CEIBA
A Scientific and Technical Journal
Published by Zamorano

Vol. 58, No. 1, 2025
Enero – Junio

**Artículo Original**

# Facing headwinds: potential impacts of wind energy expansion on Central American bats

Luis Girón-Galván
luis.egiga@gmail.com
Investigador Asociado
Asociación Territorios Vivos El Salvador
El Salvador

Jonathan Hernández
jonathanhs_hn@yahoo.com
Programa de Conservación de Murciélagos
Honduras

Melissa E. Rodríguez
melissa.rg784@gmail.com
Directora
Dirección de Ecosistemas Terrestres
Asociación Territorios Vivos El Salvador
El Salvador

Oliver Komar
okomar@zamorano.edu
Profesor Pleno
Centro Zamorano de Biodiversidad | Departamento de Ambiente y Desarrollo
Universidad Zamorano
Honduras

John van Dort
john.vandort@gmail.com
Investigador
Centro Zamorano de Biodiversidad | Departamento de Ambiente y Desarrollo
Universidad Zamorano
Honduras

Roselvy Juárez
Investigadora
roselvy.juarez@gmail.com
Centro Zamorano de Biodiversidad | Departamento de Ambiente y Desarrollo
Universidad Zamorano
Honduras

Bernal Rodríguez-Herrera
bernal.rodriguez@ucr.ac.cr
Director
Centro de Investigación en Biodiversidad y Ecología Tropical | Escuela de Biología
Universidad de Costa Rica
Costa Rica

Historial del artículo:
Recibido Enero 9, 2024. Aceptado Noviembre 6, 2024. Publicado Junio 30, 2025.

Cómo citar: Girón-Galván, L.; Hernández, J.; Rodríguez, M. E.; Komar, O.; van Dort, J.; Juárez, R. & Rodríguez-Herrera, B. (2025). Facing headwinds: potential impacts of wind energy expansion on Central American bats. *Ceiba, 58*(1), 53-74. http://doi.10.5377/ceiba.v58i1.20669

---

**Abstract.** Wind energy became an alternative electricity source after the oil crisis of the 1970s. However, wind energy is not environmentally neutral, as it causes fatalities in many species of bats and birds. Central America is home to 170 bat species and 30 wind farms are currently operating in five of the seven countries in the region, with others under construction or planned. Our objectives are to assess current policies and legislation related to wind energy and bat conservation; to present regional bat fatality estimates based on current and future wind development; to analyze which species could be affected by wind power projects in Central America and where; and to recommend actions that can mitigate these threats. Through a bibliographic review, we compiled three classes of data: (1) laws and regulations currently in force; (2) present and projected wind power projects; and (3) species and landscapes potentially affected. Environmental protection laws are in force in all seven countries, and biodiversity legislation provides protections for all native bat species, especially threatened species. The countries with the highest wind energy installed capacity are Costa Rica (390 MW), Panama (270 MW), and Honduras (241 MW). In the future, Panama is expected to have the highest capacity (1.24 GW), followed by Costa Rica (400 MW), and Honduras (368 MW). Wind energy projects currently create threats for bats in six landscapes within the region. Policy changes should be considered immediately to develop more stringent regulations. An increase from current installed capacity to projected installed capacity leads to an increase in projected regional bat fatality. Mitigation measures have the potential to reduce bat fatality, but studies that demonstrate the effectiveness of these measures are needed. Data and studies of bats in wind farms should be available, and publications in peer review should be allowed by the companies. Wind energy is an important alternative energy source to reduce environmental problems globally; however, it is very important to do so with the least possible impact on wildlife. Single wind farms may not directly cause species' extinctions, but the cumulative effect of multiple wind farms as stressors on bat populations may be too great to overcome if nothing is done.

**Keywords:** conservation, legislation, priority landscape, renewable energy.

## Vientos en contra: posibles repercusiones de la expansión de la energía eólica en los murciélagos centroamericanos

**Abstract.** La energía eólica se convirtió en una fuente alternativa de electricidad después de la crisis del petróleo de la década de 1970. Sin embargo, la energía eólica no es ambientalmente neutra, ya que causa mortalidad en muchas especies de murciélagos y aves. Centroamérica alberga 170 especies de murciélagos y actualmente hay 30 parques eólicos en funcionamiento en cinco de los siete países de la región, y otros están en construcción o en proyecto. Nuestros objetivos son evaluar las políticas y la legislación actual relacionadas con la energía eólica y la conservación de los murciélagos; recopilar información sobre proyectos eólicos en Centroamérica; analizar las posibles amenazas a las que se enfrentan los murciélagos debido a los proyectos de energía eólica; y recomendar acciones que puedan mitigar estas amenazas. A través de una revisión bibliográfica, recopilamos tres clases de datos: (1) leyes y regulaciones actualmente vigentes, (2) proyectos de energía eólica presentes y proyectados, y

(3) especies y paisajes potencialmente afectados. Existen leyes de protección ambiental vigentes en los siete países y la legislación sobre biodiversidad brinda protección para todas las especies nativas de murciélagos. Los países con mayor capacidad instalada de energía eólica son Costa Rica (390 MW), Panamá (270 MW) y Honduras (241 MW). En el futuro, se espera que Panamá tenga la capacidad más alto (1,24 GW), seguido de Costa Rica (400 MW) y Honduras (368 MW). Los proyectos de energía eólica amenazan murciélagos actualmente en seis paisajes dentro de la región. Cambios en las políticas deben considerarse de inmediato para desarrollar regulaciones más estrictas. Un aumento de la capacidad de producción de energía instalada conduce a un aumento en la mortalidad proyectada de murciélagos regional. Las medidas de mitigación tienen el potencial de reducir la mortalidad de los murciélagos, pero se necesitan estudios que demuestren la eficacia de estas medidas. Los datos y estudios de murciélagos en parques eólicos deben estar disponibles, y las empresas deben permitir publicaciones en revisión por pares. La energía eólica es una importante fuente de energía alternativa para reducir los problemas ambientales a nivel mundial; sin embargo, es muy importante hacerlo con el menor impacto posible en la vida silvestre. Es posible que los parques eólicos individuales no causen directamente la extinción de especies, pero el efecto acumulativo de múltiples parques eólicos como factores de estrés en las poblaciones de murciélagos puede ser demasiado grande para superar si no se hace nada.

**Palabras clave:** conservación; legislación; paisajes prioritarios; energías renovables.

## Introduction

The first experiences using wind to produce electricity date back to the end of the 19th century; subsequently, the oil crisis in the 1970s forced countries to implement energy policies aimed at reducing oil consumption and boosting other sources such as wind energy (OLADE, 2012). Currently, due to rapidly increasing energy demands and the urgent need to combat climate change by reducing greenhouse gas emissions from fossil fuels, the development of renewable energy alternatives has become a priority worldwide (Sims 2004, Arnett et al. 2016, Owusu & Asumadu-Sarkodie 2016). Cost competitiveness, technological advances, and fiscal incentives have helped wind energy to become one of the world's most rapidly growing sources of renewable energy (IRENA Renewable Energy Statistics, 2020).

In Central America, Costa Rica has been at the forefront of wind energy development since 1997 (OLADE, 2012). Currently, 30 wind power projects are operating in five of seven Central American nations (CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023). It is expected that by 2030, 54 projects will be operating, in all seven nations, doubling generation capacity (CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023).

Wind power is not environmentally neutral. Significant effects of wind farms on wildlife and wildlife habitats have been documented and are a cause for concern (Saidur et al., 2011; Arnett et al., 2016). It is known that they cause direct and indirect environmental impacts, such as decreased vegetation, soil removal, as well as mortality (fatalities) of flying vertebrates (Neri et al., 2019).

