

SURVEY OF MEGAPODE NESTING MOUNDS IN PALAU, MICRONESIA

ALAN R. OLSEN and MILANG EBERDONG, Belau National Museum, P. O. Box 666, Koror, Palau 96940; bnm@palaunet.com or kerallang@yahoo.com

HEATHER KETEBENGANG, Palau Conservation Society, P. O. Box 1181, Koror, Palau 96940

PRINCESS BLAILES and PO-HAO CHEN, Koror Department of Conservation and Law Enforcement, P. O. Box 116, Koror, Palau 96940

ABSTRACT: The Palau subspecies of the Micronesian Megapode, *Megapodius laperouse senex*, incubates its eggs by burying them in earthen nesting mounds built on level forested terrain near a beach. As a contribution to a better understanding of the abundance and distribution of Palau's megapodes, we surveyed 122 beach sites for active nesting mounds. We detected birds at 61 sites and found 173 active mounds distributed over 53 of the 61 sites. Eighty-six percent of the active mounds were concentrated in or near a conservation area in southern Palau (55%) and on an atoll in northern Palau (31%). Following a super typhoon, we found undamaged six of 19 active nesting mounds at five sites in southern Palau. Megapodes eventually restored nine of the damaged mounds and abandoned the other four. After a stronger super typhoon struck northern Palau less than a year later, we confirmed the survival of megapodes and active nesting mounds on the atoll but were unable to search our original survey sites thoroughly because of impassable debris fields.

Megapodius laperouse senex (Figure 1) is currently recognized as a subspecies of the Micronesian Megapode or Micronesian Scrubfowl endemic to Palau (Amadon 1942, Jones et al. 1996, Dickinson and Remsen 2013). It shares endangered species status with nominate *M. l. laperouse*, of the



Figure 1. *Megapodius laperouse senex*, the Palau subspecies of the Micronesian Megapode, Ulong Islet, Rock Islands, Palau, 30 March 2012.

Photo by Alan R. Olsen

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Mariana Islands (www.iucnredlist.org, version 2015.1 downloaded 14 June 2015). The two subspecies occupy disjunct ranges and differ in morphology, vocalizations (Pratt et al. 1980, Jones et al. 1995, Dekker et al. 2000, Pratt and Etpison 2008), and, most profoundly, in their nesting behaviors (Harris et al. 2014). The Mariana subspecies typically buries its eggs in a burrow in a field of volcanic cinders, relying on geothermal heat or warmth from solar-heated cinders to incubate the eggs (Amidon et al. 2010). The Palau subspecies builds a mound with a core of leaf litter that provides compost heat to incubate the eggs (Engbring 1988). Ornithologists familiar with both subspecies have suggested that they might better be classified as species (Pratt et al. 1980, Wiles 2005, Pratt and Etpison 2008). The field ornithologists who conducted prior surveys suggested monitoring of nest mounds as an index to the relative abundance of megapodes, beginning with baseline surveys (Wiles and Conry 1990, Engbring 1992, VanderWerf 2007). Therefore, we began a field survey of nest mounds in Palau in November 2011.

STUDY AREA

Our study area encompassed all of the islands inside the coral barrier reef that surrounds the Palau archipelago, as well as an atoll located outside the barrier reef to the north. We divided our study area into four geographic zones: (1) Kayangel, a classic tropical atoll located north of the barrier reef. Kayangel Atoll consists of four islets, the inhabited islet of Kayangel and three uninhabited islets. (2) Babeldaob; this island and its offshore islets occupy the northern half of the area inside the barrier reef. Volcanic in origin, Babeldaob is the largest island (~400 km²) in Palau. Volcanic activity in Palau ceased 20–25 million years ago (Colin 2009). (3) Rock Islands; these islands, including the Southern Lagoon Conservation Area (SLCA), a UNESCO World Heritage Site, encompass hundreds of raised limestone islets located in the southern half of the area inside the barrier reef. This zone includes the uninhabited areas of the volcanic islands of Koror, Arakebesang, and Malakal, just north of the conservation area. (4) Odesangel: Peleliu Island and nearby islets are situated inside the barrier reef and south of the Rock Islands Conservation Area. Peleliu is a raised coral platform; the nearby islets are similar to those in the conservation area. We surveyed the Rock Islands and Odesangel from 20 November 2011 to 14 September 2012, three months before Super Typhoon Bopha, Kayangel and Babeldaob from 12 June 2013 to 25 August 2013, two months before Super Typhoon Haiyan. We were unable to survey Angaur, a raised coral platform island outside the barrier reef to the south, where VanderWerf (2007) reported the megapode population in decline.

