabitants (0.17% of Lima's population) (INEI, 2023; Municipalidad de Pucusana, 2023). This data would

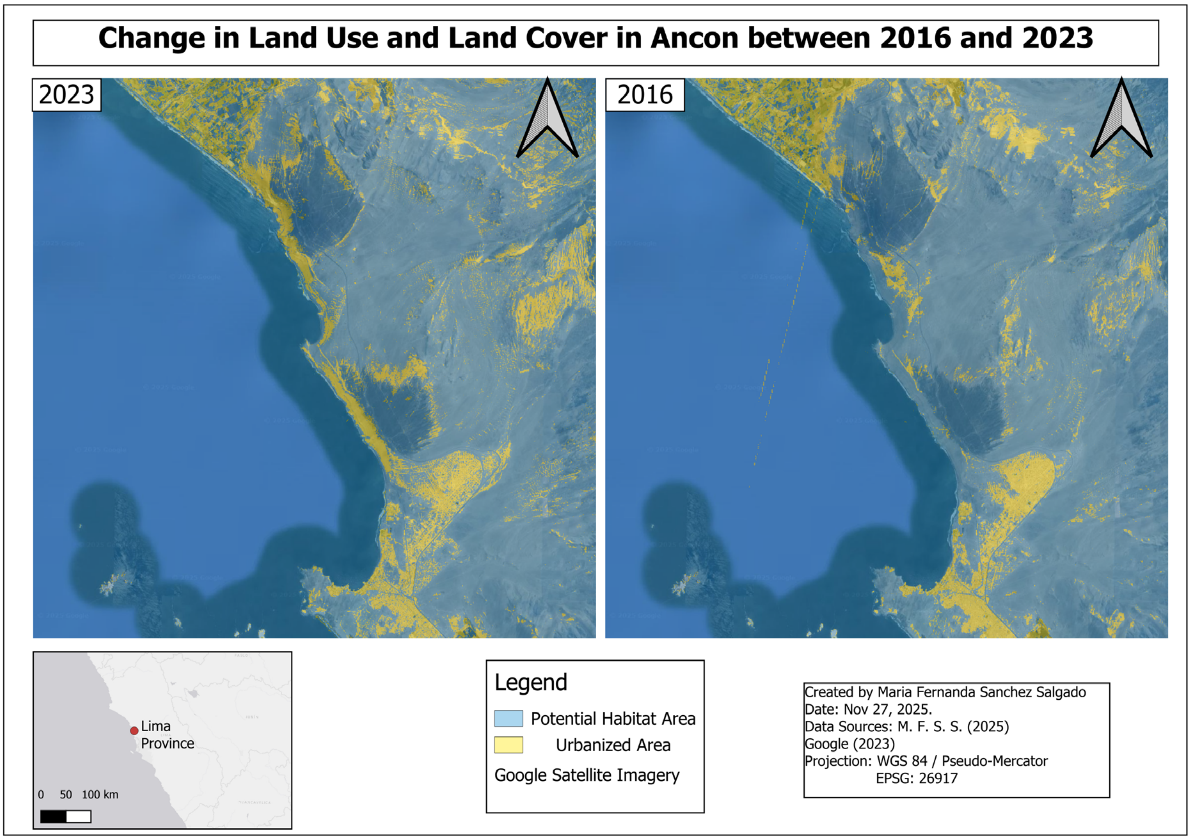


Figure 2. Change in land use and land cover in Ancón between 2016 and 2023.

