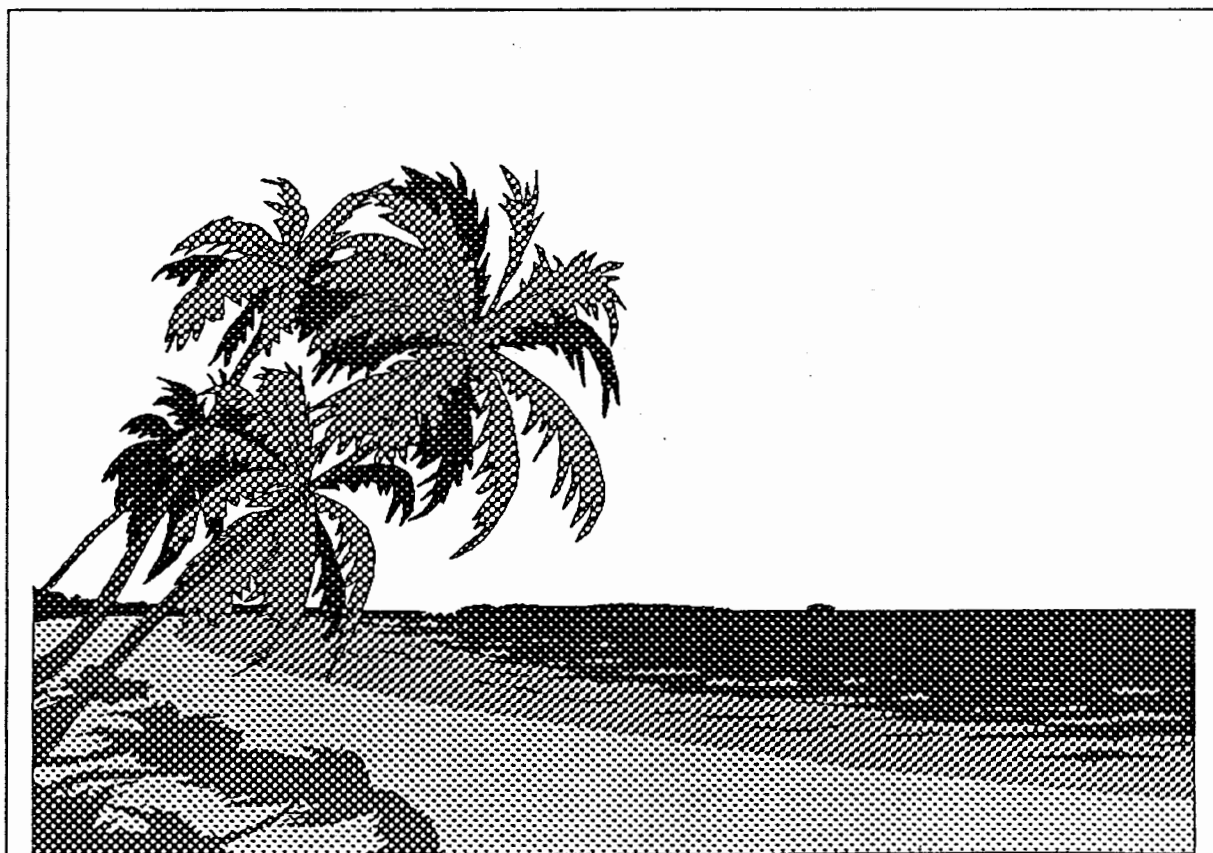


STATUS OF THE FRUIT BAT, *Pteropus samoensis*, IN SAMOA

BY

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1993



## EXECUTIVE SUMMARY

Pteropus samoensis, a uniquely adapted diurnal fruit bat, is limited in distribution to Samoa and Fiji. Recent concerns about declining populations of this species in Samoa led to a series of surveys beginning in 1986 and culminating in January-February, 1993. In 1986, 1989, and 1993, 50 sites were surveyed by a US Fish and Wildlife Service team to yield comparable count data. In the intervening years, the American Samoa Department of Marine and Wildlife Resources made complementary surveys that provide additional data.