Researchers have recorded turbine-associated fatalities in species of six of the nine families of bats found in Central America (Arnett and Baerwald, 2013; Barros et al., 2015; Rodríguez-Durán and Feliciano-Robles, 2015; Bolívar-Cimé et al., 2016; Cabrera-Cruz et al., 2020, Agudelo et al. 2021). These six families are Emballonuridae, Noctilionidae, Mormoopidae, Phyllostomidae, Molossidae, and Vespertilionidae (Arnett and Baerwald, 2013; Barros et al., 2015; Rodríguez-Durán and Feliciano-Robles, 2015; Bolívar-Cimé et al., 2016; Cabrera-Cruz et al., 2020). These families are insectivorous, except for Noctilionidae and Phyllostomidae which include ictivorous, frugivorous, hematophagous and nectarivorous species.

Potential population consequences from bat fatality are especially worrisome because long-lived bats have low reproductive rates and their slow population growth limits capacity to recover from population declines (Barclay and Harder, 2003). Concerns about bat conservation in developed nations have been well-publicized and have led to numerous published studies of bat fatality in wind farms. In contrast, Central America, which hosts 170 bat species (Rodríguez-Herrera and Sánchez, 2015), still lacks information from most individual wind farms to analyze their effects as stressors on bat populations. Today mitigation measures to reduce the impact on bats are well known; however, the effectiveness of such measures has only been proven in temperate zones, and their effectiveness in Central America still needs to be tested. For example, increasing the wind cut-in speed to start the blades rotating and using sound deterrents have been effective in reducing bat mortality and should be tested in wind projects in Central America.

## Objectives

This study has four objectives: (a) to assess current policies and legislation that facilitate and/or regulate the generation of wind energy in Central America and are related to bat conservation; (b) to compile current and projected information on the size of wind projects in Central America; (c) to analyze which species could be affected by wind power projects in Central America and where; and (d) to recommend actions to mitigate these threats to bats.

## Materials and Methods

### Study area

The study area consists of the seven Central American nations: Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama (Fig. 1). Central America is tropical, located between the Pacific Ocean and the Caribbean Sea at latitudes 7°–21° N and longitudes 76°–93° W, and exposed to northeast trade winds (Bonilla, 2014).

### Data compilation and analysis.

We compiled five classes of data for Central America: (1) wildlife laws and regulations currently in force; (2) geographical location and installed capacity of current and projected wind power projects; (3) published bat fatality estimates for Neotropical wind farms; (4) species especially vulnerable to wind development in the region; and (5) important bat conservation areas.

***Laws and regulations.*** At the global scale, we reviewed the Convention on Biological Diversity or CBD (UN, 1992) and the Strategic Plan for Biodiversity 2011–2020 (UN, 2010). We did not review international legislation to protect migratory species because there are no documented cases of true bat migration in Central America, even though some species which are known to be migratory in temperate zones also are resident in Central America. At the regional scale, we reviewed the Regional Environmental Strategy for 2015–2020 of the Comisión Centroamericana de Ambiente y Desarrollo (CCAD, 2014), and the Guide to the Technical Review of Environmental Impact Studies Particular to Energy Generation and Transmission (CCAD, 2011). Furthermore, for each Central American country, we reviewed legislation on incentives for renewable energy development, regulations on the generation of electrical energy, environmental protection, biodiversity conservation, and wildlife conservation (Table 1).

***Current and future wind power projects***. We compiled the number of projects per country that are currently operating, as well as the installed capacity of energy production, the number of projects currently in the planning stage, and the projected generating capacity of each (OLADE, 2012; CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023). Additionally, we obtained geographic coordinates of current and future projects, when available (CNE, 2014; ANSPDNE, 2015; TWP, 2023). Using these coordinates, we created a regional map using ArcGIS pro-2.5.

We evaluated potential impacts of wind energy in Central America on regional bat faunas from three perspectives: (a) estimates of bat fatality; (b) bat species potentially affected; and (c) landscapes of importance to bats.

***Annual bat fatality***. We derived estimates from four published studies conducted in the Neotropics as hypothetical examples to illustrate scenarios: one from Uruguay (Rodríguez et al., 2009– hereafter referred as "A" Sierra de los Caracoles), and three from Mexico (Cabrera-Cruz et al., 2020, hereafter referred to as "B" Eastern Wind Farm and "C" Northern Wind Farm; and Bolívar-Cimé et al., 2016– hereafter referred as "D"). These rates were expressed as annual bat fatalities per megawatt of wind power generation (hereafter bf/MW/year), and values were, respectively 16.32 bf/MW/year, 20.47 bf/MW/year, 43.79 bf/MW/year, and 57.41 bf/MW/year. The studies all include some species of bats that have experienced fatalities in Central America (Bolívar-Cimé et al., 2016; Cabrera-Cruz et al., 2020; Agudelo et al., 2021).

These four scenarios were adjusted per country and for the Central America region, multiplying each estimate of annual bat fatality estimates by current and projected generating capacity. Using only the most conservative fatality estimate (Uruguay), the hypothetical total number of bat fatalities per year 1997–2020 and for the year 2030 were also estimated. We note, however, that wind farms throughout Central America are in different biomes and at different elevations, and thus will have variable fatality rates. Thus, we do not know if an average fatality rate of 16.32 bf/MW/year at the regional level is commensurate for Central America, or if actual fatality rates in Central America are on average higher or lower.

***Bat species potentially affected***. Lists of bat species recorded from the landscapes with current or future wind power projects were compiled, as well as those species whose geographic range includes such projects (Timm, et al., 1999; Reid, 2009; Owen and Girón, 2012; Medina-Fitoria, 2014). Species for which turbine-related fatalities have been reported from wind farms in Mexico, Honduras, Puerto Rico, Brazil, Chile, and Uruguay were identified and considered as vulnerable (Mora and López 2010; Arnett and Baerwald, 2013; Barros et al., 2015; Rodríguez-Durán and Feliciano-Robles, 2015; Bolívar-Cimé et al., 2016; Espinal et al. 2016, Mora et al. 2016; Cabrera-Cruz et al., 2020; Agudelo et al. 2021); as well as species with migratory behavior outside Central America (Fleming and Eby, 2003) and species considered threatened or at risk of extinction at regional or global levels (Rodríguez-Herrera and Sánchez, 2015; IUCN, 2021).

***Potential priority landscapes***. Using ArcGIS pro-2.5, we plotted 30 km radius circles centered on the coordinates of present and future wind farms (OLADE, 2012; CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023). The 30 km radius was adopted based on a hypothetical minimum home range size for non-migratory bats (Fleming and Eby, 2003), but some large frugivorous bats in tropical Africa tracked with satellite transmitters forage up to 59 km from day roosts (Fleming 2019). We consider any area within 30 km of a wind turbine, to be areas generating potentially important threats to bat populations.

## Results

### Laws and regulations in force

All seven Central American countries have ratified the Convention on Biological Diversity (CBD) and participate in the Comisión Centroamericana de Ambiente y Desarrollo (CCAD). Both actions obligate the signatory countries to take measures to prevent biodiversity loss. At least one environmental law is in force at the national level in all seven countries. All countries except Guatemala and Nicaragua have wildlife conservation laws. Costa Rica, Nicaragua, and Panama also have biodiversity legislation in force. The environmental protection legislation requires environmental impact evaluation of all development projects; wildlife conservation laws require that development projects develop strategies to protect wildlife, and biodiversity legislation is aimed to conserve all native species. Information on regulatory status is summarized in Table 1.

