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The Potential for Typhoon Impact on Bird Populations on the Island of Rota, Northern Mariana Islands

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Abstract—Numerous independent analyses of climate change have suggested that changing weather patterns are resulting in increasing frequency or intensity of hurricanes and typhoons. We explore the relationship between cyclonic event frequency and severity on measures of bird abundance on the island of Rota, in the Northern Mariana Islands to determine if changes in cyclonic event pattern might be related to the local decline of avian species. We developed a database of Rota cyclonic event encounters since 1952 and three primary variables for analysis of cyclonic event behavior were then derived from this data: Time-Between-Typhoon-Encounters, Distance from Rota at closest approach, and Pressure at the center of the cyclonic event at the point of closest approach. Three similar smoothed variables were derived relative to each Breeding Bird and Variable Circle Plot census time point. Multivariate general linear models were constructed separately for each bird abundance data set with multiple species as dependent variables and smoothed cyclonic event time-between-encounter, distance-at-closest-point, and central-pressure-at-closest-point as independent variables. Cyclonic event behavior in relation to Rota did not exhibit an increase in frequency, as sometimes perceived, but did show a significant decrease in distance to the island and an increase in intensity as measured by central pressure. Several species abundances showed significant relationships with cyclonic event pressure or distance, including the Mariana Crow, Philippine Turtle Dove, and Rufous Fantail. It appears that changes in cyclonic event "behavior" could be impacting forest-bird populations on Rota. Overall, bird population declines may be due to a combined effect of habitat loss, introduced species pressure, and cyclonic events, where any one of the factors might be enough to tip a species into decline.

Introduction

Numerous independent analyses of climate change have suggested that changing weather patterns are resulting in increasing frequency or intensity of hurricanes and cyclonic events (e.g. Emanuel 2005, Trenberth 2005, Webster et al. 2005, Santer et al. 2006, Sriver and Huber 2006). Concerns over the impact of climate change on species survival and ecological stability have been growing worldwide (Hulme 2005, Shoo et al. 2005). Evidence is accumulating that climatal change has impacted avian species distribution (Thomas and Lennon 1999, McCarty 2001, Walther et al. 2002), abundance (McCarty 2001, Walther et al. 2002, Rittenhouse et al. 2010), or community similarity (Rittenhouse et al. 2010), and models predict additional declines in species and high extinction rates due to climate change (Shoo et al. 2005). In fact, Shoo et al. (2005) found that their most conservative model predicts that 74% of rainforest birds in northeastern Australia could become threatened due to climate change in the next 100 years. On the other hand, more recent studies have further clarified the specific role of cyclonic storms activity in specific avian community types and suggested little long-term concern (Rittenhouse et al. 2010, Devney et al. 2009).

Severe oscillations in cyclonic storm activity have also been observed, often cycling from high to low activity over several decades. It has been suggested that increases in typhoon activity in the Western Pacific observed from the 1980's into the early 2000's may simply be a result of oscillatory activity (Lander 2004, M.A. Lander unpublished). In fact, since our data set was collected, the Western Pacific has entered a period of very low storm activity (Maue 2011). Regardless of the cause for changes in cyclonic storm activity, the effects of more severe storm activity on avian populations may have significant consequences, especially on small island populations experiencing other negative effects such as habitat loss and predation or competition from exotic species.

Our work focuses on the island of Rota, near Guam in the northwestern Pacific Ocean. There has been a widespread decline of a number of species on the island (Fancy et al. 1999, Amar et al. 2008). The Mariana Crow *(Corvus kubaryi)* is currently listed as an endangered species (U.S. Fish and Wildlife Service 2005b). While the Mariana Crow's decline on Guam has been associated with the introduced brown tree snake (*Boiga irregularis*, Savidge 1987, Wiles et al. 2003), this is not thought to be the reason for the decline of this forest crow on Rota (National Research Council 1997). Rather, predation and habitat loss have been cited in recent literature (Plentovich et al. 2005, Ha et al. 2010, 2011). The Rota White-eye, found at higher altitudes on Rota, is also endangered (U.S. Fish and Wildlife Service 2005a). Due to the immediate concern for the endangered species on Rota, and a more general concern for the entire avifauna of the island and Mariana archipelago, it is vital to understand the factors influencing the decline of this avifauna.