Results of all previous surveys and reports are included in this report. These results suggest a continuing decline in the populations of P. samoensis on almost every island in the Samoan Archipelago. This decline is not without considerable variation between counts and between years. In 1986, 221 bats were counted, 154 in 1989, and 75 in 1993. This suggests a decline of about 50% since 1989, and about 67% since 1986. However, the data collected in intervening years showed a pattern of variation that seems to be related to the occurrence of severe hurricane events.

In 1987, Hurricane Tusi severely affected the bat population, as reflected in counts for the following year. The 1989 counts seemed to show some recovery from the low points following that hurricane, but additional major hurricanes in 1990 and 1991 resulted in the lowest totals yet recorded in 1993. Thus, there seems to be a pattern of serious declines following major storms, followed by recovery between storms. The two large storms in back-to-back years in 1990 and 1991 may have resulted in the current low population numbers.

There is considerable variability from Island to Island. In general, Western Samoa was hit much harder by the last Hurricane, and the amount of forest destruction was much greater than in American Samoa. Consequently, the bat populations seem to be relatively much lower in Western than in American Samoa. Within Western Samoa, the Island of Upolu has relatively few bats left. The recent storm damage, coupled with almost complete degradation of natural rainforest into agricultural land at the lower elevations, has left the outlook bleak for the bats on that island. Savai'i was also devastated, but the total amount of inaccessible land area suggests that there may remain sufficient stock to repopulate appropriate habitat barring further insults to the population.

In American Samoa, although the count statistics suggest a serious decline, there also remains a significant amount of inaccessible forest, and we found bats remaining in low numbers throughout the islands of Tutuila, Ta'u and Olesaga. We feel that this population will also recover, barring additional impacts. Obviously, there is no way to mitigate future hurricane events, but this species has evolved in such conditions for thousands of years. The impact of human-caused habitat destruction in recent years has magnified the effects of these natural events, leading to the current low population levels. This suggests that every effort should be made to mitigate additional habitat destruction to allow for recovery of the population. The current ban on hunting should be continued until some evidence of population recovery is obtained.

We recommend continuation of the monthly monitoring of the population currently being conducted by the American Samoa Department of Marine and Wildlife Resources. Such monitoring should be instituted on Western Samoa if at all possible. In addition, we encourage additional research directed at those life-history parameters that would allow for estimation of minimum viable population levels, and that would improve efforts to obtain density estimates for all of the islands. Finally, we applaud and encourage the ongoing efforts to educate the public as to the importance of the fruit bats to a healthy ecosystem, and to the necessity for their conservation for the future.

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Introduction

Two species of fruit bats, or flying foxes, are known from Samoa (Andersen 1912). Traditionally, these two species (Pteropus tonganus and P. samoensis) have been hunted for food on these islands. In the past, bats have been harvested commercially and shipped to Guam from Samoa and a number of other islands (Wiles and Payne 1986). This added take from market hunting, coupled with a continuing loss of native forest habitat, caused concern that the less common of the two species, P. samoensis, might be endangered (Cox 1983).

In November 1984, a petition was submitted to the U.S. Fish and Wildlife Service (USFWS) to add P. samoensis to the U.S. endangered species list. In June and July 1985, USFWS personnel conducted limited field studies in American Samoa and gathered data suggesting that P. samoensis was more common than indicated in the petition. As a result, a finding of "warranted but precluded" was designated for the Samoan population of this bat.

From 19 June to 7 August 1986, additional field data were gathered by a team of four USFWS biologists. Assistance was provided by the American Samoa Office of Marine and Wildlife Resources and the Western Samoa Division of Forestry. The survey team spent 25 days on Tutuila, 8 on Ta'u, 8 on 'Upolu, 5 on Ofu and Olosega combined, 2 on Savai'i, and 1 on Aunu'u (Figs. 1-4). Based partly on the results of this survey, the population was classified as a candidate endangered species by the USFWS in 1988.