**Table 1**
Regulations and laws currently in force that facilitate and/or regulate wind power generation projects in Central America.

| Scale | Title | Comments | Applicable in: GT | BZ | SV | HN | NI | CR | PA |
|---|---|---|---|---|---|---|---|---|---|
| *Global* | Convention on Biological Diversity (CDB) | The first global agreement to recognize biodiversity conservation as a concern common to all humanity, and an integral adjunct to development | x | x | x | x | x | x | x |
| *Regional* | Regional environmental strategy for 2015-2020 of the Comisión Centroamericana de Ambiente y Desarrollo (CCAD). | Among the strategic actions are a) recovery of vulnerable species and ecosystems, b) development of clean energy sources (hydroelectric, geothermic, wind, solar, and biomass), and c) promote environmental responsibility among social and business circles | x | x | x | x | x | x | x |
| | Guide to the Technical Review of Environmental Impact Studies Particular to Energy Generation and Transmission, CCAD. | An environmental impact study's description of the biological context of a power project must list all species affected negatively by the project and all critical habitats potentially within range of the project. The study must include plans for broad-scope monitoring in the short and long term | x | x | x | x | x | x | x |
| *National* | Legislation on incentives for the development of projects in renewable energy. (Ley N° 6 1997; Ley N° 52 2003; Ley N° 70 2007; Ley N° 462 2007; Ley N°682 2009). | Defines the fiscal benefits, such as tax reductions, that national government's offer to enterprises dedicated to developing renewable energy sources | x | | x | x | x | | x |
| | Legislation regarding the generation of electric energy. (Ley N° 7200 1990; Ley N° 158 1994; Ley N° 843 1994; Ley N° 6 1995; Ley N° 93 1996; Ley N° 221 2000; Ley N° 682 2009). | Regulates activities associated with the generation, transmission, distribution, and commercialization of electricity. Requires environmental impact studies for projects proposed for any of these activities. | x | x | x | x | x | x | x |
| | Environmental protection legislation. (Ley N° 68 1986; Ley N° 104 1993; Ley N° 7554 1995; Ley N° 217 1996; Ley N° 41 1998; Ley N° 79 1998; Ley N° 328 2000). | Requires environmental impact studies in all development projects | x | x | x | x | x | x | x |
| | Biodiversity legislation. (Ley N° 2 1995; Ley N° 7788 1998; Ley N° 807 2012). | Promotes the conservation and sustainable use of biological diversity. | | | | | x | x | x |
| | Legislation on wildlife conservation. (Ley N° 7317 1992; Ley N° 844 1994; Ley N° 24 1995; Ley N° 220 2000). | Stipulates that development projects must provide strategies for protecting wildlife | | x | x | x | | x | x |

*Note.* GT = Guatemala, BZ = Belize, SV = El Salvador, HN = Honduras, NI =Nicaragua, CR = Costa Rica y PA = Panama

## Present and future wind power projects

At present, 30 wind power projects are operational in five of the seven Central American countries while 25 more, across all seven countries, are projected to be operational within five years (Fig. 1 and Table 2). Countries with the highest number of operational wind farms are Costa Rica (17), Nicaragua (4), and Honduras (4) (Fig. 1 and Table 2). In a decade, Costa Rica is expected to be the country with the highest number (18), followed by Panama (14) and Honduras (10) (Fig. 1 and Table 2). The estimated annual power generation capacity for all 31 current projects is 1.25 GW, led by Costa Rica and Panama (Table 2). The estimated capacity for 2030, however, is 2.6 GW (Table 2), of which Panama is expected to contribute almost half (Table 2).

**Figure. 1**
Current and future wind power projects in Central America and their potential impact areas with respect to bats, estimated as circles 30 km in radius to consider home ranges of non-migratory species (Fleming and Eby, 2003). Important Bat Conservation Areas are also indicated (Rodríguez-Herrera and Sánchez, 2015). Letters represent landscapes currently with overlap among the impact areas of different projects (CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023). A= Guatemala and El Salvador, B= Honduras, C= Nicaragua, D and E= Costa Rica, F= Panama.

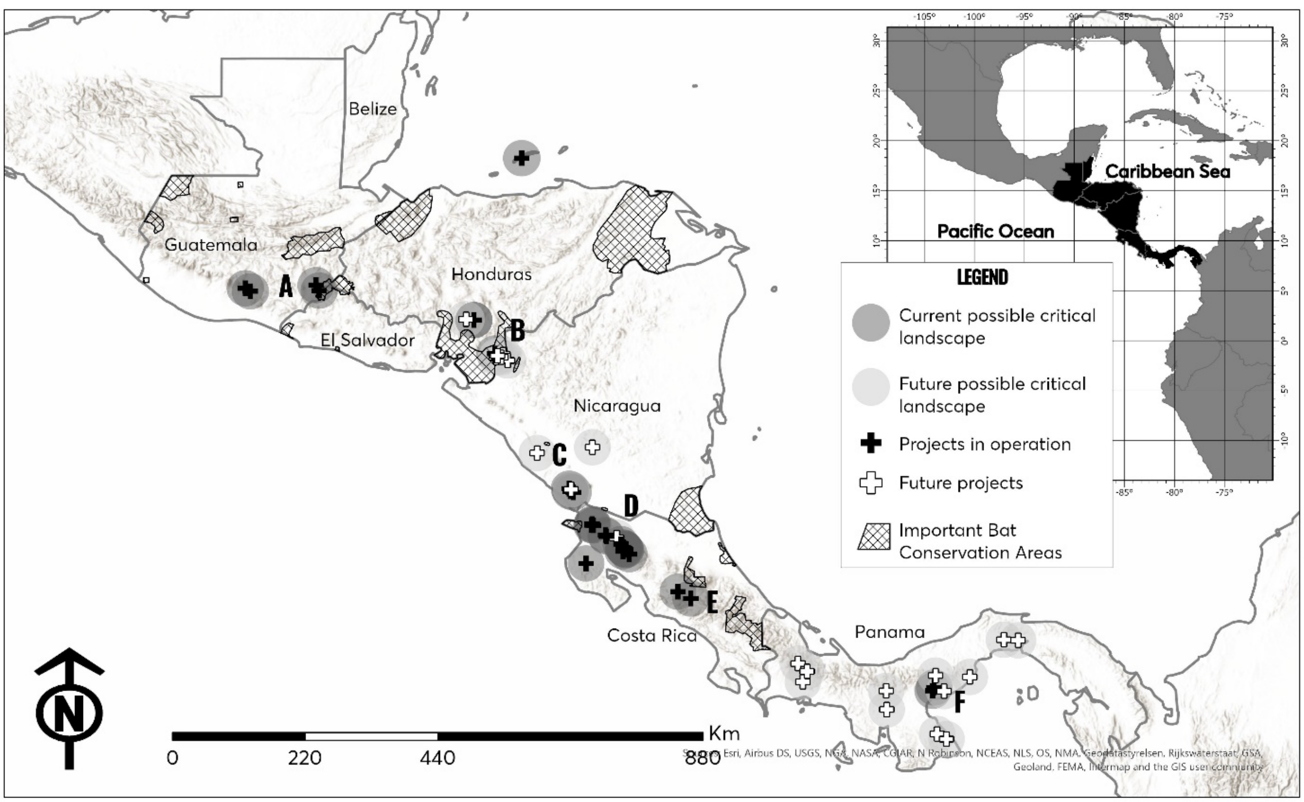


**Table 2**
Summary of operational and planned wind power projects in Central America and their energy production capacities (Data sources: OLADE, 2012; CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023). MW= Megawatts.

| Country | Wind power projects | | | Energy production capacity (MW) | | |
|---|---|---|---|---|---|---|
| | Current | Projected | Total | Current | Projected | Total |
| Guatemala | 3 | 0 | 3 | 107 | 0 | 107 |
| Belize | 0 | 1 | 1 | 0 | 75 | 75 |
| El Salvador | 1 | 1 | 2 | 54 | 36 | 90 |
| Honduras | 4 | 6 | 10 | 241 | 127 | 368 |
| Nicaragua | 4 | 3 | 7 | 186 | 142 | 328 |
| Costa Rica | 17 | 1 | 18 | 390 | 10 | 400 |
| Panama | 2 | 12 | 14 | 270 | 971 | 1,241 |
| **Total** | **31** | **23** | **55** | **1,248** | **1,361** | **2,609** |

## Potential threats to bats

***Fatality estimates.*** Extrapolating from the most conservative published bat fatality estimates of the four we considered for this study (source "A"), at present, around 20,000 bats may die annually in Central American wind farms. Extrapolating from source "B", the estimate rises to 25,000 fatalities annually, while extrapolating from sources "C" and "D", the number of possible fatalities in the region increases to 55,000 and 72,000 bats/year respectively. In eight years, fatalities could reach from 42,000 to 149,000 bats/year (Table 3).

