Range-Wide Population Assessment of the Endangered Yellow-Naped Amazon (*Amazona auropalliata*)

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Abstract: Yellow-naped amazons, *Amazona auropalliata*, have experienced a dramatic population decline due to persistent habitat loss and poaching. In 2017, BirdLife International changed the species' status from threatened to endangered and estimated that between 10,000 and 50,000 individuals remained in the wild. An accurate estimate of the number of remaining wild individuals is critical to implementing effective conservation plans. Wright et al. conducted roost count surveys in Costa Rica and Nicaragua during 2016 and published their data in 2019; however, no population data exists for the rest of the range. We conducted roost counts at 28 sites across Mexico, Guatemala, and the Bay Islands in Roatan during 2018 and 2019. We counted 679 birds and combined our data with the published Wright et al. (2019) data for a total of 2361 wild yellow-naped amazons observed across the species' range. There were fewer roosts detected in the northern region of the range than in the southern region. We found that roosts were most likely to occur in built-up rural and pasture habitat, with 71% found within 100 m of human habitation. Our results illustrate the need for immediate conservation action to mitigate decline, such as enforced legal action against poaching, nest guarding, and increased community education efforts.

Keywords: eBird; endangered species; parrot conservation; population survey; roost counts

1. Introduction

The rapid collection of population and demographic data on wild populations of endangered species has become increasingly imperative in the face of the modern mass extinction. It is estimated that in the upcoming decades we will see drastic population declines which could result in the extinction of 54% of all species due to global warming, habitat loss caused by agricultural expansion, deforestation, unregulated grazing, urbanization, and other human activities [1,2]. Human alterations to the environment have already resulted in a substantial proportion of habitat types becoming rarer and more fragmented. Fragmentation of a species' habitat minimizes the opportunity for affected individuals to breed, forage, and interact socially with conspecifics, which can result in population decline and increases the likelihood of local extinction [3].

Seasonally dry tropical forest habitat, which once covered major swaths of Mesoamerica, has suffered significant losses due to deforestation and increased agricultural production [4,5]. This habitat type is home to a substantial proportion of the world's diversity, especially with regard to bats and birds; however, in the year 2000, only 30% of the original extent of this land cover remained in Central America [5]. As tropical dry forests become smaller and more fragmented, remaining patches sustain fewer residents and other individuals are pushed into human-altered habitat such as pastures and rural villages, where they are often exposed to human interaction. This change puts

threatened and endangered individuals at a higher risk for events which can exacerbate population decline, such as direct persecution and poaching [4,6,7].

Parrots and cockatoos of the order Psittaciformes have been experiencing an especially rapid decline for the past four decades, largely due to a combination of anthropogenic factors (e.g., poaching for the pet trade, habitat destruction, introduction of exotic species, and direct persecution) and biological ones (e.g., disease, lack of breeding individuals) [7,8]. As a result, they are one of the most threatened avian orders, with over 28% of species classified as vulnerable, endangered, or critically endangered and an additional 14% classified as near threatened by the International Union for the Conservation of Nature (IUCN) [9]. Berkunsky et al. [7] found that 38% of 192 neotropical parrot populations were experiencing decline, primarily due to agricultural activity and poaching for the pet trade. To combat these declines, basic population data are necessary to allow biologists to craft management plans and determine where to most effectively concentrate management actions. However, population data is time-consuming and costly to collect from many parrot species due to their generally high mobility and large ranges [10]. Management actions, including captive breeding, reintroduction programs, or nest protection programs, can cost organizations millions of dollars, and therefore should be targeted to key areas [11].

Yellow-naped amazons, *Amazona auropalliata*, are large, charismatic parrots that are native to Mesoamerica, occupying lowland mangrove and tropical dry forest habitat from southern Mexico to northern Costa Rica along both the Pacific and Caribbean coasts [12] (Figure 1). In 2017 the IUCN declared yellow-naped amazons endangered [12]. This status change was supported in part by data Wright et al. collected in 2016 and published in 2019 [13]. The study showed that populations sampled in Costa Rica had experienced a mean decline of 54% in only 11 years. Additionally, long-term nest monitoring of this species indicated that only 11% of yellow-naped amazon young successfully fledged the nest, and the highest cause of mortality was due to poaching for the pet trade [14,15]. Yellow-naped amazons exhibit fission-fusion flock patterns throughout the day and sleep in temporally stable, communal roosts [16]. Long-term monitoring of populations via roost counts in Costa Rica and Nicaragua have shown that yellow-naped amazons are particularly tolerant of human-disturbed habitat, which means that fragmentation increases the risk of poaching or persecution for this species [13]. An informal survey of Costa Rican inhabitants indicated overall compassion for the species, but also a lack of fear regarding the legal repercussions of illegal poaching [14,17]. While periodic monitoring of populations of yellow-naped amazons in the southern region of the range has demonstrated an ongoing decline, at present there is only fragmentary data available regarding the status of populations in the northern regions of the range [13].

