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Suitability of the South Caribbean Coast of Costa Rica for Reintroduction of the Great Green Macaw *Ara ambiguus*

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Abstract

The Great Green Macaw *Ara ambiguus* is an endangered species whose most important food resource and nesting site in Costa Rica is the mountain almond tree *Dipteryx panamensis*, threatened mainly by deforestation. In this study, we analyse the suitability of reintroducing *A. ambiguus* in the South Caribbean Coast of Costa Rica by examining whether the ecological and socio-cultural conditions required for the reintroduction are met in the area. The methods developed in this work include biological sampling, cartographical analysis and semi-structured interviews, among others. We set La Ceiba Nature Reserve as study unit and starting point of the analysis due both to its conservation status, favouring the potential release of individuals, and its ecosystem representativeness. Our results suggest that the habitat is suitable for reintroduction, with frequent presence of *D. panamensis* in the region, as well as other feeding options and potential nesting sites in the study area. The cartographic study reveals that the species could rely on a forested surface of up to 7000 hectares, which would be sufficient for sustaining a viable population. As for the socio-cultural analysis, illegal logging and low protective frameworks were identified as the main potential threats for the species. Nevertheless, we perceived positive conservation attitudes among local people and a pro-active commitment of political stakeholders. We conclude that a viable South Caribbean reintroduction of *A. ambiguus* is possible in conjunction with a threat mitigation programme.

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Keywords

Psittacine Conservation, Reintroduction, Threatened Species, Suitability Analysis

1. Introduction

1.1. Parrot Threats and Conservation Effectiveness

More than 30% of the nearly 140 species of parrots (Psittacidae) of the Neotropics are listed as endangered [1] [2]. The combination of habitat loss and illegal parrot trade, the latter particularly worrying in Latin America [3], is considered the most important cause of decline in parrot populations [4] [5].

Reintroduction, defined by IUCN as "an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct" [6], represents an increasingly used strategy in psittacine bird conservation throughout the world [7]. Several authors recommend the release of individuals solely within the historic range of species as part of the reintroduction process [8] [9]. However, successful reintroduction to the historical range is only possible after identifying and addressing the original causes of population decline [10] [11]. Because there is a broad range of methodologies and assessments that can be potentially employed in reintroduction programmes [7], the use of reintroductions as a tool for conservation certainly needs further research and improvement to ensure the chances of success (based on King's *et al.* definition of "success" [12]). In this sense, it is crucial to update and refine the reintroduction process based on the lessons learned from different case studies (e.g., [7]).

Despite the several unsuccessful parrot reintroduction attempts (e.g., [8] [13]), there are various examples in which viable populations of many species have been well-established (e.g., [14] [15]), yet not always deliberately [16] [17]. In the case of macaws, there are quite a few examples of reintroductions undertaken in Central American countries [18]. For instance, ongoing releases of Scarlet Macaw *Ara macao* and Great Green Macaw *A. ambiguus* in Costa Rica have resulted in high survival rates [19]. In Costa Rica, numerous years of experience in reintroductions and a rate success of more than 70% after 2 - 3 years [18] suggest a potential long-term success.

1.2. Ecological Associations

Within the context of the so-called parrot conservation crisis is *A. ambiguus*, an endangered parrot whose distribution area in Costa Rica has been reduced by up to 90% mostly because of deforestation [20]-[23]. This alarming situation calls for urgent conservation projects for the species and its habitat. *A. ambiguus* is one of the two macaw species found in Costa Rica and the second biggest parrot of the New World [24] [25]. It inhabits the canopy of the humid and wet lowland tropical rainforests, flying over great distances during the non-breeding season to obtain food [26] [27]. In Costa Rica, the fruit seeds of the mountain almond tree *Dipteryx panamensis* represent the main component of its diet [28] [29], even though different diet composition has been reported in other countries (e.g., Ecuador [30]). Studies on *A. ambiguus* nesting indicate that the species chooses to nest in tree hollows of *D. panamensis* in over 90% of cases [31] [32]. In this sense, this tree can be considered as the most important nesting and food resource for the species in the country [32] [33]. *D. panamensis* is an emergent tree of the tropical rainforest and is largely distributed along the Caribbean Coast of Costa Rica [25] [34].

A decrease in the international price of cattle and reforestation state policies made incentives for livestock being replaced by new incentives for forest management during the mid-1980s [24]. Further modernization of sawmills and changes in industry increased forest degradation, and high commercial value of *D. panamensis* encouraged indiscriminate felling [25] until it became a threatened species in 2005 [35] [36]. The substantial reduction of the nesting area of *A. ambiguus* in Costa Rica motivated a total ban on the exploitation of *D. panamensis* that is still effective today [22] [37].

This study reports on how the suitability of a reintroduction can be empirically assessed for an endangered species. Based on some of the criteria for parrot reintroductions [4], including improvement of the causes originating the population decline and careful evaluation of potential release sites [7], we analysed the suitability of reintroducing *A. ambiguus* in the South Caribbean Coast of Costa Rica within the historical distribution range of the species. We set La Ceiba Nature Reserve as study unit and starting point of the analysis due both to its conservation status, favouring the potential release of individuals, and its ecosystem representativeness, and examined the ecological and socio-cultural conditions for reintroduction of the species. As a second step and related to *A. ambiguus* conservation, we aim to help establishing a scientific basis for its reintroduction in the South Caribbean Coast of Costa Rica, highlighting the importance of suitability studies as means of maximizing the chances of success of a reintroduction.