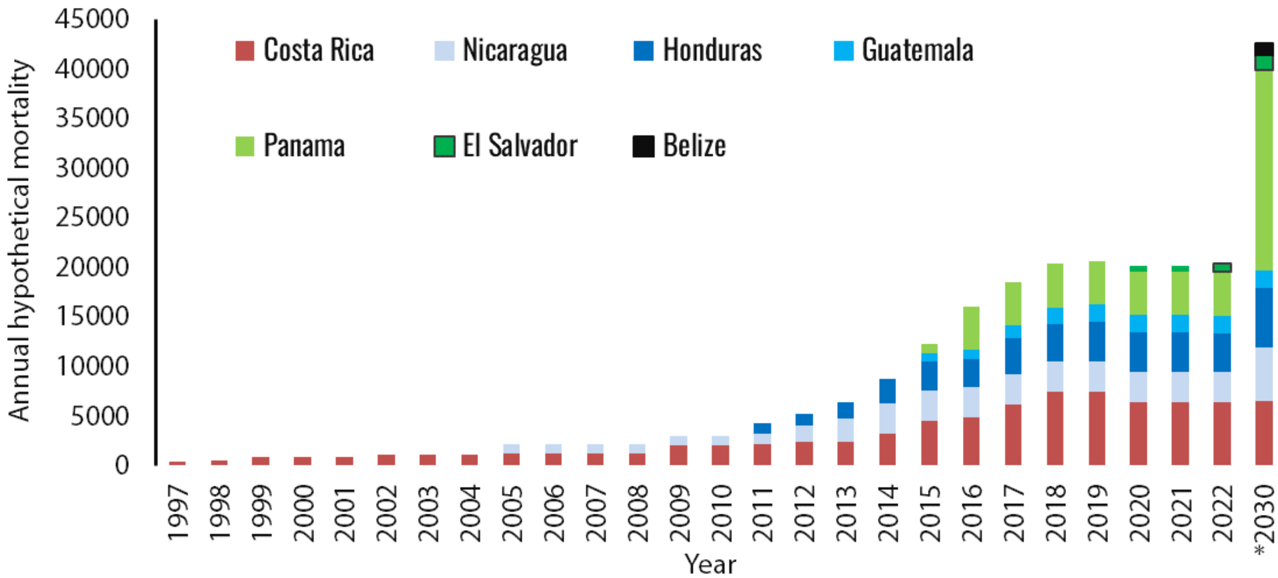
**Table 3**
Estimated annual bat fatality associated with wind farms in Central America, using the four published rates (A, B, C and D) described in the methodology.

| Country | Annual bat fatality (current) | | | | Annual bat fatality (2030) | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A | B | C | D |
| Guatemala | 1,746 | 2,190 | 4,686 | 6,143 | 1,746 | 2,190 | 4,686 | 6,143 |
| Belize | 0 | 0 | 0 | 0 | 1,224 | 1,535 | 3,284 | 4,306 |
| El Salvador | 881 | 1,105 | 2,365 | 3,100 | 1,469 | 1,842 | 3,941 | 5,167 |
| Honduras | 3,933 | 4,933 | 10,553 | 13,836 | 6,006 | 7,533 | 16,115 | 21,127 |
| Nicaragua | 3,036 | 3,807 | 8,145 | 10,678 | 5,353 | 6,714 | 14,363 | 18,830 |
| Costa Rica | 6,365 | 7,983 | 17,078 | 22,390 | 6,528 | 8,188 | 17,516 | 22,964 |
| Panama | 4,406 | 5,527 | 11,823 | 15,501 | 20,253 | 25,403 | 54,343 | 71,246 |
| **Total** | **20,367** | **25,547** | **54,650** | **71,648** | **42,579** | **53,406** | **114,248** | **149,783** |

***Note.*** A = 16.32 fatalities per Megawatt (MW), B = 20.47 fatalities per MW, C = 43.79 fatalities per MW, and D = 57.41 fatalities per MW (Agudelo et al. 2021). In the 2030 estimate it is assumed that the planned projects are operating for that year.

Using the value from conservative estimate "A", we estimate bat fatalities in Central American wind farms to have risen from 375 in 1997 to a two-decades total of some 190,000 (Fig. 2). The projection of country-by-country trends into the future (Fig. 2) suggests that in six years the highest number of fatalities will occur in Panama, followed by Costa Rica, Honduras, and Nicaragua (Table 3, Fig. 2).

**Figure. 2**
Annual hypothetical fatality of bats in wind farms in Central America from 1997 through 2030, using an estimate of 16.32 fatalities per MW of power generated, (Rodríguez et al., 2009) and based on known and projected power generation capacities (CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023).




***Bat species possibly affected.*** We compiled a list of 35 species, of which 28 have been reported in wind power-related fatalities from the United States to Brazil; five are documented to present some type of migratory behavior outside Central America, including four long-distance migrants, nine species are considered locally threatened or endangered, and three are considered globally near-threatened (Table 4 and Fig. 1). The species included in the list are considered potentially vulnerable in wind projects in the Neotropics. For nine species (*Artibeus lituratus, Molossus molossus, M. nigricans, Nyctinomops laticaudatus, Tadarida brasiliensis, Lasiurus cinereus, L. ega, L. frantzii.,* and *L. intermedius*), fatalities associated with wind power projects have been documented in at least two countries (Table 4). Three species with documented fatalities have some migratory populations and are of regional or global conservation concern: *Leptonycteris yerbabuenae, T. brasiliensis* and *L. cinereus* (Table 4). There is no evidence that any of these species are migratory within Central America.

**Table 4**
Species of bats present in and around Central American wind farms, with documented fatalities in wind farms from the United States to Brazil (Mora and López 2010; Arnett and Baerwald, 2013; Espinal et al., 2016; Mora et al., 2016; Agudelo et al., 2021), migratory status (if known; Fleming and Eby, 2003) and conservation status (if listed).

| Family | Species | Fatalities | Migratory status | Regional conservation status* | Global conservation status** |
|---|---|---|---|---|---|
| Emballonuridae | *Balantiopteryx plicata* | M | | | |
| Noctilionidae | *Noctilio leporinus* | PR | | T | |
| Mormoopidae | *Mormoops megalophylla* | M | | E | |
| | *Pteronotus fulvus* | M | | | |
| | *P. mesoamericanus* | M | | | |
| | *P. psilotis* | M | | | |
| Phyllostomidae | *Phyllostomus discolor* | M | | | |
| | *Vampyrum spectrum* | | | T | NT |
| | *Choeronycteris mexicana* | | LD | T | NT |
| | *Glossophaga commissarisi* | M | | | |
| | *G. soricina* | M | | | |
| | *Leptonycteris yerbabuenae* | M | LD | T | NT |
| | *Carollia perspicillata* | | SD | | |
| | *Artibeus inopinatus* | | | T | DD |
| | *A. jamaicensis* | M, P | | | |
| | *A. lituratus* | B, M | | | |
| | *A. toltecus* | M | | | |
| | *Enchisthenes hartii* | | | E | |
| | *Centurio senex* | M | | | |
| Molossidae | *Eumops auripendulus* | M | | | |
| | *E. underwoodi* | M | | | |
| | *Molossus molossus* | B, M, P | | | |
| | *M. nigricans* | M | | | |
| | *M. (sinaloae) alvarezi* | M | | | |
| | *Promops centralis* | M | | | |
| | *Nyctinomops laticaudatus* | B, H | | | |
| | *N. macrotis* | H, M | | | |

