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AVIFAUNA OF THE MACHE CHINDUL ECOLOGICAL RESERVE, NORTHWEST ECUADOR

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Resumen. – Avifauna de la Reserva Ecológica Mache Chindul, noroeste de Ecuador. – Reportamos la avifauna de la Reserva Ecológica Mache Chindul (REMACH) de 120.000 ha al noroeste de Ecuador. El área de estudio se encuentra en una zona de transición poco estudiada entre tres grandes regiones biogeográficas neotropicales – el Chocó, Tumbes y los Andes Tropicales – cada una de las cuales contiene una excepcional diversidad y endemismo de aves y otros organismos. Reunimos datos desde 1998–99 y 2004–11 en la Estación Biológica Bilsa (una reserva privada de 3500 hectáreas), en varias fincas, fragmentos forestales y comunidades distribuidas a través de la parte central de REMACH. En estos sitios utilizamos observaciones (registros auditivos y visuales), grabaciones de audio, redes de niebla, puntos de conteo y fotografías. Se registraron 360 especies de aves (263 géneros, 51 familias), incluyendo 57 especies amenazadas de la Lista Roja de Ecuador, 14 de las cuales también se encuentran amenazadas a nivel mundial; 23 especies endémicas 'rango restringido' (15 y 8 Tumbes y Chocó), y 16 especies migratorias. Se registró evidencia reproductiva en 130 especies, y documentamos dos picos bien definidos de reproducción, los que corresponden a las estaciones seca y lluviosa. Nuestros resultados proponen que REMACH representa una zona importante de transición entre las zonas biogeográficas del Chocó y Tumbes, por lo tal debe ser considerada una prioridad para la conservación de la avifauna y otros taxones.

Abstract. – We report on the avifauna of the 120,000 ha Mache Chindul Ecological Reserve (REMACH), northwest Ecuador. The study area is located in a poorly studied transition zone between three major Neotropical biogeographic regions - the Chocó, Tumbesian, and Tropical Andes - each of which contains exceptional diversity and endemism in birds and other organisms. We collected data from 1998–99 and 2004–11 from the Bilsa Biological Station (a 3500 ha private reserve) and several farms, forest fragments, and communities distributed across the central portion of REMACH using observations (aural and visual), audio recordings, mist netting, point counts and photographs. We recorded 360 species of bird (263 genera, 51 families), including 57 threatened species on the Red List of Ecuador, 14 of which are also globally threatened; 23 'restricted range' endemic species (15 Chocó and 8 Tumbesian); and 16 migratory species. We recorded breeding activity for 130 species, and documented two distinctive peaks of reproduction, corresponding to the wet and dry seasons, respectively. Our results suggest that REMACH represents a transition zone between Chocó and Tumbesian biogeographic zones, and as such should be considered a priority for conservation of avifauna and other taxa. *Accepted 7 November 2013.*

Key words: Avifauna, conservation, Chocó, Ecuador, endangered species, endemism, Neotropical migration, Tropical Andes, Tumbesian.

INTRODUCTION

Northwest Ecuador is situated at the confluence of three major Neotropical biogeographic zones: the Chocó, Tumbesian, and Tropical Andes. Each of these biogeographic zones contains significant levels of diversity and endemism in birds and other organisms (Stattersfield *et al.* 1998, Stotz *et al.* 2007, Freile & Vázquez 2005, Conservation International 2007). The humid rainforests of the Chocó biogeographic zone expand from a narrow mid-elevation band in southern Ecuador to encompass most of western slope of the Andes in northwest Ecuador, and continue along the Pacific coast of Colombia and into southwest Panama. Chocó forests contain the highest number of endemic bird species (62) in the Americas (Devenish *et al.* 2009). The drier, deciduous and semi-deciduous forests of the Tumbesian zone occur to the south of the Chocó, along the Pacific coast of Ecuador to northern Peru, and contain the second highest number of endemic bird species (55) in the Americas (Devenish *et al.* 2009). Both the Chocó and Tumbesian zones are tied for third highest number of globally threatened species (18) in the Americas (Devenish *et al.* 2009). To the east, as elevation increases, one enters the 'Tropical Andes' biogeographic zone (Ridgely & Greenfield 2001a) or the 'North Central Andes' Endemic Bird Area (Stattersfield *et al.* 1998, Devenish *et al.* 2009), another hotspot of diversity and endemism. The overlap of these three biogeographic zones makes northwest Ecuador an exceptional priority for conservation of biodiversity at the global level (BirdLife International & Conservation International 2005, Orme *et al.* 2005).