METHODS

Pratt et al. (1980), Engbring (1988), Wiles and Conry (2001), and VanderWerf (2007) have noted the apparent linkage in Palau between beach strand habitats and megapode nesting mounds. We began our survey by scouting every uninhabited beach in the study area, landing on the beaches and making 15-minute point counts of birds. We then walked the length of the beach to scout for birds, mounds, tracks, and other signs of

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megapode activity. Later we returned to the sites where megapode activity had been detected and to several randomly selected control sites at beaches where no activity had been detected. On each return visit, we searched all terrain suitable for nesting mounds, including the beach, the strand forest behind the beach, and any other nearby level forested areas. We counted all megapodes seen or heard during these searches and documented each active mound by coordinates, maps, and photographs. We used the criteria of Wiles and Conry (2001) to categorize each mound as active or not. We used topographic maps to determine the area of suitable terrain in the Rock Islands and Kayangel, where the majority of active nesting mounds were found. Our size estimates for Babeldaob and Odesangel were rough because we did not have precise topographic maps for those areas.

RESULTS

We located and scouted 122 uninhabited beaches in the study area. We estimated that 800 ha of level forested terrain suitable for nesting mounds was associated with the beaches, ranging from <1 ha to 21 ha of suitable terrain per beach. We detected signs of megapode activity at 61 of the 122 (50%) beaches that we scouted. Our subsequent area searches of suitable terrain at those 61 beaches found 173 active nesting mounds among 53 of the 61 (87%) sites. The number of active nesting mounds per site ranged from one (several sites) to 21 (a site in Kayangel). The estimated combined area of suitable terrain at the 53 sites with active nesting mounds was 450 ha. We found no nesting mounds in searches of suitable terrain at six control sites representing 10% of the beaches where no megapode activity had been detected during the earlier scouting trips. We are confident that we located and documented nearly all of the active nesting mounds in the study area at the time of our survey.

Fifty-five percent of the active nesting mounds (95 of 173 mounds) were concentrated in the Rock Islands zone, 92 of them within the boundaries of the Rock Islands SLCA and three on nearby uninhabited beaches outside the northern boundary of the conservation area. The 95 active mounds in the Rock Islands zone were distributed over 37 sites with a combined total of 181 ha of suitable terrain, ranging from 0.5 ha to 21.5 ha per site. The number of mounds per site ranged from 1 to 15, and the density of active nesting mounds ranged from 0.2 to 1.4 mounds/ha. The highest densities (≥ 1 mound/ha) were found on the westernmost islets of the Rock Islands SLCA.

Thirty-one percent of the active nesting mounds (54 of 173 mounds) were located on Kayangel Atoll. Those 54 were distributed over four sites with a combined 44 ha of suitable terrain, ranging from 10.0 to 11.1 ha/site. Three of the sites were on Ngeriungs Islet and one was on Ngerbelas Islet. The number of active mounds per site ranged from 4 to 21 and density ranged from 0.4 to 1.9/ha. The highest density was at the northernmost site on Ngeriungs. Eight percent of the active mounds (13 of 173 mounds) were located in the Babeldaob zone, distributed over eight sites on coastal islets with an estimated 100 ha of suitable terrain. The remaining 6% of the active mounds (11 of 173 mounds) were in the Odesangel zone, distributed over six sites on Peleliu Island (three) and nearby offshore islets (three) with an estimated combined total of 125 ha of suitable terrain. Sites in the

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Babeldaob and Odesangel zones were estimated to encompass 5 to 20 ha, mound densities at $\leq 0.2/\text{ha}$.