*Table 4 continues*

| Family | Species | Fatalities | Migratory status | Regional conservation status* | Global conservation status** |
|---|---|---|---|---|---|
| | *Tadarida brasiliensis* | B, C, M, P, U, US | LD | T | |
| Vespertilionidae | *Eptesicus fuscus* | US, P | | | |
| | *Bauerus dubiaquercus* | | | | NT |
| | *Lasiurus cinereus* | B, C, H, M, US | LD | T | |
| | *L. ega* | US, M, B | | | |
| | *L. frantzii* | US, M | | | |
| | *L. intermedius* | US, M | | | |
| **Total** | **35** | **28** | **5** | **9** | **5** |

***Note.*** B = Brazil, C = Chile, H = Honduras, M = Mexico, P = Puerto Rico, U = Uruguay, US= United States, SD = short distance migrant, LD = long distance migrant, NM = non-migratory, T = threatened, E = endangered, NT = near threatened, and DD = data deficient. *= Rodríguez-Herrera and Sánchez (2015). **= IUCN (2023)

***Potential priority landscapes.*** We identified six potential priority landscapes for bats in the region based on the overlap of several projects in operation (Fig. 1): one in Guatemala (A), one in Honduras (B), one in Nicaragua (C), two in Costa Rica (D and E), and one in Panama (F). The six areas cover the known geographical ranges of a total of 113 bat species. Areas C, D, and F alone cover the ranges of more than 70 bat species (Table 5). Twenty-seven of the 113 species are considered regionally threatened or endangered, and area C alone covers the ranges of 17 of these (Table 5). Our analysis suggests that in five years the number of priority landscapes will increase, with C and D forming a corridor from southern Nicaragua to northern Costa Rica (Fig. 1). Additionally, there could be new priority landscapes in Panama (Fig. 1).

**Table 5**

Summary of number of bat species (Timm et al., 1999; Reid, 2009; Owen and Girón, 2012; Medina-Fitoria, 2014), long distance migratory species (Fleming and Eby, 2003) regionally and globally threatened species (Rodríguez-Herrera and Sánchez 2015; IUCN 2021), species with fatalities in wind farms (Mora and López 2010; Arnett and Baerwald, 2013; Espinal et al. 2016, Mora et al. 2016; Agudelo et al. 2021), and power generation capacity of wind projects (CNE, 2014; ANSPDNE, 2015; BWE 2015; TWP, 2023) for each landscape designated in Figure 1.

| Description | Potential priority landscapes (see Figure. 1) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | Total |
| Total species recorded for landscape | 65 | 62 | 75 | 72 | 48 | 72 | 113 |
| Long distance migratory species* | 4 | 5 | 2 | 2 | 2 | 1 | 5 |
| Regionally threatened species | 11 | 10 | 17 | 8 | 5 | 12 | 27 |
| Globally threatened species | 3 | 3 | 1 | 2 | 2 | 0 | 5 |
| Species with fatalities in wind farms ** | 27 | 22 | 22 | 20 | 18 | 16 | 30 |
| Current power generating capacity (MW) | 107 | 242 | 186 | 377 | 28 | 270 | 1,210 |
| Future power generating capacity (MW) | 191 | 364 | 288 | 386 | 28 | 745 | 2,532 |

*Note.* * Species with migratory behavior outside Central America. **Species with fatalities recorded on any wind farm from the United States to Uruguay, not necess3arily on the wind farms of the highlighted Central American landscapes.

Current wind power projects with the greatest generating capacity are in areas D (377 MW), F (270 MW) and C (186 MW). By the end of the decade, the situation will change in this order (Table 5): F (745 MW), D (386 MW), and B (364 MW), although areas C and D may form a single “corridor” with a total of 674 MW (Fig. 1).

***Mitigation measures.*** Studies in North America have shown that mitigation measures such as raising cut-in speeds, curtailing operations during weather conditions associated with high fatality, and employing deterrence methods such as ultrasound, are effective in reducing bat fatalities at minimal production loss (Martin et al., 2017; Weaver et al., 2020).

## Discussion

In Central America as a whole and in each of its seven nations, the regulations and laws that already exist are expected to protect bats to prevent fatalities in wind projects, since the intention is to protect all wildlife, although nothing specific to bats was established for this type of project. (UN, 1992; UN, 2010; CCAD, 2011; CCAD, 2014). These regulations and laws oblige wind power projects to undertake environmental impact studies that must include possible impacts on fauna (CCAD, 2011). Prior to 2010, the faunal component tended to focus on the threats that wind turbines posed to birds, not bats (CCAD, 2011). It may be necessary to develop more stringent regulations that demand more complete environmental impact assessments and continuous monitoring of bat fatalities in wind farms at least for the medium term. Such policy changes should be considered immediately. For example, it may be necessary to develop threshold values for incidental take that trigger mitigation, such as has been developed in Ontario, Canada, and Pennsylvania, United States, although some workers caution that such thresholds may be arbitrary and ineffective (Arnett et al, 2013). In South Africa, the South African Bat Assessment Association have developed species-specific bat fatality thresholds from calculations that consider acoustically measured bat densities (bats/ha) for various landscapes, for wind energy installations operational in these landscapes, on the assumption that >2% population declines are irreversible and not sustainable (MacEwan et al., 2017).

The lack of baseline information on population sizes of Central American bat species should not be considered an excuse for avoiding mitigation, and powerful stakeholders such as financers and governments should work together to develop a framework for enforcing effective mitigation strategies, rather than leave it up to the industry to voluntarily adopt such strategies.

By 2030, wind power generation capacity in Central America will have at least doubled compared to 2022 power generation (CNE, 2014; ANSPDNE, 2015; BWE, 2015; TWP, 2023). If immediate action is not taken, many wind farms will be under construction or operational before adequate bat monitoring studies can be implemented, especially in Panama (ANSPDNE, 2015; TWP, 2023)—and thus baseline or "pre-impact" data will be missing. Furthermore, rapid growth of wind power projects implies that bat fatality will grow rapidly also, potentially growing from an estimated 190,000 fatalities over the last 25 years to 42,000 in a single year, assuming fatality rates remain constant.

Unfortunately, bats are being killed by wind power turbines worldwide. These fatalities are not limited to migratory species at higher latitudes, as was once thought (Kunz et al., 2007; Arnett et al., 2008). Fatalities are increasingly reported among other species, such as non-migratory insectivores and frugivores (Arnett and Baerwald, 2013; Barros et al., 2015; Rodríguez-Durán and Feliciano-Robles, 2015). In fact, all Central American bat fatality is currently presumed to pertain to non-migratory populations. The vulnerability of tropical bats to wind turbines is a potentially serious problem that should be immediately addressed, preferably before increasing numbers of large wind power projects are planned and constructed (Arnett and Baerwald, 2013; Agudelo et al. 2021).

It is important to emphasize that the population dynamics of most affected bats is poorly known in the neotropics, especially in the Molossidae family. There are two aspects that are particularly important to learn to better understand the impact: local population sizes and movements. Local abundance per species, especially for high-flying insectivorous species, has not been evaluated. Mobile acoustic monitoring, which allows the collection of quantitative bat data, has the potential to fill this knowledge gap (Britze and Herzog, 2009; Roche et al., 2011). In North America, the nascent North American Bat Monitoring Program (NABat) aims to collect abundance data on bats in a standardized manner; we recommend that similar programs using the same data collection protocols are developed in Central America to measure populations trends (Loeb et al., 2015). Several technologies, such as radio tracking, data loggers, and satellite tracking, are available to evaluate local bat movements (Fleming, 2019).