It has been suggested that cyclonic event encounters on Rota had become more frequent in the years from 1985 to 2005, and that this phenomenon might be contributing to the declines in some forest-bird species (J. Morton pers. comm., Plentovich et al. 2005, U.S. Fish and Wildlife Service. 2005b). Severe weather may impact birds directly through effects that cause immediate mortality such as nest destruction, mortality of eggs, nestlings or fledglings (Plentovich et al. 2005), and creating opportunities for predator attacks. Numerous additional indirect effects could result in limited food supply (Lynch 1991), increased intra and inter-specific competition for limited resources (Hulme 2005), fewer nesting trees and less canopy cover due to storm damage (Cole et al. 1999) or delayed nesting due to vegetation limitations (Lin et al. 2003). Lin et al. (2003) found a significant increase in litterfall and a significant decline in canopy cover following typhoons. Typhoon damage to forest canopy may result in producing habitats that favor species that are typically associated with edge habitats or farmland (Lynch 1991). Additionally, severe hurricane damage has been shown to impact forest-associated frugivores and nectivores most profoundly, even in areas prone to hurricanes (Lynch 1991).

In this study, we explored the relationship between cyclonic event frequency and severity on measures of lowland bird abundance on the island of Rota to determine whether changes in cyclonic event pattern might be related to the local decline of avian species. Specifically, we proposed that an increase in cyclonic activity in the 1990's and early 2000's in which cyclonic events became more frequent, more severe, and closer to Rota would explain a significant proportion of the decline in multiple avian populations on Rota.

Methods

Study Area

The island of Rota (14° 10' N, 145° 12' E) is part of the Mariana Archipelago in the Northwestern Pacific. It is of ancient volcanic origin with an area of 85 km2 and a maximum elevation of 491 m. The geology is primarily composed of limestone, but containing exposed areas of volcanic origin, and is classified as high volcanic with raised coral (limestone) terraces. The ecosystem is described as limestone forest, grasslands, second-growth forest, and agricultural lands (Falanruw et al. 1989, Dahl 1991, Mueller-Dombois and Fosberg 1998).

Cyclonic Event Data

We developed a database of Rota cyclonic event encounters since 1952, including frequency, distance, strength, and direction relative to Rota. Our data was drawn from the Digital Typhoon Database (Kitamoto 2005). The project has built a large-scale scientific database of Pacific cyclonic events, and established algorithms and database models for the recovery of information and knowledge useful for cyclonic event analysis and prediction. Three primary variables for analysis of cyclonic event behavior were then derived from this data: Time-Between-Typhoon-Encounters, Distance from Rota at closest approach, and Pressure at the center of the cyclonic event at the point of closest approach, for all cyclonic events approaching within 150km of Rota from 1952 to 2005. Central pressure is inversely related to the intensity (e.g., wind speed) of the storm. Three similar variables were derived relative to each avian census time point: Time-Since-Encounter (for the last cyclonic event within 150km), Pressure (of last encounter) and Distance (at closest approach of last cyclonic event encounter). For the ease of reading, we will refer to these cyclonic events as 'typhoons' from this point on.

Island-Wide Variable Circular Plot Survey (VCP)

This survey protocol was based on the Variable Circular Plot method described by Reynolds et al. (1980). The procedures were modified to suit the types of vegetation encountered in the Mariana Islands, the species under consideration, and the skill level of the observers. These survey data were collected periodically from 1982–2003. Unfortunately, these data were not collected consistently, with both season and stations varying across the 20+ year time period. Because of this inconsistent effort, we converted the data to a weighted average based on the number of transects and stations in an attempt to produce results which would be comparable across years.