FIELD OBSERVATIONS

We counted a total of 350 megapodes in our searches at the 61 beaches where we detected them. The number per site ranged from one (several sites) to 35 (at a site on Kayangel). We did not see or hear megapodes at seven sites in the Rock Islands, even though we had detected them at those sites earlier, and even though each of the sites had one or more active nesting mounds. Conversely, there were five sites in the Rock Islands where we saw or heard megapodes on our scouting trips, yet we found no active nesting mounds during the area searches of those sites.

We heard duetting of pairs of megapodes throughout the two-year survey period. At Ngerechong Islet in the Rock Islands on 22 August 2012 we witnessed aggressive “cockfighting” behavior between two presumed males. We saw two megapode chicks on Ulong Islet in the Rock Islands on 7 September 2012. Both were on the ground. A megapode chick perched on a tree limb ~ 3 m above the ground on Ngeriungs Islet in Kayangel on 20 August 2013 was reminiscent of Gressitt’s (1951) account of the emergence of megapode chicks from a nesting mound on Ngeriungs in mid-September 1951. During a survey of sea turtle nesting grounds on 29 July 2014, we saw a megapode chick on Ngeanges Islet in the Rock Islands, the first seen after Super Typhoon Bopha passed over southern Palau in December 2012.

Monitor lizards are anecdotally suspected of preying on megapode chicks and eggs in the Mariana Islands (Amidon et al. 2010). Crombie and Pregill (1999:61) listed the distribution of Palau’s monitor lizard “*Varanus cf. V. indicus*” as Babeldaob, Kayangel, Koror, and Angaur. We encountered monitor lizards on Kayangel, on Ngerchur Islet north of Babeldaob, and at four survey sites in the Rock Islands, where we found two fresh carcasses, the stomach contents of which included small crabs and other invertebrates, picnic scraps, and a rat, but no evidence (feather fragments, eggshells, bones, feet, beaks) of birds.

Nesting Mound Construction

One hundred sixty-seven (97%) active nesting mounds were located ≤ 5 m above sea level on flat terrain in forests near beaches and were constructed of sand, soil, and detritus in varying proportions (Figure 2). We found two atypical mounds constructed of coral rubble on Ngerechong Islet in the Rock Islands. One of those was at the base of a tree on the edge of a severely eroded beach where tidal action had washed away the seaward portion of the mound, but the landward side was still active. The other was propped against a banana tree, slightly inland. We discovered six atypical mounds constructed entirely of leaf litter and situated at higher elevations ranging from 20 to 50 m above sea level. Three of the leaf-litter mounds were on an islet off the central western coast of Babeldaob, one was on another islet off the central west coast of Babeldaob, one was on an islet off the southern coast of Babeldaob Island, and one was on an islet in the Rock Islands. All six leaf-litter mounds were within 500 m of a beach. Our observations are consistent with Pratt et al. (1980), who reported that mounds are constructed



Figure 2. Typical megapode nesting mound on Ngerbelas Islet, Kayangel Atoll, Palau, 7 August 2013.

Photo by Alan R. Olsen

of sandy soil, coral rubble, or leaf litter, and with Wiles and Conry (2001), who described two leaf-litter mounds at elevations of 50 m and 60 m above sea level and 10 soil mounds on sandy flats behind beaches.

Early reports that nesting mounds are constructed of sandy soil over a leaf-litter core (Pratt et al. 1980, Engbring 1988) were not confirmed by Wiles and Conry (2001), who reported no obvious evidence of a vegetative interior from the probing of four active mounds composed of sandy soil. Our field observations reaffirm the earlier reports of mounds constructed of soil over leaf litter. During our survey of the Rock Islands we discovered a total of 17 mounds under construction, all of sandy soil over leaf litter. A noteworthy example was a nesting mound in the very beginning stage of construction when discovered during our scouting trip to Ngeanges islet in the Rock Islands on 20 March 2012. It consisted then of leaf litter piled ~25 cm high between the protruding roots of a living tree in a surrounding area clear of leaf litter and vegetation. By 7 August 2012, when we searched Ngeanges thoroughly, the mound was ~70 cm high, with the addition of sandy soil over the leaf litter core. When we resurveyed Ngeanges on 9 January 2013 we found that the mound was ~1 m high. It was still active on 30 January 2014 and 9 February 2015. We will continue to monitor the lifespan of this mound.