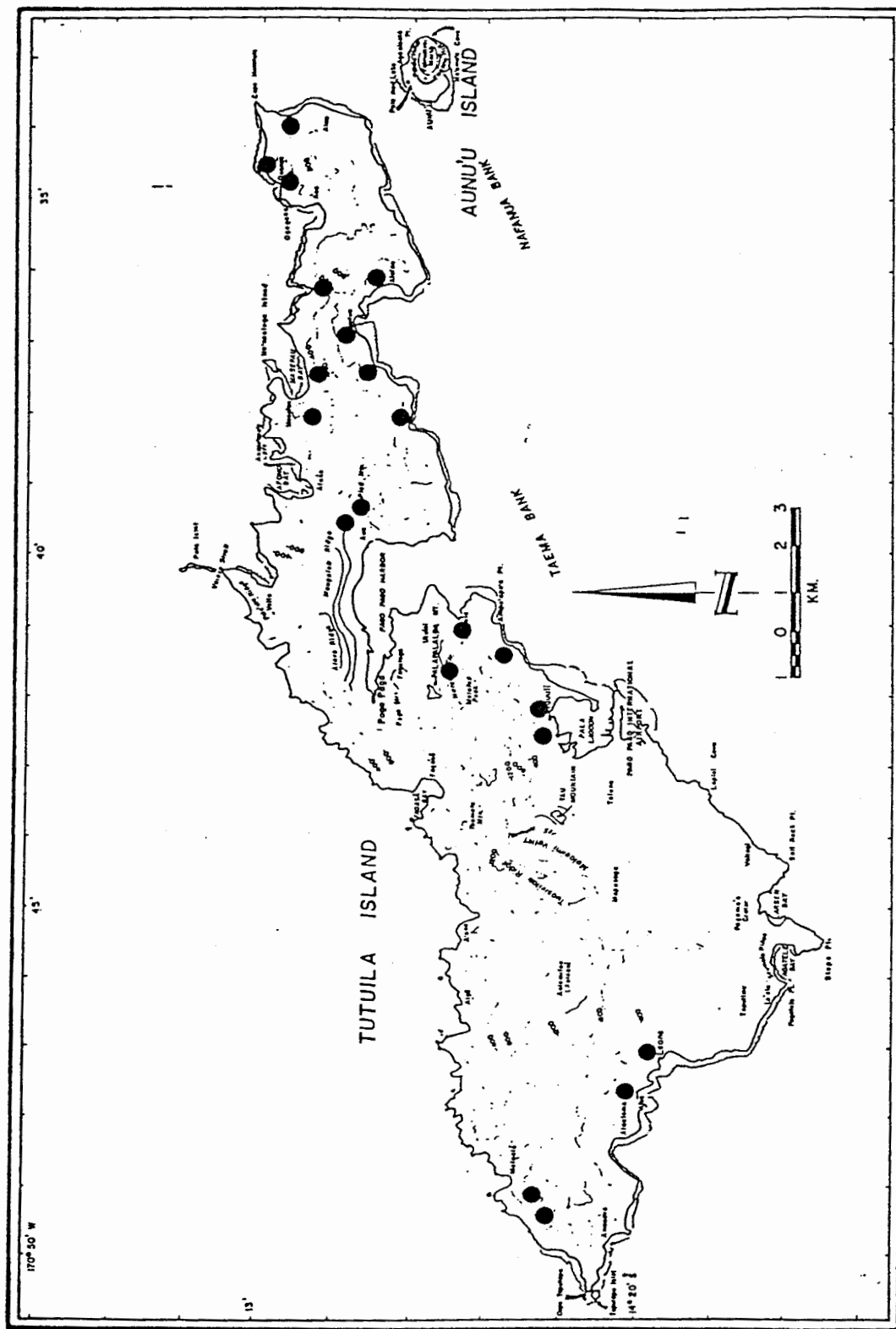


Fig. 1. Tutuila Island, American Samoa, showing the 21 stations surveyed for fruit bats.