Seventeen transects were spaced at least 200 m apart and cut across all vegetation types and major geological land formations in the forest (Engbring et al. 1986). Transects range in length from a few hundred meters to over a kilometer long and were marked with flagging (Fig. 1). Stations were temporarily established approximately 150 m apart on the transects. Trained observers counted all birds heard, seen, or heard then seen and the distance to bird were recorded. Count duration was limited to 8 min. All counts were conducted between sunrise and 4

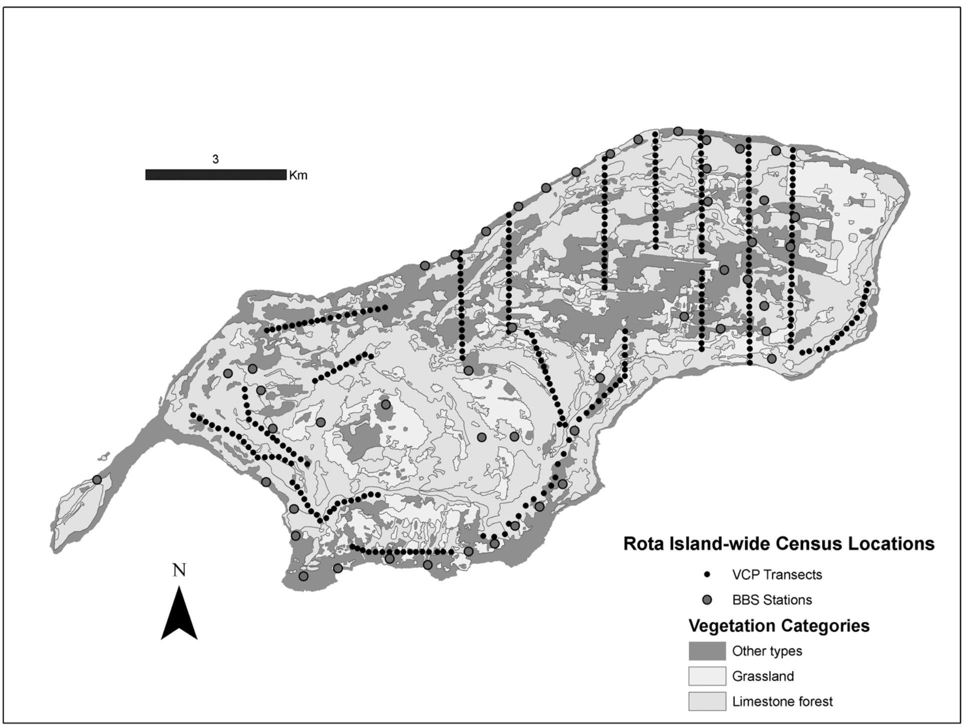

Figure 1. Map of BBS and VCP Transect Stations

hrs after sunrise. Counts were abandoned if rain persisted for more than a short time or if the wind blew consistently above force 4 on the Beaufort scale. A total of 16 observers were involved in the 7 surveys, and 7 of these observers conducted counts in 2 or more years. VCP surveys were conducted in 1982, 1987, 1994, 1995, 1998, and 2003. The average length of time following a typhoon passage until the following VCP census was 225 days, ranging from 16 to 446 days.

Road-based Breeding Bird Surveys (BBS)

The road-based breeding bird survey route consists of 50 stations distributed on roads throughout Rota. Each station is marked with flagging and spaced 0.5 km apart (Fig. 1, Plentovich et al. 2005). Here we report quarterly data recorded every January, April, July, and October from January 2000 to October 2005. All observations were made between sunrise and four hrs after sunrise. During each survey, all bird species (including the number of individuals per species) detected by sight and/or sound for a period of 3 min were recorded at each of the 50 stations.