2. Methods

2.1. Study Area

The study area is the South Caribbean Coast of Costa Rica, which is restricted to the coastal region between the southern extreme of the Cahuita National Park and the village of Gandoca, bordering Panama. As for the study unit, La Ceiba Nature Reserve is composed of 42 ha and is located within the large Gandoca-Manzanillo Wildlife National Refuge (Refugio de Vida Silvestre Gandoca-Manzanillo; hereinafter REGAMA), extending from Puerto Viejo to the Panamanian border (see **Figure 1**).

2.2. Research Schedule

All the fieldwork was carried out from September to November 2010, corresponding with the start of the fruiting season of *D. panamensis* (from December to February [24]).

2.3. Sampling of *D. panamensis* at La Ceiba

All the almond trees were sampled in the reserve to assess the availability of both food and nesting sites for *A. ambiguus*. The sampling was performed in plots of 20 × 30 m processed with MiraMon program [38] [39], a

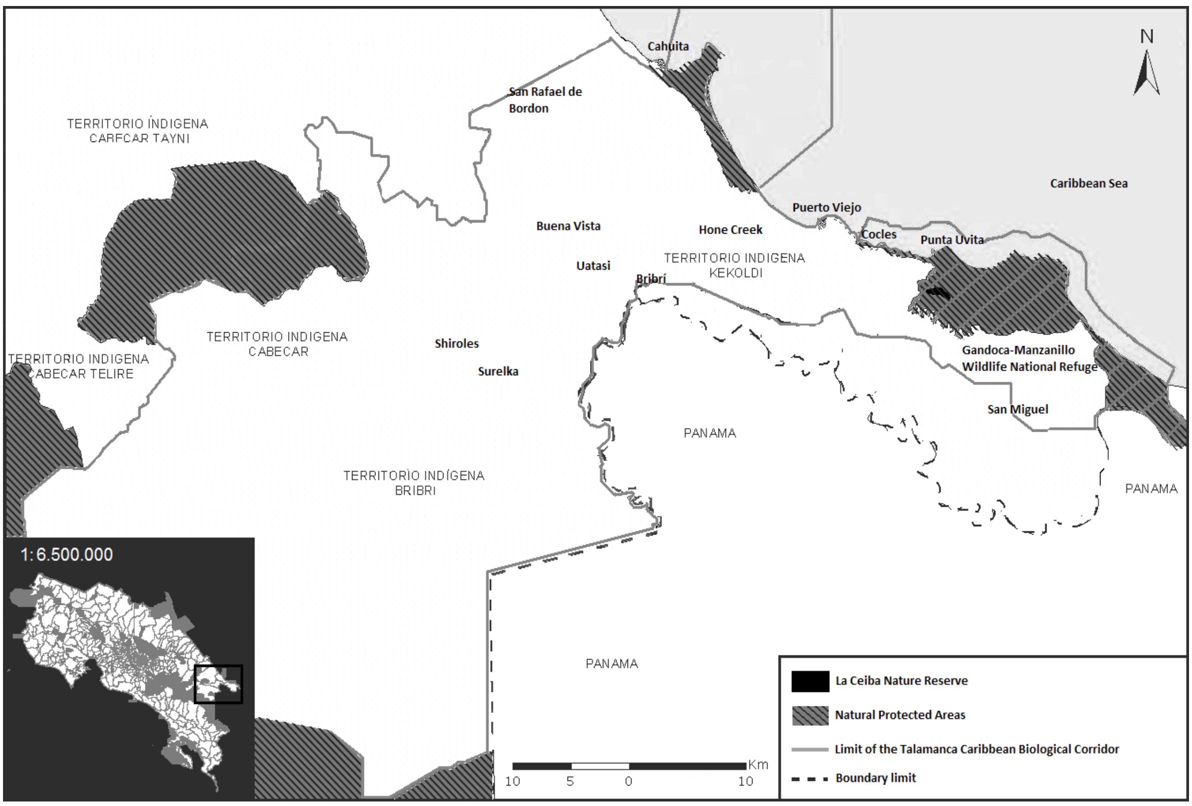

Figure 1. Study area and location of La Ceiba Nature Reserve in the Gandoca-Manzanillo Wildlife National Refuge (Refugio de Vida Silvestre Gandoca-Manzanillo, REGAMA). Source and author: Association of the Talamanca Caribbean Biological Corridor, Asociación Corredor Biológico Talamanca-Caribe, ACBTC.

Geographic Information System (GIS) and Remote Sensing (RS) software [40]. As a result of the division of the 42 ha of the reserve, we obtained a total of 836 plots that were located in the field using a GPS device.

The diameter of each tree was measured using the DBH (Diameter at Breast Height) method. According to Madriz-Vargas [24], individuals with an average DBH higher than 1.24 m are likely to have suitable cavities for *A. ambiguus* nesting. Cavities were located, registered and classified into two categories, suitable and unsuitable. Suitability was defined following the study of Brenes *et al.* [41], in which cavities exceeding 40 cm in diameter are considered as suitable for *A. ambiguus* nesting. This variable was estimated visually with binoculars when complete observation was possible. We only made observations from the ground due to the lack of equipment for climbing trees.

We also calculated the percentage of mature trees to estimate the food resource potential of the reserve. This was done by calculating the percentage of seeds and/or seedlings nearby the identified specimens.

