U.S. Fish & Wildlife Service

Draft Revised Recovery Plan for the Mariana Fruit Bat or Fanihi

(Pteropus mariannus mariannus)

A young fanihi, orphaned when his mother was killed by poachers

Photograph by Julia Boland, used by permission

Draft Revised Recovery Plan for the Mariana Fruit Bat or Fanihi (*Pteropus mariannus mariannus*)

November 2009
(Original approved 2 November 1990)

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Regional Director, U.S. Fish and Wildlife Service

Date: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the U.S. Fish and Wildlife Service, publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State agencies, Tribal agencies, and others. The necessary funds to attain objectives identified in a recovery plan are subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Costs indicated for action implementation and time for achievement of recovery are only estimates and subject to change. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in plan formulation, other than the U.S. Fish and Wildlife Service. Recovery plans represent the official position of the U.S. Fish and Wildlife Service *only* after they have been signed by the Director or Regional Director as *approved*. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

Literature citation of this document should read as follows:

U.S. Fish and Wildlife Service. 2009. Draft Revised Recovery Plan for the Mariana Fruit Bat or Fanihi (*Pteropus mariannus mariannus*). U.S. Fish and Wildlife Service, Portland, Oregon. xiv + 83 pp.

Electronic copies of this document will be made available at:

- http://pacific.fws.gov/ecoservices/endangered/recovery/default.htm
- http://endangered.fws.gov/recovery/index.html

ACKNOWLEDGMENTS

This draft revised recovery plan was written with extensive input and assistance from the Fanihi Recovery Team. A recovery team is a formal advisory group that provides information and advice about recovery needs and opportunities for species listed as threatened or endangered. The recovery team focuses on development of the recovery plan and may be involved in implementation of the plan. Recovery teams are convened at the discretion of the Regional Director and are not required. The U.S. Fish and Wildlife Service has administrative responsibility for preparing recovery plans and approving their content.

Members of the Fanihi Recovery Team are identified below. Many other individuals also contributed their time and expertise to the preparation of this document, including Fred Amidon, Nathan Hawley, Curt Kessler, Patrick Leonard, Gina Shultz, and Marilet Zablan of the U.S. Fish and Wildlife Service's Pacific Islands Fish and Wildlife Office, George Phocas of the U.S. Fish and Wildlife Service's Office of Law Enforcement, Scott Vogt of the U.S. Navy, and Dustin Janeke of e2M Environmental and Engineering Management.

Members of the Fanihi Recovery Team:

Herman A. Apatang
Commonwealth of the Northern Mariana Islands
Department of Lands and Natural Resources
P.O. Box 924
Songsong Village
Rota, MP 96951

Anne Brooke
Joint Region Marianas
PSC 455, Box 195
FPO AP 96540-2937

Joseph T. Lizama
CNMI Department of Lands and Natural Resources
P.O. Box 172
Tinian, MP 96952

Dana T. Lujan
USDA/APHIS/Wildlife Services
233 Pangelinan Way
Barrigada, GU 96913

Tammy Mildenstein
Department of Ecosystem and Conservation Sciences
University of Montana
Missoula, MT 59812

Laura Williams
CNMI Division of Fish and Wildlife
P.O. Box 10007
Saipan, MP 96950

Jeffrey Quitugua
Guam Division of Aquatic and Wildlife Resources
192 Dairy Road
Mangilao, GU 96923

Chris Tidemann
Australia National University
School of Resources, Environment and Society
Canberra 0200 Australia

Gary Wiles
Washington Department of Fish and Wildlife
521 Rogers St. SW
Olympia, WA 98502

Julia Boland
CNMI Division of Fish and Wildlife
PO Box 1397
Rota, MP 96951

Dave Worthington
Capitol Reef National Park
HC 70 Box 15
Torrey, UT 84775

Holly Freifeld (Team Liaison)
U.S. Fish and Wildlife Service
300 Ala Moana Blvd., Rm.3-122
PO Box 50088
Honolulu, HI 96850

EXECUTIVE SUMMARY

Current Species Status

The Mariana fruit bat or fanihi (*Pteropus mariannus mariannus*) is a subspecies endemic to the Mariana archipelago (the Territory of Guam and the Commonwealth of the Northern Mariana Islands [CNMI]), where it is known from 14 of the 15 major islands. Surveys on most or all islands in the archipelago were conducted in 1983 (Wiles *et al*. 1989), 2000 (Cruz *et al*. 2000a-f), and 2001 (Johnson 2001). These surveys indicated that the relatively isolated northern islands of the CNMI (i.e., the islands north of Saipan) have supported the majority of fanihi in the archipelago for at least the past few decades, despite the relatively small land mass of these islands in comparison to the southern islands.

Survey effort for fanihi throughout the archipelago historically has been uneven. Despite this, published reports indicate that fanihi numbers on the southern islands in the archipelago declined precipitously through the 20th century as a result of hunting and habitat loss and degradation (Fritz 1901, 1904; Schnee 1911; Lemke 1984; Wiles et al. 1989; Marshall et al. 1995; Wiles 1996; Worthington and Taisacan 1996; Krueger and O'Daniel 1999). Habitat loss and degradation has resulted from agriculture; introduction of non-native ungulates, plants, and other organisms; economic development; and war (Baker 1946; Bowers 1950; Fosberg 1960; Stone 1970). In the remote northern islands of the archipelago, chronic habitat degradation by ungulates, hunting, and, more recently, volcanic eruption on Anatahan, may be responsible for declines in bat numbers over the past several decades (Wiles et al. 1989; Rice and Stinson 1992; Marshall et al. 1995; Kessler 2000a, Cruz et al. 2000a-f).

Although variation in survey methods and effort render rigorous comparisons between islands and surveys periods difficult, conservative interpretation of existing survey data indicates a 40 percent decline in fruit bat numbers between 1983 (Wiles *et al.* 1989) and 2000 (Cruz *et al*. 2000a-f) among the six northern islands surveyed in both years. The majority of this decline was recorded on two of the three largest northern islands, Anatahan and Pagan, which together harbored the majority of the archipelago's fanihi in the 1980s (Wiles *et al*. 1989).

Habitat Requirements

Fanihi habitat use is influenced by several characteristics of the species. Fanihi typically are highly colonial, and can form large, dense roosts in multiple adjacent trees. Fruits, nectar, pollen, and some leaves comprise the majority of the bats' diet; rapid digestion and metabolism of such foods makes these animals reliant on forest habitat containing diverse food resources that are available throughout the year. Fanihi are strong fliers and highly mobile; although the pattern and frequency of interisland movements is unknown, fruit bats have been observed flying over the ocean between islands. Connectivity of the archipelago's islands for fanihi depends on the presence of enough suitable forest for roosting and foraging to sustain resident and in-transit bats.

Fanihi forage and roost primarily in native forest and forage occasionally in agricultural forests composed primarily of nonnative plants (Wiles 1987b; Worthington and Taisacan 1996). Wiles (1987b) described six bat roost sites on Guam, all within native limestone forest. On Rota, fanihi used primary and secondary limestone forest for roosting and foraging; at least eight native and one introduced tree species were used for roosting (Glass and Taisacan 1988). A small colony also was observed roosting in *Casuarina equisetifolia* (ironwood) trees on Aguiguan (Worthington and Taisacan 1996). On Sarigan, fanihi were observed roosting and foraging in the small patch of native forest, and foraging to a lesser extent in the large area dominated by coconut (Wiles and Johnson 2004).

Limiting Factors

Five factors are considered in decisions to list, delist, or reclassify a species. These factors are:

- A – The present or threatened destruction, modification, or curtailment of its habitat or range;
- B – Overutilization for commercial, recreational, scientific, or educational purposes;
- C – Disease or predation;
- D – Inadequacy of existing regulatory mechanisms; and
- E – Other natural or man-made factors affecting its continued existence.

Factor A: The degradation and loss of primary and other forest habitats resulting from ungulate damage, invasion by alien plant species, and economic development has substantially diminished the extent of habitat for fruit bats in the Mariana archipelago since human settlement of the islands; all of these processes accelerated during the 20th century. These sources of habitat degradation and loss all are still present in the islands and may lead to further reduction in the availability of resources critical for the survival and reproduction of fanihi and thus to a potential reduction in the number of bats that the remaining habitat is able to support.

Factor B: Fanihi have been used as food since humans first arrived on the islands, and consumption of bats represents a significant cultural tradition. Overhunting, however, is cited as a causal factor in the initial fanihi declines on Guam, Saipan, and Tinian. In response to plummeting fanihi numbers, hunting of bats became illegal under local law in both Guam and the CNMI in the 1970s, and commercial trade in fanihi largely has been curbed. However, illegal hunting for local consumption remains a chronic, population-level threat that precludes the recovery of the species to healthy, self-sustaining numbers.

Factor C: The brown treesnake (*Boiga irregularis*), which has caused the extinction or extirpation of most native landbird species on Guam, is considered capable of preying on non-volant young bats, and may contribute to the lack of recruitment of young bats on Guam.

Factor D: Although current CNMI hunting regulations (Part 4, Section 10.7.i) prohibit the hunting, killing, or possessing of protected species, including fanihi, and the CNMI Department of Fish and Wildlife (DFW) has statutory authority to promulgate and enforce these regulations to protect bats and impose fines for violations, it has been reported that there is little enforcement of the hunting ban, and few investigations or convictions have taken place. The Mariana fruit bat is listed as an endangered species by the Government of Guam and take is prohibited under this designation, but it is widely believed that illegal hunting of Guam’s few remaining bats occurs opportunistically.

Factor E: The small number of fanihi remaining on some islands (e.g., Guam and Saipan) may face significant risk of extirpation from natural disturbances, environmental changes, and other chance events to which small populations typically are vulnerable. Fanihi do fly between islands, although the frequency of these events throughout the Mariana archipelago is unknown. Recolonization of islands where bats were extirpated likely has occurred in the past, but the likelihood of recolonizations probably is declining with the decline in total numbers and with gaps of one or more islands in the bats' distribution. Although this subspecies has evolved in the presence of natural disturbance, today a declining population and anthropogenic threats such as illegal hunting erode the resilience of the population and reduce the likelihood of complete recovery in the wake of typhoons and volcanic eruptions. Typhoons, in particular, could eliminate bats that persist in small numbers on one or more of these islands (see Wiles and Brooke in press for a discussion of density-dependent typhoon effects). Military training activities such as live fire and aircraft overflight exercises in areas used by fanihi could disrupt the behavior of these bats and may impede recolonization if military activities create a gap in distribution. Farallon de Medinilla may provide an example of this situation: the use of this island as a bombing range has rendered it unsuitable habitat for resident fanihi (although a transiting bat may occasionally use the island as stopover), thus creating a disjunction between the northern and southern islands in the archipelago. An increase in air traffic at Andersen Air Force Base, which harbors the single remaining fruit bat colony on Guam, is likely to occur in conjunction with a proposed base expansion.

Recovery Priority Number

The Mariana fruit bat is assigned a recovery priority number of 9 on a scale of 1C (highest) to 18 (lowest; the "C" indicates the potential for conflict with human economic activities), based on the moderate degree of threat, a high potential for recovery as stated above, and its status as a subspecies.

Recovery Criteria

The recovery criteria discussed below address the major threats to the species, including general criteria for population distribution and post-delisting monitoring, as well as additional criteria organized by the five Listing Factors to be used in a delisting analysis. The fanihi may be considered for delisting when the following criteria have been met:

1. Population and Distribution

   The total size of the fanihi population has increased, based on data from scientifically defensible monitoring protocols, and stable or increasing subpopulations of sufficient size to avoid genetic and demographic risks associated with very small populations are distributed among the Mariana Islands so that the probability of the fanihi's persistence over 100 years is high (at least 90 percent).

   To meet this criterion, we propose that stable or increasing fanihi subpopulations should be distributed as follows: three of the five southern islands (Saipan, Tinian, Aguiguan, Rota, and Guam), and six of the eight islands north of Saipan where fanihi have persisted historically (Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug). Of the six northern islands with stable or increasing fanihi numbers, two of these must include Pagan, Anatahan, or Agrihan, the three largest of the northern islands. This distribution may be modified as appropriate based on future monitoring data or population viability modeling (Recovery Action 5.2).

2. Post-delisting monitoring

   A post-delisting monitoring program for the species has been developed to reliably detect population trends and is ready for implementation.

3. Listing Factor A: Habitat Loss and Degradation

   Specific actions to restore habitat (including ungulate control and control of invasive non-native plants as appropriate for specific islands – see Table 3) have been identified and management plans developed as necessary for recovery under Criterion 1, and these actions and plans are being successfully implemented so that habitat loss and degradation no longer endanger the survival of the fanihi.

4. Listing Factor B: Hunting
   Specific actions to reduce illegal hunting have been identified and management plans developed as necessary for recovery under Criterion 1, and these actions and plans are being successfully implemented so that illegal hunting no longer endangers the survival of the fanihi.

5. Listing Factor C: Brown Treesnakes
   Long term measures are being successfully implemented to control the incipient brown treesnake population on Saipan and to prevent the introduction of the brown treesnake from Guam and Saipan to other islands in the CNMI.

6. Listing Factor E: Development and Military Training Activities
   Impacts of urban development and military training on the fanihi are successfully being avoided, minimized, or mitigated so that they do not endanger the survival of the fanihi.

Date of Recovery: Delisting could occur by 2030 if all of the criteria have been met.

Important Recovery Actions *(for details, see the Narrative Outline and Implementation Schedule)***:**
Recovery of the fanihi focuses on the following actions:

1. Immediate management to reduce risks and stabilize the existing population.
2. Specific actions to reduce or eliminate illegal hunting to allow increase in fanihi numbers throughout the archipelago.
3. Protection of the best existing habitat and enhancement of additional suitable habitat.
4. Effective control and interdiction of the brown treesnake.
5. Research to address gaps in our knowledge of fanihi life history and ecology and improve our ability to model the population, assess its sensitivity to specific threats and management actions, and forecast its persistence. This research is essential to eventually determining thresholds for bat numbers and other conservation criteria on each island that could indicate when the fanihi

population has recovered sufficiently for some legal hunting to resume. The fanihi population is clearly too precarious at present to support a hunting season. However, if illegal hunting and other threats are reduced so the species' status can improve substantially and our knowledge of population dynamics and threats allows us to identify a limited, sustainable hunting regime consistent with recovery of the species, such a hunt might be allowed under the Endangered Species Act either by delisting the species as indicated above or through a special rule under section 4(d) of the Act.

Total Estimated Cost of Recovery

The estimated cost for recovery actions over the next 5 years is $12,578,000, distributed as follows:

Year	Priority 1	Priority 2	Priority 3	Total
2010	163,000	2,849,000	253,000	$ 3,265,000
2011	170,000	2,379,000	200,000	$ 2,749,000
2012	170,000	2,329,000	101,000	$ 2,600,000
2013	163,000	2,159,000	60,000	$ 2,382,000
2014	163,000	1,979,000	71,000	$ 2,213,000
Total	$ 829,000	$ 11,695,000	$ 685,000	$ 13,209,000

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. BACKGROUND

A. Status Overview and Structure of the Recovery Plan

The Mariana fruit bat, or fanihi (*Pteropus mariannus mariannus*), was Federally listed as endangered on Guam in 1984 (USFWS 1984). In January 2005 we published a final rule listing *P. m. mariannus* as threatened throughout its range (the Mariana archipelago: Guam and the Commonwealth of the Northern Mariana Islands (CNMI)) (USFWS 2005). This rule represented a reclassification of the fanihi on Guam from endangered to threatened, a change reflecting our determination that the fruit bats on Guam are a subset of a single population distributed throughout the archipelago. We determined that the fanihi faces threats that should be managed rangewide, and in this expanded geographic context, the fanihi merited listing as threatened throughout the islands.

We prioritize listed species for recovery, assigning recovery priority to a species based on degree of threat, recovery potential, taxonomic status, and conflict with human activities. Numerical ranks range from 1 to 18, with a letter designation of “C” indicating conflict with human economic activities. The highest priority is 1C; the lowest priority is 18 (USFWS 1983). The fanihi has a recovery priority number of 9, indicating that it faces a moderate degree of threat (i.e., extinction is not imminent, but threats are ongoing), has a high potential for recovery, and has taxonomic status as a subspecies. Conservation of the fanihi generally is not in conflict with economic activities. A final rule designating critical habitat for the fanihi on Guam was published in the *Federal Register* on October 28, 2004 (USFWS 2004). Critical habitat refers to areas occupied by the species at the time of listing under the Endangered Species Act that contain resources essential for the species’ survival and reproduction, and that may require special management so that the species may recover. No critical habitat was designated in the CNMI because at that time the fanihi was not listed there. Therefore, the critical habitat designated for fanihi on Guam does not reflect the true extent of habitat required for the survival of the fanihi throughout the archipelago. Recovery planning is not constrained by critical habitat designations and this recovery plan includes all those actions and areas we deem necessary for the recovery of the fanihi.

The original recovery plan for the fanihi on Guam was issued in 1990 (USFWS 1990). In the subsequent 18 years, knowledge of this species has improved. In addition to providing a recovery strategy, this recovery plan represents a revision of the original plan for Guam and incorporates significant new information about the Mariana fruit bat. The plan is divided into four main sections. Part I, Background, provides an overview of the biology of the subspecies, the reasons for its decline, current threats to its persistence, and current conservation measures. Part II, Recovery, describes the recovery strategy, goals, and objectives for the fanihi, and includes discussion of the criteria established to determine recovery. Part III, Recovery Actions, describes the conservation and research activities required to achieve the recovery goals. Part IV, the Implementation Schedule, provides in tabular form a list of the recommended recovery actions, with emphasis on actions needed to meet interim recovery objectives within the next five years. This structure reflects the need for effective adaptive management in advancing the recovery of the Mariana fruit bat, as many variables remain unknown and long-term planning without inherent flexibility is unlikely to succeed. These short-term implementation plans will be prepared every five years to reflect the knowledge gained and to refine the management program to maximize the success of the Mariana fruit bat recovery program.