Statistical Analyses

Descriptive statistics on all variables were examined for satisfaction of parametric assumptions: no data transforms were required. Typhoon data (Time-Between-Typhoon-Encounters, Distance from Rota, and Pressure) was analyzed for trends over time using a multivariate general linear model. Typhoon data was then smoothed via a LOWESS method, and the smoothed values for the three typhoon measures for the date of each bird survey was used as predictor variables for bird abundance measures from the two data sets. Multivariate general linear models were constructed separately for each data set (VCP and BBS) with multiple species (total number of birds detected) as dependent variables and smoothed values for time between encounters, distance, and pressure as independent variables. The adjusted R^2 (overall proportion of variance explained by the independent variables) was used to establish the best model for each species and data set. Rota White-eyes were excluded from the analysis due to their poor representation in the avian sampling records.

Results

Typhoon Analyses

We determined that 70 cyclonic storms passed within 150km of Rota between 1952 and 2005. At their point of closest approach to Rota, their average distance was 93km, their average pressure was 979mmHg, and the average time between encounters was 283 days.

Typhoon encounters on or near Rota did not change in frequency over the 54-year time period (t=0.587, p=0.56, R^2=0.005, Fig. 2). This variable was dropped from further analyses with bird numbers. However, typhoon paths have shifted significantly closer to Rota (t=-2.096, p=0.040, R^2=0.061), and the strength of typhoons, at their point of closest approach to Rota, have been significantly greater (t=-2.154, p=0.035, R^2=0.064).

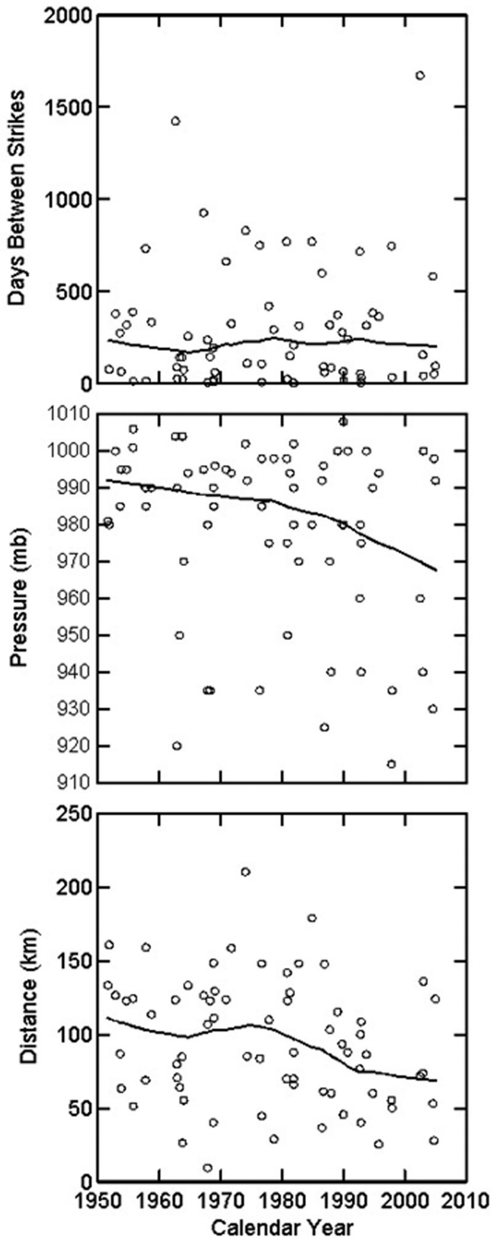

Figure 2. Changes in typhoon behavior over the past 55 years in the vicinity of Rota, Mariana Islands. Lines are LOWESS-smoothed averages (see text). DAYS BETWEEN refers to the number of days between consecutive typhoons approaching within 150km of Rota (p=0.559), PRESSURE refers to the strength of the typhoon measured in pressure at the point of closest approach to Rota, in millibars (p=0.040), and DISTANCE refers to the distance (km) at the point of closest approach to Rota(p=0.035).