2.4. Partial Sampling of Other Forage Species

A partial sampling of other forage species was also carried out in the reserve to verify that *A. ambiguus* had other feeding options when the almond trees were not fruiting. For this purpose, four species were chosen in view of their dietary complement to *D. panamensis*: the barrigona palm [23] *Iriartea deltoidea*, the andiroba [24] *Carapa guianensis*, the yellow laurel [26] *Cordia megalantha*, and the golden fruit [42] *Virola koschnyi*.

We conducted a preliminary random sampling of the first 50 plots of 20 × 30 m. The number of trees of each species was treated as a random variable with a Poisson distribution $X \sim \text{Pois}(\lambda)$ and a parameter $\lambda > 0$. The estimate of λ corresponds to the rate of trees of a single species per plot from n plots. The results of this preliminary sampling allowed us determining that 304 plots was the minimum number of plots to sample for a confidence level (γ) of 0.90 and an error of 0.045 trees/plot (*i.e.* a relative error of 28%; [43]).

We used the same plots and protocol as those established for the sampling of *D. panamensis*. The selection of the plots to sample was made through the statistics software developed by the Office for Research Development and Education of the University of Colorado [44]. For *C. guianensis* and *V. koschnyi*, only individuals with diameter exceeding 30 cm were considered. For *C. megalantha*, a minimum diameter of 20 cm was determined, while for the *I. deltoidea* only individuals over 10 m in height were taken into account. Preliminary field observations in the first 50 plots enabled to relate these values to the age at which the species begin to bear fruit. In the case of *I. deltoidea*, the height was considered instead of the diameter, as not all palm trees experience a proportional growth in their trunk related to age. Densities for the total surface of the reserve were extrapolated from data collected in the random sampling for each of the four species, with a γ of 0.95 so that we could finally estimate the abundance of the selected forage species in the territory.

2.5. Competition/Predation Study

This survey was conducted to determine the species that could exert some pressure on *A. ambiguus* in the study area. A first review permitted us to rule out the possibility of any predators of adult individuals (as few records of predation on adult macaws have been reported, probably because of their size and flight [45] [46]) and focus only on competing species and egg and chick predators. Competing species were regarded as those that could exert some pressure on *A. ambiguus* both in terms of food and nesting, *i.e.* individuals feeding on fruits of *D. panamensis* or nesting in its cavities. Nesting predators were defined as species feeding on eggs or chicks of *A. ambiguus* in almond tree cavities.

The study was performed by observing the fauna associated with a specimen of *D. panamensis* located in a wooded area of Punta Uva (see **Figure 1**). We selected this particular tree because of its size and easy visualization of the top from different viewing angles. Observations were made once a week and we scheduled three daily observation intervals of 15 minutes, yielding a total of 33 sampling periods.

2.6. Connectivity Study

We developed a connectivity study of the reserve with nearby natural areas to find out: a) how present mature almond trees were outside the reserve to provide food and shelter to *A. ambiguus*' individuals; and b) whether a continuous forest area sufficiently large to sustain an *A. ambiguus* population existed. The first part of the study was evaluated through an informative campaign carried out during October to establish contact with the local people who might know *D. panamensis* locations in the villages of Bribrí, Puerto Viejo, Gandoca and Manzanillo (see **Figure 1**). The distribution of informative leaflets and subsequent contact with local peoples helped us in the location, marking and characterization of *D. panamensis* in the area, following the same protocol developed for the sampling in the reserve. To answer the second question, we performed a cartographic analysis of the land use in the study area. We put special focus on vegetation and computed the area covered by tropical rainforest found around the reserve. The processing of the cartographic data was developed using MiraMon program [38] [39].

2.7. Socio-Cultural Approach to the Natural History of *A. ambiguus* in the Region

A socio-cultural approach to the natural history of *A. ambiguus* was required to establish the original causes of its decline in the study area and to analyse the socio-cultural aspects that could affect a hypothetical reintroduction. These results might help determining whether the previous causes of extinction have been removed when implementing a reintroduction programme. Research design involved data collection at local, regional and national levels. We used a number of techniques common to social science research, mainly including semi-structured interviews, participant observation and document analysis.

We arranged twenty semi-structured interviews with experts and local people who were familiar with the natural history of the species. To capture variation in local perceptions regarding conservation initiatives, we interviewed: a) men (n = 13) and women (n = 7); b) subjects with different political views and roles; and c) subjects with various levels of participation in local conservation initiatives. Interviews lasted from 20 minutes to more than 1 hour. The sample was composed of naturalist guides, graduates in Anthropology, Environmental Sciences and Zoology, conservationists, indigenous representatives, local activists and researchers. The involved organisations were institutions such as the Tropical Science Centre (Centro Científico Tropical, CCT), environmental associations as ACBTC or the Kèköldi Wakka Köneke Indigenous Association (Asociación Indígena Kèköldi Wakka Köneke), and the regional delegation of the Ministry of Environment, Energy and Telecommunications (Ministerio de Medio Ambiente, Energía y Telecomunicaciones; hereinafter MINAET). Semi-structured interviews were chosen among other survey techniques because they are useful for addressing certain topics while allowing for more interaction than a formal questionnaire [47]. During interviews, respondents were asked to assess, according to their perception, the suitability of the species reintroduction, the current state and legal protective framework of the habitat, and the levels of environmental awareness in the region. At the end of the interviews, as a mode of conclusion, we read a list of statements concerning: a) several potential effects of an eventual reintroduction programme of *A. ambiguus*; and b) the possibilities of success of the reintroduction of *A. ambiguus* in the area. We asked informants whether they agreed or not with each statement.