B. The Mariana Islands

The Mariana Islands consist of the 15-island Commonwealth of the Northern Mariana Islands (CNMI) and the Territory of Guam, both within the jurisdiction of the United States (Figure 1). This archipelago lies in the Western Pacific approximately 1,500 kilometers (900 miles) east of the Philippine Islands, and extends 750 kilometers (470 miles) from 13º14' north latitude (N), 144 º45' west longitude (W) to 20º3' N, 144º54' W. The nine northernmost islands (Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Uracas) are volcanic in origin, and the six southernmost islands (Guam, Rota, Aguiguan, Tinian, Saipan, and Farallon de Medinilla) are uplifted limestone plateaus, some of which have volcanic outcrops. Fanihi historically have inhabited all of these islands except Uracas, the northernmost island (Wiles et al. 1989). The climate in the archipelago is tropical, with daily mean temperatures of 75º to 90º Fahrenheit

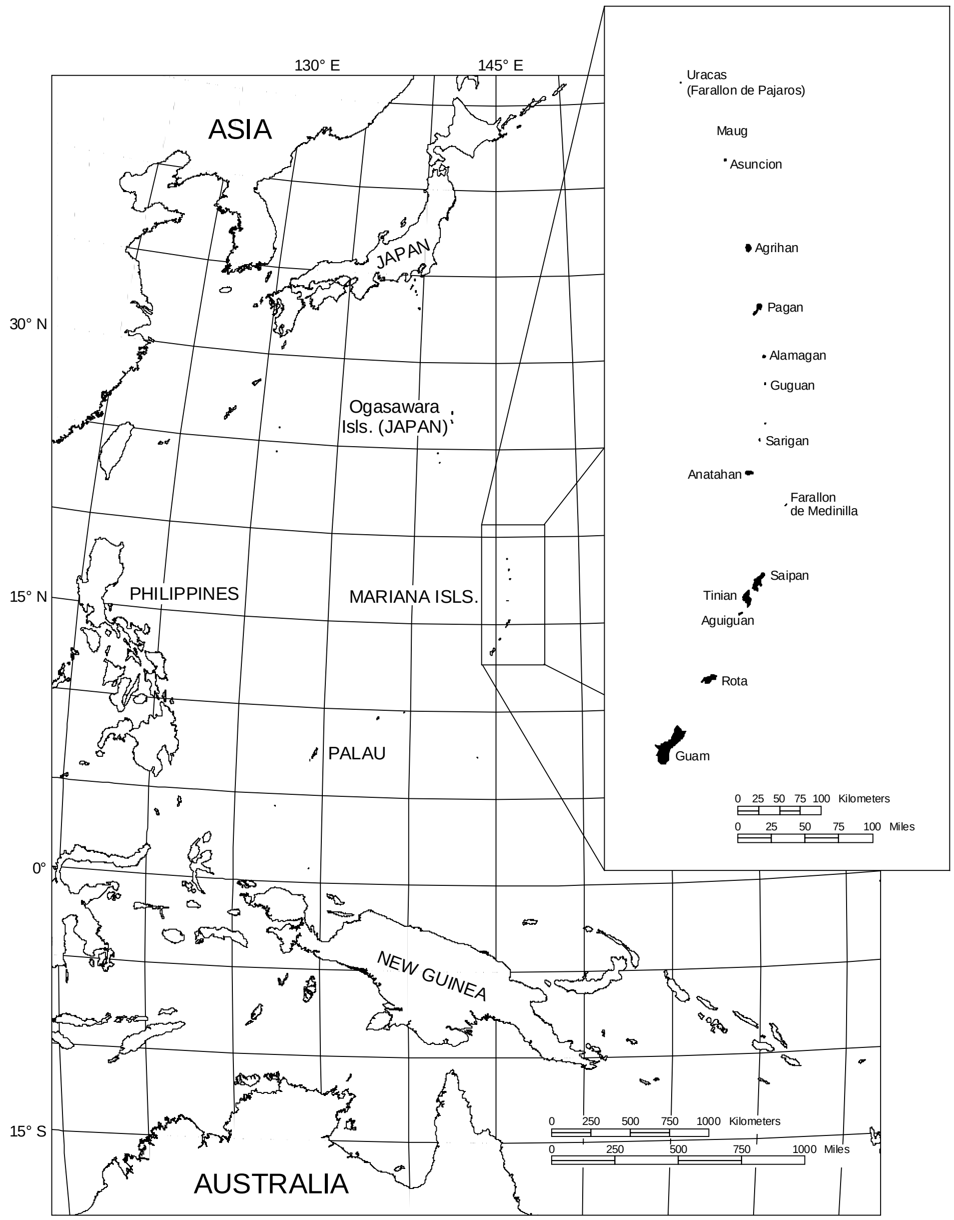

Figure 1. The Mariana Islands.

(24º to 32º Celsius), high humidity, and average annual rainfall of 200 to 260 centimeters (80 to 100 inches). The natural vegetation of the islands is predominantly various types of low-stature tropical and coastal forest, but these have been extensively altered, particularly over the past century (Fosberg 1960; Stone 1970; Engbring *et al*. 1986; Falanruw *et al*. 1989). Typhoons may strike the Mariana Islands during any month of the year, but are most frequent between July and October. The large southern islands (Guam, Rota, Tinian, and Saipan) support nearly the entire human population of the archipelago, with most people on Guam (155,000) and Saipan (62,000). The northern islands (north of Saipan) are either unoccupied or support only small human settlements (as many as 40 people total, seasonally).

C. Species Description and Taxonomy

The fanihi is a medium-sized bat in the family Pteropodidae that weighs 330 to 577 grams (0.66 to 1.15 pounds) and has a forearm length ranging from 13.4 to 15.6 centimeters (5.3 to 6.1 inches). The underside (abdomen) is colored black to brown, with gray hair interspersed, creating a grizzled appearance. The shoulders (mantle) and sides of the neck are usually bright golden brown, but may be paler in some individuals. The head varies from brown to dark brown. The well-formed and rounded ears and large eyes give the face a canine appearance; medium and large members of the genus *Pteropus* are often called flying foxes.

The paleotropical genus *Pteropus* is represented by 67 species distributed across the Indian Ocean, southern Asia, Australia, and Oceania as far east as the Cook Islands (Simmons 2005). Thirty-nine species (58 percent) are considered critically endangered, endangered, threatened, near threatened, or vulnerable under the definitions of the IUCN (IUCN 2008). Most of these face the risk of extinction because of a combination of habitat loss and hunting (Wiles and Brooke in press).

Excluding the possibly extinct little Mariana fruit bat (*Pteropus tokudae*), the fruit bats of the Mariana Islands consistently have been treated as one or two endemic subspecies of the single species *P. mariannus*; that is, the taxon (or taxa) occurring in the Marianas occurs nowhere outside the archipelago (e.g., Andersen 1912; Kuroda 1938; Corbet and Hill 1980, 1986, 1991; Koopman 1982, 1993;

Flannery 1995; Simmons 2005). Other subspecies of *P. mariannus* have been described from Palau (*pelewensis*), Kosrae (*ualanus*), Yap (*yapensis*), Ulithi (*ulthiensis*), and the Ryukyu archipelago (*loochoensis*) (Pierson and Raney 1992, Koopman 1993); some or all of these taxa are treated as separate species by other authors (e.g., Anderson 1912, Corbet and Hill 1980, Flannery 1995). Flannery (1995) and Simmons (2005) recognize two subspecies restricted to the Mariana Islands: the Mariana fruit bat or fanihi (*P. mariannus mariannus*) and the so-called Pagan fruit bat (*P. mariannus paganensis*). The slight morphological differences used to distinguish *P. mariannus paganensis* from *P. mariannus mariannus*, based on four specimens, are likely attributable to natural variation that occurs not only between islands but within individual island subpopulations (Tom Lemke, Montana Department of Fish, Wildlife, and Parks, *in litt*. 1986; Gary Wiles, Washington Department of Fish and Wildlife, pers. comm. 2005). Thus, the Pagan fruit bat is likely not distinct from the Mariana fruit bat (Pierson and Rainey 1992; Worthington and Taisacan 1996; G. Wiles, pers. comm. 2007), particularly in light of the strong evidence of movement and probable gene flow between islands of the archipelago (e.g., Wiles *et al*. 1989; Wiles and Glass 1990; Wiles and Johnson 2004). Future studies may elucidate the genetic relationships among the fanihi on different islands in the Marianas; at this time we do not consider *Pteropus mariannus paganensis* as distinct from *Pteropus mariannus mariannus*. Furthermore, recent analysis of tissue from *P. mariannus* collected in the Mariana Islands and Palau found that fruit bats in the Marianas were not distinct from one another when compared to Palau bats (Gary McCracken, University of Tennessee, pers. comm. 2007).

D. Historical and Current Population Status and Distribution

Similar to other animal species, obtaining accurate estimates of fruit bat populations in Pacific archipelagos depends on regular monitoring, standardized survey methods, and consideration of the unique ecology and physiographic environment of bat populations in various island groups. In addition, monitoring of population size and trends depends on accurate assessment of detectability, variation in skill among observers conducting surveys, and the statistical power of survey data. The difficult terrain of the Mariana Islands, remote location of the northern islands of the CNMI, and the high cost of interisland transportation by sea and aerial surveys of individual islands introduce additional complications that have hindered the establishment of a standard monitoring program for fanihi.

No known historical records exist to document the status of the fanihi prior to the 20th century. The history of bat surveys and changes in numbers summarized in Table 1 and subsequent text represent a variety of methods and analyses. Furthermore, the existing data do not reflect consideration of detection problems peculiar to fruit bats or variation among observers or seasons, nor have they been collected in a manner appropriate for rigorous analysis to generate statistically meaningful confidence intervals (around individual points) or trends.

Prior to recent volcanic activity on Anatahan, the relatively isolated northern islands (i.e., the islands north of Saipan) supported the majority of the fruit bats in the archipelago, but because of their remote location, these islands have been surveyed much less frequently than the southern islands. Individual surveys have been conducted on several of the larger and more accessible northern islands at relatively frequent intervals, and surveys of all or most islands in the archipelago were conducted in 1983 (Wiles *et al*. 1989), 2000 (Cruz *et al*. 2000a-f), and 2001 (Johnson 2001).

The survey methods used in the northern islands in 2001 were significantly different from those used in 1983 and 2000; we therefore consider only Wiles *et al*. (1989) and Cruz *et al*. (2000a-f) for purposes of comparison (Table 1). A conservative interpretation of this comparison indicates a decline in the northern islands between 1983 and 2000, especially on Anatahan and Pagan, which supported the largest numbers of fruit bats in the archipelago 20 years ago (Table 1). Bat numbers in the southern islands also have declined during this time period (Esselstyn *et al.*, 2006; Wiles *et al*. 2006; Anne Brooke, U.S. Navy, pers. comm. 2007), although this is not evident in Table 1.

1. Guam

On Guam, the sighting of fanihi was considered to be “not... uncommon” in 1920 (Crampton 1921). However, by 1931, bats were uncommon on Guam, possibly because the introduction of firearms led to more hunting (Coultas 1931). Woodside (1958) reported that in 1958 fanihi on Guam were estimated to number

Table 1. Summary of results from two archipelago-wide fanihi surveys: minimum estimates. Two of the northern islands are not included in this table: Uracas, the most northerly, where fruit bats are not known to occur; and Farallon de Medinilla (FDM), where fanihi have been observed on only one occasion. Additional and more recent surveys and observations have been made on the southern islands, and on FDM, Anatahan, Sarigan, and Pagan (see text; Table 3).

Island	Area Sq. mi (Sq. km)	Estimated minimum number of bats 1983[1]	Estimated number of bats 2000[2]
Maug	0.8 (2.0)	<25	not surveyed
Asuncion	2.9 (7.4)	400	not surveyed
Agrihan	18.3 (47.4)	1,000	1,000
Pagan	18.4 (47.7)	2,500	1,500
Alamagan	4.3 (11.0)	0[3]	200
Guguan	1.5 (4.0)	400	350
Sarigan	1.9 (5.0)	125	200
Anatahan	12.5 (32.3)	3,000	1,000
	Subtotal (Northern Islands)	7,450	
	[Subtotal six islands]	[7,025]	[4,250]
Saipan	47.5 (122.9)	<50	not surveyed
Tinian	39.3 (101.8)	<25	not surveyed
Aguiguan	2.7 (7.0)	<10	150-200
Rota	32.9 (85.2)	800-1,000	not surveyed
Guam	212.0 (549.0)	425-500	119-179
Subtotal (Southern Islands)		1,310-1,585	insufficient data
TOTAL (All Islands)		8,760-9,035	insufficient data

[1] Wiles *et al*. 1989. Dates: August 17-September 10, 1983; 1-4 days/island. Count methods: Evening dispersal counts at colonies; evening station counts of solitary fruit bats. All counts considered to be minimum estimates.
[2] Cruz *et al*. 2000a-f. Dates: June 4-August 16, 2000; 7-9 days/island. Count methods: Evening dispersal counts at colonies, evening and morning station counts of solitary fanihi. Data for Guam represents the range of 10 counts conducted in a separate effort in 2000 (A. Brooke, pers. comm. 2007).
[3] Alamagan was inadequately surveyed in 1983 and may have held some fanihi. Some were observed there in 1988 (Wiles *et al*. 1989).

no more than 3,000, although the method used to make this estimate is not known (Utzurrum *et al*. 2004). The abundance of fanihi on the island continued to decline during the 1960s and 1970s so that by 1978, fewer than 50 bats were believed to remain (Perez 1972; Wiles 1987b). Fanihi numbers increased to an estimated 850-1,000 in 1982 through movement from Rota (Wiles 1987b), but have been in decline on Guam overall since then.

During the 1990s, numbers on Guam remained in the range of several hundred animals with occasional spikes to nearly a thousand bats; presumably these spikes reflected temporary immigration events from Rota (Wiles *et al*. 1995; Wiles 1996, 1998, 1999). Surveys conducted between 2000 and 2006 indicated further decline to fewer than 100 individuals (Jeff Quitugua, Guam DAWR, pers. comm. 2006), and at this writing the number of fanihi on Guam may have slipped to fewer than 50 (J. Quitugua, pers. comm., 2009). Predation by brown treesnakes on non-volant young probably prevents recruitment of juvenile bats on Guam (Wiles 1987b, Wiles *et al*. 1995; Wiles 1996), and losses from illegal hunting are also likely to be a factor.

2. CNMI Southern Islands

Fruit bats on the southern islands of the CNMI (Rota, Tinian, Aguiguan, and Saipan) were not surveyed prior to the 1970s, but historical accounts indicate that fruit bats once were common on these islands (Fritz 1904).

<u>Rota</u>

Fanihi from Rota are believed to move episodically among the southern islands, and this island thus is considered to be important to the long-term stability of the species in the southern part of the Mariana archipelago and to the existence of the colony on Guam (Wiles and Glass 1990; Wiles *et al*. 1995). Fanihi surveys have been conducted on Rota regularly by numerous workers since 1986, using methods described by Stinson *et al*. (1992): primarily evening dispersal counts, with some station counts of solitary or extracolonial bats and direct counts of colonial roosts (Glass and Taisacan 1988; Stinson *et al*. 1992; Worthington and Taisacan 1995, 1996; Johnson 2001; Esselstyn *et al*. 2006). This monitoring effort has yielded numbers that vary widely both intra- and interannually (e.g., Glass and Taisacan 1988; Worthington and Taisacan 1995, 1996; CNMI-DFW unpublished data, 2007). Owing to variation in methods, observers, and coverage, a significant trend cannot be extracted from these data. However, visual inspection of the data suggests a decline over the past seven years (CNMI-DFW, unpublished data 2007).

Fanihi numbers on Rota and perhaps consistency in survey methods and effort have fluctuated sharply through time (CNMI-DFW unpublished data, 2007); in 2008 methods were modified in an effort to yield improved information about the status of this subpopulation. Island-wide estimates from 1999 to 2008 were based on departure counts at seven historically occupied roost sites. However, the disturbance of bats caused by illegal hunting results in unpredictable and relatively frequent turnover of roost sites used by fruit bats on Rota. In 2008, it was determined that colonies were no longer occupying most of the roost sites that had been monitored in previous years (Julia Boland, CNMI Department of Fish and Wildlife, pers. comm., 2009). Therefore, an intensive search of the island for currently occupied roost sites took place, and count and monitoring methods were revised. As of 2009, new methods consist of direct counts of colonies and of extra-colonial bats at currently occupied roost sites. Colonies are observed weekly to monitor possible movements and determine the cause. In the event of roost abandonment, colonies are tracked to new locations where counts resume. Where possible, pictures of roosting colonies are taken and bats are counted from the pictures to confirm direct counts made in the field. Data generated using revised count methods suggests that approximately 1200-1400 fruit bats occur on Rota (in early 2009; J. Boland, pers. comm., 2009). We do not think this estimate represents an increase in numbers; rather, it reflects new count stations and more accurate methods. A reliable estimate of the trend cannot be generated now, owing to the short period that the new methods have been in effect.

Severe storms (and associated hunting) at short intervals combined with low and fluctuating numbers could erode what resilience exists in this population. Fanihi numbers on Rota declined following Typhoon Roy in 1988 from an estimated 2,400 animals to just under 1,000 (Stinson *et al*. 1992). Prior to Typhoon Pongsona in 2002, fanihi numbers on had risen to about 1,300-2,000 bats (Esselstyn *et al*. 2006). However, in the months following the storm, repeated surveys indicated that numbers had again declined sharply to perhaps 500 bats (Esselstyn *et al*. 2006). Numbers remained relatively low through April 2004, when about 700 bats were counted (Esselstyn *et al*. 2006). It is unlikely that the naturally low reproductive rate of this species can sustain the level of hunting pressure observed on Rota.

<u>Saipan</u>

Schnee (1911) reported that fanihi were commonly seen and heard on Saipan, where they were heavily hunted by local residents. The Navy restricted civilian access to the northern part of Saipan until the early 1970s, effectively providing the bats with protected roost sites. Fanihi on Saipan were observed to decline rapidly after the U.S. Navy turned over control to the CNMI government, and access to the whole island became unrestricted (Wiles *et al*. 1989). Observations made between the late 1970s and 2007 suggested that Saipan harbored a small number of bats; typically 50 bats or fewer (Wheeler 1980; Lemke 1984; Glass and Taisacan 1988; Wiles *et al*. 1989; Worthington and Taisacan 1996; Johnson 2001; Ann Marshall, U.S. Fish and Wildlife Service, pers. comm. 2007).

<u>Tinian</u>

Fritz (1901) reported a "large number" of bats on Tinian in 1900. Since the late 1970s fruit bats have been seen rarely and only in small numbers, with estimates of fewer than 25 animals usually given for the island (Wheeler 1980; Glass and Taisacan 1988; Wiles *et al*. 1990; Marshall *et al*. 1995; Krueger and O'Daniel 1999; Johnson 2001). Observations during the 1990s suggested that the presence of bats on Tinian was intermittent, and their numbers were low (Worthington and Taisacan 1996). Brief surveys on Tinian conducted in 2001 found no fruit bats (Johnson 2001), and between 2002 and 2007 fruit bats have been observed only once during forest surveys conducted on Tinian each month by U.S. Navy biologists (Scott Vogt, U.S. Navy, pers. comm. 2007).

<u>Aguiguan</u>

Since the early 1980s fewer than 50 fanihi typically have been observed on the island, but bats have been observed on most survey trips to the island (Wiles *et al*. 2006). Typically, bats are dispersed and roost alone or in small groups (Wiles *et al.* 2006). Higher estimates of 75 to 300 animals are sometimes made (Glass and Taisacan 1988; Wiles *et al*. 1989; Stinson *et al*. 1992; Wiles 1996;

Esselstyn *et al.* 2006), suggesting arrivals from Rota (Wiles and Glass 1990). Bats on Aguiguan are observed anecdotally to be wary of people, suggesting that illegal hunting occurs there (A. Brooke, pers. comm. 2007).

3. CNMI Northern Islands

The 1983 survey of the northern islands resulted in a minimum estimate of 7,450 fanihi for Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug (Wiles *et al*. 1989; see Table 1). Because fanihi are gregarious and often roost in large colonies during the day, this and subsequent surveys focused on locating colonies. Wiles *et al*. (1989) located colonies by circumnavigating islands by boat, traversing portions of each island on foot, and interviewing residents on islands with human inhabitants. Count methods used included evening dispersal counts at colonies and evening counts of solitary or extra-colonial bats made from vantage points determined to overlap least with the apparent dispersal trajectory of colony bats. Island-wide estimates were based on the number of fruit bats recorded, island size, extent of forest cover and abundance and diversity of food-plant species (Wiles *et al*. 1989).

Surveys of the northern islands undertaken in 2000 (Cruz *et al*. 2000a-f) employed a combination of the same methods used by Wiles *et al*. (1989) in 1983 and, on Anatahan, by Worthington *et al*. (2001) in 1995: land- and sea-based colony searches, evening dispersal counts, station-counts of extra-colonial bats, and direct day-time counts at roosts. On each island they visited, Cruz *et al*. (2000a-f) spent periods conducting fruit bat surveys equal to or greater than periods spent by Wiles *et al*. (1989) on the same six islands. The individual island-wide estimates of Cruz *et al*. (2000a-f) thus are comparable to those of Wiles *et al*. (1989), but owing to logistical and fiscal constraints, Cruz *et al*. (2000a-f) did not visit Asuncion and Maug. The 2000 surveys yielded an estimate of 4,250 fruit bats for the 6 northern islands they visited (Cruz *et al*. 2000a-f). The 1983 surveys yielded an estimate of 7,025 fruit bats for the same six islands (Wiles *et al*. 1989). A conservative interpretation of these data indicates roughly a 40 percent decline in fruit bat numbers between 1983 and 2000 among these six northern islands.