Counting wild parrot populations is challenging but essential for understanding population trends of species on both regional and range-wide scales. Historically, population data is collected via traditional field-based counts which are a reliable method to determine the number of individuals in an area and evaluate population fluctuations due to immigration, emigration, and mortality events [18]. Publications using roost counts have generally been successful in estimating the number of parrots in a particular area or region; however, roost counts also present many challenges due to required time and funding, detectability of animals, and unpredictable roost use in some species [19,20]. Other forms of field counts such as transects and point counts are less commonly used on wild parrots due to their highly mobile lifestyles, sparse distribution, and large home ranges, and their general wariness around humans, which makes them difficult to count [10] (but see Joyner's transect guide [21]). Thus, scientists have been seeking alternative ways to collect population data on various species in the wild.
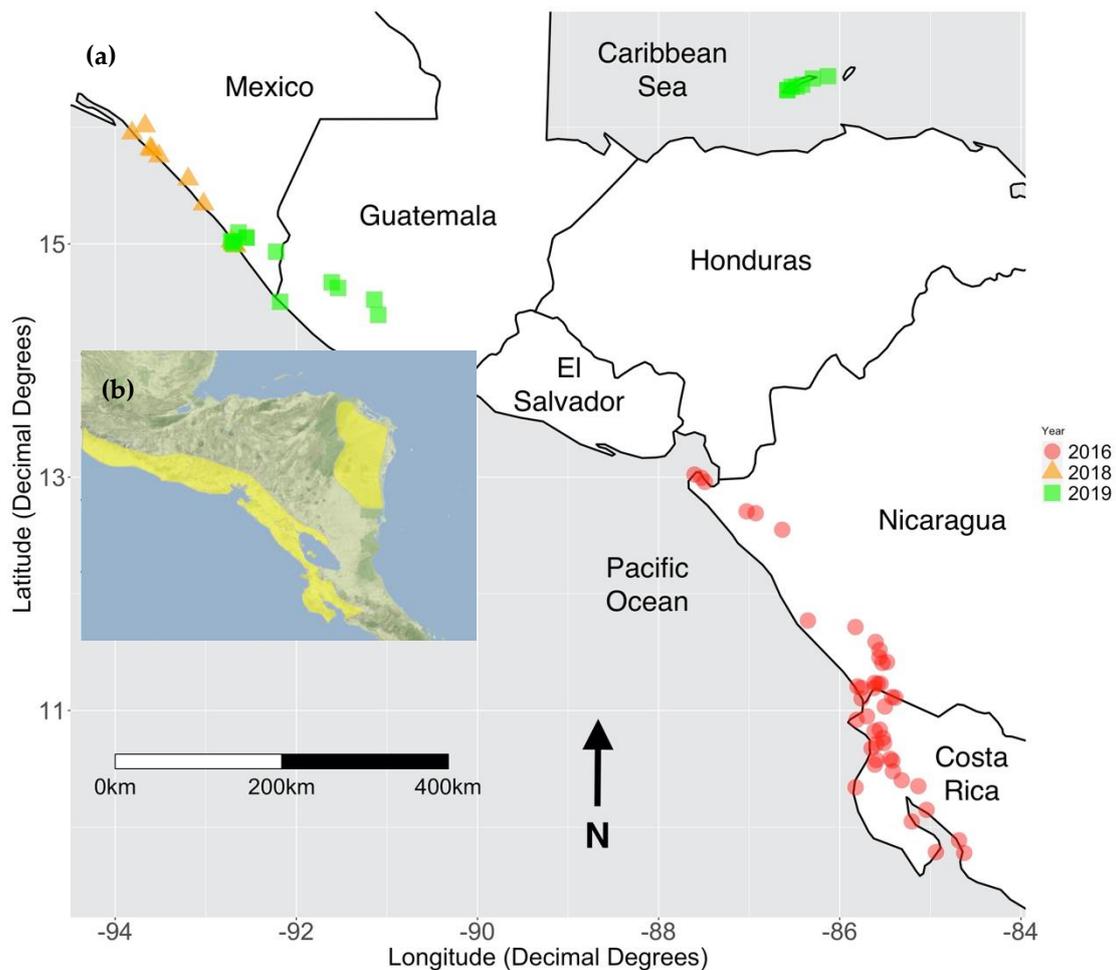
Figure 1. (**a**) A map of all sites sampled during 2018 and 2019. Sites from the Wright et al. study [13] conducted in 2016 are also included. The color and shape of each point corresponds to the year the site was sampled. (**b**) A species range polygon for the yellow-naped amazon provided by BirdLife [22].