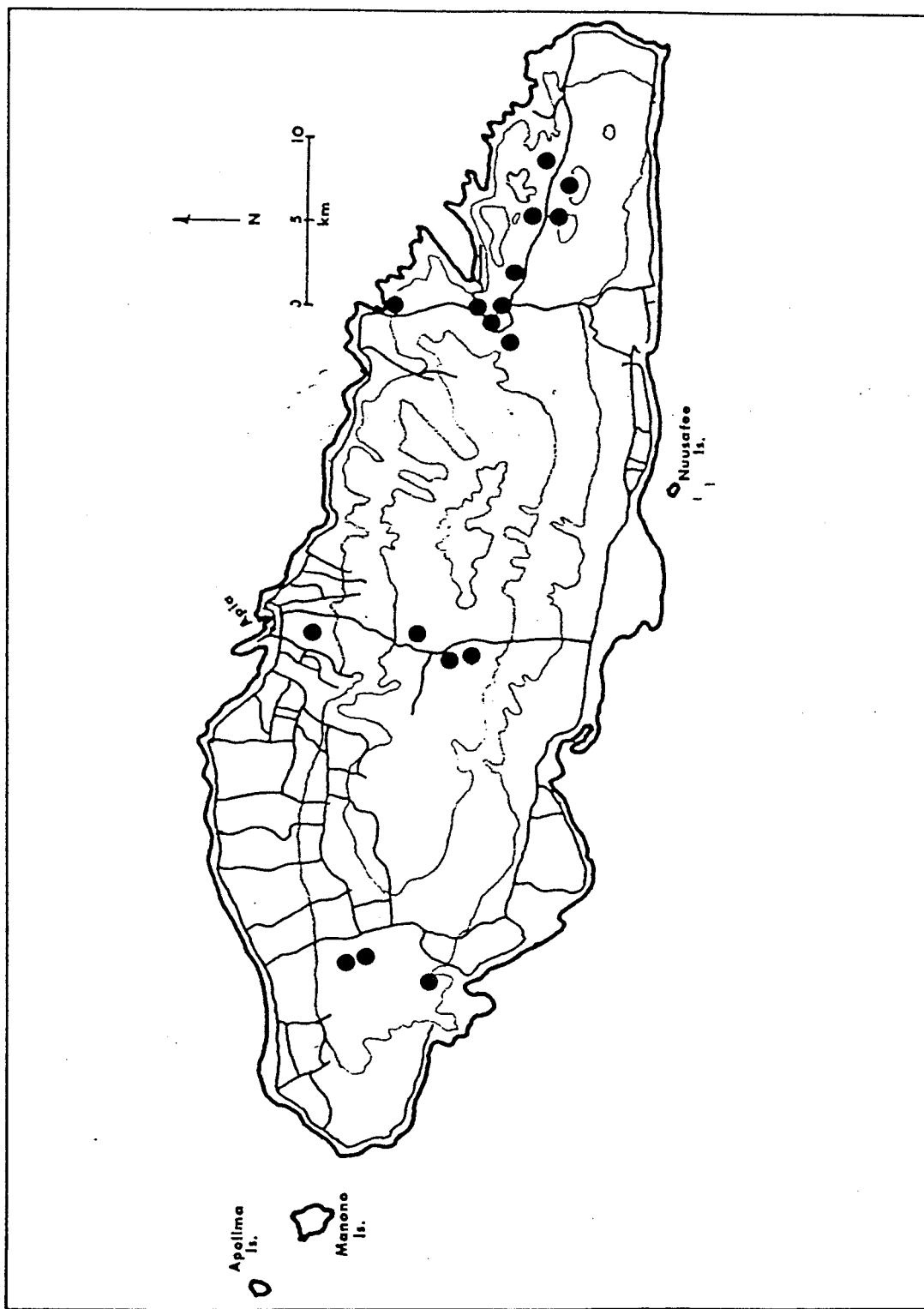


Fig. 3. Upolu Island, Western Samoa, showing the 17 stations surveyed for fruit bats.