Typhoon Characteristics and Bird Abundance

Our expectation was that greater Time-Between-Encounters, Pressure, and Distance would be related to increased bird numbers (a direct relationship was indicated by a positive regression slope; an inverse relationship [greater Time, Pressure and Distance related to fewer birds] was indicated by a negative regression slope). After dropping the variable Time-Between-Encounters as not exhibiting any change, long-term (VCP) bird abundance patterns were statistically related to remaining typhoon behavior (Pressure, and Distance) in the following instances: Mariana Crow numbers exhibited a significant relationship with typhoon behavior ($R^2 = 0.93$, overall $F_{2,4} = 28.05$, $p = 0.004$): the relationship with Distance was inverse while the relationship with Pressure was direct. Likewise, a similar pattern was exhibited by the Philippine Turtle Dove ($R^2 = 0.84$, overall $F_{2,4} = 10.83$, $p = 0.024$). Thus, the greatest number of crows and turtle doves were seen following mild typhoons that were close. The pattern was exactly the opposite for the Rufous Fantail ($R^2 = 0.98$, overall $F_{2,4} = 126.27$, $p < 0.0001$): lower abundances were associated with mild typhoons that were close. Abundances for none of the other species examined were related to typhoon Distance or Pressure, including the Mariana Fruit Dove, White-throated Ground Dove, Collared Kingfisher, Micronesian Honeyeater, Black Drongo, Micronesian Starling, and Eurasian Tree Sparrow.

Short-term (BBS) bird abundance patterns were not statistically related to typhoon behavior in the multivariate analysis (Distance: overall Wilks $F_{11,11}$ = 1.62, $p = 0.22$; Pressure: overall Wilks $F_{11,11} = 1.62$, $p = 0.22$). In univariate tests, the Philippine Turtle Dove abundances exhibited significant relationships with Distance and Pressure, in the same manner as the long-term VCP data. No other species was significant over the short-term data set.

Discussion

Typhoons near Rota did not increase in frequency over the period 1952–2005, as sometimes perceived, but they did come closer to the island and were more intense, as measured by central pressure. In parallel with these patterns, several species have shown significant declines in population over the long term (1982-2003), including Philippine Turtle Dove, Mariana Fruit Dove, Collared Kingfisher, Mariana Crow, Rufous Fantail, and Micronesian Honeyeater, while no species significantly increased its population (Amar et al. 2008).

Mariana Crows and Philippine Turtle Dove abundances may be impacted by typhoons in similar ways: greater numbers were seen following milder typhoons even when the typhoons approach more closely, but more severe typhoons had adverse effects on numbers. Therefore, the recent decrease in average pressure (increase in intensity) may have adversely effected their populations, even when these storms pass at some distance from the island. Conversely, Rufous Fantails appear to be impacted by the increasingly close approaches of recent storms of any strength, with less effect of intensity. Interestingly, many effects of typhoon intensity and distance were contrary to our predictions of a direct negative impact on populations; instead, the more intense or closer the storm, the *greater* the number of birds seen in the following census. This may result from a methodological confound in that the more intense typhoon winds may leave habitats more open and birds more visible, thus apparently increasing the counts of some species. To deal with this confound, we have proposed to conduct a series of vegetation visibility surveys both before and at intervals beginning immediately following a typhoon encounter. This information could then be used to adjust bird counts for the degree of habitat visibility.

Typhoons may have affected bird populations in the way that we predicted in the case of long-term patterns of distance effects on the Rufous Fantail, and pressure (intensity) effects on the Mariana Crow and Philippine Turtle Dove, and perhaps in the short-term case of the Philippine Turtle Dove. It appears that changes in typhoon "behavior" could be impacting forest-bird populations on Rota. The mechanism of this impact would be through more powerful encounters than in past years, not more frequent encounters. Overall, bird population declines on Rota may be due to a combined effect of habitat loss, introduced species pressure (Plentovich et al. 2005, Ha et al. 2010, 2011), and typhoons, where any one of the factors might be enough to tip a species over the edge. The impact of changes in weather patterns on diet specialists or residents may be more pronounced than that of diet generalists or migrants (Lynch 1991). There may be second-order effects in which the effects on one species may affect other species, through either effects on direct competition or indirect and more complex connections.