The majority of this decline was recorded on two of the three largest northern islands, Anatahan (32.3 square kilometers [12.5 square miles]) and Pagan (47.7 square kilometers [18.4 square miles]), which together harbored roughly 70 percent of the archipelago's fruit bats in the 1980s (Wiles *et al*. 1989). These two islands, which were estimated to support a total of 5,500 fruit bats in 1983, were estimated to have only 2,500 fruit bats in 2000, approximately a 45 percent decline since 1983 (Cruz *et al*. 2000d, 2000e). Declines on both islands may be related to hunting and severe habitat damage caused by ungulates (Cruz *et al*. 2000d, 2000e; Kessler 2000a).

<u>Anatahan</u>

On Anatahan, surveys suggested a minimum estimate of 3,000 fanihi in 1983 (Wiles *et al*. 1989), about 1,902 to 2,136 individuals in 1995 (Marshall *et al*. 1995; Worthington *et al*. 2001), and roughly 1,000 individuals in 2000 (Cruz *et al*. 2000d; Kessler 2000a). In conjunction with an ungulate eradication project, fanihi on Anatahan have been surveyed by helicopter at least four times each year since 2002. These surveys are performed over 2 days with 4 hours spent over the island each day. Coverage of the island during each survey is complete. Fanihi colonies are rapidly reconnoitered to verify known roost sites and identify new ones, colonies are counted and mapped, and individual bats in flight also are counted. After the volcanic eruption in May 2003, the island's devegetated state facilitated accurate location of all colonies (C. Kessler, *in litt*. 2003, pers. comm. 2004). In 2002 and early 2003, estimates of the island's bat numbers ranged from 950 to 1,250 (USFWS unpublished data 2007). Following Anatahan's volcanic eruption in May 2003, aerial surveys conducted in 2003 yielded estimates of 350 to 700 bats. Four surveys conducted between March and November of 2004 documented increasing numbers, with a high estimate of 1,570 to 1,805 in November (USFWS unpublished data 2007). This localized increase in fruit bat numbers over a short period of time (1 to 1.5 years) was concomitant with some vegetation recovery and indicates that Anatahan's fanihi numbers may have been approaching their pre-eruption level, whether the source of the additional bats was immigration, recruitment of newly volant (flying) young, or both (see Summary of Factors Affecting the Species section). However, Anatahan erupted in January, April, and August of 2005. Aerial surveys conducted after these eruptions have documented new declines, with numbers fluctuating but remaining low.

Estimates from counts between December 2005 and August 2007 have been 160 or fewer (USFWS unpublished data, 2007).

Pagan and Agrihan

On Pagan, fanihi numbers were estimated at a minimum of 2,500 in 1983 (Wiles *et al*. 1989), and at roughly 1,500 in 1999 and 2000 (Cruz *et al*. 2000e). A rapid reconnoiter of Pagan in August 2007 yielded a very rough estimate of 500 to 800 bats (C. Kessler, pers. comm. 2007). On the second-largest northern island, Agrihan (47.4 square kilometers [18.3 square miles]), surveys have yielded very rough estimates of about 1,000 animals in both 1983 and 2000, suggesting that abundance may have been stable during that interval (Wiles *et al*. 1989; Cruz *et al*. 2000f). Pagan and Agrihan harbor feral ungulate populations, and both islands have a long history of intermittent human settlements of variable size. Fanihi on these islands likely are under pressure at least intermittently from illegal hunting, and their forest habitats are suffering degradation by goats and pigs, and, on Pagan, cattle.

Maug, Asuncion, Alamagan, Guguan, and Sarigan

The remaining northern islands that harbor fanihi are all smaller than 13 square kilometers (5 square miles) (see Table 1), and each has harbored from 100 to 500 fanihi (Wiles *et al*. 1989; Cruz *et al*. 2000a, b, c). Sarigan, the island immediately north of Anatahan, has been surveyed the most frequently in recent years in conjunction with the ungulate eradication there. Four surveys between 1983 and 2000 yielded fairly consistent estimates of 125 to 235 bats (Wiles *et al*. 1989; Fancy *et al*. 1999; Wiles and Johnson 2004). Observed numbers increased to an estimated 300 to 400 bats in 2001; however, this temporary increase is thought to be an anomaly that likely reflects immigration to Sarigan from a neighboring island, probably Anatahan, which is 37 kilometers (23 miles) to the south (Wiles and Johnson 2004), and numbers have not remained this high. The most recent estimate, based on 2007 surveys, was roughly 140 bats (CNMI-DFW, unpublished data 2007; C. Kessler, pers. comm. 2007). The potential for increase in fruit bat numbers on Sarigan is thought to be limited by the island's small size (4.9 square kilometers (1.9 square miles)) and the small extent of native forest (Wiles and Johnson 2004).

Of the other four islands, Guguan, Asuncion, and Maug are designated for conservation, but Guguan and Maug have not been visited by biologists since 2001 (Asuncion was visited in 2008). Therefore, the current status of fahini on these islands is unknown. Alamagan has a small human settlement and populations of non-native goats and pigs and thus the likelihood is high that fanihi face hunting pressure there and that the island's forest is degraded by the browsing and rooting of ungulates. Fanihi have been elusive during most surveys on Alamagan (Wiles *et al*. 1989; Johnson 2001); it is thought that they roost in the crater in the center of the island (G. Wiles, pers. comm. 2007).

E. General Biology and Ecology

1. Habitat Use: Roosting and Foraging

Fanihi inhabit several native forest types, including primary and secondary limestone forest, volcanic (or ravine) forest, old coconut plantations, and groves of *Casuarina equisetifolia* (gagu or ironwood) (Glass and Taisacan 1988; Wiles *et al*. 1989, 1995; Worthington *et al*. 2001; Wiles and Johnson 2004). Most of these habitats are dominated by a variety of native trees, with introduced trees present in lower abundance. Grasslands with isolated trees are also used by fanihi (Wiles and Johnson 2004) and foraging sometimes occurs at farms and suburban residential areas with flowering or fruiting trees (G. Wiles, unpubl. data). On islands inhabited by humans, bat colonies usually occur in remote sites, especially near or along clifflines. Fanihi often prefer to roost in locations with large, emergent trees. On Guam, large *Ficus* spp. were heavily favored as roosting sites in the 1980s and early 1990s (Wiles 1987a). After many of these were lost to typhoons, roosting shifted to *Aglaia mariannensis* (mapunao), *Macaranga thompsonii* (pengua), *Mammea odorata* (chopak), and *Neisosperma oppositifolia* (fagot) (G. Wiles, unpubl. data). Glass and Taisacan (1988) reported *Artocarpus* spp. (breadfruit), *Elaeocarpus joga* (yoga or blue marble tree), *Guettarda speciosa* (beach gardenia or zebrawood), *Hernandia labyrinthica* (oschal), and *Macaranga thompsonii* as common roost trees on Rota. Colonies have been observed in *Casuarina equisetifolia*, *Ficus* spp. (fig), and *Elaeocarpus joga* on Anatahan, Sarigan, and Aguiguan, as well as in isolated *Cocos nucifera* (coconut) trees in grasslands on Sarigan (Wiles *et al*. 1989; Wiles and Johnson 2004; Worthington *et al*. 2001; G. Wiles, unpublished data).

Fanihi have been observed to feed on the fruits, flowers, and leaves of 39 plant species, including 11 introduced species. Reported foods include the fruits of 29 species of plants, the flowers of 17 species, and the leaves of two species (Wiles and Fujita 1992). Favored foods (Table 2) vary somewhat by island. Pteropodid bats are an important component of tropical forest ecosystems because they disperse plant seeds and thereby help maintain forest diversity and contribute to plant regeneration following typhoons and other catastrophic events (Cox *et al*. 1992).

Most of the known fanihi roost sites in the Mariana Islands are located on public lands. On Guam, the single remaining colony and probably most foraging occur on U.S. military lands (Wiles 1998; Janeke 2006) that are managed as part of the Guam National Wildlife Refuge under a cooperative agreement between the U.S. Fish and Wildlife Service and the U.S. Air Force. In the CNMI, most roosting and foraging areas occur on public lands (belonging to the Commonwealth).

2. Life History

Fanihi are strongly colonial, forming colonies ranging from a few to as many as 2,000 animals (Wiles 1987a; Wiles *et al*. 1989; Worthington and Taisacan 1995). Large colonies with more than 1,000 bats occur infrequently. Islands with small bat numbers usually feature smaller roosts with fewer than 75 animals (e.g., Wiles and Johnson 2004). Within colonies, fanihi group themselves into harems (one male and two to 15 females) or bachelor groups (predominantly males), or roost as single males scattered throughout (Wiles 1987a). On Guam, the average estimated sex ratio in a single colony varied from 37.5 to 72.7 males per 100 females (Wiles 1982). Guam and Rota also harbor a small percentage of non-colonial animals that roost solitarily, but on some smaller islands, such individuals may comprise as much as half the subpopulation (Wiles 1987a, Wiles and Johnson 2004, Janeke 2006).

Table 2. Plant parts commonly eaten by fanihi on different islands in the Marianas (Wiles 1987a, Glass and Taisacan 1988, Worthington *et al*. 2001, Wiles and Johnson 2004, Janeke 2006). Fl = flowers, fr = fruits, lv = leaves.

Species	Parts Eaten	Guam	Rota	Aguiguan	Northern Islands
Artocarpus mariannensis	fr, lv	x	x		
*Artocarpus altilis**	fr	x	x	x	
*Ceiba pentandra**	fl	x	x		
*Cestrum diurnum**	fr	x			
Cocos nucifera	fl, sap	x			x
Cycas micronesica	fr	x			
Elaeocarpus joga	fr, fl		x		
Erythrina variegata	fl	x	x		x
Ficus spp.	fr	x	x		x
Guettarda speciosa	fl		x		
Mammea odorata	fr, fl	x			
Mucuna gigantea	fl		x		
Neisosperma oppositifolia	fr	x			x
Ochrosia mariannensis	fr			x	
Pandanus tectorius	fr	x			x
*Persea americana**	fr, fl		x		
Premna obtusifolia	fr				x
Terminalia catappa	fr, fl	x			x

* = introduced species

Reproduction occurs throughout the year in *Pteropus mariannus mariannus* on Guam (Wiles 1987a) and in the subspecies *P. m. yapensis* on Yap (Falanruw 1988). Mating and the presence of nursing young have been observed year-round on Guam with no consistent annual peak in births (Perez 1972; Wiles 1987a). Glass and Taisacan (1988) suggested a similar pattern on Rota, but also indicated that a peak birthing season may occur during May and June, as has been observed in other fruit bats (Pierson and Rainey 1992). Female bats of the family Pteropodidae generally have one offspring per year (Pierson and Rainey 1992), and observations on Guam between July 1982 and May 1985 documented a total of 262 female bats, each with a single young (USFWS 1990). Based on these reproductive traits, several authors have suggested that *Pteropus* bats have a low maximum population growth rate and thus a slow rate of recovery when a population is diminished (Pierson and Rainey 1992; McIlwee and Martin 2002). However, some Pacific island populations of *Pteropus* have recovered fairly quickly in response to reduced hunting pressure (e.g., *P. mariannus pelewensis* in Palau [Wiles et al. 1997], *P. m. yapensis* in Yap [Mickleburgh et al. 1992], and *P. tonganus* in American Samoa [Brooke et al. 2000; Utzurrum et al. 2003]); thus, reproductive rates may be higher than believed in some populations (Wiles and Brooke in press).

Length of gestation, age of sexual maturity, and average lifespan are unknown for the fanihi, but other related bats have a gestation period of approximately 4.6 to 6.3 months (Pierson and Rainey 1992). Many *Pteropus* species typically do not give birth before 18 months of age (Pierson and Rainey 1992; McIlwee and Martin 2002). Mean longevity of a substantially larger species, *P. alecto*, in Australia is four to five years, with a maximum of eight years (Vardon and Tidemann 2000).

3. Interisland Movement

Pteropus bats are well known to be strong fliers and traverse long distances (Eby 1991; Palmer and Woinarski 1999; Nelson 2003), and significant evidence exists that fanihi fly between islands in the archipelago (Lemke 1986; U.S. Fish and Wildlife Service 1990; Wiles and Glass 1990; Worthington and Taisacan

1996). The geography of the archipelago, as well as the flight capability of fruit bats, facilitates interisland exchange. Distances between islands in the Mariana archipelago generally range from 29 to 100 kilometers (18 to 62 miles), and a few islands in the southern part of the chain are much closer (e.g., Aguiguan to Tinian is 9 kilometers (5.6 miles); Tinian to Saipan is 5 kilometers (3 miles). Each island in the chain is visible from neighboring islands (Wiles and Glass 1990).

Temporary spikes in fruit bat numbers on Guam were observed in 1992-1993 (from about 350 to 550) and in 1998 (from about 150 to 760 bats) (A. Brooke, *in litt*. 2003). Each of these spikes lasted for several months, with the likely explanation being a temporary relocation of bats from Rota, which lies 77 kilometers (48 miles) from Guam and is visible from Guam's north shore. More modest but equally sudden increases in bat numbers on Guam were noted 2 and 4 days following typhoons Chataan and Pongsona respectively, in 2002 (D. Janeke, University of Guam, *in litt*. 2003). Several other instances of apparent immigrations from Rota to Guam documented in the late 1970s and 1980s are described in detail by Wiles and Glass (1990). The presence of fruit bats on the islands of Tinian and Aguiguan, which are close to one another and to Saipan, is ephemeral (Worthington and Taisacan 1996), indicating that interisland travel likely occurs among these three islands as well.

In the northern islands of the CNMI, fanihi surveys on Sarigan documented a roughly stable level of approximately 125 to 235 bats between 1983 and 2000 (Wiles *et al*. 1989; Fancy *et al*. 1999; Wiles and Johnson 2004), and a temporary increase to 300 to 400 bats in 2001 (Wiles and Johnson 2004). Recruitment of juvenile bats alone cannot account for this increase, and Wiles and Johnson (2004) posited Anatahan, 37 kilometers (23 miles) to the south, as the likely source for immigrants. Wiles *et al*. (1989) twice observed individual fruit bats 2 kilometers (0.8 mile) from Guguan, flying south in the direction of Sarigan, which lies 63 kilometers (39 miles) away. Anecdotal observations of likely transits among other northern islands are described in Wiles and Glass (1990) and by other species experts (Worthington and Taisacan 1996; Wiles and Johnson 2004).

Typically, observations of vertebrates flying between islands over tens of miles of open ocean are extremely rare. In the wider context of Pacific biogeography, the evidence described above of interisland movement of fanihi within the Mariana Islands is extraordinary. Immigration rates of perhaps one individual per generation might be necessary for an island subpopulation to maintain genetic homogeneity with the populations on other islands (Mills and Allendorf 1996; Wang 2004). The chances of witnessing such a low rate of immigration are slight; the evidence described above, therefore, suggests even greater rates of movement and probable gene flow among fruit bats on various islands in the Mariana archipelago.

F. Reasons for Decline and Current Threats

The initial declines in the Mariana fruit bat and their likely causes are outlined in the previous section for each island. Table 3 summarizes by island our understanding of these historical mechanisms and the current threats to the continued existence of the fanihi. Today, illegal hunting, loss of native forest, predation by the brown treesnake (on Guam and possibly on Saipan), and the increased risk of extirpation or extinction faced by small, fragmented populations are the most significant threats to the survival of the Mariana fruit bat. These current known and potential threats are discussed below.

1. Hunting [Listing Factor B]

A long history of hunting has contributed to archipelago-wide declines in the numbers of the Mariana fruit bat and its near-extirpation from all of the southern islands except Rota, where illegal hunting continues but bats persist in low numbers. Hunting also threatens bats on some of the northern islands, although bat numbers and the history of human settlement throughout the archipelago suggest that hunting pressure north of Farallon de Medinilla probably has not been as severe as in the southern islands (Wiles *et al*. 1989). Hunting of Mariana fruit bats has been restricted or prohibited by Territorial, Commonwealth, and/or Federal law since the 1970s. Nonetheless, evidence of chronic hunting is consistent, plentiful, and reliable; that illegal hunting of bats is ongoing and widespread is a generally accepted if not widely discussed reality.

Mariana fruit bats have been used as food since humans first arrived on the islands (Lemke 1992a), and consumption of bats represents a significant Chamorro cultural tradition. Social events and cultural status in the Mariana Islands are often enhanced by a variety of foods, and the fruit bat is a highly

Table 3. Island summary of historical factors and current threats affecting the fanihi. See text for full discussion.

Island	Area km^2 (mi^2)	Historical Factors	Known and Potential Current Threats	Known (K) or Potential (P) Threat	Listing Factor*	Fruit bat numbers and status (current estimates**, year)
Guam	549.0 (212.0)	Habitat loss • development • agriculture • ungulates • invasive non-native plants Hunting*** Brown treesnakes	Habitat loss • degradation of native forests • ungulates • invasive non-native invertebrates • invasive alien plants • development Hunting*** Brown treesnakes	 K K K K K K K	A B C	<100; declining, 2007[1]
Rota	85.2 (32.9)	Habitat loss • development • agriculture • ungulates Hunting	Habitat loss • development • ungulates Hunting	 K K K	A B	500; declining, 2007[2]
Aguiguan	7.0 (2.7)	Habitat loss • agriculture • ungulates Hunting	Habitat loss • ungulates Hunting Military training activities	 K K P	A B E	<50; fluctuating, 2005[3]
Tinian	101.8 (39.3)	Habitat loss • development • agriculture • invasive non-native plants • ungulates Hunting	Habitat loss • development • invasive non-native plants • ungulates Hunting Military training activities	 K K K K P	A B E	<10; no known colonies; rarely observed, 2007[4]

Island	**Area km^2 (mi^2)**	**Historical Factors**	**Known and Potential Current Threats**	**Known (K) or Potential (P) Threat**	**Listing Factor***	**Fruit bat numbers and status (current estimates**, year)**
Saipan	122.9 (47.5)	Habitat loss • development • agriculture • invasive non-native plants Hunting	Habitat loss • development • invasive non-native plants Hunting Brown treesnakes	 K K K P	A B C	Occasional, small colonies; 30-50
Farallon de Medinilla	2.0 (0.8)	Military training activities (disturbance and habitat loss)	Military training activities (disturbance and habitat loss)	K	E	No colonies; 2 fruit bats observed in 1996[6];
Anatahan	32.3 (12.5)	Habitat loss • agriculture • ungulates Hunting	Habitat loss • ungulates • invasive non-native plants Hunting Volcanic activity	 K P P K	A B E	220-330; decline between 1983 and 2000, 2009[7,9]]
Sarigan	5.0 (1.9)	Habitat loss • agriculture • ungulates Hunting	Habitat loss • invasive non-native plants Hunting	 K P	A B	140; stable, 2007[7,8]
Guguan	4.0 (1.5)	Volcanic activity	Hunting	P	B	350; status unknown, 2000[9]
Alamagan	11.0 (4.3)	Habitat loss • agriculture • ungulates Hunting	Habitat loss • ungulates Hunting Volcanic activity	 K K P	A B E	200; numbers and status uncertain[9, 10]
Pagan	47.7 (18.4)	Habitat loss • agriculture • ungulates Hunting Volcanic activity	Habitat loss • ungulates • invasive non-native plants Hunting Military training activities Volcanic activity	 K K P P	A B E E	500-800; decline between 1983 and 2000, recent numbers uncertain, 2007[7,9]

Island	Area km^2 (mi^2)	Historical Factors	Known and Potential Current Threats	Known (K) or Potential (P) Threat	Listing Factor*	Fruit bat numbers and status (current estimates**, year)
Agrihan	47.4 (18.3)	Unknown	Habitat loss • ungulates Hunting Volcanic activity	 K K P	A B E	1,000; status unknown, 2000[9]
Asuncion	7.4 (2.9)	Volcanic activity	Volcanic activity Hunting	P P	E	600; status unknown, 2001[11]
Maug	2.0 (0.8)	Unknown	Unknown Hunting	 P		<25, status unknown, 1983[10]

* Listing Factors (as described in Section 4(a)(1) of the Endangered Species Act:
A – Destruction or curtailment of habitat or range
B – Overutilization for commerce, recreation, education, or scientific purposes
C – Disease or predation
D – Inadequacy of existing laws
E – Other natural or human-related factors
** Note: most estimates are rough and represent a range of methods and survey effort and frequency.
*** Based on anecdotal information from local hunters, it is believed that hunting of fruit bats once occurred throughout the Marianas. Today, hunting of fruit bats is illegal under Territorial, Commonwealth, and Federal law.