One such alternative method is the use of volunteer-based data collection. For example, during the yearly American Breeding Bird Survey (ABBS) hosted by the United States Geological Survey and Canadian Wildlife Service, volunteers across North America collect visual and aural data on bird species encountered in various areas [23]. Another popular example is the online, open-access database eBird (www.eBird.org), which displays observations reported by birdwatchers, including information on species, geographic location, and date of observation. eBird has been used previously to assess species' presence and diversity, migration patterns, distribution, and in some cases, general population trends [23]. However, it should be noted that eBird reports do not follow a standardized protocol and individuals submitting reports are untrained, therefore the data are not standardized in the same way as structured field counts [24]. This presents a dilemma for conservationists who wish to use citizen science as a tool for tracking population trends. In fact, while Walker and Taylor [25] found that eBird reports closely followed those of the ABBS, Kamp et al. [24] found that citizen science databases did not accurately indicate the well-known decline of several common bird species in Denmark. Furthermore, there have been no such comparisons for tropical species like the yellow-naped amazon.

We aimed to estimate the number of remaining yellow-naped amazon individuals in the wild across the species' Mesoamerican range using traditional roost counts and, for comparison, eBird reports from the same months and years. We performed roost counts in the northern range of the yellow-naped amazon during 2018 and 2019 and combined these data with those collected by Wright et al. [13] in 2016 using the same methodology. We also recorded the distance to human habitation, habitat

type, and elevation at each site and combined these results with previously collected data published by Wright et al. [13]. We assessed the difference between our field counts of yellow-naped amazons with reports on eBird over the same period of time. Finally, for each region we used habitat type and number of individuals observed at communal roosts to determine locations which should be considered conservation priorities for this species.

2. Materials and Methods

We conducted population counts of the yellow-naped amazon in Mexico in 2018 and in Mexico, Guatemala, and the Bay Islands, Honduras in 2019. Specific sites were chosen using a site selection process, which entailed a detailed examination of unsampled areas within the range to identify locations in which yellow-naped amazons were most likely to occur. Multiple sources were utilized in this process, including detailed consultation with local experts and other conservationists, and historical reports of the species on www.eBird.org. Areas where parrots had been reported within the past two years were selected as priority sites during the field season and were scouted thoroughly. We also explored some historically populated areas where this species was reported to no longer exist.

Roost counts were conducted at each site using the same protocol as Wright et al. [13] to maximize data compatibility between the two studies. Counts took place in the morning beginning before dawn, and in the evening prior to sunset, and were done in both the morning and evening at each site when time and weather permitted. Counts were performed during June and July, outside the species breeding period. No single site was counted more than twice in one year. Observers were stationed within each site in a manner which allowed maximum visibility of the parrots' flight path. Each observer was equipped with binoculars, a notepad, a compass, a GPS device, and a watch. Observers recorded the number of birds flying into or out of the roost, the direction of flight, time of day, and the location and altitude of the roost using GPS. In some cases, roosts were difficult or even impossible to reach, therefore GPS location was taken as close to the roost as possible and a thorough description of the roost itself was recorded. In the event that multiple observers counted at the same site and the number of birds differed between observers, the highest number was used. Roost behavior was noted even if the physical roost could not be directly observed. This includes groups of parrots consistently flying from the same direction during and shortly after dawn, or groups of parrots flying in the same direction or toward the same area during or shortly before dusk. In addition to direct counts, we made estimations of roost size in which we supplemented our visual observations with aural observations; we separately report both counts and estimates for each roost (see Table 1). At each roost site for 2018 and 2019, the dominant habitat type was classified as one of five habitat types: mangrove, tropical dry forest, tropical pine, agricultural, or built-up rural. These types were categorized by: (i) the presence of trees and shrubs flooded with brackish or saltwater along coasts and waterways (mangrove); (ii) dense swaths of tall trees like *Ceiba pentandra* (ceiba), *Hura crepitans* (jabillo), and *Enterolobium cyclocarpum* (guanacaste) (tropical dry forest); (iii) the presence of open fields with some tree stands and low-intensity agricultural areas (pasture/agriculture); (iv) stands dominated by *Pinus caribaea* stands (tropical pine); or (v) human-modified landscape that included features such as homes, small buildings, schools, and roads (built-up rural). We combined the 2018 and 2019 datasets with unpublished roost habitat data from the sites counted by Wright and Dahlin in 2016. We also recorded the proximity of human habitation by recording whether roosts were within 100 m of human infrastructure.

Table 1. A list of data collected from Mexico, Guatemala, and Honduras during 2018 and 2019.