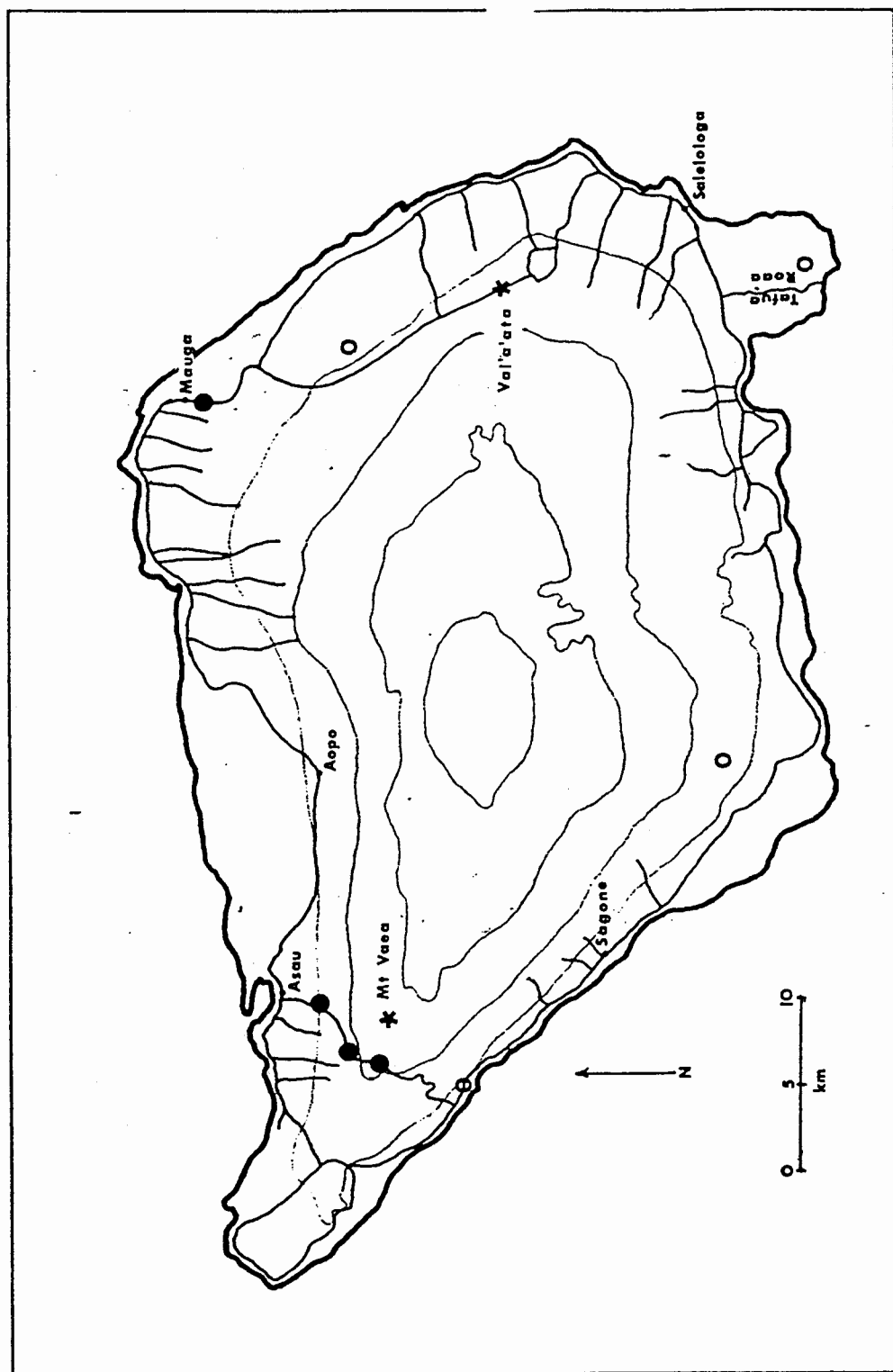


Fig. 4. Savai'i Island, Western Samoa, showing the six stations surveyed for fruit bats. All-day counts (\*) were conducted at Mt. Vaea and Vai'a'ata in 1989.

From 25 July to 15 August 1989, we surveyed P. samoensis in Samoa, and gathered incidental information on P. tonganus. Using identical methods to obtain comparable data, we resurveyed 50 sites in Western and American Samoa that had been examined in 1986. From 22 January to 3 February 1993, we re-surveyed those 50 sites in both Western and American Samoa, yielding comparable samples from 1986, 1989, and 1993. This last survey was occasioned by the occurrence of two devastating typhoons in the interval between 1989 and 1993. We summarize all survey results herein.

The taxonomy and ecology of the two species of Pteropus in Samoa have been unclear. Pteropus tonganus was described from Tonga (Quoy and Gaimard 1830). It was first reported from Samoa (as P. flavicollis) by Alston (1874). Pteropus samoensis was described from Samoa by Peale (1848).