Sources:
[1] A. Brooke, pers. comm.. 2007
[2] C. Kessler, pers. comm. 2007
[3] G. Wiles, pers. comm. 2007
[4] S. Vogt, pers. comm.. 2007
[5] Laura Williams, CNMI-DFW, pers. comm. 2004
[6] Tim Sutterfield, U.S. Navy, *in litt*. 1997
[7] C. Kessler, pers. comm. 2009 (estimate for Pagan based on brief 2007 survey)
[8] Wiles and Johnson 2004
[9] Cruz *et al*. 2000f (Agrihan); 2000e (Pagan); 2000b (Alamagan), 2000a (Guguan)
[10] Wiles *et al*. 1989
[11] Johnson 2001

prized delicacy. In a Guam survey of Chamorros, the culture indigenous to the Mariana Islands, 53 percent of the respondents indicated that they enjoyed eating fruit bats (Sheeline 1991). The Mariana fruit bat clearly is an important symbol in the Mariana Islands, as 82 percent of the respondents to the same survey believed that fruit bats had cultural value. However, 85 percent of the respondents also expressed a belief that people should stop hunting and eating fruit bats if such activity would lead to the species' extinction (Sheeline 1991).

Traditional hunting methods, such as nets, traps, thorny branches on poles, and stone projectiles, ensured limited success in capturing fruit bats (Lemke 1992a). Today, bats are taken more efficiently and in greater numbers with shotguns and rifles fired at roosting and feeding sites or along flyways. Gregarious species such as the fanihi are particularly vulnerable to hunting at their roost sites. One shotgun blast may kill several bats or knock them to the ground, and a successful raid can glean up to 50 bats (Wiles 1987b; Lemke 1992a). Hunting at colonies can also result in direct mortality and abandonment of infant and juvenile bats (Lemke 1992a).

Demand for fruit bats for human consumption in the Marianas is clearly demonstrated by the large commercial trade in bats that existed from the 1960s to 1990s (Wiles and Payne 1986; Stinson *et al.* 1992; Wiles 1992; Wiles *et al.* 1997). It is estimated that several hundred thousand fruit bats were imported to Guam and the CNMI from other sources in the Pacific region during this period. This number included about 16,500 Mariana fruit bats shipped to Guam from Rota, Saipan, Tinian, and Pagan from 1975 to 1982 (excluding 1977), although this figure is likely inflated to some extent. This trade ended in 1994, leaving a void in the availability of bats for Chamorro consumers and potentially increasing illegal hunting for bats within the island chain. In recent years, a single locally killed fruit bat can sell for $40 to $75 in the CNMI (Worthington and Taisacan 1996; C. Kessler, *in litt*. 2003; A. Brooke, pers. comm. 2007, Dana Lujan, U.S. Department of Agriculture, pers. comm. 2007). Despite this, many of the bats killed are taken for personal consumption (often for important social and cultural occasions) rather than for commercial purposes.

<u>Southern Islands</u>

Hunting was one of the important causal factors in the fruit bat declines on Guam, Saipan, Tinian, and Aguiguan through the 1970s (Perez 1972; Wheeler 1980; Wiles 1987b), although bans on the hunting of bats were enacted on Guam in 1973 and in the CNMI in 1977 (Public Law 5-21, September 1977). Today, although few bats remain on Guam, they are probably still hunted opportunistically on private property when they transit the island, and by deer hunters or poachers on Andersen Air Force Base and other military lands on northern Guam near the last remaining colonial roost (Guam National Wildlife Refuge staff, pers. comm. 2005). Numerous documented reports indicate that illegal hunting continues to be a major threat to the Mariana fruit bat in the CNMI, particularly on Rota (see below). In 1987, between three and eight bats were reported to be taken by hunters in a small colony on Saipan (Glass and Taisacan 1988). In 1997, there was a report of nearly 90 bats shot and killed on Tinian from a colony that roosted on the island briefly (T. Sutterfield, pers. comm. 1998).

Rota

Numerous documented reports indicate that hunting continues to be a major threat to the Mariana fruit bat on Rota (Glass and Taisacan 1988; Lemke 1992b; Marshall *et al*. 1995; Worthington and Taisacan 1996; Stan Taisacan, CNMI-DFW, pers. comm. 1997; Rainey 1998; Nathan Johnson, CNMI-DFW, pers. comm. 2000; C. Kessler, pers. comm. 2004; Arlene Pangelinan, U.S. Fish and Wildlife Service, pers. comm. 2004; Esselstyn *et al*. 2006, J. Boland, pers. comm., 2009). This long history of observations by biologists on Rota indicates that hunting is ongoing in spite of the law. Although hunting pressure is difficult to quantify, an interview of 29 hunters suggested an annual mean hunting rate of 9.4 bats/hunter during normal years (e.g., those without major storms) (Esselstyn *et al*. 2006).

Most recently, CNMI-DFW biologists have made the following observations (J. Boland, pers. comm., 2009): between April 2008 and April 2009 four maternity colonies and an unknown number of commuting and foraging individuals were disturbed by poachers. Disturbances have resulted in complete abandonment of three roost sites occupied by maternity colonies and partial abandonment of the fourth. Disturbances to bats while they commute between roosts and foraging areas have resulted in bats changing preferred flight paths. Alternate flight paths may put bats at greater risk of death and injury due to an increase in energy expenditure required to travel longer distances over open water with greater exposure to strong winds and rain. Poaching incidents since April 2008 have resulted in the loss of an estimated 200 bats.

Post-typhoon Hunting on Rota

Defoliation and other habitat damage caused by severe storms can increase the vulnerability of fruit bats to illegal hunting (see the "Natural Disturbance" section, below). Following supertyphoon Roy in 1988, the near-total defoliation of the island's forests (Fancy and Snetsinger 1996) and other damage caused by the storm forced bats on Rota to forage during the day in areas close to human habitation (Stinson *et al*. 1992). As a result, extensive opportunistic hunting occurred, contributing to a reduction of total bat numbers on Rota by more than half (Stinson *et al*. 1992). Bat numbers recovered to more than 2,000 before supertyphoon Pongsona in December 2002, but again declined by more than half following this storm, most probably with hunting as a significant contributing factor. This decline was documented by monthly surveys conducted by the same individuals using the same techniques (evening colony departures, direct colony counts, and searches for solitary bats). These surveys yielded estimates of fewer than 750 animals for most of the 15 months following the supertyphoon (Esselstyn *et al*. 2006). Similar sharp increases in hunting of fruit bats following severe storms have been documented elsewhere in the Pacific as well as in the Mariana Islands (Craig *et al*. 1994; McConkey *et al.* 2004).

Continued illegal hunting on Rota diminishes the fruit bat population's ability to recover to pre-storm abundance (Worthington and Taisacan 1996). Hunter interviews indicated that hunting pressure on fruit bats increased by roughly 30 percent in the year following Pongsona (Esselstyn *et al.* 2006). In June and July 2004, residents of Rota reported that one or more illegal hunting incidents killed at least 40 fruit bats, resulting in the abandonment of the largest colony on the island, and another smaller colony was abandoned at this time as well (C. Kessler, pers. comm. 2004). On August 22 and 23, 2004, 21 months after supertyphoon Pongsona, Rota again sustained severe damage from supertyphoon Chaba, with as much as 60 to 75 percent of the island defoliated (A. Pangelinan, pers. comm. 2004). These conditions may have facilitated another pulse of post-typhoon hunting. Hypothetically, multiple episodes of increased illegal hunting would exacerbate the adverse effects of severe storms on bat numbers and impede the natural rebound of the population (see Factor E, below).

CNMI Northern Islands

Hunting of fruit bats on the northern islands is occasionally reported, but monitoring on these islands and of vessels returning from the north is limited. It is generally assumed that illegal hunting of fanihi takes place on all islands with human populations and on islands visited in transit to and from these (Wiles *et al*. 1989; L. Williams, pers. comm. 2007; G. Wiles pers. comm. 2007). In 1996, hunting in the northern islands was reported to be an increasingly significant problem (Worthington and Taisacan 1996). On Anatahan, which lies only 151 kilometers (94 miles) from heavily-populated Saipan, remains of recently cooked fruit bats were found in the main campsite area in 1995, and a team of biologists on the island observed residents of Anatahan cooking and eating fruit bats (Marshall *et al.* 1995; Worthington *et al.* 2001).

In 1998, 14 Mariana fruit bats shot in the northern islands were confiscated from a CNMI vessel returning to Saipan (T. Eckhardt, *in litt*. 1998), and hunting of Mariana fruit bats was reported on Sarigan (Zoology Unlimited LLC 1998). On Pagan, 7 recently expended .410 (very small bore) shotgun shells were found in 1999, 4 more were found in 2000, and a .410 shell and fresh remains of cooked fruit bat were found during a helicopter refueling stop in 2001 (Cruz *et al*. 2000e; Johnson 2001). Most recently, a team of CNMI officials visiting Pagan in 2007 reported being served cooked fanihi by the island's residents (L. Williams, pers. comm. 2007).

2. Habitat Loss and Degradation [Listing Factor A]

The ecological integrity of the remaining native forest habitat in the Mariana Islands is threatened by development, agriculture, and the long-term ecological impacts of ungulates, invasive plants, and, on Guam, the brown treesnake. Although some non-native forest types (e.g., forest dominated by coconut or other agricultural plants) do provide food resources for fruit bats, and bats roost in some forests that provide little or no forage (e.g., *Casuarina* forest), loss and degradation of native forest is a key threat to Mariana fruit bats because essential food and roosting resources are lost. For example, essential, limiting nutrients such as calcium are more abundant in native plants than in agricultural plants eaten by fruit bats in American Samoa (Nelson *et al.* 2000), and in the Philippines, fruit bats preferentially forage in native forest although they use both native and non-native/disturbed forests (Mildenstein *et al.* 2005).

Over the past several centuries, the southern Marianas have lost most of their original native forest, primarily to agriculture, growing human populations, economic development, and military activities (Bowers 1950; Fosberg 1960). Nonetheless, the overall extent of native forest and potential habitat for fanihi is greatest in the southern islands (Table 4), although these forests may be degraded (see below). Only a few of the northern islands are relatively unaltered by human activities; Guguan, Asuncion, and possibly Maug have for the most part escaped the effects of millennia of continuous human settlement, World War II, and post-war activities that caused the initial, extensive habitat alteration and fragmentation of forest habitat (see Table 4). Human impacts are evident on the other islands, in the form of swordgrass savannahs maintained by burning, old copra (coconut) plantations, the presence of feral ungulates, and intermittent human habitation. The absolute amount of forest habitat in the northern islands is much less than in the southern islands, in part because the islands are much smaller. In addition, the relative proportions of northern islands considered to be habitat for fanihi also are smaller than in the southern islands (see Table 4).

On many islands in the archipelago, ungulates have caused severe damage to forests by browsing on plants, causing erosion (Marshall *et al*. 1995; Kessler 1997; U.S. Fish and Wildlife Service 1998a, b), retarding plant growth and regeneration (Lemke 1992b; Wiles 2005), and facilitating the establishment of invasive plants (Marshall *et al*. 1995; Kessler 1997; U.S. Fish and Wildlife Service 1998a, b; Wiles *et al*. 1999), which can impede forest regeneration by displacing or smothering native species (Kessler 2000b). This is a particular problem on highly altered islands, where what little mature native forest remains continues to be threatened by the degradation and fragmentation associated with introduced ungulates. For example, although Guam is dominated by native forest (see Table 4), Wiles (2005) recently documented a rapid decline in the native breadfruit, an important bat food, even in the remaining native forest on the

Table 4. Estimated extent of fanihi habitat in the Marianas. "Native" includes mature and secondary forest, but these forests may be degraded by ungulates. The variety and extent of forest types provide habitat of variable quality; see text for discussion. Data compiled by USFWS from published and unpublished sources.

Island	Area km² (mi²)	Total forest cover ha	Fanihi habitat ha	Fanihi habitat (percentage of all forest cover)	Fanihi habitat (percentage of total land area)
Guam	549.0(212.0)	25,833	25,711	100	48
			Native: 25,711		
Rota	85.2(32.9)	6,977	6,663	95	70
			Native: 6,202		
			Coconut: 446		
			Agroforest: 15		
Aguiguan	7.0(2.7)	302	302	100	43
			Native: 302		
Tinian	101.8(39.3)	8,283	6,481	78	64
			Native: 6,361		
			Coconut: 118		
			Agroforest: 2		
Saipan	122.9(47.5)	9,105	5,355	59	44
			Native: 4,080		
			Coconut: 1,236		
			Agroforest: 39		
Farallon de Medinilla	2.0(0.8)	0	0	0	0
Anatahan	32.3(12.5)	Not available	Not available		
Sarigan	5.0(1.9)	162	162	100	33
			Native: 29		
			Coconut: 133		

Island	Area km^2 (mi^2)	Total forest cover ha	Fanihi habitat ha	Fanihi habitat (percentage of all forest cover)	Fanihi habitat (percentage of total land area)
Guguan	4.0(1.5)	140	140 Native: 140	100	35
Alamagan	11.0(4.3)	350	350 Native: 230 Coconut: 120	100	32
Pagan	47.7(18.4)	1,720	900 Mixed native and coconut: 900	52	19
Agrihan	47.4(18.3)	2,300	2,300 Native: 1,250 Coconut: 800 Agroforest: 250	100	58
Asuncion	7.4(2.9)	305	305 Native: 305	100	41
Maug	2.0(0.8)	Not available	Not available	Not available*	Not available

* Owing to Maug's remoteness and extreme topography, all of its forest cover is native.

northern end of the island. This decline was attributed to a combination of mortality of mature trees in the wake of several severe typhoons and a lack of recruitment caused by deer and pig foraging on fallen fruit (with seeds) and seedlings.

Non-native pigs, goats, and cattle continue to degrade native forests on some of the northern islands as well. The introduction of these ungulates to some of the northern islands as recently as 40 years ago has resulted in rapid degradation and loss of native forest cover, notably on Anatahan and Pagan, two of the largest islands that have supported relatively large numbers of fruit bats (Kessler 1997, 2000a; Worthington *et al.* 2001).

These vegetation and landscape changes can deprive fruit bats of the forests on which they depend for food and roosting. The diminished quality and extent of forest thus leads to an associated reduction in the number of fruit bats that the remaining habitat is able to support. In the most extreme case, tree loss associated with past and current live-fire training activities by the military on Farallon de Medinilla has all but eliminated roosting and foraging opportunities for bats transiting between the Southern and Northern islands.

3. Predation by Brown Treesnakes [Listing Factor C]

The brown treesnake is believed to adversely affect bat recruitment on Guam. Numerous sightings of this predator have occurred on Saipan, and treesnake interdiction is a critical concern throughout the CNMI. Predation by brown treesnakes has caused the decline or extirpation of most landbird species on Guam (Savidge 1987, Wiles et al. 2003) and is probably responsible for decreases in recruitment of young bats observed in the island's low remaining numbers of bats (Wiles 1987a; Wiles *et al*. 1995). Although only two or three cases of snake predation have been reported (e.g., Wiles 1983), the snake is considered capable of preying on non-volant young bats (U.S. Fish and Wildlife Service 1990). Data collected at the island's main bat colony from 1982 to 2006 have indicated a consistent pattern wherein small pups are routinely recorded with their mothers, but medium-sized young are much rarer and large young are virtually absent (Wiles 1987b; Wiles *et al*. 1995; G. Wiles, unpubl. data; D. Janeke, pers. comm. 2006). Most observations were made in areas where native forest bird populations had collapsed, indicating the establishment of high densities of brown treesnakes. However, for several months in 1983, after the colony moved to a new location where native birds persisted, sizable numbers of larger pups were detected (G. Wiles, pers. comm. 2007).

The brown treesnake was accidentally introduced to Guam between 1945 and 1952, probably in ship cargo (Rodda *et al*. 1992), and was present throughout the island by 1986 (Savidge 1987). Because of the snake's distribution and biology and Guam's location and role as a major transportation hub in the Pacific, the probability is high that human conveyance will disperse brown treesnakes from Guam to other Pacific islands (Fritts 1988).

Reports of brown treesnakes in the CNMI, especially on Saipan, have increased since 1982 (Brown Treesnake Control Plan 1996). As of October 2007, 76 credible treesnake sightings, including 11 captures, had occurred on the island (Nathan Hawley, U.S. Fish and Wildlife Service, pers. comm. 2007). The frequency of sightings during this period suggests that brown treesnakes are present on Saipan island (Colvin *et al.* 2005; Draft Brown Treesnake Control Plan 2009) thus leading to increased predation risks on native fauna. However, documentation of treesnakes breeding on Saipan still is lacking (Rodda and Savidge 2007; Draft Brown Treesnake Control Plan 2009). There have also been two documented captures of treesnakes on Rota and five sightings on Tinian.

4. Natural Disturbance, Development, and Military Training Activities [Listing Factor E]

Natural Disturbance

The fanihi has coexisted for millennia with typhoons, volcanic eruptions, and other natural phenomena. These disturbances, when sufficiently severe, probably have drastically reduced bat numbers at times on all islands in the Marianas. With sufficient time and suitable remaining habitat, bat numbers presumably rebounded through natural recruitment or immigration from neighboring islands.

Today, natural disturbances are likely to lead to more severe and lasting impacts on the compromised fanihi population throughout the archipelago because these impacts are exacerbated by anthropogenic pressures. Individual islands harbor smaller numbers of bats than they did historically, and numbers on some islands are so small that they are highly vulnerable to extirpation. Natural or anthropogenic disturbance and resulting changes to a population’s intrinsic demographic parameters, such as sex ratio, age structure, and other traits, are more likely to affect the population growth rate and persistence when numbers are low. The decreasing numbers and increasingly fragmented distribution of fanihi throughout the islands through time make recolonization events less likely after disturbance from severe environmental events. The total extent of high quality, native forest for bats has been reduced on most islands, which limits opportunities for bats to shift the location of their roost sites and foraging activity in response to disturbance (and by extension limits the resilience of the ecosystem as a whole). Taken together, these circumstances reduce the ability of bats to recover rapidly in the wake of severe natural disturbances.

Storms

Severe storms, in particular, pose a threat to fanihi, primarily because of the dramatic increase in hunting that sometimes occurs in the wake of such storms, augmenting the impact of that natural disturbance (Esselstyn *et al*. 2006). Evidence suggests that severe typhoons usually do not directly kill fruit bats at their roost sites (Lemke 1992b; Esselstyn *et al*. 2006; Wiles and Brooke in press; but see Wiles 1987b), but the synergistic effect on the fanihi of illegal hunting and severe storms is well documented on Rota (see “Hunting” section, above) and in other locations (e.g, Craig *et al*. 1994; McConkey *et al.* 2004). Severe storms can alter fruit bat foraging and roosting behavior by decimating food resources, removing protective foliage cover, temporarily modifying forest structure, and changing vegetation composition, especially by facilitating encroachment of nonnative species (Lemke 1992b). Loss of food resources can drive bats to forage closer to areas of human activity in daylight hours, thereby increasing their vulnerability to illegal hunting (Craig *et al*. 1994; Pierson *et al*. 1996). Finally, tropical cyclones are likely to become more severe and more frequent in coming decades as a result of human impacts to the global climate (e.g., Emanuel 2005; Webster *et al.* 2005). Environmental changes on this rapid timescale may exceed the ability of natural systems to adapt.