The Mache Chindul Ecological Reserve (Reserva Ecológica Mache-Chindul, or REMACH), the second largest protected area in northwest Ecuador, has been designated an Important Bird Area (IBA) by BirdLife International (BirdLife International & Conservation International 2005). Although established as an 'Absolute Reserve' by the Ecuadorian government, REMACH contains a large human population that contributes to ongoing deforestation and defaunation (Sierra *et al.* 1999, BirdLife International & Conservation International 2005). Relatively large tracts of intact forest remain between communities, the largest of which is Bilsa Biological Station, a 3500 ha private reserve (Fig. 1); the Laguna de Cube, a 120 ha Ramsar site (http://www.ramsar.org), is another notable feature of REMACH.

Much remains to be learned about species occurrences and basic ecology within REMACH. Published inventories exist for its herpetofauna (Ortega *et al.* 2010) and vascular plants (Neill *et al.* 1999, Clark *et al.* 2006, Cerón *et al.* 2010), but for birds most available studies focus on the behavioral ecology of individual species, or informal species lists (see below). One notable exception is the recent work by Durães *et al.* (2013) on patterns of avian diversity in relation to habitat type and quality. The most recent inventory of avian species (BirdLife International & Conservation International 2005) lists 250 confirmed bird species, several of which are species of conservation concern, but states that this number is likely an underestimate and emphasizes the need for additional sampling to better characterize local avifauna. We present information on avian species occurrences and timing of breeding within REMACH generated over a 14 year sampling period. Our findings are relevant for distributional studies and conservation planning, and provide a baseline of current conditions against which future studies of avian diversity may be compared.

METHODS

Study area. Fieldwork was conducted in the Mache Chindul Reserve (REMACH), in the

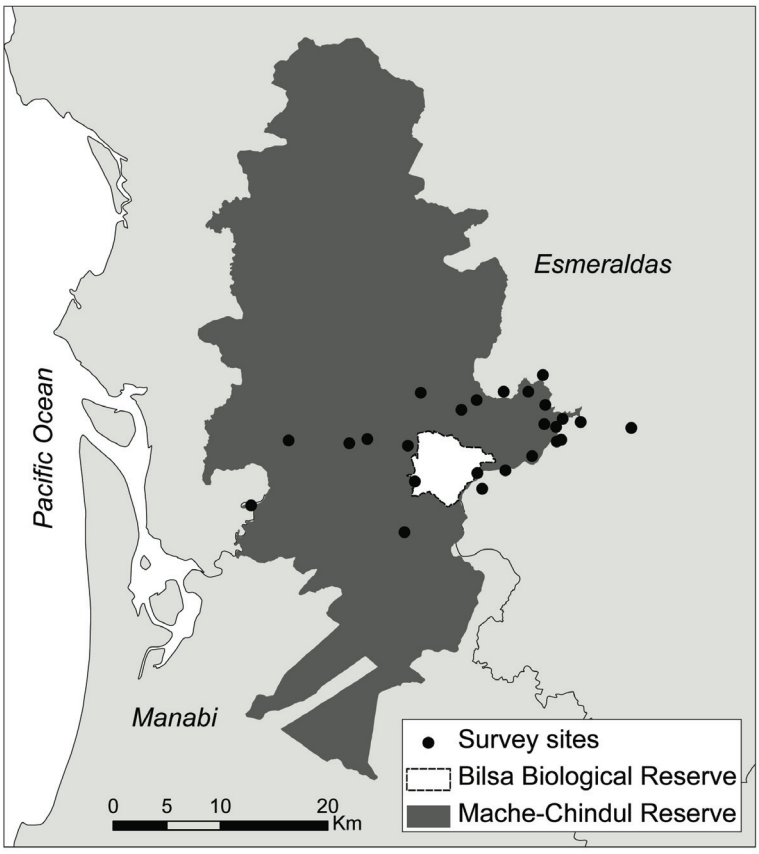

FIG. 1. Sampling locations within the Mache Chindul Ecological Reserve (REMACH), northwest Ecuador. Boundaries of Bilsa Biological Reserve, which was sampled intensively, are denoted. All mist net and point count sampling points outside Bilsa are shown by dots; sampling transects and locations for opportunistic observation fall within the area bounded by mist net sampling points.

southwest portion of Esmeraldas province and northern portion of Manabí province, northwest Ecuador (Fig. 1). This area straddles the equator and is bounded by the Pacific Ocean to the west, where the cold Peruvian current from the south and warm Equatorial counter current from the north meet, and by the Andes cordillera to the east. These geographical and oceanographic features are responsible for abrupt changes in rainfall and temperature along both latitudinal (i.e., north–south) and altitudinal (i.e., east–west) gradients. These conditions, in combination with significant barriers to dispersal in historical and contemporary times, are associated with exceptional diversity and endemism in birds and other organisms (Conservation International 2007). The Chocó biogeographic zone to the north covers approximately 100,000 km^2 in area, while the Tumbesian biogeographic zone to the south covers a total of 130,000 km^2 (Devenish *et al.* 2009).