Reducing bat fatalities under projected increase of wind energy installation in Central

America over the next decade may also be beneficial from an ecosystem services point of view. For example, studies in North America demonstrated that a population of *Tadarida brasiliensis* was able to provide pest control services worth more than $740,000 annually to the cotton industry in south-central Texas (Cleveland et al., 2006). Another example, in corn plantations bat consumption of crop pests initiates a trophic cascade, suppressing damage to economically valuable row crops during both reproductive and vegetative stages (Maine and Boyles, 2015). Since most bat fatalities in Central America are likely to concern insectivorous species, taking out tens of thousands of pest-controlling bats may have negative impacts on the region's already fragile agriculture.

Other ecosystem services provided by some species affected in wind farms are the dispersal of seeds and the pollination of plants, some of which are economically important such as the *Agave tequilana* from which the drink Tequila is extracted and whose pollination is carried out by the species *Leptonycteris yerbabuenae* know as tequila bat (Menchaca et al., 2020).

Mitigation measures such as raising the cut-in speed, which have been demonstrated to reduce bat fatalities by more than 50% at minimal production loss (up to 5%) in temperate zones (Baerwald et al., 2009; Arnett et al., 2011; Rodrigues et al., 2015; Martin et al., 2017; Richardson et al., 2021), have the potential to reduce bat fatality estimates that we present here. For example, by 2030, based on projections we present here, a 50% reduction in bat fatalities could mean 15,000 bat lives spared in a single year.

Ultrasonic deterrents have shown moderate success in reducing bat fatalities at wind farms, with reported reductions ranging from 30% to 60% (Arnett et al., 2013; Weaver et al., 2020). Installation and equipment costs are relatively low, typically under USD 10,000 per turbine—and they have negligible effects on energy production (Hayes et al., 2019). In contrast, curtailment strategies that raise the cut-in speed of turbines are highly effective—often reducing bat mortality by over 50%—but can result in annual energy losses of 1% to 3%, depending on site conditions and wind regimes (Baerwald et al., 2009; Martin et al., 2017). Despite the effectiveness of both approaches, widespread adoption remains limited due to variability in outcomes, lack of regulatory mandates, and uncertainties about long-term cost-benefit balance (Frick et al., 2017; Allison et al., 2019).

We are aware that increases in installed capacity may not generate a proportional increase in bat fatalities. Bats are long-lived, slow-reproducing organisms whose populations may not be able to sustain high levels of fatality. Thus, our projection of future bat fatalities may be too high, as there may be fewer bats left in the affected “landscapes" we identify here. In fact, these landscapes, here defined as 30 km areas of influence around wind farms or wind farm aggregations, may extend much further than 30 km in areas with high installed capacity, as such areas have the potential to become sinks, where the number of bats killed annually is too high for local populations to sustain and are replaced by individuals from surrounding source populations. This is a scenario that has thus far not been considered in temperate zones, where most bat fatalities concern migratory species, but may be realistic in the Neotropics, where most species are sedentary.

Studies that demonstrate the effectiveness of these mitigation measures in Central America are in urgent need of development. Wind energy generators are likely to continue to use large moving blades, and thus cause bat fatality, for two decades or more. Next generation generators with no exposed moving parts (e.g., Epstein 2019) are not yet commercially available, at least not for large-scale operations. While we hope that energy companies will be proactive in seeking new, wildlife-safe technologies at the earliest possible opportunity, we also encourage companies to consider their cumulative impacts now on bat populations and begin as soon as possible to test options for mitigation.

We recommend that governments require data sharing from environmental impact studies and fatality monitoring projects, even when privately funded. Such data should be available through web-based clearinghouses, or databases. We also recommend wind energy companies to allow publication of their proprietary fatality estimates in peer-reviewed literature. This will greatly facilitate information access and decrease reaction times to emerging crises in bat populations affected by the region´s wind farms. Requiring data reporting will also solve another problem, at least in some countries; lack of access to data often means that governments are not equipped to enforce their wildlife laws. Having access to data permits governments to get involved in requiring mitigation solutions, when such are in fact required by existing laws. Achieving a goal of public data sharing of wildlife data generated from wind farms will require coordination with national environmental and wildlife policy agencies, at a regional (Central American) level.

In conclusion, policy changes should be considered immediately to mandate more impact assessments and continuous monitoring of bat fatalities in wind farms by independent parties. An increase from current installed capacity to projected installed capacity leads to a projected regional bat fatality estimate could reach from 41,000 to 145,000 bats/year.

The species *Artibeus lituratus, Leptonycteris yerbabuenae, Molossus molossus, M. nigricans, Nyctinomops laticaudatus, Tadarida brasiliensis, Lasiurus cinereus, L. ega, L. frantzii.,* and *L. intermedius*, have fatalities associated with wind farms in at least two countries. If nothing is done, some of these species are likely to have a regional population decline.

Mitigation measures such as raising the cut-in speed, have the potential to reduce bat fatality, and must be implemented, but given projections of increasing bat fatality from wind energy in Central America, greater efforts are needed to implement and evaluate potential mitigation strategies. Furthermore, data and studies of bats in wind farms should be available, and publications in peer review should be allowed for the companies.

We believe the generation of wind energy as an alternative energy source is important to reduce environmental problems globally; however, it is very important to do so with the least possible impact on wildlife. The potential threats of wind farms to bat populations should not merely be addressed project by project but also at the regional scale. Single wind farms may not directly cause species' extinctions, but the cumulative effect of multiple wind farms as stressors on bat populations may be too great to overcome.

A great deal of research is needed to develop innovative strategies that will sustain one of the world's most diverse bat faunas. This could be achieved through the coordinated work of bat conservation programs already established in the region.

**Acknowledgements**

We thank P. Feinsinger, K. Wolfe and two anonymous reviewers for their valuable contributions to this manuscript.

**Contribuciones de autores**

**L. Girón-Galván** - Conceptualización de la investigación; planificación y supervisión de la investigación; recolección, procesamiento y análisis de datos; redacción de borrador original. **J. Hernández** - Revisión y edición de borrador original y artículo final. **M. E. Rodríguez** - Revisión y edición de borrador original y artículo final. **O. Komar** – Escritura, revisión y edición de borrador original y artículo final. **J. van Dort** – Curación de datos; escritura, revisión y edición de borrador original y artículo final. **R. Juárez** - Curación de datos; escritura, revisión y edición de borrador original y artículo final. **B. Rodríguez-Herrera** - Conceptualización de la investigación; planificación y supervisión de la investigación; revisión y edición de borrador original y artículo final.

**References**

Agudelo, M. S., Mabee, T. J., Palmer, R. and Anderson, R. (2021). Post-construction bird and bat fatality monitoring studies at wind energy projects in Latin America: A summary and review. Heliyon 7: e07251.

Allison, T. D., Butryn, R., and Stenhouse, I. (2019). A review of options for mitigating take of migratory birds at wind energy facilities. *Environmental Practice*, 21(3), 211–229. https://doi.org/10.1080/14660466.2019.1680796

Arnett, E. B., Baerwald, E. F., Mathews, F., Rodrigues, L., Rodríguez-Durán, A., Rydell, J., Villegas-Patraca, R. and Voigt, C. C. (2016). Impacts of Wind Energy Development on Bats: A Global Perspective. In: *Bats in the Anthropocene: Conservation of Bats in a Changing World*: 295- 324 (C. C. Voigt and T. Kingston, Eds.). Springer International Publishing, Switzerland.