Volcanism

The Mariana Archipelago was formed by volcanic activity along the Mariana Trench, a subduction zone where one tectonic plate of the Earth’s crust is moving beneath another. The northern islands of the CNMI are still volcanically active; eruptions have altered the landscapes and habitats of many of these islands in recorded history. The potential thus exists for volcanic eruptions to destroy habitat for fruit bats in the northern islands. Pagan last erupted in 1981, when ash and a lava flow covered much of the northern half of the island. Anatahan erupted multiple times between 2003 and 2005, and much of the island was denuded. As described above, fruit bat numbers on Anatahan declined precipitously following the 2003 eruption, and after a brief increase during 2004, have remained at fewer than 200 individuals since 2005 (C. Kessler, pers. comm. 2007).

Few people have visited Anatahan since the eruptions began, and illegal hunting there is thus unlikely to have confounded the response of the island's bats to this natural disturbance. However, owing to anthropogenic disturbance, the islands on either side of Anatahan, Sarigan and Farallon de Medinilla, harbor few and no bats, respectively (Table 3). Therefore, more time and opportunity will be necessary for significant number of bats from other islands to immigrate to Anatahan, even when the island's vegetation has recovered sufficiently to support greater numbers of bats. An increase in bat numbers on Anatahan may be more dependent on intrinsic growth than on immigration for some time to come.

Development and Military Training Activities

Urbanization and other forms of development remain a threat to the Mariana fruit bat. This threat may manifest as fragmentation or degradation of forest habitat, direct disturbance of bats, and/or increased likelihood of new introductions of the brown treesnake or other predators to islands. On Guam, development takes the form of urbanization associated with an increasing population and tourism industry and the expansion and refurbishment of military infrastructure. On Rota and Tinian, development includes the clearing of lands set aside as agricultural homesteads (CNMI Senate Bill 13-32, C.S. 1, November 2002; CNMI Senate Bill 14-44, S.S. 1, July 2004), military infrastructure and new businesses such as the casino on Tinian. On Saipan, increasing urbanization, road building, and the tangantangan charcoal industry are ongoing issues of concern.

The Department of Defense has several military installations and training programs in the Mariana Islands. The Department of Defense live fire and bombing exercises on Farallon de Medinilla have effectively precluded that island as a foraging or roosting site for fruit bats. However, survey crews in 1996 and 2008 each observed a single bat on the island, indicating that Farallon de Medinilla may still function as a stopover site for bats in transit (A. Brooke, pers. comm., 2009). Recent and new activities proposed by the U.S. Air Force at Andersen Air Force Base on northern Guam have been determined likely to adversely affect fruit bats under section 7 of the Endangered Species Act, prompting formal consultation with the U.S. Fish and Wildlife Service to estimate the risk of take and develop measures to avoid and minimize that take.

As of this writing, the Department of Defense is developing Environmental Impact Statements for new training, development, and other activities on Guam and in the CNMI associated with the redeployment of a U.S. Marine Corps Expeditionary Force from Okinawa to the Marianas. We do not currently have sufficient information to summarize in this draft revised recovery plan the potential threat to fanihi posed by these actions and will evaluate these proposed activities under section 7 of the Endangered Species Act once the data have been provided.

G. Conservation Efforts

Prompted by severe declines in fanihi numbers, the CNMI legislature passed a moratorium on the taking of bats on all islands in 1977 (Public Law 5-21, September 1977); however, hunting of bats was subsequently permitted on Anatahan. The bat has since been listed as threatened or endangered by the CNMI government on Rota, Saipan, Tinian, and Aguiguan (CNMI 1991), but the CNMI's designation of threatened or endangered species did not include prohibition on take (K. Garlick, U.S. Fish and Wildlife Service, *in litt*. 1997) or any other protection (A. Palacios, *in litt*. 1990; Worthington and Taisacan 1996). Current CNMI hunting regulations (Part 4, Section 10.7.i (Commonwealth Register Vol. 23, August 16, 2001, p. 18266)) prohibit the hunting, killing, or possession of threatened, endangered, and protected species.

The Mariana fruit bat is listed as an endangered species by the Government of Guam and take is prohibited under this designation (Wiles 1982). The species was originally listed under the Federal Endangered Species Act as an endangered subspecies endemic to Guam in 1984 (49 FR 33881). We designated critical habitat for the Mariana fruit bat on Guam in a final rule published in the *Federal Register* on October 28, 2004 (USFWS 2004). On Guam, the bat is legally protected from hunting by its status under U.S. and Guam laws.

In January 1990, declines in bat populations throughout Micronesia resulted in the reclassification of *P. mariannus* from Appendix II to Appendix I of the

Convention on International Trade in Endangered Species (CITES). This reclassification was an effort to control shipments of other subspecies from Palau, Yap, and Kosrae into the Mariana Islands and to encourage exporting countries to conserve their bat populations. Enforcement of CITES regulations, outreach by the U.S. Fish and Wildlife Service and the governments of Guam and the CNMI, and Palau's change in political status to one of free association with the United States resulted in the termination of all legal *Pteropus* imports into the Marianas in 1994. CITES protection has been highly successful and very few illegal shipments of bats now enter Guam and the CNMI (Wiles and Brooke in press).

Since the 1970s, surveys of fanihi have been conducted on various islands and at variable intervals by the Guam Division of Aquatic and Wildlife Resources (DAWR) and CNMI DFW. Personnel at these agencies and at the Guam National Wildlife Refuge have conducted studies to obtain information about the ecology, life history, movements, and take by hunters of fanihi (e.g., Perez 1972; Wheeler and Aguon 1978; Wheeler 1980; Wiles 1982, 1983, 1987a, 1987b; Glass and Taisacan 1988; Wiles *et al*. 1989, 1995; Wiles and Glass 1990; Lemke 1992; Rice and Taisacan 1992; Stinson *et al*. 1992; Worthington and Taisacan 1995, 1996; Worthington *et al*. 2001, Wiles and Johnson 2004; Esselstyn *et al*. 2006). The CNMI DFW has a staff biologist position dedicated to study and monitoring of fanihi. A University of Guam student recently concluded a study of fanihi movements and habitat use on Guam (Janeke 2006). Studies of fruit bats by biologists at the agencies listed above, the U.S. Navy, and other institutions are ongoing. Genetic analysis of differentiation between island groups is currently being conducted by Gary McCracken at the University of Tennessee. Wiles (2005) reported on Guam's declining population of native breadfruit, a favored food of fanihi.

Other projects in the Mariana Islands may not specifically address bat conservation, but indirectly benefit the species. Examples of such projects include: the designation of conservation status for Guguan, Asuncion, and Maug, the three northernmost islands of the CNMI; locally legislated conservation lands in the CNMI Sabana Conservation Area and on Guam; the establishment of Guam National Wildlife Refuge at Ritidian Point and the overlay refuges on most military lands on Guam; ungulate eradications on Sarigan and Anatahan; ongoing, multi-agency research and management to control brown treesnakes on Guam;

and research and recovery implementation for other listed species in the Marianas, for example the aga or Mariana crow (*Corvus kubaryi*), the nosa Luta or Rota bridled white-eye (*Zosterops rotensis*), and the ga`ga` karisu or nightingale reed-warbler (*Acrocephalus luscina*).

Because illegal hunting of fanihi continues, we conclude that to date, enforcement of laws that prohibit hunting has been mostly ineffectual. Survey efforts and research listed above have contributed information about the threat posed by hunting that can aid in recovery, but this information has not yet been implemented effectively on the ground in the form of outreach, education, and/or punitive consequences for those who break the law. Because habitat degradation and loss is a principal threat to the fanihi, projects that protect or restore native forest are likely to have high conservation benefits. At this time, few section 7 consultations have been conducted that have included measures to conserve fanihi, and no section 10 incidental take permits have been issued that directly address fanihi recovery. However, section 10 habitat conservation planning efforts that are currently underway on Rota for the Mariana crow may result in mitigation that will benefit other native birds and fanihi as well, by protecting native forest habitat on Rota.

II. RECOVERY

A. Recovery Goal and Objective

The goal of this recovery plan is to bring about the recovery of the fanihi and delist the species in the Mariana Islands. The major objective of this recovery plan is to outline a strategy and describe actions that will result in increasing numbers of fanihi and the establishment of a viable metapopulation in the Mariana Islands. To do this, one aim is to strengthen individual island subpopulations across the archipelago as well as increase potential for interaction among island subpopulations within the archipelago. Such interactions among multiple islands provide insurance against a catastrophe such as a severe typhoon or volcanic eruption that may decimate bat numbers on one or more islands. A viable, archipelago-wide population is one that is resilient to natural disturbances and has a probability of extinction that is ten percent or less over 100 years. Meeting this overarching objective will require a combination of extensive community outreach and law enforcement to curb illegal hunting and disturbance of bats at their roosts, habitat restoration projects, and ongoing research and monitoring. Background for and description of these actions are provided in parts I and III, respectively, of this plan.

B. Recovery Strategy

The strategy for achieving the distribution and long-term population stability described above will involve several broad categories of actions: unlawful hunting of fanihi must be effectively controlled throughout the archipelago; habitat on islands where bats occur must be protected and enhanced, and habitat where bats do not currently or regularly occur must be protected or restored to facilitate movement of bats among islands and address existing or incipient disjunctions in the fanihi's distribution; and brown treesnakes must be controlled on Guam and Saipan, and most importantly, must be prevented from dispersing to other islands.

Re-establishing and maintaining a widely distributed, robust metapopulation of fanihi in the Mariana Islands is critical to the long-term persistence of the species. Distribution of bats in both the Northern and Southern islands is essential, including relatively large numbers of bats on some islands (e.g., Rota, Pagan, Agrihan, and/or Anatahan) and smaller numbers on small islands (e.g., Aguiguan, Guguan, and Asuncion) or islands with limited habitat (e.g., Sarigan). We anticipate that establishment of bats in currently unoccupied habitat will occur by natural colonization from adjacent sites or other islands, once numbers in those locations are released from hunting pressure and can grow. Even if numbers on individual islands fluctuate, for example, as a result of a volcanic eruption or severe typhoon, the distribution of healthy numbers of bats on other islands provides insurance against a single environmental catastrophe which otherwise may have significant population-level effects on the fanihi and hinder recovery.

Illegal hunting is a major threat to fanihi, and implementing recovery actions (e.g., outreach, education, and enforcement measures) to address this threat will be challenging, because the bat has great cultural value as a food item among the indigenous people and some immigrant groups in the Marianas. In the near term, consistent enforcement of Federal, Territorial, and Commonwealth law that prohibits hunting these animals is essential to ensure their continued existence. Immediately and in the long term, however, our efforts must focus on raising awareness of the fact that until the archipelago-wide fanihi population recovers, a sustainable hunt will not be possible. The public comments we received on the proposed rule to list the fanihi as threatened throughout its range suggest that the conservation constituency for this animal within the Mariana Islands is small. Thus, a key aspect of the recovery strategy for fanihi is involving hunters and the general public in on-the-ground research and conservation efforts to build that constituency. This involvement will be essential as a means of both tapping into an important source of natural history information and garnering local community support for and commitment to fanihi recovery and conservation for the long term.

Implementing these actions requires building long-term support for and participation in the recovery effort; enhancing existing survey methodologies; conducting research and monitoring to address critical gaps in our knowledge and provide new information for effective conservation and recovery; and application of research and monitoring through adaptive management. The recovery strategy will be implemented as a collaborative effort among technical experts, agencies, the governments of the CNMI and Guam, and other participants and stakeholders.

Recovery of the fanihi will be tracked via monitoring and annual reporting through federal and local wildlife agencies. Research recommended in this recovery plan will provide the information needed to ensure the recovery strategy is as effective as possible. As we acquire new information through monitoring, research, and other sources, we will revise this recovery plan and adapt the strategy for its implementation to ensure the greatest efficiency and effectiveness of recovery efforts for the fanihi. The specific recovery actions described in the narrative outline address the threats to fanihi with a focus on islands, and areas within islands, as necessary. The fanihi is widely distributed in the Mariana archipelago, and threats and recovery potential vary among islands. The expensive and complex logistics of working on the remote northern islands may pose significant challenges to recovery implementation. Long-term recovery objectives will likely require prioritization among islands.

C. Recovery Criteria

Delisting of a threatened species is achieved through a formal rulemaking process. The recovery criteria set forth in a recovery plan are intended to serve as objective, measurable guidelines to assist us in determining when a listed species has recovered to the point that the protections afforded by the Endangered Species Act are no longer necessary. However, the actual delisting process is not dependent solely on achieving the recovery criteria. The formal rulemaking process is based upon a five-factor analysis (per section 4(a)(1) of the Endangered Species Act), in conjunction with an analysis of the recovery criteria, that results in a determination that the threats have been sufficiently controlled or eliminated such that delisting is warranted.[1]

To achieve the goal of delisting the fanihi, we have defined recovery criteria that will demonstrate we have ensured the conservation and survival of the species, and that the threats to the species have been reduced to the point that the protections afforded by the Endangered Species Act are no longer necessary. These criteria are listed below. However, currently we lack information necessary for refining these criteria and the methods, such as population models, for measuring progress toward them. We need new estimates of the numbers of bats occurring on most islands and improved information on population

[1] See section I.F above for a summary of the five factors as they apply to fanihi.

dynamics and demographics (for example, fanihi-specific data on productivity, survivorship, age structure, sex ratios), specific habitat requirements, interisland movements, genetic structure of the fanihi population, and mortality rates associated with disturbances such as typhoons and hunting. We need this information to develop a scientifically credible estimate of the target population size, growth rate, distribution, and extent and characteristics of the habitat necessary to ensure the long-term viability of fanihi. Further research on the life history and ecology of the species thus is needed to set measurable thresholds for recovery and accurately monitor and project the fanihi's response to management of threats. Results of such research may require us to revisit and revise these criteria.

Recovery criteria below address the major threats to the species, including general criteria for population distribution and post-delisting monitoring, as well as additional criteria organized by the five Listing Factors to be used in a delisting analysis. Although storms and volcanic eruptions are a threat under Listing Factor E, no foreseeable management effort is likely to reduce the incidence of these threats. However, a well-distributed and stable or increasing population that meets Criterion 1 below is expected to be resilient enough to accommodate some local catastrophic events without endangering the overall survival of the species.

The fanihi may be considered for delisting when the following criteria have been met:

1. Population and Distribution

   The total size of the fanihi population has increased, based on data from scientifically defensible monitoring protocols, and stable or increasing subpopulations of sufficient size to avoid genetic and demographic risks associated with very small populations are distributed among the Mariana Islands so that the probability of the fanihi's persistence over 100 years is high (at least 90 percent).

   To meet this criterion, we propose that stable or increasing fanihi subpopulations should be distributed as follows: three of the five southern islands (Saipan, Tinian, Aguiguan, Rota, and Guam), and six of the eight islands north of Saipan where fanihi have persisted historically (Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug). Of the six northern islands with stable or increasing fanihi populations, two of these must include Pagan, Anatahan, or Agrihan, the three largest of the northern islands. This distribution may be modified as appropriate based on future monitoring data or population viability modeling (Recovery Action 5.2).

2. Post-delisting monitoring
   A post-delisting monitoring program for the species has been developed to reliably detect population trends and is ready for implementation.

3. Listing Factor A: Habitat Loss and Degradation
   Specific actions to restore habitat (including ungulate control and control of invasive non-native plants as appropriate for specific islands – see Table 3) have been identified and management plans developed as necessary for recovery under Criterion 1, and these actions and plans are being successfully implemented so that habitat loss and degradation no longer endanger the survival of the fanihi.

4. Listing Factor B: Hunting
   Specific actions to reduce illegal hunting have been identified and management plans developed as necessary for recovery under Criterion 1, and these actions and plans are being successfully implemented so that illegal hunting no longer endangers the survival of the fanihi.

5. Listing Factor C: Brown Treesnakes
   Long term measures are being successfully implemented to control the incipient brown treesnake population on Saipan and to prevent the introduction of the brown treesnake from Guam and Saipan to other islands in the CNMI.

6. Listing Factor E: Development and Military Training Activities
   Impacts of urban development and military training on the fanihi are successfully being avoided, minimized, or mitigated so that they do not endanger the survival of the fanihi.

III. RECOVERY ACTIONS

A. Outline of Recovery Actions

1. Develop education, outreach and enforcement programs to control illegal hunting of fanihi
    - 1.1. Develop education programs
        - 1.1.1. Elementary and secondary schools education
        - 1.1.2. Provide public access to fanihi, with interpretation
        - 1.1.3. Education for conservation officers and other public servants
    - 1.2. Develop outreach and incentive programs
        - 1.2.1. Involve hunters and local residents in research and recovery
        - 1.2.2. Work with local government officials, managers of protected areas, and private landowners to establish protected roost site sanctuaries for the bats where they can be monitored by local participants.
        - 1.2.3. Foster the creation of grass-roots conservation clubs and non-profit organizations (similar to Audubon chapters), and provide these with community habitat restoration projects
        - 1.2.4. Establish an "ambassador" program
    - 1.3. Minimize illegal hunting of fanihi through law enforcement actions
        - 1.3.1. Provide law enforcement support to CNMI and Guam Conservation Officers for effective patrolling to prevent hunting at known roost sites and flyways on public and private lands, especially on Rota.
        - 1.3.2. Develop a multi-agency strategy, including roles and responsibilities of all agencies involved, to curb fanihi hunting though proactive law enforcement.
        - 1.3.3. Encourage local and Federal judicial authorities to investigate and prosecute illegal fanihi hunting aggressively.
        - 1.3.4. Improve inspection of all aircraft and vessels at ports of entry in the CNMI and on Guam to prevent illegal traffic of fanihi and other *Pteropus* species.
        - 1.3.5. Improve monitoring of permitted deer and pig hunters on Andersen Air Force Base
2. Protect and restore habitat

- 2.1. Determine Management Areas on islands where necessary, and prioritize sites for recovery actions
- 2.2. Control ungulates
  - 2.2.1. Eradicate or significantly reduce populations of ungulates in Management Areas on Guam, Rota, Tinian, Aguiguan, and Saipan
  - 2.2.2. Eradicate or significantly reduce populations of ungulates and maintain reduction on Alamagan, Pagan, and Agrihan such that native forest can recover and fanihi numbers can be maintained or improved.
  - 2.2.3. Complete the ungulate eradication on Anatahan.
  - 2.2.4. Prevent the introduction of ungulates to Guguan, Asuncion, Maug, and prevent the reintroduction of ungulates to Sarigan
  - 2.2.5. Discourage the release of ungulates on public lands on all islands.
- 2.3. Restore native vegetation
  - 2.3.1. Control invasive non-native plant species that limit native forest persistence and sustainability
  - 2.3.2. Propagate and out-plant native trees and shrubs

3. Control the threat of brown treesnake predation on fanihi
   - 3.1. Determine impact of brown treesnakes to fanihi on Guam and determine best methods for protecting bats from treesnakes
   - 3.2. Prevent the spread of brown treesnakes and support brown treesnake control and interdiction efforts undertaken by all agencies
4. Develop Federal cooperative conservation projects and amend existing plans and agreements with willing landowners to implement recovery on Federal and non-Federal lands
5. Conduct monitoring and research to increase the knowledge base for management and updating the recovery plan
   - 5.1. Improve monitoring methods and monitor populations
   - 5.2. Conduct research on fanihi biology and ecology
     - 5.2.1. Conduct life history studies
     - 5.2.2. Conduct ecological studies
     - 5.2.3. Determine the genetic diversity within the fanihi population and across the range of *Pteropus mariannus*
   - 5.3. Conduct research on human-fanihi interaction

- 5.4. Conduct or support relevant research on habitat restoration and conservation
  - 5.4.1. Support research to quantify impacts of alien ungulates and plants on native forest resources critical to fanihi.
  - 5.4.2. Support research to develop improved control and eradication methods for these alien species.