Country	Year	Site Name	Latitude	Longitude	Roost Behavior	Roost Observed	Roost Count	Roost Estimate	eBird Count	Habitat Type
Mexico	2018	Aztlan Site 3	14°58.841′	92°40.158′	Yes	Yes	33	-	24	Pasture/Agriculture
Mexico	2018	Aztlan Site 2	14°59.596′	92°40.731′	Yes	No	38	-	24	Pasture/Agriculture
Mexico	2018	Aztlan Site 1	15°0.045′	92°41.431′	Yes	No	51	-	24	Pasture/Agriculture
Mexico	2018	Las Brisas de Hueyate	15°1.422′	92°43.166′	Yes	No	113	114	0	Mangrove
Mexico	2018	Manguito	15°45.18′	93°30.99′	No	No	0	-	0	Mangrove
Mexico	2018	Rancho el Piñon	16°0.667′	93°40.2′	No	No	2	4	0	Built-up rural
Mexico	2018	Ponte Duro	15°48.485′	93°35.728′	No	No	3	4	3	Built-up rural
Mexico	2018	Ponte Duro Mangroves	15°49.063′	93°36.816′	Yes	No	16	-	8	Mangrove
Mexico	2018	Puerto Arista	15°56.98′	93°48.871′	No	No	0	-	0	Built-up rural
Mexico	2018	Roberto Barrios	15°20.435′	93°1.412′	Yes	Yes	23	-	4	Pasture/Agriculture
Mexico	2018	Salto de Agua	15°33.326′	93°11.633′	Yes	Yes	12	-	33	Pasture/Agriculture
Mexico	2019	Aztlan Town Roost	15°1.003′	92°42.278′	Yes	Yes	33	74	19	Built-up rural
Mexico	2019	Las Palmas	14°59.943′	92°41.455′	Yes	No	39	40	0	Built-up rural
Mexico	2019	Huixtla	15°3.233′	92°32.991′	No	No	0	-	41	Built-up rural
Mexico	2019	Hidalgo	15°5.872′	92°38.266′	No	No	0	-	0	Built-up rural
Mexico	2019	Tapachula	14°55.965′	92°13.33′	No	No	0	-	0	Built-up rural
Guatemala	2019	Tilapa	14°30.18′	92°10.753′	No	No	0	-	8	Built-up rural
Guatemala	2019	San Martín Zapotitlan	14°37.303′	91°32.358′	No	No	0	-	3	Built-up rural
Guatemala	2019	Finca Patrocinio	14°40.221′	91°36.538′	No	No	5	10	2	Tropical dry
Guatemala	2019	Los Tarrales	14°31.328′	91°8.34′	No	No	3	8	9	Tropical dry
Guatemala	2019	Pineapple Plantation	14°23.458′	91°5.732′	Yes	No	8	12	43	Pasture/Agriculture
Honduras	2019	Sandy Bay	16°19.133′	86°34.716′	No	No	22	-	55	Built-up rural
Honduras	2019	Guava Grove	16°18.985′	86°34.701′	Yes	Yes	20	24	4	Pasture/Agriculture
Honduras	2019	Mud Hole	16°20.81′	86°31.843′	No	No	0	-	0	Built-up rural
Honduras	2019	Parrot Tree	16°21.866′	86°24.851′	No	No	0	-	0	Built-up rural
Honduras	2019	Los Fuertes	16°20.913′	86°28.481′	No	No	0	-	0	Built-up rural
Honduras	2019	Undisclosed	–	–	Yes	No	248	266	0	Tropical dry
Honduras	2019	Port Royal National Park	16°25.083′	86°17.8′	Yes	No	10	-	10	Tropical pine forest

The roost count results were summed at both the country and range-wide levels to provide a minimum count of yellow-naped amazons per country and to assess the species population as a whole. This was accomplished by combining survey data from Costa Rica and Nicaragua published by Wright et al. [13] with the data we collected in 2018 and 2019. When making these totals we removed one of two repeat counts at two sites in Mexico during 2018/2019. We compared these data to reports of yellow-naped amazon sightings on www.eBird.org and used a paired t-test to assess whether the difference between the two totals was significant. We then used a Spearman's rank correlation to evaluate the relationship between eBird reports and roost count data. To maximize comparability, we only counted eBird reports that were located within 5 km of the roost GPS location that we recorded in the field.

We tested for differences in mean roost size between countries using a Kruskal-Wallis test, due to the unequal variances present in the data. We compared the sizes of roosts within 100 m and farther than 100 m from human habitat by using Welch's two-sample t-test, which accounts for unequal variances. We tested for an association between roost size and elevation using a Spearman's rank correlation. All means are listed ± SD, and all alpha values of significance were $p < 0.05$.