Post-Typhoon Observations

We completed our field work in southern Palau shortly before Super Typhoon Bopha, a category 4 tropical cyclone, struck on 3 December 2012 and in northern Palau just before Super Typhoon Haiyan, a category 5

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tropical cyclone, struck on 5 November 2013. Less than a year apart, these back-to-back catastrophes were the first storms to cause serious damage in Palau since Typhoon Utor, in 2001.

On 8 January 2013, in the immediate aftermath of Super Typhoon Bopha, we returned to Ulong Islet and searched a site on its west coast that had had six active mounds before the typhoon and a site on the east coast that had had two active mounds. The forest and the six active mounds on the west coast site were undamaged, having been shielded from high winds and tidal surge by the central ridge of the islet. At the east coast site, both mounds had been washed completely away by tidal surge, and wind had destroyed the forest. We did not see or hear any megapodes. We visited Ulong again on 8 August 2013 and found no evidence of megapode activity at the east coast site. When we visited that site on 9 February 2015, however, we found the forest regenerated and megapodes and nesting mounds again present.

Our post-typhoon area search of Ngeanges Islet in the Rock Islands on 9 January 2013 found the forest canopy ~50% depleted by wind and that one of the four active nesting mounds from the original pre-typhoon area search had been inundated by tidal surge. Megapodes had already begun clearing debris from the remaining three active mounds. We searched Ngeanges again on 30 January 2014 to find a replenished forest canopy. The three surviving mounds were completely restored, and comparisons of photographs showed that one of them was noticeably larger than before the typhoon. The mound that had been inundated by the tidal surge was abandoned. The megapodes from the abandoned mound might have relocated to the newly enlarged mound on Ngeanges or to a new mound discovered on nearby Ngermeaus Islet after the typhoon. When, after the typhoon, we searched Ngeruchebtang Islet in the Odesangel zone on 4 June 2013, we found that many trees had already recovered from the typhoon, so that the original active mounds were in partial or full shade. Megapodes had cleared away debris and restored all four of the active mounds that we had documented during our original pre-typhoon search (Figure 3). On the same date, we visited a picnic area on Ngerechong Islet in the Rock Islands that had had three active mounds before the typhoon. The trees that were there before the typhoon had been cleared away by a clean-up crew using power tools, and there was no semblance of a forest or canopy cover. We did not see or hear any megapodes and did not find any trace of the nesting mounds.

Super Typhoon Bopha passed south of Palau at a strength of category 4, impacting the Rock Islands and Odesangel. The center of Typhoon Haiyan, the strongest tropical cyclone ever recorded, passed directly over Kayangel Atoll at a strength of category 5, causing much more damage than Bopha. On our most recent field trip to Kayangel Atoll in mid-November 2014, we spotted ten megapodes and five active nesting mounds on Ngeriungs Islet. We also saw or heard a total of 14 megapodes on Ngerbelas, Orak, and Kayangel islets. Because of impassable debris fields throughout the atoll, we were unable to conduct thorough area searches to document surviving nesting mounds.

OTHER SURVEYS

Wiles and Conry (1990) found six active nesting mounds in the Rock Islands during their 1988 wildlife survey. During the 1991 survey of bird

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diversity (Engbring 1992), they located ten additional active mounds (Wiles and Conry 2001) for a combined total of 16 active nesting mounds in Kayangel (2), Babeldaob (1), the Rock Islands (10), and Odesangel (2), as well as on Angaur Island (1), outside our study area. Two of the active mounds reported by Wiles and Conry were on Orak Islet in the Kayangel zone, four were in the Ngerukewid Nature Reserve in the Rock Islands, and two were on nearby Kmekumer Islet. Our area searches found two abandoned mounds on Orak, three active mounds on Ngerukewid, and four active mounds on Kmekumer. We found other active mounds in the localities included in the 1991 survey, but we could not confidently match the locations of any of ours with theirs. Wiles and Conry also described in detail 12 of the 16 mounds, including two atypical leaf-litter mounds, one in the Rock Islands and one on Babeldaob Island that was used as a landmark on the 1991 survey's transect along the Ngeremasech River in northern Babeldaob.