REMACH, which was created in 1996 with an area of 119,172 ha (BirdLife International & Conservation International 2005),

represents the northernmost extent of an isolated, coastal mountain chain that begins approximately 250 km to the south in the provinces of Santa Elena and Guayas. The reserve extends from 0–800 m a.s.l. and is bordered by the Pacific Ocean to the west and, to the east, by a plain approximately 50 km wide which separates REMACH from the Andes proper. Average annual rainfall in the reserve ranges from 2–3.5 m per year, with the majority occurring January–May; the dry season extends from October–December and is marked by cloudy and misty conditions (JK unpub. data). Rainfall is highest in the most elevated portions of the reserve, and also in the northern, Chocóan portions of the reserve. The most common habitat types are humid and sub-humid evergreen forest. Dominant tree families include Arecaceae, Lauraceae, Rubiaceae, Myristicaceae, and Moraceae, (Clark *et al.* 2006) and canopy height of primary forest is typically 30–40 m.

The habitat in REMACH is a mix of pristine and secondary forest fragments with agricultural lands, with the proportion of agricultural lands increasing rapidly over the past 30 years (Sierra *et al.* 1999). REMACH contains approximately 6500 human inhabitants living in 50 communities of mestizo, Afro-Ecuadorian, or indigenous (Chachi, Awa) descent separated by forest fragments of varying size and isolation (Ministerio de Ambiente 2010). Mestizos and Afro-Ecuadorians typically work 20–50 ha farms with approximately two-thirds of the land under agriculture (cacao, pasture for cattle, corn, beans, rice, plantain, and African oil palm are the principal crops) and one-third consisting of primary or secondary forest; indigenous groups subsist primarily from hunting and timber extraction.

Bilsa Biological Station, a private reserve of 3500 ha established in 1994 and operated by Fundacion Jatun Sacha, is the largest contiguous tract of forest remaining in REMACH. Bilsa is approximately two-thirds primary forest and one-third secondary forest, regenerating 15–25 years. It is located at the eastern border of REMACH, approximately in the center of the Reserve, near the border of Esmeraldas and Manabí provinces (Fig. 1), and contains the highest point in the reserve. Outside of Bilsa, other forest fragments of varying size and quality, up to approximately 500 ha in size, are scattered through out the reserve. Unpublished bird lists have been generated for Bilsa by J. Carrión, R. Clay, J. Hornbuckle, D. & M. Wolf among others, providing an important foundation of knowledge for the current study. Another publication reported on range expansions for eight species observed in Bilsa (Carrasco *et al.* 2008).

Data collection. Data collection occurred within a rectangular sampling area (approximately 50,000 ha. or 40% of REMACH) extending along an east–west axis bisecting the central portion of REMACH (Fig. 1). The sampled area ranges from 100–800 m a.s.l, and corresponds to the most heavily forested area in the reserve (though significant forested areas also remain in the unsampled, northern portion of the reserve). Within the sampled area, a disproportionate amount of data collection took place in Bilsa and surrounding communities to the east, with less time and effort devoted to sampling lower elevation sites to the west. Thus, despite the fact that our sampling area was centrally located and captured most elevation and habitat types found in the reserve, our data should be treated as a minimum estimate of species richness in REMACH that is likely to increase with further sampling in additional areas.

Field data were collected from 1998–1999 (by KSB) and 2004–2011 (by remaining authors) using mist nets, point counts, transect surveys, audio recordings, and opportunistic observations. Data from 1998

(February–October) were collected via repeated point counts along transects (established trails) within Bilsa (12 km of transect), and via audio recording transect surveys between Bilsa and surrounding communities (60 km of transects). Data from 1999 (March–April) were collected via recordings of vocalizations and additional transect surveys. Recordings were deposited at the Bioacoustics collection, Florida Museum of Natural History, Gainesville. From 2004–11, we conducted 33 months of intensive sampling using mist nets (October 2004–August 2006, July–August 2007, November 2008, October 2009, August–December 2010, February 2011). Our mist netting methodology was initially designed to assess patterns of avian diversity in relation to habitat type, and the inventory we present here is a by-product of these studies (see Durães *et al.* 2013). In each sampling session, eight mist nets (32 mm gauge, 12 x 2.5 m) were distributed in a 250 m linear transect and operated for 3 consecutive days from 06:30–13:00 h. Mist net sampling was conducted at several sites within Bilsa (n = 21 sites for 297 total days) and in smaller forest fragments distributed throughout the reserve (n = 14 sites for 42 total days). Additional data were collected opportunistically at these sites, during travel between sampling sites, and during visits to other areas in REMACH.