There are some significant flaws in this analysis, as in any retrospective analysis of an archival data set, including the poor quality of the (long-term) VCP data set, the relatively short time-span of the (better quality) BBS data sets, and the lack of vegetation visibility data, a potentially confounding effect which could influence these results if birds are differentially visible before and after a typhoon. We believe, however, that our results clearly suggest that recent changes in typhoon behavior may have played a role in the decline of some forest bird species on Rota, and that our results indicate the need for continued and improved census data collection. Future work should also explore the timing of typhoons around the breeding season, and the influence of lost opportunities for breeding as an indirect impact of typhoons. Fortunately, in recent years (2005 to present), the typhoon activity has decreased dramatically, and it is unknown how long this period of inactivity will persist, or when it will become active again. Most of the world's ocean basins have exhibited substantial inter-decadal variation. Currently only the North Atlantic basin is within a period of heightened hurricane activity, while the rest of the globe has fallen quiet. This decrease in typhoon activity provides us with an opportunity to clarify these effects, and perhaps improve the chances for recovery of these endangered avian species.

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References

Amar, A., F. Amidon., B. Arroyo., J.A Esselstyn & A.P Marshall. 2008. Population trends of the forest bird community on the Pacific island of Rota, Mariana Islands. The Condor 110: 421–427.

Cole, T.G., K.C. Ewel. & N.N. Devoe. 1999. Structure of mangrove trees and forests in Micronesia. Forest Ecology and Management 117: 95–109.

Dahl, A.L. 1991. Island Directory. UNEP Regional Seas Directories and Bibliographies No. 35. UNEP, http://islands.unep.ch/.

Devney, C.A., M. Short & B.C. Congdon. 2009. Cyclonic and anthropogenic influences on tern populations. Wildlife Research 36: 368–378.

Emmanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436: 686–688.

Engbring, J., F. L. Ramsey & V. J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish and Wildlife Service, Honolulu, HI.

Falanruw, M.C., T.G. Cole & A.H. Ambacher. 1989. Vegetation survey of Rota, Tinian, Saipan, Commonwealth of the Northern Marianas. U.S. Department of Agriculture Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Resource Bulletin PSW-27.

Fancy, S.G., M.R. Lusk. & D. Grout. 1999. Status of the Mariana crow population on Rota, Mariana Islands. Micronesica 32: 3–10.

Ha, J.C., A. Butler, & R.R. Ha. 2010. Age-specific survival and population viability of the Mariana Crow *(Corvus kubaryi)* on Rota, CNMI. Bird Conservation International 20: 335–342.

Ha, R.R, J. Morton, J.C. Ha, L. Berry & S. Plentovich. 2011. Nest site selection and the consequences for reproductive success for the endangered Mariana crow *(Corvus kubaryi)*. Wilson Journal of Ornithology 123: 236–242.

Hulme, P.E. 2005. Adapting to climate change: Is there scope for ecological management in the face of a global threat? Journal of Applied Ecology 42: 784–794.

Kitamoto, A. 2005. Digital Typhoon: Near Real-Time Aggregation, Recombination and Delivery of Typhoon-Related Information, Proceedings of the 4th International Symposium on Digital Earth, pp. (CD-ROM), and http://agora.ex.nii.ac.jp/digital-typhoon/.

Lander, M.A., 2004: Rainfall climatology for Saipan: distribution, return-periods, El Niño, tropical cyclones, and long-term variations. Water and Environmental Research Institute of the Western Pacific University of Guam (WERI) Technical Report No. 103, December 2004

Lin, K.-C., S.P Hamburg., S.-L. Tang., Y.- J. Hsia & T.C. Lin. 2003. Typhoon effects on litterfall in a tropical subforest. Canadian Journal of Forest Research 33:2184–2192.