Although two species have been known to occur on Samoa for more than a hundred years (Gray 1870; Alston 1874), many naturalists have assumed that there was only a single species present. Several additional names have been proposed for Pteropus from Samoa, but all are now considered synonyms of either P. tonganus or P. samoensis.

Ecological observations have frequently been attributed to the wrong species. Whitmee (1875) reported a group of more than a thousand individuals on Savai'i as P. whitmeei (= P. samoensis), but they were almost surely P. tonganus. Similarly, Nicoll (1908) was probably observing both species on Tutuila but reported all as P. ruficollis (= P. samoensis).

This taxonomic confusion continued. Amerson et al. (1982) reported a population estimate of 140,700 for P. samoensis on American Samoa. This figure seems inflated, even allowing for the inclusion of all observations of P. tonganus. The seriousness of this type of misinformation is understood only when subsequent estimates of correctly identified P. samoensis reveal a fraction of that number. The magnitude of the apparent decline in numbers is far out of proportion to reality, and probably masks a smaller-scale, but still serious, decline in the population of P. samoensis in recent years.

Cox (1983) presented the first detailed ecological observations correctly attributable to P. samoensis. Although he identified several differences between the two species, his speculations on body size, habitat use, population size, and primary activity period were perhaps prematurely conceived.

Characteristics that allowed correct field identification of the two species had not been detailed. Our first goal was to determine and describe such field traits. Then, with a clear impression of how to identify the two species, we concentrated on determining the status of P. samoensis, the less common of the two species. Nevertheless, we also recorded observations of P. tonganus on Samoa.

#### Description of Study Sites

The Samoan Islands, located in the South Pacific (14°S. 170°W.), are a biogeographical unit politically divided into American Samoa, an unincorporated territory of the United States, and Western Samoa, an independent country. About 50,000 people live in American Samoa, where the economy is based largely on government jobs, tuna canneries, and tourism (Anonymous 1987). American Samoa comprises four major islands: Tutuila (Fig. 1), Ofu, Olosega, and Ta'u. Ofu, Olosega, and Ta'u are collectively known as the Manu'a Islands (Fig. 2). Land area is about 195 km<sup>2</sup>, 75% of which is on the main island of Tutuila (Anonymous 1987). The islands are steep and rugged. The highest point is on Ta'u (966 m). The capital, Pago Pago, is located on Tutuila.

Western Samoa is composed of two main islands: 'Upolu (1,115 km<sup>2</sup>) and Savai'i (1,814 km<sup>2</sup>). Their combined area, 2,929 km<sup>2</sup>, is nearly 15 times the land area of American Samoa. 'Upolu (Fig. 3) and Savai'i (Fig. 4) have extensive coastal plains, which have been converted to agriculture in most areas. The maximum elevation is 1,860 m on Savai'i. Savai'i is still volcanically active, and a number of recent lava flows are found there. The capital city, Apia, is on 'Upolu. About 90% of the 163,000 people in Western

Samoa are involved in agriculture, major exports being copra, cocoa, bananas, and timber (Adams 1985b).

#### Climate

Samoa is in the tropics and is warm and humid. There is considerable variation in climate depending on elevation and exposure to trade winds. The average annual temperature ranges from 21° to 27°C, the warmer temperatures occurring at the lower elevations. Rainfall ranges from 200 cm at the lower elevations to 750 cm at the usually cloud-shrouded upper elevations. Trade winds prevailing from the east and southeast blow most of the year; the monthly average wind speed is 7-18 kph (Amerson et al. 1982).

The most significant climatic events are occasional tropical storms and typhoons that bring heavy rains and potentially destructive high winds to the islands. During the period covered by our surveys, three hurricanes caused extensive damage to the natural vegetation of the islands: Hurricane Tusi in 1987, Hurricane Ofa in 1990, and Hurricane Val in 1991. The damage caused by these Hurricanes has reduced the amount of natural habitat for Pteropus samoensis on all of the Samoan Islands. In February, 1993, Tropical Storm Lin afforded us a first-hand look at the destructive potential of these storms.