We also gathered data on avian breeding behavior during each month during the study period. Each of our data points consists of an observation of "reproductive activity" by a given species in a given month. Of 302 such observations, 152 (50%) were of females with active brood patches that we captured in mist nets, and 121 (40%) were of active nests. We consider these observations to be valid indicators of reproductive condition within a given month, and therefore included them in our analyses. The remaining 29 observations (10%) were of fledglings or dependent young, which we consider to be less reliable indicators of reproduction in a given month because of variation across species in duration of retaining dependent young. We excluded observations of fledglings when assessing monthly reproductive activity when they were not immediately adjacent to a month in which an active brood patch or active nest was recorded for the same species. In other words, if we (hypothetically) observed active nests for a given species in September and November, and we recorded fledged young in January thru July for this same species, the fledged young observations would not be included in our analyses, but fledged young observed in August, October, or December would be included. This led us to include 13 observations of fledglings and to exclude 16 observations.

Birds were identified using Ridgely & Greenfield (2001a, b) and, for species recorded 1998–99, using Hilty & Brown (1986) and Ridgely *et al.* (1989, 1994). When any doubts existed about species identity, photographs or recordings were sent to referees for assistance with identification. We took a conservative approach when preparing this article, and only species identified with high degrees of confidence are included. Our primary nomenclature follows the South American Classification Committee (SACC), an official committee of the American Ornithologists Union (Remsen *et al.* 2013); we also include nomenclature of BirdLife International (BirdLife International 2013) in cases where it differs from that of SACC. Neotropical migrants were classified as such using detailed species accounts of Ridgely & Greenfield (2001a). When categorizing species as endemic to a given biogeographic zone, we employed BirdLife International's definition of a 'restricted range endemic species': a species whose historical range is < 50,000 km^2 and is centered within a particular biogeographic zone (Stattersfield *et al.* 1998, Devenish *et al.* 2009). We also provide

information on those species considered endemic by Ridgely & Greenfield (2001a) that are not included in Devenish *et al.* (2009). Threatened species were identified at the global level following the IUCN Red List of Threatened Species (www.iucnredlist.org, IUCN 2011), and within Ecuador using Granizo *et al.* (2002). A bird species was considered to be 'common' in REMACH if it was observed or heard during 50% of our visits to REMACH (of 50 total visits during the study period) and/or if more than 50 total individuals were captured in mist nets; 'less common' if it was observed or heard during 10–49% of our visits and/or between 5–49 individuals were captured in mist nets; and 'rare' it was observed or heard during < 10% of our visits and/or < 5 individuals were captured in mist nets.

RESULTS AND DISCUSSION

We registered a total of 360 species of birds (263 genera, 51 families) in REMACH. The full list of species with information on migratory, endemism, conservation, and breeding status is provided in a Supplementary Appendix (available online at karubian.tulane.edu/publications or by contacting the authors). The distribution of avian families was similar to most humid Neotropical sites: the family with the largest number of species and genera was Tyrannidae (35 genera, 47 species), followed by Thraupidae (13, 25), Trochilidae (15, 21), Thamnophilidae (15, 21), Accipitridae (15, 21), and Furnariidae (11, 14). Other species-rich families include Emberizidae, Picidae, Parulidae, Columbidae, Troglodytidae, and Psittacidae.

Our mist netting work from 2004–2011 provides insights into relative species abundances of forest-dwelling understory species in REMACH. During this period, we captured and marked a total 7173 individual birds (i.e., excluding replicate captures of the same individual), representing 186 species (52% of the total number of species we recorded). In Bilsa, 10 of the 12 species most commonly captured in mist nets were hummingbirds and small frugivores, whereas in forest fragments outside Bilsa, insectivores were more common (7 of the 12 most common species). Of the 186 total species captured in mist nets in REMACH, only 12 (6.5%) were exclusive to areas outside Bilsa, suggesting that the reserve's avifauna outside of Bilsa may largely be a nested sub-set of the avifauna found in Bilsa (see also Durães *et al.* 2013).

Breeding. We observed breeding behavior in 130 total species in REMACH, with reproductive behavior observed in every month of the year (Supplementary Appendix). Two clear peaks of breeding activity, from February–May and October–November, correspond to periods of maximum and minimum rainfall, respectively (Fig. 2). The wet season is associated with a peak in insect abundance (JK unpub. data), and most species appear to breed in this period. The dry season coincides with high levels of fruit production in at least some trees (e.g., *Miconia* spp., *Virola dixonii*) and may be associated with an overall peak in fruit production in REMACH (JK unpub. data). Species that appear to breed mainly in this period include small frugivores such as most manakin and tanager species. Many species appear to breed year-round; breeding activity was recorded at least eight months of the year for eight species including insectivores, frugivores, and nectarivores (Supplementary Appendix). The data presented here are minimum values for reproduction, and we consider it likely that at least some individuals of many species may breed in all months of the year in REMACH.