In 2005, VanderWerf (2007) retraced the original transect routes of the 1991 bird survey. He mentioned seeing from a distance several nesting mounds on a beach on Peleliu Island in Odesangel. Our survey located a total of three active mounds on Peleliu, one near the beach mentioned by VanderWerf. His unpublished field notes from the 2005 survey mention a nesting mound as a landmark along a transect route on Angaur Island, possibly the same mound described earlier by Wiles and Conry. His unpublished notes also include descriptions of nine landmarks that he used to retrace the Ngeremasech River transect on northern Babeldaob Island, but there is no mention of the nesting mound that served as a landmark on that same transect in 1991. It seems that that mound was abandoned sometime between the 1991 and 2005 surveys.

The Belau National Museum began surveying the forest bird diversity of the interior of Babeldaob Island in May 2006. In May 2010, the museum expanded its bird-surveillance program to include all of Palau under a newly established National Program for Monitoring Forest and Coastal Birds. The museum regularly conducts bird counts for the national program at coastal monitoring stations and along coastal transects as well as at inland locations. Its unpublished database for the national program contains 2787 data entries from 14 inhabited beach sites, which were excluded from our survey of uninhabited beach sites. The 14 inhabited beaches are located on the islands of Babeldaob (nine), Koror (one), Arakebesang (two), Malakal (one) and Peleliu (one). Our review of the museum's database for the 14 inhabited beach sites found no records of megapode activity.

DISCUSSION

All of the active nesting mounds that we found were fully shaded by forest canopies. Our post-typhoon observations highlight the importance of the forest canopy to megapode nesting and the need to prevent deforestation in general. Megapodes completely abandoned the picnic area where the trees were removed by a clean-up crew after Super Typhoon Bopha. On Ngeanges Islet in the Rock Islands and on Ngeruchebtang Islet, where the forest canopies were damaged but not completely destroyed by the typhoon, megapodes promptly restored their original mounds despite having to contend with considerable amounts of debris (Figure 3). An exception was one



Figure 3. Nesting mound that megapodes restored following Typhoon Bopha. Note the damage to the trees from the typhoon and the debris remaining around the perimeter of the mound. Ngeruchehtang Islet, Odesangel, Palau, 7 June 2013.

Photo by Alan R. Olsen

of the original active mounds on Ngeanges that was located on a beach so eroded by the typhoon tidal surge that the mound had vanished and its original location was under water at high tide.

The timely restoration of a typhoon-damaged mound that is salvageable, especially one that might still contain incubating eggs, makes sense. Salvage was not an option on the east coast of Ulong Islet, where winds and tidal surge completely altered the landscape, flattening the forest and obliterating the two nesting mounds there. Megapodes did not return until the forest and its canopy regenerated, over a year after the typhoon. When they finally returned, they built new nesting mounds from scratch on the same spots where the original mounds had stood, even though there was no trace of the original mounds and there was ample (2.4 ha) suitable terrain for building new nesting mounds elsewhere under the forest canopy. One mound was built on the same spot where the pre-typhoon mound had been, and the other was built over the portion of a fallen tree trunk that covered the position of the original mound. Our observations reflect what appears to be long-term fidelity to very specific nest sites, provided the location is shaded by a forest canopy.

Commuting between Nesting Grounds and Feeding Grounds

Some species of megapode commute between nesting grounds and feeding grounds (Jones et al. 1995), and Pratt et al. (1980) and Wiles and Conry

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(1990, 2001) suggested Palau's megapodes may as well. Commuting offers the most plausible explanation for our observations of the occasional absence of megapodes at sites in the Rock Islands with active nesting mounds and their presence at other sites with no active mounds. In the case of Babeldaob Island, we think that commuting explains why megapodes are occasionally seen or heard on the island, yet despite numerous surveys only one nesting mound, the 1991 Ngeremasech mound in the northern part of the island, has been reliably documented and described.