Furthermore, we took part in regular local activities and meetings (e.g., indigenous assemblies in Bribrí, working meetings with the reserve board team members, local demonstrations, reintroductions of animals into the wild along with the Jaguar Rescue Center, etc.) where same topics as those included in the semi-structured interviews were discussed. Participant observation involves the researcher establishing rapport in a social setting while removing him or herself from cultural immersion so that they can retain an objective position [47]. This technique allowed us to observe not only the everyday life of the local people in the area (with particular regard to conservation attitudes and values), but also understanding processes within and between institutions involved in the implementation of conservation initiatives, with a special focus on decision-making among stakeholders. Document analysis was also used to gather relevant information through the analysis of key documents (including reports, project plans, maps and environmental evaluation assessments). This analysis provided specific information on the conservation schemes of REGAMA.

2.8. Data Analysis and Statistical Processing

Statistical tests were carried out to validate hypotheses and verify statistical significance. In all cases, a hypothesis test with unknown variance (σ^2) was applied using the *t-statistic* whose distribution is *Student's t-distribution* with $n - 1$ df when $\mu = \mu_0$. The hypothesis tests were performed using the predictive analytics software *PASW Statistics* 17 [48].

3. Results

3.1. Sampling of *D. panamensis* at La Ceiba

A total of 46 specimens of *D. panamensis* were counted, which resulted in a density of 1.1 ind./ha. The distribution of the species was regular for all the sampled area (see **Figure 2**) and the average DBH was 1.51 ± 0.15 m ($n = 46$; $s = 0.504$; $\gamma = 95\%$). This value was significantly higher than 1.24 m ($n = 46$; $t = 3.63$; $P < 0.001$), being 71.7% of the sampled trees potential holders of suitable cavities for *A. ambiguus* nesting.

Cavities were observed in 50.0% of the sampled trees, 47.8% of which had only one cavity. The suitability could only be checked in 11 cavities, 7 of which were considered as suitable for *A. ambiguus* nests. The average DBH of the almond trees with cavities was 1.63 ± 0.15 m ($n = 23$; $s = 0.355$; $\gamma = 95\%$).

Regarding the presence of seeds and seedlings, 41.3% of the counted specimens were surrounded by seeds, whereas 45.7% had seedlings nearby. The percentage of mature almond trees in the reserve was 65.2%.

3.2. Partial Sampling of Other Forage Species

The abundance estimate for the selected forage species is shown in **Table 1**. *I. deltoidea* was the most abundant species in the reserve, followed by *V. koschnyi*.

3.3. Competition/Predation Study

A total of two mammal species and eight bird species were found at the observation point. For reptiles, snakes and ctenosaurs (both nesting predators [49] [50]) were unfortunately ruled out because identification was not possible from the ground.

Even though various mammal species can also act as egg and chick predators (e.g., rats, tayras, felids [45] [49]), only the Central American Spider Monkey, *Ateles geoffroyi* and the White-faced Capuchin, *Cebus capucinus* could be detected (a total of three times during the observation intervals). Toucans (mainly the Keel-billed Toucan, *Ramphastos sulfuratus* and the Chestnut-mandibled Toucan, *R. swainsonii* were observed) are known to