Information on selected focal taxa provides a more detailed look at the diversity of species-specific breeding strategies among REMACH avifauna. Activity of male

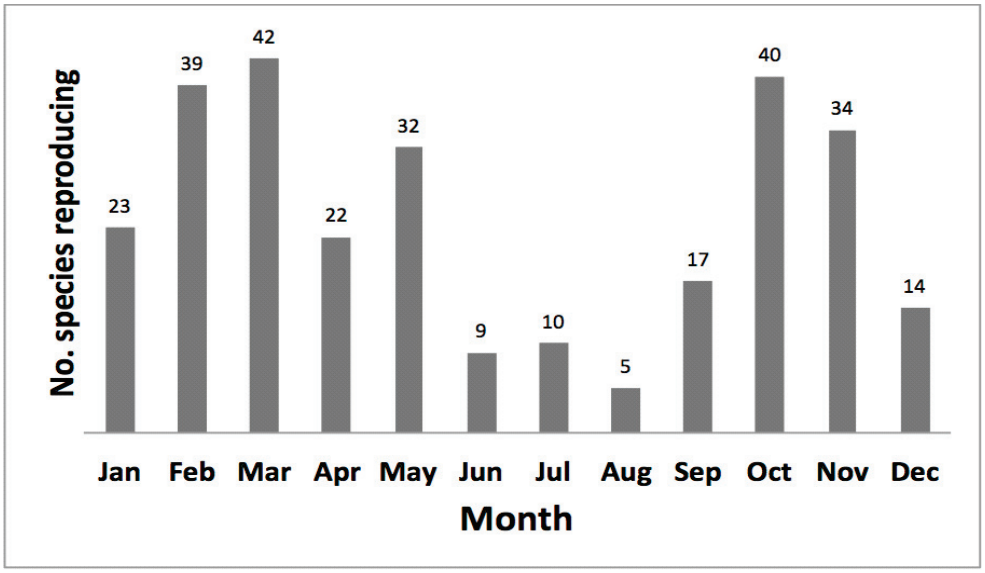

FIG. 2. Number of bird species recorded breeding in each month in the Mache Chindul Ecological Reserve, northwest Ecuador, summed across 2004–2011.

Long-wattled Umbrellabirds (*Cephalopterus penduliger*) at lek sites is highest in the dry season, but most nests are recorded during the wet season, perhaps suggesting a temporal disconnect between display and nesting behavior in this species (Tori *et al.* 2008). Umbrellabird nests have been reported from other sites in Ecuador at transition periods between rainy and dry seasons, in June (Mindo, Pichincha Province by Karubian *et al.* 2003) and January (Buenaventura, El Oro Province by Greeney *et al.* 2008); information from lek activity at these sites is not available. The frugivorous Green Manakin (*Xenopipo holochlora*), which appears to nest exclusively in riparian areas in our study area (JK and P. Mena, unpub. data), exhibits two distinctive peaks in nesting, one in the dry season and one in the wet season. A similar bimodal breeding pattern has recently been described for another riparian specialist in eastern Ecuador, the insectivorous Spotted Barbtail (*Premnoplex brunnescens*) (Greeney 2010). Flame-rumped Tanager (*Ramphocelus icteronotus*) and Brown Wood-Rail (*Aramides wolfii*) both have relatively short and focused breeding seasons, lasting only 2–3 months during the peak of the wet season (Karubian *et al.* 2011, JK and J. Olivo, unpub. data). The Banded Ground-Cuckoo (*Neomorphus radiolosus*) also breeds during the peak of the rainy season, and has the ability to re-nest following nest failure (Karubian *et al.* 2007). This information from REMACH adds to the growing body of information being generated by H. Greeney, J. Freile, and others on the rich diversity of reproductive strategies among tropical bird species, and highlights the need for additional studies that elucidate basic reproductive biology.

Migratory species. We recorded 16 migratory or potentially migratory species as classified by Ridgely & Greenfield (2001a) (Table 1). The majority of these species are Neartic-Neotropical (boreal) migrants which breed in the Northern Hemisphere and migrate southward

TABLE 1. Migratory bird species recorded in the Mache Chindul Ecological Reserve (Reserva Ecológica Mache-Chindul, REMACH), northwest Ecuador, during 1998–99 and 2004–11. Classification of migratory status follows Ridgley & Greenfield 2001a. For more information refer to Supplementary Appendix (available online at karubian.tulane.edu/publications).