3. Results

3.1. Roost Count Results

Twenty-eight roost counts were completed within the northern portion of the yellow-naped amazon range during 2018 and 2019 (Figure 1), during which our team counted 679 yellow-naped amazons. Birds were observed at 18 of the 28 sites, and only three of those had more than 50 birds counted (Figure 2). Eleven sites were sampled in Chiapas, Mexico during 2018, and five sites were sampled in Mexico during 2019, with a total of 363 birds observed in Mexico. In 2019 in Guatemala, 16 birds were counted within five sites; on the island of Roatán, Honduras, we counted 52 birds within six sites, and we counted 248 birds at a private, undisclosed location in the Bay Islands (see Table 1). Roosts in Guatemala were no larger than eight birds, and on Roatan, the largest roost was 22 birds. Previously Wright et al. [13] reported surveying 25 sites in Costa Rica, only four of which had no parrot sightings. They counted 990 individuals across the remaining 21 sites. In the same study, Wright et al. surveyed 19 areas in Nicaragua, of which two had no observations of yellow-naped amazons, and 692 parrots were reported [13]. To summarize, in Mexico, 363 yellow-naped amazons were observed, while 16 were seen in Guatemala, and 300 were observed across the Bay Islands. Wright et al. [13] reported 692 parrots in Nicaragua and 990 in Costa Rica. Across these two complementary studies, a total of 2361 yellow-naped amazons were counted across the range. Using the combined dataset, the Kruskal-Wallis test did not detect any significant differences in median roost size between the countries we surveyed in the number of yellow-naped amazons observed (chi-squared = 6.8985, df = 4, $p = 0.141$).

3.2. Estimated Differences between Traditional Roost Counts and eBird Database Reports

We combined our roost count data with previously published roost count data from Costa Rica and Nicaragua collected with the same methodology by Wright et al. [13]. This added 44 sites to our data, for a total of 72 sites sampled across the yellow-naped amazon range. We found a significant relationship between eBird and roost count data ($R_s = 0.369$, $p = 0.00143$). There was, however, a consistent difference between counts obtained with the two approaches, with the number of birds counted using roost counts (33.0 ± 55.3) significantly higher than those from eBird reports (16.5 ± 35.3) for submissions within 5 km the corresponding roost count location (N = 72, t = 2.6061, $p = 0.011$).
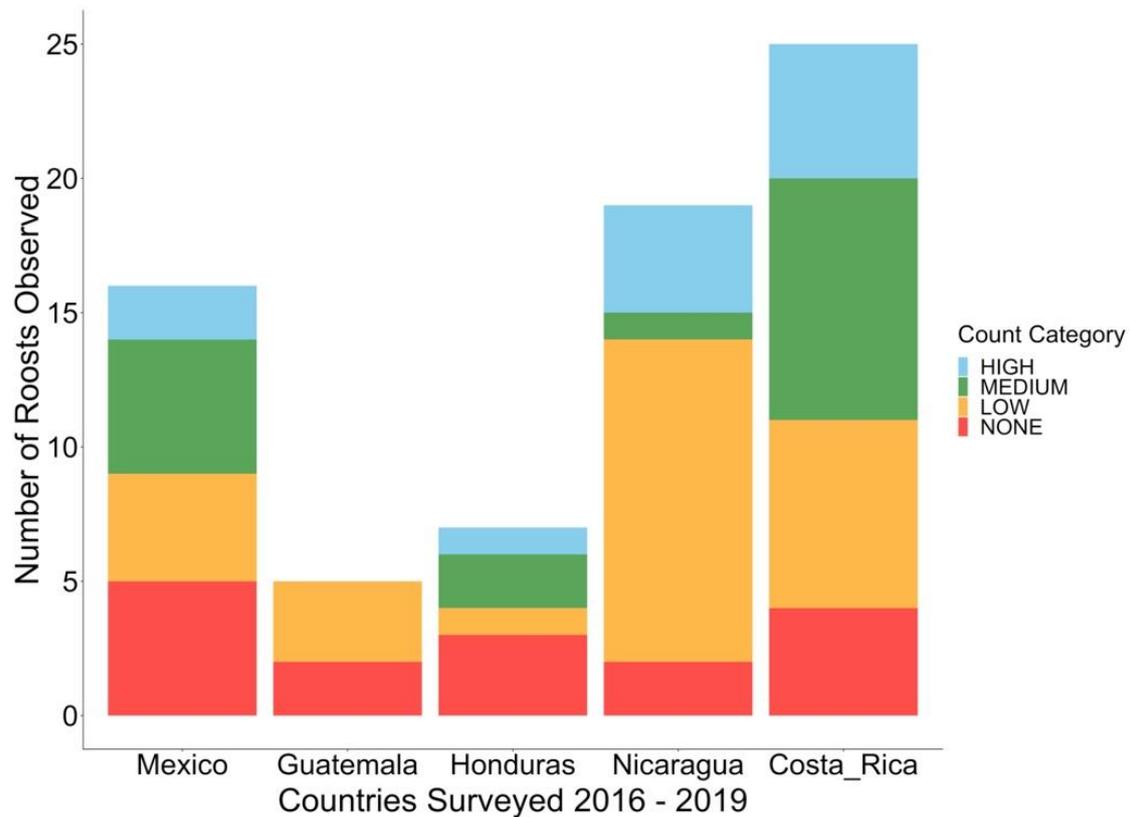
Figure 2. The number of none, low, medium, and high roosts in each country. Roosts were assigned a count category based on the number of birds present. None = 0 birds counted at the roost, low = 1–20 birds, medium = 21–50 birds, and high = 51+ birds.