6. Monitor implementation of the recovery plan and practice adaptive management in which recovery tasks are revised by the U.S. Fish and Wildlife Service in coordination with the Recovery Team and other partners as pertinent new information becomes available.
   - 6.1. Periodically review the recovery plan and revise or update it as appropriate
   - 6.2. Maintain an active recovery team, as needed
     - 6.2.1. Establish short-term objectives for the recovery program
     - 6.2.2. Coordinate recovery actions with other recovery and ecosystem management efforts

B. Recovery Action Narrative

1. Develop outreach, education, and enforcement programs to control illegal hunting of fanihi

Building grassroots public support for fanihi recovery is vital to overcoming administrative and political barriers to recovery. Because such barriers develop as a result of the sociocultural environment, enhancement of public perception of the value of a healthy fanihi population will be a critical component of successful recovery efforts. To this end, this recovery plan includes a strong focus on education, outreach, and the close involvement of local landowners, communities, and decision-makers in the planning and implementation of recovery projects.

1.1. Develop education programs

1.1.1. Elementary and secondary schools education

Improving children's knowledge of natural systems and understanding of the role fanihi plays in the ecosystems of their islands is one of the most important and proactive long-term recovery actions for this species. This can be accomplished through a wide variety of specific projects, such as educating teachers in fanihi biology and ecology and developing natural science curricula that include fanihi; equipping local biologists to visit schools with fanihi awareness lessons; and "citizen science" school projects that involve school children in hands-on research that contribute to fanihi conservation (e.g., collecting fanihi droppings under a roost and have students assist with germinating the seeds and planting these in areas to be restored).

1.1.2. Provide public access to fanihi (zoos, interpretation)

Opportunity to view fanihi and have their behavior and ecology interpreted is a key step in increasing community acquaintance with fanihi as a living animal that is not only a delicious treat but also an essential part of the natural heritage of the Mariana Islands. Potential locations for developing fanihi viewing and interpretive materials and programs for the public include the Rota zoo and other facilities in the CNMI and on Guam.

1.1.3. Education for conservation officers and other public servants

To gain local support for fanihi conservation and enforcement of local and Federal laws, conservation officers and government officials at the island and Territorial and Commonwealth levels must become better educated about the ecology of the animal, the impacts that hunting has on the fanihi population, and the impossibility of sustainable hunting without a recovered population. This education could be accomplished through annual or quarterly classes or workshops organized and taught by multi-agency staff drawn from local and Federal natural resources management agencies. Certificates of completion could be offered to provide incentive for attendance.

1.2. Develop outreach and incentive programs

Public outreach and broad-based community planning can help promote public support and understanding of recovery actions for the fanihi. Fostering activities that engage, and ideally employ, the community in population monitoring and long-term management of fanihi will be crucial to conservation that has long term effects on both the fanihi and the perceptions and attitudes of the community. It will be important to identify the sectors of society in which outreach efforts will be most effective, and this may be accomplished by conducting marketing-style surveys to identify target audiences. In addition, monitoring the success of outreach projects is essential (for example, through surveys before and following to determine whether views and behaviors have changed). For all of the actions described below, even if an "offshore" firm is contracted to design and implement the work, individuals in the community must be sought who can model and champion local participation in conservation and stewardship of fanihi.

1.2.1. Involve hunters and local residents in research and recovery

Local hunters and other residents have specific local knowledge of fanihi and can provide assistance with location of roosts, seasonal feeding locations, and flight paths; fanihi diet research; and discussion of how best to control hunting. This community should be closely involved and employed if possible in information gathering and recovery implementation. The development of a community-based, "citizen science", monitoring program is one way to do this. It will be essential to engage such a program in monitoring activities during periods when fanihi are most vulnerable (e.g., before fiestas and after large storms.

1.2.2. Work with local government officials, managers of protected areas, and private landowners to establish protected roost site sanctuaries for the bats where they can be monitored by local participants

This effort can be used to obtain information about roosting bats such as reproductive status, resighting of banded bats, etc., as well as generate a sense of "ownership" and stewardship of fanihi and their roost sites in the community.

1.2.3. Foster the creation of grass-roots conservation clubs and non-profit organizations, and provide these with community habitat restoration projects

Involving local people in projects such as controlling invasive plants, propagating and outplanting native species, and participating in other restoration work and in study and monitoring of fanihi (e.g., similar to the work done by Audubon Society chapters) creates a lasting investment by local communities and commitment to the ongoing conservation of specific places they have worked hard to restore. Currently outreach efforts of this kind are minimal in the Marianas.

1.2.4. Establish an "ambassador" program

A team of community members, scientists and agency personnel should meet with groups of citizens on Guam and in the CNMI to discuss fanihi recovery. Such meetings could be organized and hosted by clubs/organizations described in 1.2.3., above. These ambassadors should be prepared to discuss the causes of endangerment, findings to date, planned actions for achieving recovery, the ramifications of the Draft Revised Recovery Plan for the fanihi, Federal and local laws concerning endangered species, and the special needs and concerns of citizens.

1.3. Minimize illegal hunting of fanihi through law enforcement actions

1.3.1. Provide law enforcement support to CNMI and Guam Conservation Officers

In the close-knit communities of the Pacific, enforcing laws can be a social and cultural challenge. In the Marianas, conservation officers would benefit from collaboration with and support from Federal law enforcement officers, such as USFWS special agents, to improve effective patrolling of known hunting areas, apprehend illegal hunters, and conduct other actions to prevent hunting at roost sites and flyways on public and private lands, especially on Rota. An exchange program could be developed to strengthen ties between Federal, Territorial, and Commonwealth officers, facilitate additional training for Territorial and Commonwealth officers, and build capacity for conservation law enforcement in the Marianas.

1.3.2. Develop a multi-agency strategy, including roles and responsibilities of all agencies involved, to curb fanihi hunting though proactive law enforcement

The fanihi is protected under Guam, CNMI, and U.S. Federal law. Greater cooperation and coordination are needed among entities responsible for enforcing these laws to ensure this is done consistently, proactively, and in a manner that promotes rather than discourages voluntary compliance by the public. Coordination and outreach through the Stakeholder Subgroup of the Recovery Team and other avenues will be pursued to inform the public of this recovery plan and to include public input into recovery implementation.

1.3.3. Encourage local and Federal judicial authorities to investigate and prosecute illegal fanihi hunting aggressively

Ongoing and new education and outreach efforts to curb hunting of fanihi will take time to reach the target communities in the CNMI and on Guam. In the interim, local and Federal judicial authorities should be made aware of the serious threat that illegal hunting poses to the fanihi, and, together with law enforcement agencies, should be provided the resources to effectively investigate and successfully prosecute cases of unlawful hunting. In tandem with education, effective law enforcement is a key component of conservation.

1.3.4. Improve inspection of all aircraft and vessels at ports of entry in the CNMI and on Guam to prevent illegal traffic of fanihi and other *Pteropus* species

Better and more frequent inspections are needed of boats and aircraft arriving on Saipan from the Northern Islands and Rota, arriving on Guam from Rota, and arriving anywhere in the Marianas from other sources of or transit points for illegal shipments of fanihi or other fruit bats. Sniffer dogs and increased inspection and enforcement staff are needed to carry out these inspections.

1.3.5. Improve monitoring of permitted deer and pig hunters on Andersen Air Force Base

Anecdotal reports exist of ungulate hunters on AAFB opportunistically taking fanihi that are transiting or foraging in the tracts of forest on the base. Ingress and egress of hunters should be monitored; sniffer dogs and conservation officers could be placed at stations to check bags of ungulate hunters on AAFB for illegally taken fanihi.

2. Protect and restore habitat

2.1. Determine Management Areas on islands where necessary, and prioritize sites for recovery actions

Opportunities for fruit bat recovery will vary among islands in the archipelago; conservation actions may not be pressing or necessary on every island, and recovery does not depend upon an even geographic distribution of recovery efforts. Rather, we anticipate that recovery efforts will be focused on islands, and in specific Management Areas where necessary (i.e., on the islands with large human populations), that are determined by the U.S. Fish and Wildlife Service in consultation with our partners in the Mariana Islands and the recovery team to offer the best opportunities to meet the criteria for recovery of the fanihi. These Management Areas within islands might be areas that harbor active or historically active roost sites or fanihi habitat determined to be essential to recovery. We recognize that some jurisdictions and landowners on the islands may not wish to participate in the recovery effort. Within these conditions, priorities for habitat protection and restoration should be (a) areas/islands currently harboring fanihi, (b) areas/islands critical to recovery whether or not they harbor fanihi now, and (c) other islands/areas.

2.2. Control ungulates

2.2.1. Eradicate or significantly reduce and confine ungulates in Management Areas on Guam, Rota, Tinian, Aguiguan, and Saipan

In the context of large and growing human populations in the Southern Islands of the Marianas, native forests must be retained and restored to a condition of natural regeneration in areas of sufficient size and connectivity to ensure that habitat containing key resources for fanihi and other native wildlife is safeguarded for the long term. In addition to data gathering and other hands-on outreach projects described above, forest restoration and maintenance are activities that should involve and employ the local community.

2.2.2. Eradicate or significantly reduce and confine ungulates and maintain reductions in the CNMI Northern Islands

The isolated Northern Islands with their occasional, small human populations are the stronghold of the fanihi population, and the habitat for native wildlife on these islands must be protected and, where necessary, restored. Ungulates must be controlled on these islands so that the native forest is retained and restored to a condition of natural regeneration to ensure that habitat containing key resources for fanihi and other native wildlife is safeguarded for the long term. Alamagan, Pagan, and Agrihan should be cleared of ungulates or, if human settlers are present, livestock should be maintained in small numbers specifically to meet the needs of people living on the island, and should be removed when settlements are abandoned.

2.2.3. Complete the ungulate eradication on Anatahan

When Anatahan's volcano erupted in 2003, eradication of goats and pigs from the island was nearing completion. This island is one of the three largest in the Northern Islands and in the past has harbored a large number of bats. Completing this eradication now, while the island is still relatively devegetated, should be the first priority for fanihi recovery in the Northern Islands.

2.2.4. Prevent the introduction of ungulates to Guguan, Asuncion, Maug, and prevent the reintroduction of ungulates to Sarigan

These four islands are designated "Conservation Islands" by the CNMI government and should remain free of ungulates and other new non-native species.

2.2.5. Discourage the release of ungulates on public lands on all islands

Additional populations of ungulates on any islands will only hamper habitat restoration and increase the degradation of existing forest habitat. Public outreach and education may help to dissuade new introductions of ungulates by individuals or groups.

2.3. Protect and restore native vegetation

Once released from hunting pressure, fanihi can potentially use habitat ranging over all of an inhabited island such as Rota. Thus, a general policy should be pursued of "no net loss" of native forest and restoration of forests on islands and in areas critical to fanihi recovery.

2.3.1. Control invasive plant species that limit native forest persistence and sustainability

The control of species such as *Leucaena leucocephala* (tangan-tangan) and *Casuarina equisetifolia* that form monotypic stands and provide few resources for native wildlife should be undertaken strategically in areas prioritized to protect and expand existing native forests.

2.3.2. Propagate and out-plant native trees and shrubs

Outplanting will increase the rate of native forest recovery (e.g., in areas where ungulates or invasive plants are removed). When undertaken around fragments of native forest, outplanting increases the resilience of these patches to incursion by alien plant species and reduces the threat of these species becoming established over large areas. However, outplanting trees and plants on their native islands is a broadly beneficial conservation action around villages and around and within agroforests, as well. In particular, plants known to be important resources for fanihi, such as *Artocarpus mariannus* (seeded breadfruit), *Pandanus tectorius* (kafu), *Cycas micronesica*, *Terminalia catappa* (umbrella tree), and native *Ficus* spp., should be propagated and planted where appropriate.

3. Control the threat of brown treesnake predation on fanihi

3.1. Determine impact of brown treesnakes to fanihi on Guam and determine and implement best methods for protecting bats from treesnakes

Scientists and land managers currently conducting treesnake research and control on Guam should provide a special focus on protecting fanihi on Guam insofar as predation by treesnakes plays a role in exacerbating the decline of bats on the island. Examining the stomach contents or conducting stable isotope analysis of tissues of snakes trapped in the vicinity of the fanihi roost in northern Guam may yield further evidence of snakes preying on bats. Control of brown treesnakes should be undertaken in the vicinity of the roost on Guam only if there is conclusive evidence that (a) such control will demonstrably benefit the bats, (b) such work can be undertaken without running the risk of the roost being abandoned, and (c) the results of such work will provide information that could be applicable to protecting fruit bats from predation by treesnakes on Saipan, or on other islands.

3.2. Prevent the spread of brown treesnakes and support brown treesnake control and interdiction efforts undertaken by all agencies

Barriers, traps, and other interdiction procedures must be maintained or established at all ports of entry to the CNMI to minimize the risk of treesnake introduction from Guam and Saipan.

4. Develop Federal cooperative conservation projects and amend existing plans and agreements with willing landowners to implement recovery on Federal and non-federal lands

An important potential source of protection for fanihi and their habitat is management codified in conservation agreements with local governments and willing landowners on Federal and non-Federal lands. Management will include maintaining or improving forest habitat, reducing or eliminating direct harvest of fanihi through education and law enforcement actions, eliminating non-native species or reducing their populations through rigorous planned management, and other actions.

Existing land use and natural resource management plans for islands or areas within islands, including Integrated Natural Resource Management Plans for military bases and other documents, should be reviewed by the U.S. Fish and Wildlife Service and the appropriate entities to ensure that recovery needs for fanihi are addressed and triggers for implementation of recovery actions and monitoring of results are included. All actions proposed on U.S. military lands on Guam and in the CNMI must receive thorough review by biologists familiar with fanihi and its habitat.

Through surveys, monitoring, and regulatory review and consultation under the National Environmental Policy Act and Endangered Species Act, we can assess the potential effects on the fanihi of activities planned by the U.S. Navy, U.S. Air Force, and other defense agencies, and determine the best methods of avoiding, minimizing, and mitigating adverse impacts to this and other listed species**.** For example, clearing of forested land in proximity to a fanihi roost is an action that should be proposed to the U.S. Fish and Wildlife Service and reviewed as appropriate before being implemented.

5. Conduct monitoring and research to increase the knowledge base for management and updating the recovery plan

Monitoring is necessary to track the status of fanihi throughout the archipelago, to assess threats to bats and their habitat, and to evaluate the implementation and effectiveness of conservation actions and this recovery plan. Development of scientifically acceptable monitoring protocols is needed to accomplish these tasks. Significant gaps remain in our scientific knowledge of the fanihi. It is incumbent on us to see that those gaps are filled as they pertain to achieving a recovered fanihi population; we must ensure that the objectives we set and the tools used to meet them are the right ones to reach our definition of "recovered" for this species. Therefore some research will be integral to recovery for this animal. The results of recovery-oriented research will over time aid in refining the fanihi recovery program. Specifically, research is needed to address questions about life history and ecology that are crucial to accurately projecting population persistence, monitoring response to management, and adapting and refining our approach to management to reflect new information. Critically, the results of this research will aid in determination of thresholds for bat numbers and other conservation criteria on each island that could indicate when the fanihi population has recovered sufficiently for some legal hunting to resume. The fanihi population is clearly too precarious at present to support a hunting season. However, if illegal hunting and other threats are reduced so that the species' status can improve substantially and our knowledge of population dynamics and threats allows us to identify a limited, sustainable hunting regime consistent with recovery of the species, such a hunt might be allowed under the Endangered Species Act either by delisting the species or through a special rule under section 4(d) of the Act.

5.1. Improve monitoring methods and monitor populations

A great deal of effort has been invested in fanihi surveys and monitoring in the past, but the goals for monitoring were not always identified, methods used were not standardized, and there has been little coordinated monitoring among the islands. Thus, we currently have imprecise estimates of population size and trends and limited ability to make comparisons among islands.

Enhancement of existing monitoring methods is needed to develop scientifically rigorous population monitoring programs for the Southern and Northern Islands. Such enhancement must include: improved measures of the variability in survey data (e.g., observer error; detection of bats at roosts, where not all bats may be visible) and in numbers through time (e.g., are there seasonal increases associated with recruitment of juveniles and/or seasonal declines associated with event-specific hunting?). Study and experimentation are needed to determine the most efficient monitoring schedule and best suite of survey methods for monitoring fanihi bats on individual islands and throughout the archipelago. Monitoring programs in the Southern Islands may be intensive and involve frequent surveys; in the Northern Islands, infrequent access and logistical constraints may require development of rapid but rigorous monitoring methods. To the extent that logistical considerations permit, monitoring methods must be standardized or statistically comparable between islands and between surveys. Finally, training programs are needed to ensure consistency and full understanding of monitoring methods and objectives. This applies equally to expert and "community" observers participating in bat monitoring. Monitoring data will be compiled into reports to assess recovery plan implementation and whether the recovery criteria are being addressed. Where appropriate, summaries of monitoring data should be made available to the public as part of the outreach program.

A project that includes intensive monitoring at intervals through the year on an island without (e.g., Sarigan) and with (e.g., Rota) hunting or other human disturbance would provide much needed information about sources and magnitude of variability in survey data. This information is needed to refine survey methods so that data collected may be used to detect trends on a timescale sufficient to address threats and measure progress toward recovery.

5.2. Conduct research on fanihi biology and ecology

We have conducted preliminary experiments with population viability analysis (PVA) to examine the sensitivity of the fanihi population to various threats and to potential recovery actions. These models will help us further refine recovery criteria, set population thresholds, and project the species' response to management. Available data describing fanihi vital rates (and other traits of the species) to refine input parameters for population projection are minimal and need improvement. Two areas where more research is needed to develop better parameter estimates are migration patterns among islands, and the response of bat populations (mortality, migration, reproduction rates) after natural disturbance events of different severity.

5.2.1. Conduct life history studies

Length of gestation, age of sexual maturity, reproductive success, annual survivorship of various age classes, and recruitment into the breeding population are unknown for the fanihi; these life history parameters influence the population-level effects of natural and anthropogenic disturbance events. These parameters also influence the response of the population to recovery actions. Data describing these traits as well as reproductive strategies, generation time, and reproductive rates and success are needed for modeling intrinsic capacity for population growth and long term persistence with any degree of confidence. This research could be undertaken using direct observation of bats at roosts, mark-resight studies, and potentially more invasive study of closely related proxy species, as has been done for the critically endangered Guam Micronesian kingfisher or sihek (*Halcyon cinnamomina cinnamomina*), which currently survives only in captivity.

5.2.2. Conduct ecological studies

Conservation-directed ecological study of fanihi includes determination of dietary and other habitat selection requirements, foraging range, seasonal variation in foraging behavior, the quality and areal extent of habitat for bats on each island (and investigation of how this relates to carrying capacity for individual islands), and direct and indirect impacts of typhoons on bat mortality. This information will inform and refine habitat conservation and restoration efforts. This research could be undertaken using a combination of many approaches, such as radio-tracking; direct foraging observation; interviews with hunters and fruit farmers; collection and analysis of bat ejecta and feces beneath foraging and roosting trees; and defining, mapping, and quantification of bat habitat and typhoon impacts using ground surveys, remotely-sensed imagery, and Geographic Positioning and Information Systems (GPS and GIS).