Family	Scientific name	English name	Migrant type
Accipitridae	*Elanoides forficatus*	Swallow-tailed Kite	Neartic-Neotropical
Scolopacidae	*Tringa semipalmata* (*Cototrophorus semipalmatus*)	Willet	Neartic-Neotropical
Scolopacidae	*Actitis macularius*	Spotted Sandpiper	Neartic-Neotropical
Tyrannidae	*Contopus sordidulus*	Western Wood-Pewee	Neartic-Neotropical
Tyrannidae	*Empidonax virescens*	Acadian Flycatcher	Neartic-Neotropical
Vireonidae	*Vireo olivaceus*	Red-eyed Vireo	Neartic-Neotropical
Turdidae	*Catharus ustulatus*	Swainson's Thrush	Neartic-Neotropical
Hirundinidae	*Pygochelidon cyanoleuca*	Blue-and-white Swallow	Neartic-Neotropical
Parulidae	*Dendroica castanea*	Bay-breasted Warbler	Neartic-Neotropical
Parulidae	*Dendroica fusca*	Blackburnian Warbler	Neartic-Neotropical
Parulidae	*Mniotilta varia*	Black-and-white Warbler	Neartic-Neotropical
Parulidae	*Wilsonia canadensis*	Canada Warbler	Neartic-Neotropical
Cardinalidae	*Piranga rubra*	Summer Tanager	Neartic-Neotropical
Cuculidae	*Coccyzus lansbergi*	Gray-capped Cuckoo	Intra-Tumbesian
Tyrannidae	*Tyrannus niveigularis*	Snowy-throated Kingbird	Intra-Tumbesian
Emberizidae	*Rhodospingus cruentus*	Crimson-breasted Finch	Intra-Tumbesian

during the northern winter, including shorebirds, flycatchers, and warblers. Spotted Sandpiper (*Actitis macularius*), Summer Tanager (*Piranga rubra*), Acadian Flycatcher (*Empidonax virescens*), and Swainson's Thrush (*Catharus ustulatus*) are relatively common in REMACH; other Neotropical migratory species appear to be relatively scarce among the areas we sampled. Prior to this study, the Bay-breasted Warbler (*Dendroica castanea*) had been reported from only three other localities in Ecuador (Ridgely & Greenfield 2001a), and REMACH currently represents the southernmost extent of its known range. The Swallow-tailed Kite *Elanoides forficatus* has two subspecies, a resident breeder in Ecuador (*E. f. yetapa*) and a boreal migrant (*E. f. forficatus*) (Ridgely & Greenfield 2001a). At Bilsa, this species fluctuates in a manner consistent with boreal migration (*i.e.,* commonly observed in the northern winter and absent in the boreal summer), but at least some individuals are present year-round in lower-lying southern parts of the reserve (J. Olivo pers. comm.). Additional information is required to resolve the migratory status of this species in REMACH, but we include it as migratory until such information becomes avaialable. Osprey (*Pandion haliaetus*), Little Blue Heron (*Egretta caerulea*), and Turkey Vulture (*Cathartes aura*) also have migratory and non-migratory populations in Ecuador (Ridgely & Greenfield 2001a), but based on our anecdotal observations, we consider it likely that REMACH populations are resident.

We recorded no long-distance Austral migrants (species that breed in the Southern Hemisphere and migrate northward during the southern winter), corroborating observations that long-distance Austral migration is rare for birds occurring west of the Andes in Ecuador (Ridgely & Greenfield 2001a).

The Red-eyed Vireo (*Vireo olivaceus*) has Austral migrant, boreal migrant, and resident breeding populations in Ecuador but the subspecies thought to occur in western Ecuador, *V. o. griseobarbatus*, is considered resident (Ridgely & Greenfield 2001a). We recorded overwintering (non-breeding) individuals of three putative intratropical Austral migrants that migrate short distances bet-ween southern (breeding) and northern (non-breeding) ranges: Snowy-throated Kingbird (*Tyrannus niveigularus*), Crimson-breasted Finch (*Rhodospingus cruentatus*), and Gray-capped Cuckoo (*Coccyzus lansbergi*) (Ridgely & Greenfield 2001a, J. Freile pers. com.)

Endemism. We recorded a total of 15 species endemic to the Chocó and 8 species endemic to the Tumbesian biogeographic zones following BirdLife International's 'restricted range species' (RRS) classification scheme (Stattersfield *et al.* 1998, Devendish *et al.* 2009) (Table 2). The number of endemic species increases to 21 for the Chocó and 13 for the Tumbesian using the classification scheme of Ridgely & Greenfield (2001a) (Supplementary Appendix). In all cases, BirdLife International RRS species are nested within Ridgely & Greenfield's (2001a) list of endemics. We recorded an additional six species considered endemic to the 'Tropical Andes' region by Ridgely & Greenfield (2001a), but no RRS species from BirdLife International's 'North Central Andes' region (Devendish *et al.* 2009). Thus, depending upon which scheme one uses, REMACH contains anywhere from 23 to 42 'endemic' species. This nearly two-fold discrepancy indicates the need for a single, unified classification scheme. We give precedence to BirdLife International's RRS categorization scheme in the current study and promote its use for other studies because, while noting that it is somewhat restrictive and arbitrary, it applies a standardized methodology using up-to-date information that can be applied at the global scale, and thus can be compared across regions and time periods.