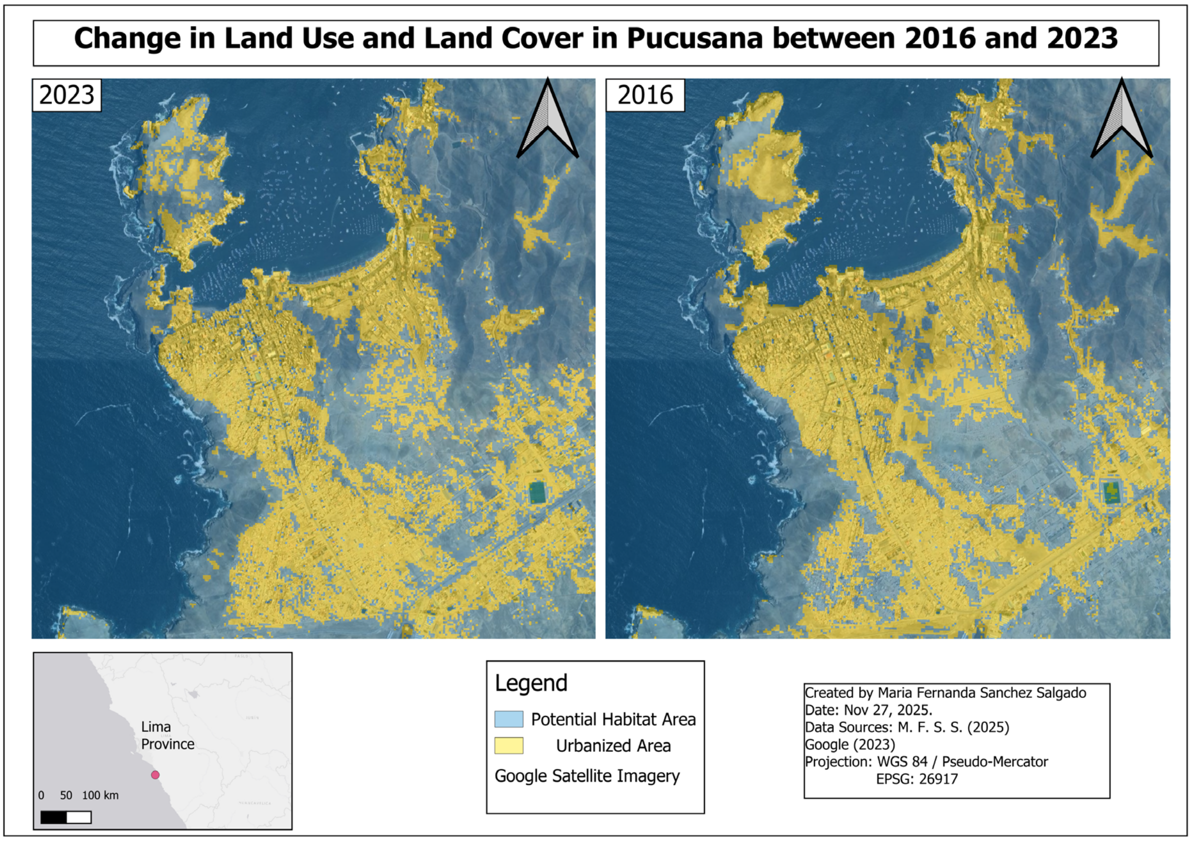


Figure 3. Change in land use and land cover in Pucusana between 2016 and 2023

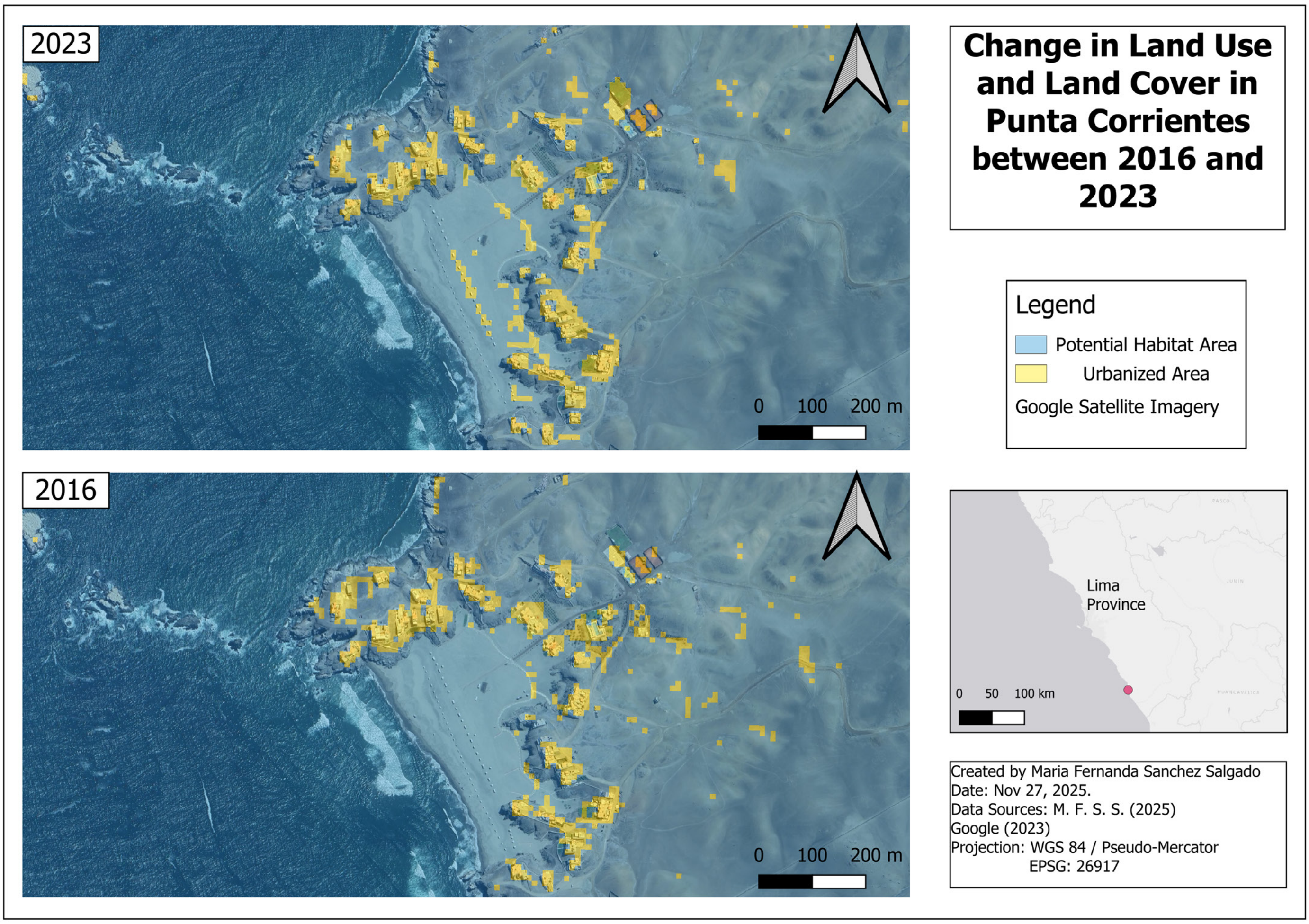


Figure 4. Change in land use and land cover in Punta Corrientes between 2016 and 2023

explain the percentage of the increase in the Urbanized Areas in the coastal zones of those localities.

Along with the increase in population, the coastal habitat has been modified and urbanized. That implies the modification of the natural structure with coastal facilities like artificial docks, stone foundations for houses, defense walls, and others, replacing the natural configuration of the rocky coast, which was seen through satellite imagery on the coast of Punta Corrientes, where there was an enhancement of the recreation areas of the beach condos developed in the locality.

Marine otter occurrence in rocky areas is affected by human influence and rocky seashore size (Medina-Vogel et al., 2008). Small rocky patch areas might represent extinction rates for marine otter populations, since immigration potential and colonization depend on seashores with large sized rocks (Medina-Vogel et al., 2008). The fragmentation of coastal areas in Ancón and Pucusana due to the reduction of rocky areas creates more isolated rocky coastal patches. That condition produces barriers for dispersion, with the consequence of modifying the ecological interrelationship between marine otters and the rocky seashore patches (Medina-Vogel et al., 2008).