5.2.3. Determine the genetic diversity within the fanihi population and across the range of *Pteropus mariannus*

Genetic information is needed to infer the historical connectivity between islands, determine whether negative inbreeding effects may be a concern, and determine the relatedness of fanihi with subspecies of *Pteropus mariannus* in other archipelagos. Some genetic work is needed to ascertain whether additional endemic subspecies occur in the Mariana archipelago and should be listed as separate entities. Molecular analysis could be undertaken using genetic material extracted from tissue samples or, potentially, from fecal matter and ejecta.

With further research, DNA extracted from fecal material and ejecta also holds potential for conducting non-invasive mark-recapture studies, and assessing maternity and paternity rates and connectivity among roost sites. By collecting these samples beneath roosts, the potential injury and other trauma that may be associated with trapping bats is avoided.

5.3. Conduct research on human-fanihi interaction

Hunters and other residents are a critical source of information about local knowledge of fanihi ecology and biology as well as perceptions of the limits of bat populations (as an exploitable resource). Understanding the interests and perspectives of hunters is also crucial to identifying the best ways to address hunting regulation. Finally, hunters and local residents are likely to provide insights into other strategies for promoting fanihi conservation, such as how fanihi may play a role in local pride-of-place or as a flagship conservation species. Hunters and other local stakeholders are important links to the local community and their input should help to identify strategies for engaging local communities and encouraging participatory conservation management.

Interviews of hunters and other local residents will be conducted to help determine mortality rates and spatial and temporal patterns in hunting pressure. This information will help to refine our understanding of population-level impacts of hunting and to target implementation of education, outreach, and enforcement efforts where and when they will be most effective.

5.4. Conduct or support relevant research on habitat restoration and conservation

5.4.1. Support research to quantify impacts of alien ungulates and plants on native forest resources critical to fanihi

Foraging by ungulates is known generally to reduce or preclude recruitment of plant species, reduce native species diversity, and ultimately lead to devegetation and erosion. However, ungulate eradication can result in "release" of alien plant species that can impede the recovery of native vegetation. The dynamics of alien species invasions of native plant communities in the Marianas are poorly known. Study of the impacts of alien invaders on plant species that provide resources for fanihi (e.g., *Artocarpus mariannensis*, *Erythrina variegata* (Indian coral tree), and *Ficus* spp.) will help us develop strategies for control of alien species such as goats and the vine *Operculina ventricosa* (St. Thomas lidpod) and prioritize sites for treatment.

5.4.2. Support research to develop improved control and eradication methods for alien species.
Efficient and cost-effective methods are needed for control and eradication of alien species, especially invasive plants. A particular need exists for methods that can be used effectively in the remote northern islands, where access is difficult and intermittent at best.

6. Monitor implementation of the recovery plan and practice adaptive management in which recovery tasks are revised by the U.S. Fish and Wildlife Service in coordination with the Recovery Team and other partners as pertinent new information becomes available.
The list of actions above is necessarily broad and not all-inclusive. As additional information becomes available, new risks and opportunities may come to light, and additional tasks will be identified and priorities shifted as appropriate.

6.1. Periodically review the recovery plan and revise or update it as appropriate
The restoration of an endangered species is an uncertain science that requires continual critique and reevaluation of approach. A regularly updated recovery plan will assure all participants that recovery is guided by the best available science and will be in keeping with our current guidance on recovery planning.

6.2. Maintain an active recovery team, as needed

The recovery team can serve as a source of recommendations and guidance regarding fanihi recovery. The team is a forum in which issues surrounding recovery may be discussed and effective, coordinated recovery strategies developed. Although significant experience and expertise are represented on the team now, we will also need access to specialists outside the team for input on specific points and questions.

Several principles should guide the team's work. The team should maintain an awareness of all activities that have a major impact on fanihi recovery. The team should encourage peer review and publication of all scientific findings used in fanihi management. Management recommendations unsuitable for publication should nonetheless be subjected to independent peer review. The team should make substantial and continuing efforts to identify stakeholders in fanihi recovery and draw them into the recovery program to make meaningful contributions.

6.2.1. Establish short-term objectives for the recovery program

With assistance from team members, we will develop 2- to 5-year implementation plans, providing the rationale for each objective. These implementation plans should: (a) describe specific objectives; (b) explain how achieving the objective will contribute to recovery; (c) provide evidence that achieving the objective is feasible; (d) describe the funding and other resources needed; and (e) provide evidence that the resources to be committed are best used for the proposed activity rather than for some other aspect of fanihi recovery. Each objective should include measures that can be used to monitor progress.

6.2.2. Coordinate recovery actions with other recovery and ecosystem management efforts

Many of the members of the recovery team are ideally situated to help us coordinate recovery implementation for the fanihi with other conservation initiatives on Guam and in the CNMI. Particular attention should be given to coordination on efforts to prepare habitat conservation plans with the government of the Commonwealth of the Northern Mariana Islands and with groups focused on the recovery of other listed species in the Marianas (e.g., Mariana crow recovery team, Guam Micronesian Kingfisher recovery committee).

IV. RECOVERY IMPLEMENTATION SCHEDULE FOR 2010-2014

The Implementation Schedule that follows lists and prioritizes the actions and estimated costs for the recovery of the fanihi. It is a guide for meeting the recovery goals outlined in this plan. Recovery actions in the Implementation Schedule have been prioritized in a ranking system with each action being assigned a "priority number" from 1 (highest priority) to 3 (lowest priority; see definitions below). The numbers in the Action Number column correspond to the descriptions of recovery actions in the Narrative Outline of Recovery Actions.

Parties with authority, responsibility, or expressed interest to implement a specific recovery action are also identified in the Implementation Schedule. When more than one party has been identified the proposed lead party is indicated by an asterisk (*). In cases where a lead party has not been identified, each party listed is individually responsible for implementing the recovery action. The listing of a party in the Implementation Schedule does not require, nor imply, that the identified party will implement the action(s) or secure funding for implementing the action(s). However, parties willing to participate may benefit by being able to show in their own budgets that their funding request is for a recovery action identified in an approved recovery plan and is therefore considered a necessary action for the overall coordinated effort to recover the fanihi. Also, section 7(a)(1) of the Endangered Species Act (16 USC 1531 *et seq*.) directs all Federal agencies to utilize their authorities in furtherance of the purposes of the Endangered Species Act by carrying out programs for the conservation of threatened and endangered species.

Definition of action priorities:

- **Priority 1:** An action that must be taken to prevent extinction or prevent the species from declining irreversibly in the foreseeable future.
- **Priority 2:** An action that must be taken to prevent a significant decline in species population or habitat quality, or some other significant negative impact short of extinction.
- **Priority 3:** All other actions necessary to meet the recovery objectives.

Definition of action durations:

- **Continuous:** An action that will be implemented on a routine basis once begun for the period of time estimated to recovery (in this case, 10 years).
- **Ongoing:** An action that is currently being implemented and will continue until the time estimated to recovery. For the purposes of cost estimation, we used our best estimate of the time that may be required to complete the action.
- **Unknown:** Either action duration or associated costs are not known at this time. For the purposes of cost estimation, we used our best estimate of the time that may be required to complete the action.

Threat categories:

We consider the role of five potential factors affecting the species in order to list, delist, or reclassify a taxon. These factors are:

(A) the present or threatened destruction, modification or curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;
(C) disease or predation,
(D) the inadequacy of existing regulatory mechanisms;
(E) other natural or manmade factors affecting its continued existence.

Recovery actions are designed to address the threats in the Listing Factor column in order to meet the recovery criteria (see Recovery Criteria section). The majority of the recovery actions in this plan address habitat loss (factor A), overutilization (factor B), predation (factor C), and other natural factors affecting its continued existence (factor E). Existing regulatory mechanisms (factor D) appear adequate, as the fanihi is listed as threatened by the Federal government and consequently receives protection under the provisions of the Endangered Species Act.

Responsible Parties for Action Implementation:

We have statutory responsibility for implementing this recovery plan. Only Federal agencies are mandated to take part in the effort under section 7(a)(1) of the Endangered Species Act (16 USC 1531 *et seq*.). However, species recovery will require the involvement of the full range of Federal, territorial, private, and local interests. The expertise and contributions of additional agencies and interested parties will be needed to implement recovery actions and to accomplish education and outreach objectives. For each recovery action described in the Implementation Schedule, the column titled “Responsible Parties” lists the primary Federal and local agencies we have identified as having the authority and responsibility for implementing recovery actions and other groups, partners, and partnerships who are actively involved in recovery.

Key to Acronyms used in the Implementation Schedule:

- **CNMI:** Government of the CNMI
- **DAWR:** Guam Division of Aquatic and Wildlife Resources
- **DFW:** CNMI Division of Fish and Wildlife
- **DLNR:** CNMI Department of Land and Natural Resources
- **DoD:** U.S. Department of Defense
- **GoG:** Government of Guam
- **NGO:** Non-governmental organizations, including community groups
- **U/P:** University or privately contracted researchers
- **USFWS-ES:** United States Fish and Wildlife Service, Ecological Services
- **USFWS-LE:** United States Fish and Wildlife Service, Law Enforcement
- **USFWS-R:** United States Fish and Wildlife Service, Refuges Division
- **USGS-BRD:** United States Geological Survey, Biological Research Discipline
- **WS:** United States Department of Agriculture, Wildlife Services

Cost estimates:

The costs of implementing the identified recovery actions are estimated over two timeframes: the first five years covered by this recovery plan (5-Year Costs column) and the total costs of recovery over a 10-year period (10-Year Costs column).

Priority Number	Action Number	Listing Factor	Action Description	Action Duration	Responsible Parties	Cost Estimate (in $10,000 units)						
						10-Year Costs	FY 10	FY 11	FY 12	FY 13	FY 14	5-Year Costs
1	1.2.2	B	Work with local government, land managers and owners to establish roost site sanctuaries	Ongoing	DLNR, USFWS-ES	3.8	.3	.5	.5	.3	.3	1.9
1	1.3.1	B	Provide law enforcement support to CNMI and Guam Conservation Officers for fanihi protection	Continuous	USFWS-LE*, ES; DAWR, DLNR	150	15	15	15	15	15	75
1	1.3.2	B	Develop a multi-agency strategy to curb illegal hunting through law enforcement	Continuous	DAWR, DLNR, USFWS-LE	6	.5	1	1	.5	.5	3.5
1	1.3.3	B	Encourage local and Federal judicial authorities to investigate and prosecute fanihi hunting aggressively	Continuous	USFWS-ES, LE; DAWR, DFW*	5	.5	.5	.5	.5	.5	2.5
2	1.2.1	B	Involve hunters and local residents in research and recovery	Continuous	DFW*, DAWR, USFWS-ES	19	1	2	2	2	2	9

Priority Number	Action Number	Listing Factor	Action Description	Action Duration	Responsible Parties	Cost Estimate (in $10,000 units)						
						10-Year Costs	FY 10	FY 11	FY 12	FY 13	FY 14	5-Year Costs
2	1.3.4	B	Improve inspection at ports of entry to prevent illegal traffic in fanihi	Continuous	USFWS-LE*, DoD, GoG, CNMI	50	3	7	5	5	5	25
2	1.3.5	B	Improve monitoring of permitted ungulate hunters on AAFB	Continuous	DoD	20	2	2	2	2	2	10
2	2.2.1	A	Eradicate or reduce and confine ungulates in Management Areas on Southern Islands	Ongoing	DOA*, DLNR*, DoD*, USFWS-R	30	3	3	3	3	3	15
2	2.2.2	A	Eradicate or reduce and confine ungulates in the CNMI Northern Islands	10 years	DLNR*, DoD	50	5	5	5	5	5	25
2	2.2.3	A	Complete ungulate eradication on Anatahan	3 years	DoD*, USFWS-ES	12	4	4	4	-	-	12

Priority Number	Action Number	Listing Factor	Action Description	Action Duration	Responsible Parties	Cost Estimate (in $10,000 units)						
						10-Year Costs	FY 10	FY 11	FY 12	FY 13	FY 14	5-Year Costs
2	2.2.4	A	Prevent the introduction of ungulates to CNMI Conservation Islands (Sarigan, Guguan, Asuncion, Maug)	Ongoing	CNMI, DLNR	2	.2	.2	.2	.2	.2	1
2	2.2.5	A	Discourage the release of ungulates on public lands on all islands	Continuous	CNMI, DLNR	2	.2	.2	.2	.2	.2	1
2	3.1	C	Determine best methods for protecting bats from BTS on Guam	2 years	USGS-BRD, USDA-WS, DAWR	6	3	3	-	-	-	6
2	3.2	C	Prevent the spread of BTS from Guam and Saipan	Ongoing	USDA-WS	1,600	160	160	160	160	160	800
2	4	E	Develop cooperative conservation projects; amend existing plans and agreements	Continuous	USFWS-ES*, DoD	230	90	30	30	20	10	180
2	5.1	A, B,C, E	Improve monitoring methods and monitor fanihi population	Continuous	DFW*, DAWR*, USFWS-ES, USFWS-R	34	5.5	5.5	5.5	2.5	2.5	21.5

Priority Number	Action Number	Listing Factor	Action Description	Action Duration	Responsible Parties	Cost Estimate (in $10,000 units)						
						10-Year Costs	FY 10	FY 11	FY 12	FY 13	FY 14	5-Year Costs
2	5.2.1	A, B, C, E	Conduct life history studies	10 years	DFW*, DAWR, USGS-BRD, USFWS-ES, U/P	52	4	8	8	8	4	32
2	5.2.2.	A, B, C, E	Conduct ecological studies	5 years	DFW*, DAWR, USGS-BRD, USFWS-ES, U/P	32	4	8	8	8	4	32
3	1.1.1.	A, B	Education in elementary and secondary schools about fanihi biology, cultural value, and threats	Continuous	DFW*, DAWR	16	4	4	1	1	1	11
3	1.1.2	B	Provide public access to fanihi in zoos or other facilities	Ongoing	DFW, DAWR	10	1	1	1	1	1	5
3	1.1.3	B	Education for conservation officers and other public servants	Continuous	DFW, DAWR	6.5	2	.5	.5	.5	.5	4

Priority Number	Action Number	Listing Factor	Action Description	Action Duration	Responsible Parties	Cost Estimate (in $10,000 units)						
						10-Year Costs	FY 10	FY 11	FY 12	FY 13	FY 14	5-Year Costs
3	1.2.3	A, B, E	Foster the creation of grass-roots conservation clubs, provide these with community habitat restoration projects	Continuous	DLNR, DOA	2.7	0.5	0.2	0.3	0.2	0.3	1.5
3	1.2.4	A, B, E	Establish an “ambassador” program	Continuous	DLNR, DOA	6	1.5	0.5	0.5	0.5	0.5	3.5
3	2.3.1	A	Strategic control of invasive plant species (e.g., *Leucaena*, *Casuarina*)	Continuous	DLNR, DOA	26	5	5	2	2	2	16
3	2.3.2	A	Propagate and outplant native trees and shrubs	Continuous	DOA, DLNR, NGO	7	2	1	0.5	0.5	0.5	4.5
3	5.2.3	A, B, C, E	Determine genetic diversity within fanihi population and across range of *P. mariannus*	3 years	U/P	6	3	2.5	.5	-	-	6
3	5.3	A, B	Conduct research on human-fanihi interaction	3 years	DFW*, DAWR, U/P	2.5	1	1	0.5	-	-	2.5

Priority Number	Action Number	Listing Factor	Action Description	Action Duration	Responsible Parties	Cost Estimate (in $10,000 units)						
						10-Year Costs	FY 10	FY 11	FY 12	FY 13	FY 14	5-Year Costs
3	5.4.1	A	Support research on ungulate impacts on native forest	3 years	DLNR, DOA, DoD, USFWS-ES, R	6	2	2	2	-	-	6
3	5.4.2	A	Support research on ungulate control and eradication methods	2	DOA, DoD, DLNR, USFWS-ES	4	2	2	-	-	-	4
3	6.1	A, B, C, E	Periodically review and revise or update the recovery plan	1 year	USFWS-ES	3	-	-	-	-	-	-
3	6.2.1	A, B, C, E	Establish short-term (2-5 year) objectives for recovery implementation	Continuous	USFWS-ES	5	1	-	1	-	1	3
3	6.2.2	A, B, C, E	Coordinate recovery actions with other recovery and management efforts	Continuous	USFWS-ES	3	.3	.3	.3	.3	.3	1.5
					TOTALS:	**2,304.3**						**1,257.8**

V. REFERENCES

A. Literature Cited

Andersen, K. 1912. Catalogue of the Chiroptera in the Collection of the British Museum. Second Edition. Volume I: Megachiroptera. British Museum of Natural History, London. 854pp.

Baker, R. H. 1946. Some effects of the war on the wildlife of Micronesia. Transactions of the North American Wildlife Conference 11:205-213.

Bowers, N. M. 1950. Problems of resettlement on Saipan, Tinian, and Rota, Mariana Islands. Coordinated Investigation of Micronesian Anthropology No. 31, Office of Naval Research and National Academy of Sciences. 258 pp.

Brooke, A. P., C. Solek, and A. Tualaulelei. 2000. Roosting behavior of solitary and colonial flying foxes in American Samoa (Chiroptera: Pteropodidae). Biotropica 32:338-350.

Brown Tree Snake Control Plan. 1996. Report prepared by the Brown Tree Snake Control Committee to the U.S. Aquatic Nuisance Species Task Force. 55 pp.

Colvin, B. A., M. W. Fall, L. A. Fitzgerald, and L. L. Loope. 2005. Review of brown treesnake problems and control programs: report of observations and recommendations. Unpublished report to the U.S. Department of Interior Office of Insular Affairs for the Brown Treesnake Control Committee. 67 pp.

Corbet, G. B., and J. E. Hill. 1980. A world list of mammalian species. British Museum of Natural History, London. 226pp.

Corbet, G. B., and J. E. Hill. 1986. A world list of mammalian species. Second Edition. British Museum of Natural History, London. 254 pp.

Corbet, G. B., and J. E. Hill. 1991. A world list of mammalian species. Third Edition. British Museum of Natural History, London. 243 pp.

Coultas, W. F. 1931. Whitney south sea expedition journals, Vol. W. Journal and letters, Vol. II, of William F. Coultas, November 1930 to December 1931. American Museum of Natural History, New York. Unpublished. 290 pp.

Cox, P., T. Elmqvist, E. Pierson, and W. Rainey. 1992. Flying Foxes as pollinators and seed dispersers in Pacific island ecosystems. Pages 18-23 *in* Wilson, D. E., and G. L. Graham, eds. Pacific island flying foxes:

proceedings of an international conservation conference. U.S. Fish and Wildlife Service Biological Report 90(23).

Craig, P., P. Trail, and T. E. Morrell. 1994. The decline of fruit bats in American Samoa due to hurricanes and overhunting. Biological Conservation 69:261-266.

Crampton, H. E. 1921. A journey to the Mariana Islands - Guam and Saipan. Natural History 21:127-145.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000a. Wildlife and Vegetation Surveys, Guguan 2000. Technical Report #3. CNMI-DFW, unpubl. 42 pp.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000b. Wildlife and Vegetation Surveys, Alamagan 2000. Technical Report #4. CNMI-DFW, unpubl. 39 pp.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000c. Wildlife and Vegetation Surveys, Sarigan 2000. Technical Report # 5. CNMI-DFW, unpubl. 51 pp.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000d. Wildlife and Vegetation Surveys, Anatahan 2000. Technical Report #6. CNMI-DFW, unpubl. 48 pp.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000e. Wildlife and Vegetation Surveys, Pagan 2000. Technical Report #7. CNMI-DFW, unpubl. 66 pp.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000f. Wildlife and Vegetation Surveys, Agrihan 2000. Technical Report #8. CNMI-DFW, unpubl. 43 pp.