We recorded more Chocó than Tumbesian endemics, both at the species and individual levels, suggesting that REMACH is more closely aligned with the Chocó biogreographic zone. There are very few large remaining tracts of forest in the drier, southern parts of REMACH, and it is possible that the Tumbesian endemics we have recorded in these areas are relatively recent arrivals exploiting newly available niches created by conversion of forests to agricultural landscapes (J. Freile pers. com.). Alternatively, habitat conversion in the drier areas of the reserve may have extirpated sensitive Tumbesian endemics. Additional sampling in this area of the reserve is a priority. The low number of Andean endemics likely reflects the fact that REMACH is separated by the Andes proper by a low lying, heavily deforested plain, and that many Andean endemics are restricted to relatively high elevations. With the exception of Crimson-breasted Finch and Gray-backed Hawk (*Pseudastur occidentalis*), we consider it likely that all the endemic species were year-round residents and breeders in REMACH. We recorded reproductive behavior in REMACH for six RRS Chocó endemics, including endangered species like Banded Ground-Cuckoo and Long-wattled Umbrellabird, and one RRS Tumbesian endemic, the Ecuadorian Thrush (*Turdus maculirostris*).

Endangered species. We recorded 14 globally threatened species in REMACH, of which 2 were Endangered (EN), 5 Vulnerable (VU), and 7 Near Threatened (NT) (IUCN 2013) (Table 2). At the national level, this number swells to 57 species threatened within Ecuador, with 1 CR, 11 EN, 26 VU, and 19 NT species (Granizo *et al.* 2002) (Supplementary Appendix). We recorded reproductive activity for 4 IUCN species and an additional 17 species on the Ecuador Red List (Supplementary

Appendix), and consider it likely that most of the 57 threatened species breed in REMACH.

A high proportion of threatened species in REMACH are also RSS endemics (7/13 Chocó and 3/8 Tumbesian endemics are IUCN listed; Table 2, Supplementary Appendix), likely because of loss of primary habitat that these species depend upon. Many of these threatened species are also frugivores whose declines may impact seed dispersal processes and, ultimately, forest structure in the reserve. In particular, large-seeded tree species such as members of the Arecaceae, Lauraceae, and Myristicaceae families (palm, avocado, and nutmeg respectively) may experience reductions in fruit removal and seed movement as large frugivores like Long-wattled Umbrellabird and Great Currasow (*Crax rubra*) become more rare (Karubian *et al.* 2010, 2012). This concern, compounded by the fact that many large seed dispersal agents are already functionally extinct in the reserve [e.g., Brown-headed spider monkey (*Ateles fusciceps*)], underscores the importance of viable avian seed dispersal processes for the long-term well-being of REMACH.

Many of the threatened bird species we recorded appear to have strongholds in Bilsa, suggesting that the primary forests found in this reserve are key for their conservation. For example, Long-wattled Umbrellabird and Banded Ground-Cuckoo have stable and robust populations within Bilsa (Karubian & Carrasco 2008, JK unpub. data), but appear to be rare or absent from many smaller and more isolated fragments where, according to local residents, they were found 20–30 years ago. Conditions for threatened species appear to be more tenuous outside the Bilsa: our one record of the Grey-backed Hawk, a species whose total population size is estimated at 100–250 birds (IUCN 2011), is of a single individual killed by a hunter. In contrast, however, the Brown Wood-rail appears to maintain healthy populations in relatively impacted secondary forest and even agricultural landscapes, although the species was always recorded in proximity to large tracts of primary forest (Karubian *et al.* 2011).

In addition to highlighting the importance of Bilsa as a core, 'source' area for avifauna in the reserve, these findings lead to several other practical considerations for conservation policy in REMACH. Additional sampling of privately owned forest fragments outside Bilsa, especially in the far northern and southwestern portions of the reserve, is a clear priority for future research. More information on habitat preferences, basic ecology, and population status of endangered species would be desirable for conservation status and planning processes. The region also houses sub-species that may represent evolutionarily independent lineages at risk of extinction in Ecuador in the short-term, such as the Sapphire Quail-Dove (VU, *Geotrygon purpurata*; *G. saphirina purpurata* in BirdLife International nomenclature), Collared Aracari (VU, *Pteroglossus torquatus*), as well as other subspecies that may be more resistant to anthropogenic activities but nonetheless deserve more detailed study, such as White-throated Thrush (*Turdus assimilis*; *T. a. daguae* in BirdLife International nomenclature) (NT), and Scarled-rumped Cacique (*Cacicus uropygialis*; *C. u. pacificus* in BirdLife International nomenclature) (NT)]. Another priority is to design and implement effective conservation measures to assist local stakeholders with conservation. As evidenced by the case of Grey-backed Hawk, environmental education designed to influence attitudes and resource management practices of local residents would also be useful for conservation in the reserve.