On the other hand, in some cases, marine otters might have an apparent benefit from human influence because they have access to fishery waste (Medina-Vogel et al., 2007). Furthermore, the coastal modification could offer new artificial habitats for marine otters. The availability of suitable galleries between rocks for burrow establishment is known as a key factor in the selection of habitat for marine otters (Cabello, 1983; Sielfield & Castilla, 1999). However, urban development implies more than habitat modification; other disturbance factors like water and air pollution and noise produced by the increase of the transit of boats, vessels, and other terrestrial vehicles could deter marine otter denning in those areas.

Marine otters around 12°00′ S and 11°00′ S are distributed in several small populations but in general have a homogeneous distribution along their distribution along the coast of Peru from 9°00′ S to 18°00′ S (Apaza & Romero, 2012). Specifically, in our study area, some conspicuous groups have been determined in Punta Corrientes, Pucusana, and Ancón (Apaza et al., 2004; Sánchez & Ayala, 2006; Valqui et al., 2010). We determined that marine otters still use the three areas, however the number of individuals seems fewer than that reported by other authors. We cannot fully confirm that trend given the limitations of our survey; however, this pattern should be addressed in the future to confirm that habitat loss encompasses a reduction in population size.

The reduction of quality habitat has an effect on prey capture success, since the otters' diving activity during their search for food might extend. The availability of low-quality prey promotes a continued search as long as their predetermined maximum dive capacity permits (Ostfeld et al., 1989). The reduction of habitat in Ancón and Pucusana might impact otter normal foraging, but it also implies a reduction of habitat for coastal fish and invertebrate populations. Besides reproduction, which is another aspect potentially disrupted by the loss of habitat, habitat modification also implies changes to burrows for cubs. Adults with cubs must prefer areas with difficult access from land that offer natural caves protected by big and steep rocks (Medina, 1993).

Finally, the analysis of habitat loss through remote sensing and classification through modelling was an appropriate methodology to assess the status of marine otter habitat. It is properly implemented in coastal areas, since marine otters' activity is limited to 30 m on land and 150 m in the water, with the strip of 20–50 m along the coastline being the most used (Sielfield & Castilla, 1999).

On the other hand, Lima's coastal climate, which is strongly influenced by the Humboldt Current, the Andes Cordillera, and its location within a desert ecosystem, result in persistent cloud cover and high atmospheric humidity (*garua*). This constant cloudiness represented challenges for image classification and model training, especially in localities from the south of Lima (Pucusana and Punta Corrientes), as cloud-related reflectance occasionally produced inaccuracies in the satellite imagery, even after applying cloud-masking filters.

Conclusion

The physical reduction of the potential habitat for marine otters is confirmed in this study. The biological and ecological aspects must be the next step in the analysis for a more profound understanding of the conservation status of the marine otter on the coast of Lima. The present study is a reference to evaluating the status of other coastal cities with groups of marine otters along their distribution, in order to bring more visibility to the problem that the province has in relation to the zoning and protection of important habitat for endangered coastal species.

Therefore, the recommendations for a long-term strategy are based on the (1) promotion and conduction of research for habitat utilization and connectivity, (2) prey availability research in highly urbanized areas or where fishery activities exist, (3) stakeholder engagement in localities where the marine otter is present, (4) promotion of educational workshops about the conservation of the marine otter and coastal ecosystems, and the (5) development of policy and management interventions: ZEE plan of Lima and establishing non-development buffers in conservation zones.

Implications for conservation

Our results showed evidence that the coastline is suffering a noticeable modification in two crowded locations, Ancón and Pucusana. Endangered marine otters are threatened directly and indirectly through habitat modification and habitat loss. This implies the need for conservation actions in coastal cities to protect them from local extinction.

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