Arnett, E. B., Brown, W., Erickson, W. P., Fiedler, J. K., Hamilton, B. L., Henry, T. H., Johnson, G. D., Kerns, J., Kolfor, N. N., Nicholson, C. P., O´Connell, T., Piorkowski, M. and Tankersley R. Jr. (2008). Patterns of bat fatalities at wind energy facilities in North America. *The Journal of Wildlife Management*, 72, 61-78.

Arnett, E. B., and Baerwald, E. F. (2013). Impacts of wind energy development on bats: implications for conservation. In: *Bat evolution, ecology, and conservation*: 435–456 (R. A. Adams and S. C. Pederson, Eds.). Springer Science Press, New York.

Arnett, E. B., Barclay, R. M. R., and Hein, C. D. (2013). Thresholds for bats killed by wind turbines. *Frontiers in Ecology and the Environment*, 11(4): 171. https://doi.org/10.1890/1540-9295-11.4.171.

Arnett, E. B., Hein, C. D., Schirmacher, M. R., Huso, M. M. P., and Szewczak, J. M. (2013). Evaluating the effectiveness of an ultrasonic acoustic deterrent for reducing bat fatalities at wind turbines. *PLoS ONE*, 8(6), e65794. https://doi.org/10.1371/journal.pone.0065794

(ANSPDNE) Autoridad Nacional de los Servicios Públicos Dirección Nacional de Electricidad de la República de Panamá. (2015). Licencias Definitivas para Generación Eólicas. Panamá, Panamá.

Baerwald, E. F., Edworthy, J., Holder, M., and Barclay, R. M. R. (2009). A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. *Journal of Wildlife Management*, 73(7), 1077–1081. https://doi.org/10.2193/2008-233

Barclay, R. M. R. and Harder, L. M. (2003). Life histories of bats: life in the slow lane. In: *Bat ecology*, 209–259 (T. H. Kunz and M. B. Fenton, Eds). University of Chicago Press, Chicago.

Barros, M. A. S., Gastal, R.and Rui, A. M. (2015). Species composition and mortality of bats at the Osório Wind Farm, southern Brazil. *Studies on Neotropical Fauna and Environment*. *50*, 31–39.

(BWE) Belize Wind Energy (2015). Downloaded from http://www.belizewindenergy.com on 12/12/2016.

Bernstein M. A., Griffin, J. and Lempert, R. (2006). *Impacts on energy expenditures of use*. Technical report prepared for the energy future coalition, RAND Corporation, California.

Bolívar-Cimé, B., Bolívar-Cimé, A., Cabrera-Cruz, S. A., Muñoz-Jiménez, O. and Villegas-Patraca, R. 2016. Bats in a tropical wind farm: species composition and importance of the spatial attributes of vegetation cover on bat fatalities. *Journal of Mammalogy* 97(4): 1197–1208.

Bonilla, A. (2014). *Patrones de sequía en Centroamérica, su impacto en la producción de maíz y frijol y uso del índice normalizado de precipitación para los sistemas de alerta temprana*. GWP Centroamérica. Tegucigalpa.

Britzke, E. R., and Herzog, C. (2009). *Using acoustic surveys to monitor population trends in bats*. U.S. Army Engineer Research and Development Center, Vicksburg, MS. Available at https://georgiawildlife.com/sites/default/files/wrd/pdf/bats/Acoustic%20Transect%20Guidance.pdf

Cleveland, C. J., Betke, M., Federico, P., Frank, J. D., Hallam, T. G., Horn, J., López, J. D., McCracken, G. F., Medellín, R. A., Moreno-Valdez, A., Sansone, C. G., Westbrook, J. K., and Kunz, T. H. (2006). Economic value of the pest control service provided by Brazilian free-tailed bats in south-central Texas. *Frontiers in Ecology and the Environment* 4(5): 238–243.

(CNE) Consejo Nacional de Energía de la Republica de El Salvador. (2014). *Actualización del Plan Indicativo de la Expansión de la Generación 2014-2024.* San Salvador.

(CCAD) Comisión Centroamericana de Ambiente y Desarrollo. (2011). *Guía de Revisión Técnica de EIA: Generación y Transmisión de Energía*. San Salvador.

(CCAD) Comisión Centroamericana de Ambiente y Desarrollo. (2014). *Estrategia regional ambiental marco 2015-2020*. San Salvador.

Escobar, L. E., Juárez, C., Medina-Vogel, G. and González, C. M. (2015). First report on bat mortalities on wind projects in Chile. *Gayana*, *79*, 11–17.

Espinal, M., Mora, J. M. and OReilly, C. M. (2016). The occurrence of the Peale's free-tailed bat (*Nyctinomops aurispinosus*, Molossidae) in Central

America. *Caribbean Journal of Science*, 49, 79–82.

Epstein, R. I. (2019). A solid-state wind-energy transformer. *Applied Physics Letters*, *115*(8): 083901.

Fleming, T. H. (2019). Bat migration. Encyclopedia of Animal Behavior 2019: 605–610. Accessed from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7149675/.

Fleming, T. H. and Eby, P. (2003). Ecology of bat migration. In: *Bat ecology*: 156-208 (T. H. Kunz and M. B. Fenton, Eds.) University of Chicago Press, Chicago.

Frick, W. F., Baerwald, E. F., Pollock, J. F., Barclay, R. M. R., Szymanski, J. A., Weller, T. J., Russell, A. L., Loeb, S. C., Medellín, R. A., and McGuire, L. P. (2017). Fatalities at wind turbines may threaten population viability of a migratory bat. *Biological Conservation*, 209, 172–177. https://doi.org/10.1016/j.biocon.2017.02.023

Gorresen, P. M., Cryan, P. M., Hein, C. D., Schirmacher, M. R., Huso, M. M. P., Hayman, D. T. S., and Frick, W. F. (2015). Behavior of Hawaiian hoary bats at wind turbines and its implications for mitigation. *Ecological Applications*, 25(4), 939–949. https://doi.org/10.1890/14-0741.1

Hayes, M. (2013). Bats killed in large numbers at United States wind energy facilities. *BioScience, 63*, 975–979.

Hayes, M. A., Hooton, L. A., Gilland, K. L., Grandgent, C., Smith, R. L., Lindsay, S. R., and Collins, J. D. (2019). A smart curtailment approach for reducing bat fatalities and curtailment time at wind energy facilities. *Ecological Applications*, 29(4), e01881. https://doi.org/10.1002/eap.1881

Hutson, A. M., and Mickleburgh, S. P. (2001). *Microchiropteran bats: global status survey and conservation action plan* (Vol. 56). IUCN.

IRENA (2020). *Renewable Energy Statistics 2020*. The International Renewable Energy Agency, Abu Dhabi.

IUCN 2022. The IUCN Red List of Threatened Species. Version 2022-1. <https://www.iucnredlist.org>

Kunz, T. H., Arnett, E. B., Erickson, W. P., Hoar, A. R., Johnson, G. D., Larkin, R. P., Strickland, M. D., Thresher, R. W. and Tuttle, M. D. (2007). Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment*, 5, 315–324.

Ley N° 68. Diario Oficial de la República de Guatemala, ciudad de Guatemala, Guatemala, 5 de diciembre 1986.

Ley N° 7200. Diario Oficial de la República de Costa Rica, San José, Costa Rica, octubre de 1990.

Ley N° 7317. Diario Oficial de la República de Costa Rica, San José, Costa Rica, 30 de octubre de 1992.

Ley N° 104. Diario Oficial de la República de Honduras, Tegucigalpa, Honduras, 8 de junio de 1993.

Ley N° 844. Diario Oficial de la República de El Salvador, San Salvador, El Salvador, 21 de abril de 1994.