3.3. Roost Characteristics

Across the entire range, we found a significant difference between the size of roosts within 100 m of human habitation and outside 100 m of human habitation (t = −2.89, df = 44.725, p = 0.006). Roosts within 100 m of human habitation were larger on average (47.18 ± 63.31 versus 14.81 ± 16.69); however, using only the 2018 and 2019 data from the northern range, we were not able to find a significant difference between roost size within and outside 100 m of human habitation (t = −0.217, df = 25.075, p = 0.83). We categorized all roost sites by dominant habitat type and found that the preferred types were built-up rural (35% of roosts) and pasture (31% of roosts) (Figure 3). Some roosts were located on the edge of intensive agricultural fields such as pineapple plantations, however no roosts were located within any high-intensity agricultural areas (Supplementary Table S1). Additionally, we found a weak negative association between roost size and elevation of roosts using a Spearman's rank test (r_s = 0.25, N = 72, p = 0.036). With few exceptions, roosts surveyed in 2018 and 2019 consistently occurred below 300 m elevation (5 of 28 roosts, 82% below 300 m).
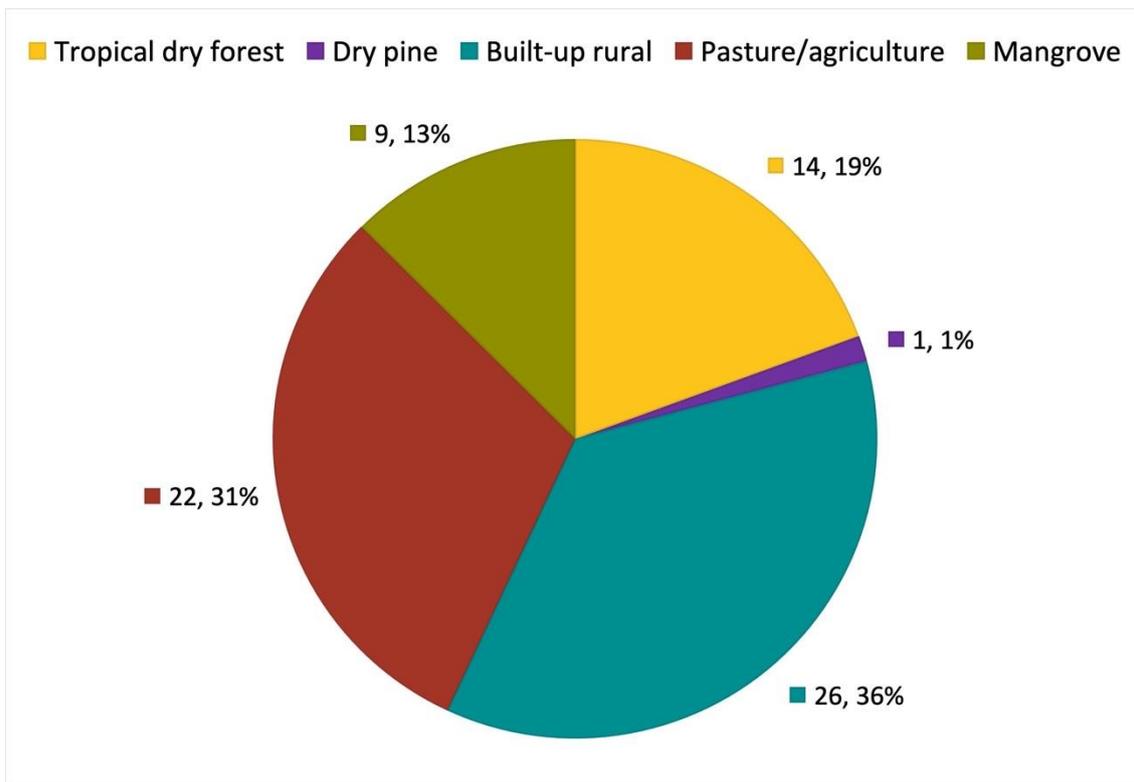
Figure 3. The proportion of yellow-naped amazon roosts in each of six habitat types (N = 72).

4. Discussion

Yellow-naped amazons have experienced a dramatic decline across their range for several decades due to habitat fragmentation, land alteration, and most persistently, poaching for the pet trade [13]. Long-term studies, however, have only been conducted in the southern portion of this species' range, despite evidence that the same threats of unregulated capture of the pet trade and loss of habitat were present in the northern portion [8,26]. In 2017, a report published by BirdLife International on the yellow-naped amazon estimated there may be less than 10,000 remaining individuals in the wild, but acknowledged great uncertainty regarding populations in the northern part of the range. This uncertainty has presented a major challenge to conservationists hoping to implement effective range-wide management strategies.