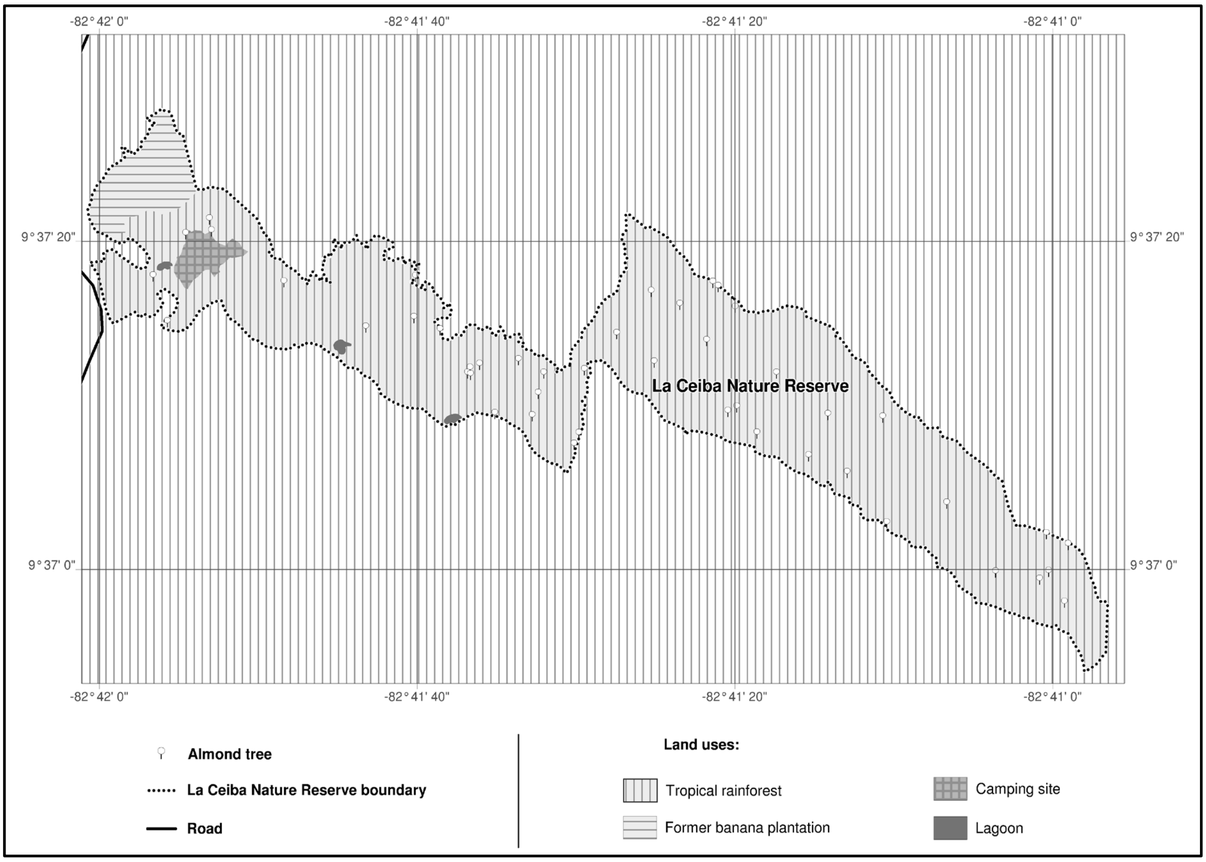

Figure 2. Land use at La Ceiba Nature Reserve along with the number and distribution of *D. panamensis* individuals. Source: own elaboration based on shapefiles previously generated by the managers of the reserve and processed afterwards with MiraMon program. Author: Borrós, M.

Table 1. Results from the random sampling of forage species and the following extrapolation for the entire reserve. Densities for the total surface of the reserve are extrapolated from data collected in the random sampling for each of the four forage species.

Variables	Forage species			
	C. guianensis	*C. megalantha*	*I. deltoidea*	*V. koschnyi*
Total number of individuals in the random ampling	53	29	278	111
Error associated with the total number of individuals	16	11	58	26
Average (ind./plot)	0.17	0.10	0.91	0.37
Standard deviation (*s*)	0.465	0.315	1.685	0.749
Error associated with the sampling	0.052	0.035	0.189	0.084
Total number of individuals for the entire reserve	142	84	761	309
Error associated with the total number of individuals	44	30	158	70
Reserve density (ind./ha)	3.4	2.0	18.1	7.4
Error associated with the reserve density	1.0	0.7	3.8	1.7
Percentage of error for the entire reserve (%)[a]	31	35	21	23

[a.] Average percentage of relative error (%) = 28.

be nest predators of macaws [49]. In connection with competing species, some parrot and toucan species can also nest in the cavities of *D. panamensis*, but neither of them shows any pattern of preference for the tree [51]. The Mealy Amazon, *Amazona farinosa* was found once eating the seeds of *D. panamensis*, but again the species does not show a preferential pattern for it [51].

3.4. Connectivity Study

The contact with 16 farmers and citizens who were interested in the survey resulted in a total of 20 visits to privately-owned properties and communal areas with presence of *D. panamensis*. The sampling in the adjoining areas allowed the registration of 85 almond trees with an average DBH of 1.18 ± 0.15 m ($n = 85$; $s = 0.710$; $\gamma = 95\%$), showing that *D. panamensis* is a frequent species in the South Caribbean forests (see **Figure 3**). Among the total amount of identified almond trees, 57 had a diameter over 1.24 m. The addition of these specimens to the 33 found in the reserve resulted in 90 individuals suitable for the nesting of *A. ambiguus* with an average DBH of 1.68 ± 0.08 m ($n = 90$; $s = 0.396$; $\gamma = 95\%$), a value significantly higher than 1.24 m ($n = 90$; $t = 10.53$; $P < 0.001$). Cavities were observed in 22.4% of the sampled trees, 63.2% of which had only one cavity. Ten over 31 cavities were considered as suitable for *A. ambiguus* nests. The average DBH of the almond trees with cavities was 1.18 ± 0.32 m ($n = 19$; $s = 0.710$; $\gamma = 95\%$).

The results of the cartographic analysis show that a continuum of tropical rainforest of more than 7000 ha exists along the study area and surrounding the reserve, covering 80.28% of the surveyed territory (see **Figure 3**).

3.5. Socio-Cultural Approach to the History of *A. ambiguus* in the Region

The results of the semi-structured interviews suggested an evident conservationist attitude in the Talamanca province, with many positive feedbacks received about the possibilities of reintroduction (see **Table 2**). For example, from our interviews, it was clear that the majority of the informants acknowledged that the reintroduction would be positive for the region (85%), particularly for the development of ecotourism programmes. However, most of the informants also recognized that illegal felling persisted in the area, even if these processes had lowered considerably since the 1990s, when the bulk of the species decline took place. A conservation agent from REGAMA stated "*What if we get the Great Green Macaw reintroduced and it disappears*? *It is not just about liberating the birds*; *it is also a matter of assuring that the population can be sustained over time*". Moreover, 45% of the informants considered current levels of illegal felling hampering the success of an eventual reintroduction in the area. According to 60% of the interviewees, increasingly stronger legal frameworks to protect natural areas and the development of conservation incentives, such as the Payment for Ecosystem Services,