Ley N° 158. Diario Oficial de la República de Honduras, Tegucigalpa, Honduras, noviembre de 1994.

Ley N° 2. Diario Oficial de la República de Panamá, ciudad de Panamá, Panamá, 12 de enero de 1995.

Ley N° 6. Diario Oficial de la República de Panamá, ciudad de Panamá, Panamá, febrero de 1995.

Ley N° 24. Diario Oficial de la República de Panamá, ciudad de Panamá, Panamá, 9 de junio de 1995.

Ley N° 7554. Diario Oficial de la República de Costa Rica, San José, Costa Rica, 4 de octubre de 1995.

Ley N° 93. Diario Oficial de la República de Guatemala, ciudad de Guatemala, Guatemala, 1996.

Ley N° 217. Diario Oficial de la República de Nicaragua, Managua, Nicaragua, 27 de marzo de 1996.

Ley N° 843. Diario Oficial de la República de El Salvador, San Salvador, El Salvador, 10 de octubre de 1996.

Ley N° 6. Diario Oficial de la República de Panamá, ciudad de Panamá, Panamá, febrero de 1997.

Ley N° 79. Diario Oficial de la República de El Salvador, San Salvador, El Salvador, 4 de mayo de 1998.

Ley N° 7788. Diario Oficial de la República de Costa Rica, San José, Costa Rica, 27 de mayo de 1998.

Ley N° 41. Diario Oficial de la República de Panamá, ciudad de Panamá, Panamá, 1 de julio de 1998.

Ley N° 220. Leyes de Belice, Belmopán, Belice, 31 de diciembre de 2000.

Ley N° 221. Leyes de Belice, Belmopán, Belice, 31 de diciembre de 2000.

Ley N° 328. Leyes de Belice, Belmopán, Belice, 31 de diciembre de 2000.

Ley N° 52. Diario Oficial de la República de Guatemala, ciudad de Guatemala, Guatemala, 2003.

Ley N° 532. Diario Oficial de la República de Nicaragua, Managua, Nicaragua, 27 de mayo de 2005.

Ley N° 462. Diario Oficial de la República de El Salvador, San Salvador, El Salvador, diciembre de 2007.

Ley N° 70. Diario Oficial de la República de Honduras, Tegucigalpa, Honduras, octubre de 2007.

Ley N° 156. Diario Oficial de la República de Honduras, Tegucigalpa, Honduras, 26 de febrero de 2007.

Ley N° 682. Diario Oficial de la República de Nicaragua, Managua, Nicaragua, 8 de mayo de 2009.

Ley N° 807. Diario Oficial de la República de Nicaragua, Managua, Nicaragua, 5 de septiembre de 2012.

Loeb, S.C., Rodhouse, T. J., Ellison, L. E., Lausen, C. L., Reichard, J. D., Irvine, K. M., Ingersoll, T. E., Coleman, J. T. H., Thogmartin, W. E., Sauer, J. R., Francis, C. M., Bayless, M. L., Stanley, T. R., and Johnson, D. H. (2015). *A Plan for the North America Bat Monitoring Program (NABat).* United States Forest Service, Research & Development, Southern Research Station, General Technical Report SRS-208. 112 pp.

Maine, J. J., & Boyles, J. G. (2015). Bats initiate vital agroecological interactions in corn. *Proceedings of the National Academy of sciences*, 112(40), 12438-12443.

MacEwan, K., Aronson, J., Richardson, K., Taylor, P., Coverdale, B., Jacobs, D., Leeuwner, L., Marais, W., and Richards, L. (2017). *South African Bat Fatality Threshold Guidelines for Operational Wind Energy Facilities.* South African Bat Assessment Association.

Martin, C. M., Arnett, E. B., Wallace, M. C., and Singh, A. (2017). Reducing bat fatalities at wind facilities while improving economic efficiency: a synthesis. *Environmental Management*, 60(5), 752–760. https://doi.org/10.1007/s00267-017-0911-5

Martin, C. M., E. B. Arnett, R. D. Stevens, M. C. Wallace. (2017). Reducing bat fatalities at wind facilities while improving the economic efficiency of operational mitigation. *Journal of Mammalogy*, 98(2): 378–385. Downloaded from https://doi.org/10.1093/jmammal/gyx005.

Medina-Fitoria, A. (2014). *Murciélagos de Nicaragua, guía de campo*. Ministerio de Medio Ambiente y Recursos Naturales. Managua.

Menchaca, A., Arteaga, M. C., Medellin, R. A., & Jones, G. (2020). Conservation units and historical matrilineal structure in the tequila bat (*Leptonycteris yerbabuenae). Global Ecology and Conservation*, 23, e01164.

Mora, J. M., and López, L. I. (2010). First record of the hoary bat (*Lasiurus cinereus*, Vespertilionidae) for Honduras. *Ceiba*, 51: 89–90.

Mora, J. M., Espinal, M. R. Ruedas, L. A. and López, L. I. (2016). The big free-tailed bat, *Nyctinomops macrotis* (Gray, 1839), in Central America. *Mastozoología Neotropical* 23: 551–556.

Neri, M., Jameli, D., Bernard, E., & Melo, F. P. (2019). Green versus green? Adverting potential conflicts between wind power generation and biodiversity conservation in Brazil. *Perspectives in Ecology and Conservation*, 17(3): 131-135.

(OLADE) Organización Latinoamericana de Energía (2012). *Desarrollo y situación actual del sector eólico en América Central*. Quito.

Owen, J. G., and Girón, L. (2012). *Revised checklist and distributions of land mammals of El Salvador*. Occasional Papers: 310. Museum of Texas Tech University, Texas

Owuso, P. A., and Asumadu-Sarkodie, S. 2016. A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering* 3(1):11679990.

Reid, F. A. (2009). *A field guide to the mammals of Central America and Southeast Mexico*. Oxford University Press, Oxford.

Richardson, S. M., Lintott, P. R., Hosken, D. J., Economou, T., & Mathews, F. (2021). Peaks in bat activity at turbines and the implications for mitigating the impact of wind energy developments on bats. Scientific Reports, 11(1), 3636.

Roche, N., Langton, S., Aughney, T., Russ, J. M., Marnell, F., Lynn, D., and Catto, C. 2011. A car-based monitoring method reveals new information on bat populations and distributions in Ireland. *Animal Conservation* 14: 642–651.

Rodríguez-Durán, A. and Feliciano-Robles, W. (2015). Impact of Wind Facilities on Bats in the Neotropics. *Acta Chiropterologica*. 17: 365–370.

Rodríguez-Herrera, B. and Sánchez, R. (2015). *Estrategia centroamericana para la conservación de los murciélagos*. Universidad de Costa Rica, Escuela de Biología, San José.

Saidur, R., Rahim, N. A., Islam, M. R., and Solangi, K. H. (2011). Environmental impact of wind energy. *Renewable and sustainable energy reviews* 15(5): 2423–2430.

Sims, R. E. 2004. Renewable energy: a response to climate change. *Solar energy* 76(1–3):9–17.

(TWP) The Wind Power. (2023). Downloaded from http://www.thewindpower.net

Timm, R., LaVal, R. and Rodríguez-Herrera, B., 1999. Clave de campo para los murciélagos de Costa Rica. *Brenesia*, *52,* 1–32.

(UN) United Nations (1992). *Convention on Biological Diversity*. Rio of Janeiro.

(UN) United Nations. (2010). *Strategic Plan for Biodiversity 2011–2020*. Montreal.

Weaver, S. P., Hein, C. D., Simpson, T. R., Evans, J. W., and Castro-Arellano, I. (2020). Ultrasonic acoustic deterrents significantly reduce bat fatalities at wind turbines. *Global Ecology and Conservation*, Downloaded from https://doi.org/10.1016/j.gecco.2020.e01099.