4.1. Range-Wide Population Estimates for the Yellow-Naped Amazon

Our study is the first of which we are aware to execute a range-wide population estimate for the yellow-naped amazon. We performed roost counts at 28 sites in Mexico, Guatemala, and Honduras, and counted a total of 679 birds between 2018 and 2019. Of the 28 sites we sampled, 10 were recorded as having no parrots at all. For comparison, Wright et al. [13] counted 1682 birds in Costa Rica and Nicaragua in 2016, with only 6 out of 44 sites having no birds. In total, only 2361 yellow-naped amazons have been observed across their Mesoamerican range between these two surveys conducted from 2016 to 2019 with similar methods and overlapping personnel. Our results, combined with those of Wright et al. [13], provide a better estimate of the global population of this iconic species and reinforce the conclusion that it has experienced a drastic population decline.

The results for our range-wide survey have indicated that there exist several regions which should be given special consideration as high conservation priorities. In the northern portion of the species range these include the Reserva de la Biosfera la Encrucijada, Mexico and the Bay Islands in Honduras. The Reserva de la Biosfera la Encrucijada was the most prominently populated region of Mexico,

with several roosts located in the southern part of the reserve. Of the 2361 birds counted across the range, approximately 15% of individuals were located in Reserva de la Biosfera la Encrucijada. The Bay Islands contained relatively few roosts, with 83% of birds there concentrated in one roost locale. We identified several locations that should be prioritized in the Southern part of the range, including the Island of Ometepe with roost sites Peña Inculta, Mérida, and Tichana in Nicaragua. Costa Rica as a whole still has 13 sites with more than 30 birds counted or estimated, and thus strong conservation measures should be undertaken throughout this country. Two sites in particular with over 100 birds each should be prioritized; they are Cuajiniquil and Finca Charlie Red [13].

Logistical constraints prevented us from surveying all of the yellow-naped amazon range. We were unable to survey El Salvador, as well as regions within southeast Honduras and northeast Nicaragua along the Caribbean coast. Anecdotal evidence suggests that El Salvador has fewer than 100 remaining individuals (Nestor Herrera, pers. comm.). Joyner's transect guide details counts from the last several years in Honduras. Her team counted 115 yellow-naped amazons in northern Honduras during 2015, 94 birds in Chismuyu Bay in 2017, and nearly 500 on Guanaja Island in 2018, emphasizing the importance of the Honduras Bay Islands for this species [21]. Wiedenfeld, Molina, Hille, and López conducted counts throughout the Caribbean regions of Nicaragua during 2013 and observed 73 yellow-naped amazons (Martín Lezama, pers. comm.).

4.2. Threats to Populations

Regions within the yellow-naped amazon range in which no birds were observed have typically experienced heavy human modification through agriculture or logging. Increased agricultural production has been influencing regions of Central America for the past several decades, and many areas of suitable habitat in Costa Rica and Nicaragua have been converted into high-intensity crop sites for export products such as sugar cane, rice, oil palm, and pineapples [27,28]. These landscapes lack tree stands used by parrots for foraging and roosting [13]. Logging of trees removes large portions of suitable habitat and creates or exacerbates already-existing fragmentation, which puts species like the yellow-naped amazon at a higher risk of exposure to humans. Humans may encourage contact with parrot populations by providing them with food and water [29]. Poaching of yellow-naped amazons removes individuals with future breeding potential and has extirpated some populations. The surveys our team conducted in the northern part of the range mirror these observations. In the western San Marcos Department of Guatemala, local inhabitants reported historical populations of yellow-napes, stating that at one time suburban areas around Aldea El Chico were more densely vegetated and home to a variety of birds, but as a result of landscape changes for agriculture and housing structures this is no longer the case (Dupin, pers. obs.). Historical submissions for sightings of yellow-naped amazons on eBird support this account, although sightings in these locations were only ever of a few birds (www.eBird.com). North of Retalhuleu in Guatemala, there exists plentiful amounts of suitable habitat, yet our team was unable to observe any birds, with the exception of 5 birds flying overhead near Finca Patrocinio. Our team's conversations with local residents revealed that low population numbers of yellow-naped amazons may be a result of historically high levels of poaching within the region, and that there still exists a market for this species (MKD, unpublished data). Yellow-naped amazons are especially popular because of their remarkable vocal mimicry skills and beautiful color.