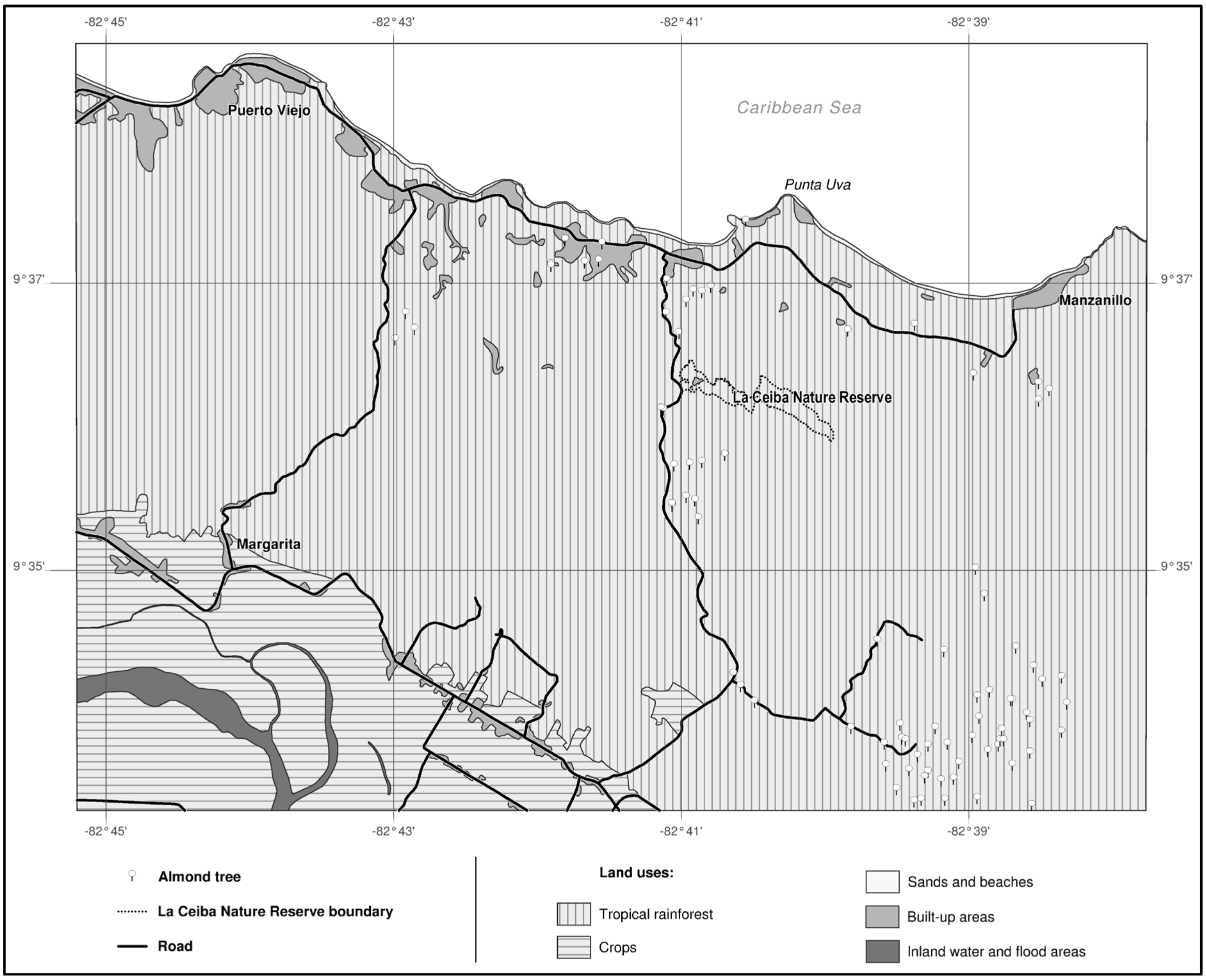

Figure 3. Land use in the study area along with the sampling of *D. panamensis* as a result of the connectivity study. Source: own elaboration based on satellite images from Digital Globe Company (2010) and generated with MiraMon program. Author: Borrós, M.

Table 2. Results from the semi-structured interviews. The table presents the list of statements concerning: a) several potential effects of an eventual reintroduction programme of *A. ambiguus* in the area; and b) the possibilities of success of the reintroduction of *A. ambiguus* in the South Caribbean. Answers are based on informants' own perceptions and experiences.

Question: Do you agree with the idea that:	*Answer* (n = 20)[a]
The reintroduction of *A. ambiguus* would be positive for the region?	85.0
The study area is prepared for the reintroduction of *A. ambiguus*?	65.0
An environmental awareness programme in the region should be carried out prior to the reintroduction of the species?	75.0
Local people show conservation attitudes that would benefit an eventual reintroduction?	60.0
The legal protective framework of the habitat is strong enough to implement the reintroduction?	50.0
The success of the reintroduction could be hampered by the current levels of illegal felling for *D. panamensis*?	45.0

[a.] Cells represent the percentage of informants that agree with the statement.

have strengthened local people's perceptions towards conservation, even if more efforts are evidently needed to improve on this direction. A local leader from Puerto Viejo de Talamanca said "*The reintroduction will surely* *engage local people and this will have a very positive impact for conservation and education in the region*". Additionally, the political stakeholders interviewed demonstrated interest on enforcing the legal status of REGAMA to fight poor management and control over natural resources and improve conservation outcomes, particularly through the development of projects such as a potential *A. ambiguus* reintroduction.