Historically, megapodes have always been considered rare on Babeldaob (Marshall 1949, Pratt et al. 1980). The surveys by Engbring and VanderWerf further confirmed that megapodes are rarely seen or heard in the interior of Babeldaob. For example, when VanderWerf surveyed the bird diversity of mainland Babeldaob in 2005, he detected a total of five megapodes, all along the same inland transects where Engbring had found similar numbers in 1991. Both speculated that megapodes nest at remote sites in the uninhabited interior of Babeldaob Island. Our survey of nesting mounds, on the other hand, found a cumulative total of 30 megapodes and a combined total of 13 active nesting mounds, all on offshore islets surrounding Babeldaob and none on the main island. Four were found on islets off the west coast opposite inland transect routes where the prior surveys had found megapodes but not nesting mounds. The discovery of nesting on offshore islets opposite mainland localities where megapodes, but not nesting mounds, have been historically reported suggests that many of the megapodes encountered on mainland Babeldaob are commuters that nest on offshore islets.

That the actual counts of megapodes during our searches far exceeded the counts from the 1991 and 2005 point-count surveys in the same general localities was not surprising because our survey was the first to target nesting grounds, where megapodes congregate. Even so, counts at nesting grounds are no more reliable a basis for estimating the megapode's abundance in Palau than point counts along transects because at any given time an unknown proportion of the megapode population might be at distant feeding grounds. Now that the locations of the major nesting grounds are known, the monitoring of changes in activity there could provide an index of relative abundance until, by locating the feeding grounds, further research clarifies the dynamics of megapode commuting.

Conservation

Our results provide a snapshot of the pre-typhoon status of megapode nesting mounds in Palau and post-typhoon insights into the resilience of this endangered bird to category-4 or 5 super typhoons, the increasing frequency and intensity of which are attributable to climate change (Bells and Daniels 2002, Knutson et al. 2010, Şekercioglu et al. 2012). The megapodes in southern Palau proved fairly resilient to the impact of Super Typhoon Bopha, and those on Kayangel have, for the moment, survived the more severe impact of Super Typhoon Haiyan. Nevertheless, the concentration of a large majority (86%) of nesting mounds at a limited number of low-lying coastal sites raises concern over the species' vulnerability to increasingly frequent and intense super typhoons, extreme tides, and sea level rising with climate change. The existing conservation plans for the species (US-

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FWS 1998, Dekker et al. 2000, Amidon et al. 2010) address only threats to the Mariana megapodes such as volcanic eruptions and deforestation by introduced ungulates. The recovery plan does not address the quite different threats of climate change to the survival of the Palau megapodes. We therefore recommend the development and implementation of a separate plan that addresses the specific threats to the survival of the Palau form and that includes a program to monitor megapode abundance in Palau.

The need to initiate monitoring programs for the Micronesian Megapode is “pressing” (Sherley 2001:41). In Palau, monitoring of nesting grounds and active nesting mounds would provide a much-needed index of the megapode’s relative abundance that takes into account the nonrandom distributions of these birds and their nest mounds, as well as related factors such as fidelity to nest sites and commuting between nesting and feeding grounds. We hope that the results of our survey will inspire the initiation of local programs to monitor megapode nesting grounds, especially in the Rock Islands SLCA, where the majority of active nesting mounds are located.

ACKNOWLEDGMENTS

We thank the Board of Trustees of the Belau National Museum for their whole-hearted support of this survey; the Palau Conservation Society for its coordination and logistical support; the Koror Department of Conservation and Law Enforcement, especially the Koror state rangers for their dedicated participation in the scouting trips and area searches; the Koror State Beach Boys; the state governments of Airai, Kayangel, Koror, Ngarchelong, and Peleliu for logistical support and access to conservation areas; and Carp Island Resort for logistical support and access to the megapodes and nesting mounds on Carp Island. We appreciate the assistance of visiting and local enthusiasts who helped us with the field work: René W. R. J. Dekker, Tiffany Harrison, Perkins Ace Kikuo, Andrea Klindworth, Darold Klindworth, Lazarus Smaserui, and Charlotte Vermeulen. We thank Mark O’Brien of BirdLife International for his guidance; H. Douglas Pratt, René W. R. J. Dekker, and Gary J. Wiles for their critical readings of our early manuscript and their valuable comments and contributions. The final manuscript was improved thanks to the masterful review and comments from Daniel D. Gibson. Financial assistance was provided by the Royal Forest and Bird Protection Society of New Zealand through the BirdLife International Community Conservation Fund, the Marisla Foundation via the Global Greengrants Fund, and the Global Environment Facility Small Grants Program through the United Nations Development Program.

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Accepted 22 October 2015