4.3. The Utility of Citizen Science Approaches to Monitoring Populations

The perceived usefulness and popularity of citizen science databases in collecting population data [23,30–32] motivated us to examine the utility of the eBird database for conducting a population census of the yellow-naped amazon. We compared our roost count data to the reports of yellow-naped amazon sightings on the citizen science database eBird. While we did detect a statistically significant relationship between these two counts, this relationship was weak and there was often a substantial disparity between the two methods in the number of individuals detected. Our standardized roost counts consistently detected more birds than did the eBird reports for the same sites. It should be noted

that eBird reports for yellow-naped amazon sightings did not provide the time of day during which observations took place. Thus, this discrepancy may be attributed to eBird users counting daytime foraging groups, which tend to be smaller, in addition to the occasional roost. Although eBird has been recognized as a useful tool for fine-scale mapping and tracking temporal changes in the distribution patterns of some species [33], our findings highlight the limitations of this approach for population estimates of an endangered species, particularly in developing countries of Central America where reporting intensity may be lower. This problem may be exacerbated by several factors exhibited by the yellow-naped amazon: they are rare, they use dense mangrove and forested habitat, they range widely, they are quiet for most of the day while foraging, and roost in very specific, sometimes inaccessible locations. Thus, knowledge of their roosting locales is important for complete censusing of populations.

An important bias to consider regarding eBird is that reports can be created and submitted by anyone who creates an account through the website, which introduces the potential for reporting error in submissions made by less experienced birders. A 2016 study showed that a citizen science database in Denmark failed to indicate the decline of several common bird species, primarily due to the inexperience of observers in bird identification or lack of standardized protocols [24]. We also noticed a pattern of inaccurate species identification on eBird. For example, when investigating eBird reports of yellow-naped amazons in the field, we would often instead find flocks of the sympatric white-fronted amazon, *Amazona albifrons*, whose similar body coloration and conformation often led to confusion by local inhabitants (Dupin, pers. obs.) and possibly birdwatchers as well. Thus, we do not consider this approach for collecting citizen science data to be an accurate estimator for endangered species such as the yellow-naped amazon.

One alternative citizen science approach which we believe has the potential to aid in the conservation of various parrot species is the long-term monitoring of populations across the range via minimally trained volunteers. The African-Eurasian Waterbird Census and the Portuguese Society for the Study of Birds are just two examples of successful programs which have incorporated the long-term monitoring of one or more species using volunteers [34,35]. In 2019, we developed the Mesoamerican Parrot Census Network for the yellow-naped amazon (https://parrotcensus.com) with the goal of joining together conservationists, researchers, and interested members of the general public in the common goal of preventing species extinction. Through this network, we aim to collect long-term population data on the yellow-naped amazon in the form of regular roost counts using a standardized protocol.

4.4. Implications for Conservation and Management

In 2017, BirdLife International estimated that there remained 10,000–50,000 yellow-naped amazons remaining in the wild, based on available data [12]. Our team counted less than 3000 scattered among fragmented habitat in our range-wide survey, which illustrates the need for immediate action to mitigate this species' decline. Our survey has shown that in order to ensure the success of the yellow-naped amazon, strategic and targeted conservation plans should be implemented immediately and focused in areas where there still remain healthy populations and suitable habitat. It is our opinion that these efforts should focus primarily on in situ conservation efforts such as habitat protection, enforcement of poaching repercussions, nest guarding, and gaining an improved understanding of population distributions and movements throughout the range. The blue-throated macaw, *Ara glaucogularis*, is a recent example of a species facing extinction that has begun to reverse its decline with the implementation and maintenance of in situ conservation measures [36–38]. An additional critical approach is enhancing community education and involvement through local pride [36]. Dahlin et al. [14] also write about their use of education programs as an added measure to teach children about why parrots are important [14,39]; similar programs have been implemented with the scarlet macaw, *Ara macao*, in Costa Rica [37]. More effort to promote eco-tourism would provide economic opportunities to members of the local community while bringing public attention to diverse

and endangered wildlife. Ecotourism measures were also suggested as conservation measures for the declining blue-throated macaw populations in the early 2000s [36]. Pires advocates for situational crime prevention, improved policy and legislation with organizations such as CITES, and eco-tourism focusing on endangered and threatened species as the most effective approach to eliminating the threat of poaching [40,41]. Finally, there are substantial numbers of yellow-naped amazons held as pets within the countries of Mesoamerica, and programs aimed at rehabilitation, captive breeding and eventually reintroduction, although resource-intensive, should be considered.

We believe that our results, in conjunction with those of Wright et al. [13], and the recent up-listing of the yellow-naped amazon to endangered status, highlight the need for immediate conservation action for this species. We recommend that conservation funding and planning should be focused on the areas that we have designated as priorities in an effort to focus limited time and funding on healthy, breeding populations. Increased efforts toward habitat and nest protection should also be considered, such as with camera traps and provision of protected artificial nests [38,39]. Surveys should be conducted routinely with the remaining wild populations of this species to monitor and manage its decline. Historically populated regions of eastern Honduras and Nicaragua should also be investigated and routinely monitored. By implementing these strategies and following examples of programs that have aided in the recovery and success of other endangered parrot species, we believe that we can reverse the trend of population decline in the yellow-naped amazon.

Supplementary Materials: The following are available online at http://www.mdpi.com/1424-2818/12/10/377/s1, Table S1: All sites surveyed for yellow-naped amazons with each site's habitat type.

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