Local informants indicated that *A. ambiguus* was a resident species in the area of study, especially in REGAMA, until one decade ago. The abundance of *D. panamensis* made possible not only its nesting but also its survival. However, from the 1980s, a number of human impacts began to take place, which probably led to the decrease of the species' population in the region. These human impacts were related to the illegal felling of *D. panamensis*, which caused the disappearance of many nests and consequently a direct impact on the reproduction of the population, the killing for pleasure of many individuals of *A. ambiguus* as well as for its meat, appreciated in some localities as San Miguel or Gandoca, and finally the poaching of chicks for further trade and distribution in Europe and North America.

All these impacts led to a reduction in the number of individuals until the year 2000, where only 12 specimens were reported around REGAMA. After few years, a couple of *A. ambiguus* was seen again in the area and its sighting was recorded several times from 2005 in the Ornithological Observatory of the Kèköldi Indigenous Reserve, the villages of San Miguel and Gandoca, and La Ceiba Nature Reserve. In late 2008, one individual of the couple was killed with a firearm by a resident of San Miguel. From that date to 2010 there was only a single specimen in REGAMA (*i.e.* only known South Caribbean population).

4. Discussion

Although documentation on reintroduction processes and outcomes has improved in the last years [52] [53], most of the reintroduction research is nowadays still retrospective. Indeed, the question of determining success in reintroduction has been the subject of inconclusive debate (e.g., [54]), and researchers and conservation managers still lack of adequate understanding on how to determine inherent technical and biological limitations of reintroductions. In this study, we present a methodology to assess the suitability for reintroduction of an endangered species. Identifying the factors responsible for the decline in *A. ambiguus* population is crucial when examining the requirements of the species, as also the disappearance or partial correction of the causes attributed to its extinction in the region, essential for individuals' reestablishment. Besides the ecological considerations, we made a special focus on socio-cultural variables, as there are still meagre works covering local attitudes and concerns towards reintroductions. We believe the approach used here—in concordance with IUCN [6] and Collar [52]—can contribute to the study of parrot reintroductions.

Given the dependence of *A. ambiguus* on *D. panamensis*, the presence and abundance of the tree in the territory can be considered as the principal parameter of habitat quality for the species. According to the categories of rarity proposed by Rabinowitz *et al.* [55], we determined that *D. panamensis* was relatively frequent on a local level. This is based on the comparison between the density found in the reserve (1.1 ind./ha) with the density estimated to the rest of Costa Rica (2.0 ind./ha [56] [57]). Two other relevant aspects must be taken into account: a) the great quantity of fruit produced by *D. panamensis*; and b) the high percentage of mature trees found in the reserve. Both factors are good indicators of the potential of the reserve as food reservoir for the species, being complemented by the presence of other forage species also abundant in the reserve. Regarding the nesting possibilities and considering the number of cavities as well as the diameter of the marked individuals found both in the reserve and in the connectivity study, we can confirm there are appropriate nesting sites in the study area. Because a high percentage of individuals of *D. panamensis* had an average DBH greater than 1.24 m, we deduced that the number of existing cavities is greater than the ones reported in this study. In addition, lack of climbing equipment made not possible to explore other potential nesting sites. Lastly, the distribution of the sampled individuals found in the connectivity study and the observed forest continuity of the surveyed area verify that the presence of *D. panamensis* is frequent in the region. All these factors indicate habitat suitability for *A. ambiguus* not only on a local but also on a large scale. On the other hand, although a few records of competitor and predator species were registered, which would mean little effect on the survival rates of *A. ambiguus*, we acknowledge the predation results might be biased by the fact that some macaw predators could not be included in the study.

The nesting habits of *A. ambiguus*, such as the careful selection of the cavities and the aggregated nesting patterns, are largely unknown [58]. Indeed, the relatively scarce information on the reproductive biology of the species, coupled with the absence of long-term datasets on the former population or the deforestation in the area, made the suitability of a reintroduction difficult to predict. Nevertheless, according to the cartographic analysis, *A. ambiguus* could rely on a surface of up to 7000 ha of reproductive area in the South Caribbean, which would be sufficient for sustaining a viable population [31] as it existed in the past. In a socio-cultural context, the results of the semi-structured interviews evidenced conservationist and positive attitudes towards a possible reintroduction in the area. However, many informants recognized that the causes leading to the decline of the former population of *A. ambiguus* in the region might not have been totally reversed. Even considering that all of them agreed that the situation has clearly improved since the 1990s, on the basis of participant observation, the accumulated information obtained from the interviews and document analysis, we recommend the performance of a programme of corrective measures both prior and synchronously to the reintroduction of the species. These measures would be needed to: a) raise the environmental awareness of the local people; b) prevent illegal felling in the forests of the region; and c) strengthen the legal protective framework of the species habitat. A rigorous and place-specific awareness programme on these directions, to be executed by MINAET and developed in co-operation with the local institutions (e.g., The Ara Project), would give a hypothetical reintroduction an unusual breath and greater chances of success in a context of increasing environmental consciousness. The fact that the local people do possess some institutional assets and count on the pro-active commitment of the political stakeholders of the region provides a valuable basis for an eventual attempt of reintroduction.