Conclusion. The high number of endemic (23) and endangered (14 global, 57 national) species from distinctive biogeographic zones in a

TABLE 2. Threatened and endemic bird species recorded in the Mache Chindul Ecological Reserve (Reserva Ecológica Mache-Chindul, REMACH), northwest Ecuador, during 1998–99 and 2004–11. Family, scientific name (following SACC nomenclature, with BirdLife International nomenclature provided in parentheses in cases of non-concordance), and common name in English are provided for each species. Classification of endemic species into either the Chocó or Tumbesian biogeographic zones follows BirdLife International's 'restricted range' species concept (Devendish *et al.* 2009). Classification of threatened species follows current IUCN Red List listings at the global level (EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern). For more information including observed breeding, the observation or capture method, and frequency of encounter for each species, refer to Supplementary Appendix (available online at karubian.tulane.edu/publications).

Family	Scientific name	English name	Endemic	IUCN
Cuculidae	*Neomorphus radiolosus*	Banded Ground-Cuckoo	Chocó	EN
Falconidae	*Micrastur plumbeus*	Plumbeous Forest-Falcon	Chocó	VU
Cotingidae	*Cephalopterus penduliger*	Long-wattled Umbrellabird	Chocó	VU
Ramphastidae	*Capito squamatus*	Orange-fronted Barbet	Chocó	NT
Caprimulgidae	*Nyctiphrynus rosenbergi*	Chocó Poorwill	Chocó	NT
Picidae	*Veniliornis chocoensis*	Chocó Woodpecker	Chocó	NT
Thraupidae	*Tangara johannae*	Blue-whiskered Tanager	Chocó	NT
Tinamidae	*Crypturellus berlepschi*	Berlepsch's Tinamou	Chocó	LC
Columbidae	*Patagioenas goodsoni*	Dusky Pigeon	Chocó	LC
Psittacidae	*Pyrilia pulchra*	Rose-faced Parrot	Chocó	LC
Ramphastidae	*Ramphastos brevis*	Chocó Toucan	Chocó	LC
Picidae	*Piculus litae*	Lita Woodpecker	Chocó	LC
Trochilidae	*Amazilia rosenbergi*	Purple-chested Hummingbird	Chocó	LC
Trogonidae	*Trogon comptus*	Chocó Trogon	Chocó	LC
Thamnophilidae	*Myrmeciza berlepschi*	Stub-tailed Antbird	Chocó	LC
Accipitridae	*Pseudastur occidentalis* (*Leucopternis occidentalis*)	Gray-backed Hawk	Tumbesian	EN
Cracidae	*Ortalis erythroptera*	Rufous-headed Chachalaca	Tumbesian	VU
Psittacidae	*Aratinga erythrogenys*	Red-masked Parakeet	Tumbesian	NT
Columbidae	*Columbina buckleyi*	Ecuadorian Ground Dove	Tumbesian	LC
Psittacidae	*Forpus coelestis*	Pacific Parrotlet	Tumbesian	LC
Turdidae	*Turdus maculirostris*	Ecuadorian Thrush	Tumbesian	LC
Parulidae	*Basileuterus fraseri*	Gray-and-gold Warbler	Tumbesian	LC
Emberizidae	*Rhodospingus cruentus*	Crimson-breasted Finch	Tumbesian	LC
Rallidae	*Aramides wolfi*	Brown Wood-Rail	NA	VU
Cracidae	*Crax rubra*	Great Curassow	NA	VU
Picidae	*Campephilus gayaquilensis*	Guayaquil Woodpecker	NA	NT
Accipitridae	*Cryptoleucopteryx plumbea* (*Leucopternis plumbeus*)	Plumbeous Hawk	NA	NT

relatively small area (120,000 ha) underscores the importance of REMACH as a transition zone between major South American avifaunas. Transition zones exhibit unusually rapid rates of species turnover and genetic, morphological, and behavioral variation within and between species (Smith *et al.* 1997, Thomassen *et al.* 2010). These conditions may serve as an engine for speciation and/or contribute to species persistence in the face of

changing conditions, such as land conversion and climate change; for this reason, transition zones are often priorities for conservation (Smith *et al.* 2001, 2005). Extensive habitat clearing for timber and agriculture has caused western Ecuador's forests to become one of the world's most threatened ecosystems (IUCN 2010). Indeed, this area is part of the only region on earth (the Tropical Andes) that combines the top 5% of threat, diversity, and endemism among avian taxa in a single terrestrial biome (Orme *et al.* 2005). These factors lead us to conclude that, with appropriate conservation planning and activities, REMACH has the potential to provide a key stronghold for biodiversity of birds and other taxa in coming years.

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