Lynch, J.F. 1991. Effects of hurricane Gilbert on birds in a dry tropical forest in the Yucatan peninsula. Biotropica 23: 488–496.

Maue, R.N., 2011: Recent historically low global tropical cyclone activity. Revision 1: 2011GL047711R Ryanhttp://coaps.fsu.edu/~maue/tropical/2011GL047711-pip.pdf.

McCarty, J.P. 2001. Ecological consequences of recent climate change. Conservation Biology 15: 320–331.

Mueller-Dombois, D. & F.R. Fosberg. 1998. Vegetation of the Tropical Pacific islands. Springer-Verlag, New York. 733 pp.

National Research Council. 1997. The scientific bases for preservation of the Mariana Crow. National Academy Press, Washington, D.C., USA.

Plentovich, S., J.M. Morton., J. Bart, R.J. Camp., M. Lusk., N. Johnson. & E. Vanderwerf. 2005. Population trends of Mariana crow *Corvus kubaryi* on Rota, Commonwealth of the Northern Mariana Islands. Bird Conservation International 15: 211–224.

Reynolds, R.T., J.M. Scott. & R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82: 309–313.

Rittenhouse, C.D., A.M. Pidgeon, T.P. Albright, P.D. Culbert, M.K. Clayton, C.H. Flather, C. Huang, J.G. Masek, V.C. Radeloff. Avifauna response to hurricanes: regional changes in community similarity. Global Change Biology 16: 905–917.

Santera, B.D., T.M.L Wigley., P.J. Gleckler., C. Bonfils., M.F. Wehner., K. AchutaRaoa., T.P. Barnett., T.S. Boyle., W. Bruggemann., M. Fiorino., N. Gillett., J.E. Hansen., P.D. Jones., S.A. Klein., G.A. Meehl., S.C.B. Raper., R.W.Reynold., K.E. Taylor., & W. M. Washington. 2006. Forced and unforced ocean temperature changes in Atlantic and Pacific tropical cyclogenesis regions. Proceedings of the National Academy of Sciences 103: 13905–13910.

Savidge, J.A. 1987. Extinction of an island forest avifauna by an introduced snake. Ecology 68: 660–668.

Shoo, L.P., S.E. Williams. & J.-M. Hero. 2005. Climate warming and the rainforest birds of the Australian wet tropics: Using abundance data as a sensitive predictor of change in total population size. Biological Conservation 125: 335–343.

Sriver, R. & M. Huber. 2006. Low frequency variability in globally integrated tropical cyclone power dissipation. Geophysical Research Letters 33: L11705.

Thomas, C.D. & J.J. Lennon. 1999. Birds extend their ranges northwards. Nature 399: 213.

Trenberth, K. 2005. Uncertainty in hurricanes and global warming. Science 308: 1753–1754.

U.S. Fish and Wildlife Service 2005a. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Rota Bridled White-Eye (Zosterops rotensis). Portland, Oregon, USA.

U.S. Fish and Wildlife Service. 2005b. Draft Revised Recovery Plan for the Aga or Mariana Crow, *Corvus kubaryi*. Portland, Oregon, USA.

Walther, GR., E. Post., P. Convey., A. Menzel., C. Parmesan., T.J.C. Beebee., J-M. Fromentin., O. & F. 2002. Ecological responses to recent climate change. Nature 416: 389–395.

Webster P.J., G. J. Holland., J.A. Curry. & H-R. Chang. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 309: 1844–1846.

Wiles, G.J.,J. Bart, R.E. Beck, Jr., C.F. Aguon. 2003. Impacts of the brown tree snake: patterns of decline and species persistence in Guam's avifauna. Conservation Biology 17:1350–1360.

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