Eby, P. 1991. Seasonal movements of grey-headed flying-foxes, *Pteropus poliocephalus* (Chiroptera: Pteropodidae), from two maternity camps in northern New South Wales. Wildlife Research 18:547-559.

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

Engbring, J., F. L. Ramsey, and V. J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish and Wildlife Service, Region 1, Portland, Oregon. Unpublished report. 143 pp.

Esselstyn, J. A., A. Amar, and D. Janeke. 2006. Impact of post-typhoon hunting on Mariana fruit bats (*Pteropus mariannus*). Pacific Science 60: 531-539.

Fancy, S. G., and T. J. Snetsinger. 1996. Potential reasons for the decline of the bridled white-eye population on Rota, Mariana Islands. USGS, Biological Resources Discipline, Pacific Islands Ecosystems Research Center, Hawaii. Unpublished report. 66 pp.

Fancy, S. G., R. J. Craig, and C. W. Kessler. 1999. Forest Bird and Fruit Bat Populations on Sarigan, Mariana Islands. Micronesica 31(2):247-254.

Falanruw, M. C. 1988. On the status, reproductive biology and management of fruit bats of Yap. Micronesica 21:39-51.

Falanruw, M. C., T. G. Cole, and A. H. Ambacher. 1989. Vegetation survey of Rota, Tinian, and Saipan, Commonwealth of the Northern Mariana Islands. Resource Bulletin PSW-27, Berkeley, California: Pacific Southwest Forest and Range Experiment Station, U.S. Department of Agriculture. 11pp +13 maps.

Flannery, T. 1995. Mammals of the south-west Pacific and Moluccan Islands. Cornell University Press, New York. 426 pp + index.

Fosberg, F. R. 1960. The vegetation of Micronesia. Bulletin of the American Museum of Natural History 119:1-75.

Fritts, T. 1988. The brown tree snake, *Boiga irregularis*, a threat to Pacific islands. U.S. Fish and Wildlife Service Biological Report 88(31). U.S. Department of the Interior, Washington, DC.

Fritz, G. 1901. Die Insel Tinian (Marianen). Deutsches Kolonialblatt 12:150-154. In German.

Fritz, G. 1904. Die Chamorro. Eine Geschicte and Ethnographie der Marianen. Ethnologisches Nottizblatt 3(3):25-110. In German. Translation by E. Craddock, 1986, Division of Historic Preservation, Saipan. 59 pp.

Glass, P., and E. M. Taisacan. 1988. Marianas fruit bat surveys and research. Pages 1-22 *in* Five-year Progress Report, Fiscal Year 1982-87. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands.

International Union for Conservation of Nature and Natural Resource (IUCN) 2008 Red List http://www.iucnredlist.org/ . Accessed on May 13, 2009.

Janeke, D. 2006. Nocturnal movements and habitat use by the Mariana flying fox, *Pteropus mariannus mariannus*, on Guam. M.S. thesis, University of Guam. 103 pp.

Johnson, N. C. 2001. A survey of Mariana fruit bats in the Mariana Islands, including recent minimum population estimates, July 2001. Unpublished report to the Commonwealth of the Northern Mariana Islands Division of Fish and Wildlife. 41 pp.

Kessler, C. 1997. Feral animal monitoring and management. Page 8-14 *in* Annual Progress Report, Fiscal Year 1996. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands.

Kessler, C. 2000a. Anatahan Island, Commonwealth of the Northern Mariana Islands: feral animals and forest destruction, July 2000. Report prepared by Zoology Unlimited, LLC, for the U.S. Fish and Wildlife Service. 11 pp + appendices.

Kessler, C. 2000b. Third follow-up survey for feral ungulates: an eradication project on Sarigan Island, CNMI, July 2000. Report prepared by Zoology Unlimited, LLC, for the U.S. Fish and Wildlife Service. 6 pp + appendices.

Koopman, K. 1982. Family Pteropodidae review. In: Honacki, J. H., K. E. Kinman, and J. W. Koeppl (eds.). Mammal Species of the World: A Taxonomic and Geographic Reference. Allen Press, Lawrence Kansas,. Washington D.C. ix +694pp.

Koopman, K. 1993. Order Chiroptera In: D. E. Wilson and D. M. Reeder (eds.). Mammal Species of the World: A Taxonomic and Geographic Reference. Smithsonian Institution Press, Washington D.C. 634pp.

Krueger, S. and D. O'Daniel. 1999. Observations of Mariana Fruit Bats on Tinian. Micronesica 31(2):367-371.

Kuroda, N. 1938. A list of Japanese mammals. L. M. Zoological Society of Japan, Tokyo, Japan.

Lemke, T. O. 1984. Marianas fruit bat surveys and inventories. Pages 3-16 *in* Annual Report, Fiscal Year 1984. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands.

Lemke, T. O. 1986. Petition to list the Marianas Fruit bat (*Pteropus mariannus mariannus*) as an endangered species in the Commonwealth of the Northern Mariana Islands. Unpublished.

Lemke, T. O. 1992a. History of fruit bat use, research, and, protection in the Northern Mariana Islands. Pages 135-142 *in* Wilson, D. E., and G. L. Graham (eds). Pacific island flying foxes: proceedings of an international conservation conference. U.S. Fish and Wildlife Service Biological Report 90(23).

Lemke, T. O. 1992b. Status of the Marianas fruit bat (*Pteropus mariannus*) in the Northern Mariana Islands north of Saipan. Pages 68-73 *in* Wilson, D. E., and G. L. Graham (eds.), Pacific island flying foxes: Proceedings of an International Conservation Conference. U.S. Fish and Wildlife Service Biological Report 90(23).

Marshall, A. P., D. J. Worthington, G. J. Wiles, D. J. Grout, C. C. Kessler, V. A. Camacho, E. M. Taisacan, and T. Rubenstein. 1995. A survey of the Mariana fruit bat (*Pteropus mariannus*) on Anatahan, Commonwealth of the Northern Mariana Islands, July 1995. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands. Unpublished report. 28pp.

McConkey, K. R., D. R. Drake, J. Franklin, and F. Tonga. 2004. Effects of cyclone Waka on flying foxes (*Pteropus tonganus*) in the Vava'u Islands of Tonga. Journal of Tropical Ecology 20:555-561.

McIlwee, A. P. and L. Martin. 2002. On the intrinsic capacity of increase of Australian flying-foxes (*Pteropus spp.,* Megachiroptera). Australian Zoologist 32:76-100.

Mickleburgh, S. P., A. M. Hutson, and P. A. Racey, eds. 1992. Old World Fruit Bats: an Action Plan for Their Conservation. IUCN, Gland, Switzerland.

Mildenstein, T. L., S. C. Stier, C. E. Nuevo-Diego, and L. S. Mills. 2005. Habitat selection of endangered and endemic large flying-foxes in Subic Bay, Philippines. Biological Conservation 126:93-102.

Mills, L. S. and F. W. Allendorf. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology 10:1509-1518.

Nelson, S. N. 2003. Nutritional landscape ecology and habitat use by Tongan flying foxes in American Samoa. Chapter 6 *in* Nutritional ecology of Old-world fruit bats: a test of the calcium-constraint hypothesis. Ph.D. thesis. University of Florida, Gainesville.

Nelson, S. L., M. A. Miller, E. J. Heske, and G. C. Fahey, Jr. 2000. Nutritional consequensces of a change in diet from native to agricultural fruits for the Samoan fruit bat. Ecography 23:393-401.

Palmer, C., and J. C. Z. Woinarski. 1999. Seasonal roosts and foraging movements of the black flying fox (*Pteropus alecto*) in the Northern Territory: resource tracking in a landscape mosaic. Wildlife Research 26:823-838.

Perez, G.S.A. 1972. Observations of Guam bats. Micronesica 8:141-149.

Pierson, E. D., T. Elmqvist, W. E. Rainey, and P. A. Cox. 1996. Effects of tropical cyclonic storms on flying fox populations on the south Pacific islands of Samoa. Conservation Biology 10: 438-451.

Pierson, E., and W. Rainey. 1992. The biology of flying foxes of the genus *Pteropus*: A Review. Pages 1-17 *in* Wilson, D. E., and G. L. Graham (eds). Pacific island flying foxes: proceedings of an international conservation conference. U.S. Fish and Wildlife Service Biological Report 90(23).

Rainey, W. E. 1998. Conservation of bats on remote Indo-Pacific islands. *In* Kunz, T. H., and P.A. Racet, eds. Bat biology and conservation. Smithsonian Institution Press. Washington D.C. 365pp.

Rice, C. G., and E. M. Taisacan. 1993. Marianas fruit bat surveys. Pp. 35-47 *in*: Five Year Progress Report, Fiscal Year 1988-92. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands. pp. 35-47.

Rodda, G., T. Fritts, and P. Conry. 1992. Origin and population growth of the brown tree snake *Boiga irregularis* on Guam. Pacific Science 46(1):46-57.

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

Rodda, G.H., and J. A. Savidge. 2007. Biology and impacts of Pacific Island invasive species. 2. *Boiga irregularis*, the brown tree snake (Reptilia: Colubridae). Pacific Science 61: 307-324.

Schnee, P. 1911. Eineges uber die hohere Tierwelt der Marianen. Zeitschrift fur Naturwissenschaften 82:458-470. In German.

Sheeline, L. 1991. Cultural significance of Pacific fruit bats (*Pteropus* spp.) to the Chamorro people of Guam: conservation implications. Report to World Wildlife Fund/TRAFFIC USA. 97pp.

Simmons, N. 2005. Family Pteropodidae. Pages 313-349 *in* D.E. Wilson and D.M. Reeder, (eds). Mammal species of the world, third edition. Johns Hopkins University Press.

Stinson, D. W., P. O. Glass, and E. M. Taisacan. 1992. Declines and trade in fruit bats on Saipan, Tinian, Aguijan, and Rota. Pp. 61-67 *in*: Wilson, D. E., and G. L. Graham, eds., “Pacific island flying foxes: proceedings of an international conservation conference.” U.S. Fish and Wildlife Service Biological Report 90(23).

Stone, B.C. 1970. The flora of Guam. Micronesica 6.

U.S. Fish and Wildlife Service. 1983. Endangered and threatened wildlife and plants; preparation of environmental assessments for listing actions under the Endangered Species Act. Federal Register 48:49244-49245. October 25, 1983.

U.S. Fish and Wildlife Service. 1984. Endangered and threatened wildlife and plants; determination of endangered status for seven birds and two bats of Guam and the Northern Mariana Islands. Final rule. Federal Register 49:33881-3385. August 27, 1984.

U.S. Fish and Wildlife Service. 1990. Guam Mariana Fruit Bat and Little Mariana Fruit Bat Recovery Plan. Portland, Oregon. 57pp + Appendix.

U.S. Fish and Wildlife Service. 1998a. Recovery plan for the Nightingale Reed-warbler, *Acrocephalus luscinia*. Portland, Oregon. 62pp.

U.S. Fish and Wildlife Service. 1998b. Recovery plan for the Micronesian megapode (*Megapodius laperouse laperouse*). U.S. Fish and Wildlife Service, Portland, Oregon. 65+pp.

U.S. Fish and Wildlife Service. 2004. Endangered and threatened wildlife and plants; Designation of critical habitat for the Mariana fruit bat and Guam Micronesian kingfisher on Guam and the Mariana crow on Guam and in the Commonwealth of the Northern Mariana Islands; Final rule. Federal Register 69:62943-62990. October 28, 2004.

U.S. Fish and Wildlife Service. 2005. Endangered and threatened wildlife and plants; Mariana fruit bat (*Pteropus mariannus mariannus*): Reclassification from endangered to threatened in the Territory of Guam and listing as threatened in the Commonwealth of the Northern Mariana Islands. Federal Register 70:1190-1210. January 6, 2005.

Utzurrum, R. C. B., G. J. Wiles, A. P. Brooke, and D. J. Worthington. 2004. Count methods and population trends in Pacific island flying foxes. Pages 49-68 *in* O'Shea, T. J. and M. A. Bogan, eds. Monitoring bat populations in the United States and territories: problems and prospects. U.S. Geological Survey Information and Technology Report 2003-003.

Vardon, M. J., and C. R. Tidemann. 2000. The black flying-fox (*Pteropus alecto*) in North Australia: juvenile mortality and longevity. Australian Journal of Zoology 48: 91-97.

Wang, J. 2004. Application of the one-migrant-per-generation rule to conservation and management. Conservation Biology 18:332-343.

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.

Wheeler, M. E. 1980. The status of the Marianas fruit bat on Saipan, Tinian, and Rota. `Elepaio 40:109-112.

Wiles, G. J. 1982. The current status, distribution, and natural history of Marianas fruit bats. Pages 204-211 *in* Annual Report, Fiscal Year 1981. Pittman-Robertson Federal Aid in Wildlife Restoration Program, Division of Aquatic and Wildlife Resources, Guam.

Wiles, G. J. 1983. The current status, distribution and natural history of Mariana fruit bats. Annual Report, Fiscal Year 1982. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Aquatic and Wildlife Resources, Guam.

Wiles, G. J. 1987a. Current research and future management of Mariana fruit bats (Chiroptera: Pteropodidae) on Guam. Australian Mammalogy 10:93-95.

Wiles, G. J. 1987b. The status of fruit bats on Guam. Pacific Science 41:148-157.

Wiles, G. J. 1992. Recent trends in the fruit bat trade on Guam. Pages 52-60 *in* Wilson, D. E., and G. L. Graham, eds. Pacific island flying foxes: proceedings of an international conservation conference. U.S. Fish and Wildlife Service Biological Report 90(23).

Wiles, G. J. 1996. Current status, distribution, and natural history of Marianas fruit bats. Annual Report, Fiscal Year 1996. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Aquatic and Wildlife Resources, Guam.

Wiles, G. J. 1998. Current status, distribution, and natural history of Marianas fruit bats. Annual Report, Fiscal Year 1998. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Aquatic and Wildlife Resources, Guam.

Wiles, G. J. 1999. Current status, distribution, and natural history of Marianas fruit bats. Annual Report, Fiscal Year 1999. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Aquatic and Wildlife Resources, Guam.

Wiles, G. J. 2005. Decline of a population of wild seeded breadfruit (*Artocarpus mariannensis*) on Guam, Mariana Islands. Pacific Science 59:509-522.

Wiles, G. J., C. F. Aguon, G. W. Davis, and D. J. Grout. 1995. The status and distribution of endangered animals and plants in northern Guam. Micronesica 28: 31-49.

Wiles, G. J., J. Bart, R. E. Beck, Jr., and 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.

Wiles, G. J. and A. P. Brooke. In press. Conservation Threats to Bats in the Tropical Pacific Islands and Insular Southeast Asia. *In* Fleming, T. H. and P. Racey, eds. Island bats: evolution, ecology, and conservation. University of Chicago Press.

Wiles, G. J., J. Engbring, and D. Otobed. 1997. Abundance, biology, and human exploitation of bats in the Palau Islands. Journal of Zoology (London) 241:203-227.

Wiles, G. J., J. A. Esselstyn, D. Janeke, D. J. Worthington, and N. C. Johnson. 2006. Population status and trends of Mariana fruit bats (*Pteropus mariannus*) in the southern Mariana Islands, 1985-2004. Unpublished report to the U.S. Fish and Wildlife Service, Honolulu, Hawaii. 13 pp.

Wiles, G. J. and M. S. Fujita. 1992. Food plants and economic importance of flying foxes on Pacific islands. Pages 24-35 *in* D. E. Wilson and G. L. Graham, eds. Pacific island flying foxes: Proceedings of an international conservation conference. U.S. Fish and Wildlife Service Biological Report 90 (23).

Wiles, G. J., and P. Glass. 1990. Interisland movements of fruit bats (*Pteropus mariannus*) in the Mariana Islands. Atoll Research Bulletin 343:1-6.

Wiles, G. J., and N. C. Johnson. 2004. Population size and natural history of Mariana fruit bats on Sarigan, Mariana Islands. Pacific Science 58: 585-596.

Wiles, G. J., T. O. Lemke, and H. H. Payne. 1989. Population estimates of fruit bats (*Pteropus mariannus*) in the Mariana Islands. Conservation Biology 3:66-76.

Wiles, G. J., and N. H. Payne. 1986. The trade in fruit bats *Pteropus* spp. on Guam and other Pacific islands. Biological Conservation 38:143-161.

Woodside, D. H. 1958. Fish and wildlife investigations. Guam, Department of Agriculture. Unpublished.

Worthington, D. J., A. P. Marshall, G. J. Wiles, and C. Kessler. 2001. Abundance and management of Mariana fruit bats and feral ungulates on Anatahan, Mariana Islands. Pacific Conservation Biology 7:134-142.

Worthington, D. J., and E. M. Taisacan. 1995. Fruit bat research. Pages 5-12 *in* Annual Report, Fiscal Year 1994. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands.

Worthington, D. J., and E. M. Taisacan. 1996. Fruit bat research. Page 6-17 *in* Annual Report, Fiscal Year 1995. Pittman-Robertson Federal Aid in Wildlife Restoration Program. Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands.

Zoology Unlimited LLC. 1998. Report on the eradication of feral ungulates from Sarigan Island, Commonwealth of the Northern Mariana Islands, USA. Unpublished report to the U.S. Fish and Wildlife Service, Pacific Islands Ecoregion, Honolulu, HI. 28 pp.

B. Personal Communications

Julia Boland, CNMI Department of Fish and Wildlife, Rota, 2009.

Anne Brooke, U.S. Navy, Joint Region Marianas, Guam. 2007.

Nathan Hawley, U.S. Fish and Wildlife Service, Saipan, CNMI. 2007.

Dustin Janeke, e2M, San Diego, CA. 2006, 2007.

Nathan Johnson, CNMI Department of Fish and Wildlife, Saipan , 2000.

Curt Kessler, U.S. Fish and Wildlife Service, Honolulu, HI. 2004, 2007.

Dana Lujan, U.S. Department of Agriculture, Wildlife Services, Guam. 2007.

Ann Marshall, U.S. Fish and Wildlife Service, Honolulu, HI. 2007.

Gary McCracken, University of Tennessee, Knoxville, TN. 2007.

Jeff Quitugua, Guam Division of Aquatic and Wildlife Resources, Guam. 2006.

Arlene Pangelinan, U.S. Fish and Wildlife Service (formerly), Honolulu, HI. 2004.

Tim Sutterfield, U.S. Navy, Pacific Command, Honolulu, HI. 1998.

Stan Taisacan, CNMI Department of Fish and Wildlife, Saipan, CNMI. 1997.

Scott Vogt, U.S. Navy, Pacific Command, Honolulu, HI. 2007.

Gary Wiles, Washington Department of Fish and Wildlife, Olympia, WA. 2005, 2007.

Laura Williams, CNMI Department of Fish and Wildlife, Saipan, CNMI. 2004, 2007.

C. *In Litt.* References

Anne Brooke. U.S. Fish and Wildlife Service, Guam National Wildlife Refuge, Dededo, Guam, 2003.

T. Eckardt. U.S. Fish and Wildlife Service, Division of Law Enforcement, Barrigada, Guam, 1998.

K. Garlick. U.S. Fish and Wildlife Service, Division of Law Enforcement, Barrigada, Guam 1997.

Dustin Janeke. University of Guam, Mangilao, 2003.

Curt Kessler. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii, 2003.

Tom Lemke. Montana Department of Fish, Wildlife and Parks, Thompson Falls, Montana, 1986.

A. Palacios. Commonwealth of the Northern Mariana Islands Division of Fish and Wildlife, Saipan, 1990.

Tim Sutterfield. U.S. Navy, Pacific Command, Honolulu, Hawaii, 1997.

U.S. Department of the Interior
U.S. Fish & Wildlife Service
Region 1 - Pacific
Ecological Services
911 NE 11th Avenue
Portland, Oregon 97232-4181

https://www.fws.gov

November 2009