A study by Vaughan *et al.* [59] on the conservation of the Scarlet Macaw in the Central Pacific, Costa Rica, showed that collaborative management practices by local stakeholders and governmental authorities had a clearly positive impact on the recovery of wild populations, increasing the reproductive rates. These management practices were coordinated through a local conservation organisation created to establish an environmental education programme as well as nest constructions, networking among stakeholders, and nest protection. We recommend the creation of such an organisation when local authorities face an *A. ambiguus* reintroduction in the South Caribbean, Costa Rica. Educational programmes fostering national pride to promote the conservation of certain species, particularly within limited areas such as Caribbean communities, have demonstrated great success and are a crucial element of reintroduction programmes [11] [60]. Consequently, suitability remains conditional on a series of corrective measures that should be carried out to ensure a successful reintroduction. No conservation results can be achieved without long-term protection of the habitat, local environmental awareness, and a real commitment of policy-makers towards conservation.

5. Conclusion

Increased awareness of reintroduction as a viable conservation option relies directly upon the success of reintroduction programs and this can only be improved through greater emphasis on fieldwork-based empirical research. Despite the importance of the topic for conservation research, the absence of canonical standards on pursuing analyses of reintroduction suitability hampers the possibilities of successfully achieving such goal. Moreover, the frequent knowledge lacunae on individual species' needs and biological requirements (e.g., the still unanswered reproductive biology of *A. ambiguus*) compel researchers to refine our approaches to empirically assess reintroduction viability. Along these lines, the methodology applied in the present work, integrating both ecological and socio-cultural factors into viability analysis, can be considered as a potentially useful tool to ensure the success of reintroduction programs and therefore, it can set the foundations of further investigations to be pursued in the field of conservation science.

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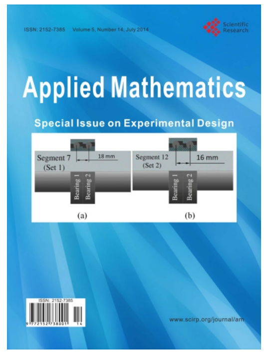
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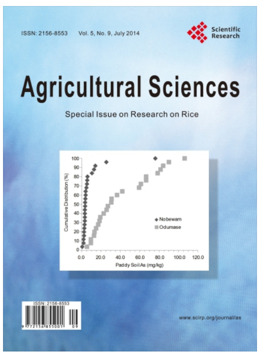
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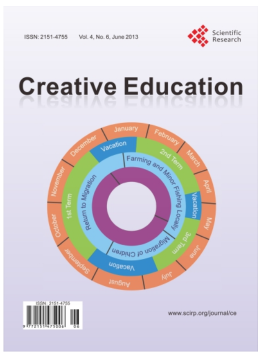
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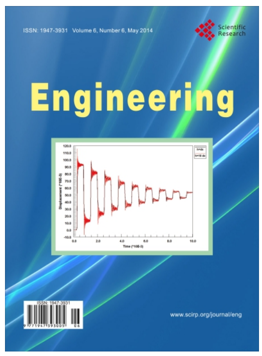
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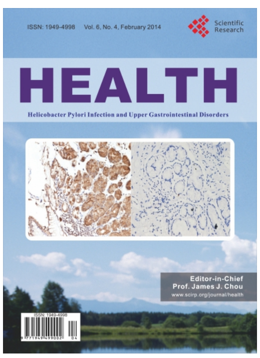
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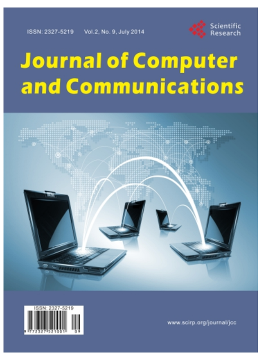
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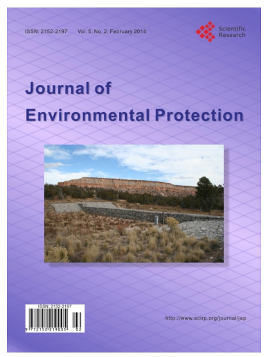
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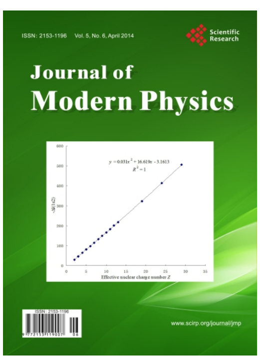
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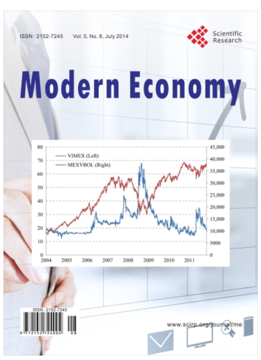
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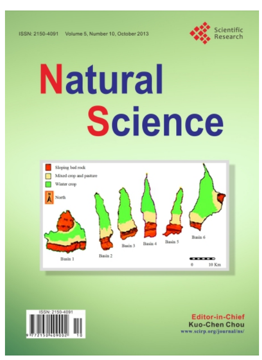
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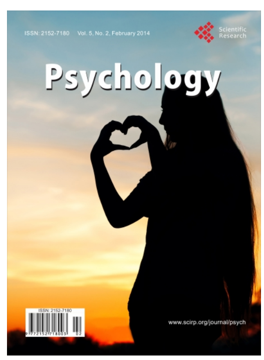
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