#### Vegetation

The natural vegetation of American Samoa consists of tropical rain forest, which is characterized by tall, broadleaf evergreen trees, abundant woody vines, and ubiquitous epiphytes (Amerson et al. 1982). Within this broad classification are a number of plant communities that reflect differences in slope, elevation, microclimate, soil type, and exposure to salt water. Amerson et al. (1982) described 13 different plant communities in American Samoa. The most extensive of these include cultivated land (40%), rain and ridge forest (26%), and secondary forest (20%). Rain forest is defined as the natural vegetation of Samoa. Ridge forest is defined as the forest growing on ridges; it supports many of the same plant species as rain forest but is less well developed because of the higher degree of slope.

Secondary forest includes all those stages of forest that have become established after agricultural land has been abandoned. If undisturbed long enough, it will revert to a forest that is virtually indistinguishable from the native rain forest. Cultivated land consists primarily of plantation land, which is mostly diverse agricultural forest. These agricultural forests consist largely of coconuts, bananas, breadfruit, taro, and other vegetation commonly associated with subsistence agriculture. They are often partly overgrown by secondary forest.

Most of the vegetation types described for American Samoa are also found in Western Samoa. There are no detailed vegetation maps currently available for Western Samoa. Most of the steep peaks near the interior support native forests. In 1982, 38% of 'Upolu and 59% of Savai'i consisted of rain forest (M. Iakopo, Western Samoa Forest Service, 1985 report). It is our subjective impression that comparable figures are much lower today, particularly for 'Upolu. Much of the remainder of the land consists of agricultural forest. On 'Upolu, most of the coastal lowlands up to an elevation of 300-500 m have been converted to cultivated land. Savai'i is less heavily populated, and more of that island remains naturally forested.

The three recent typhoons have destroyed most of the natural rainforest vegetation on Samoa. We found that virtually all exposed forest was defoliated and many large trees were snapped or uprooted. Some of the remaining snags are re-sprouting and the forest will re-generate, given sufficient time and assuming that enough trees remain to provide a flower and seed source. Pteropus samoensis serves as a major pollinator and dispersal agent for many species of natural vegetation in Samoa (Cox, 1983).

#### Survey Methodology

To establish an index on which to base population trends of Pteropus samoensis, we conducted daytime counts from stations with a commanding view of representative native or agricultural forest. At each station a 30-min count was made by one or more observers. Data recorded included the time of each

observation and whether or not bats were using or flying over the survey area. Counts were conducted throughout the daylight hours.

We also counted individuals of P. tonganus observed during these surveys, but we normally saw them only early in the morning or late in the afternoon. We made some attempt to locate roosts of P. tonganus and to count the number of individuals in those roosts. Incidental information was gathered on field identification, feeding behavior, habitat use, and other ecological variables. Data on hunting was gathered primarily by questioning local residents.

## Results and Discussion

### Taxonomy and Distribution

#### Pteropus samoensis Peale, 1848

Pteropus keraudrenius: Peale, 1848:18. Misidentification (not Pteropus Keraudren Quoy and Gaimard, 1824).

Pteropus samoensis Peale, 1848:20. Type locality Tutuila, American Samoa.

Pteropus nawaiensis Gray, 1870:107. Type locality Nauai, Fiji Islands.

Pteropus vitiensis Gray, 1870:109. Type locality Ovalau, Fiji Islands.

Pteropus whitmeei Alston, 1874:96. Type locality Samoa.

Pteropus ruficollis Nicoll, 1908:228. Part, nomen nudum.

Pteropus rufficollis Nicoll, 1908:242. Part, nomen nudum.

Pteropus samoensis was described by Titian R. Peale (1848). Peale served as a naturalist on the United States Exploring Expedition under the command of Capt. Charles Wilkes. He obtained numerous specimens, several of which are still extant in the National Museum of Natural History. Peale also obtained at least one specimen of P. samoensis from Fiji. That specimen still exists in the national collection. Peale identified the specimen as Pteropus keraudrenius, a name now in the synonymy of Pteropus mariannus. At some unknown later time, a label identifying the specimen as P. mariannus was affixed to the specimen, probably as a result of the name P. keraudrenius being placed in the synonymy of P. mariannus. The specimen has been

maintained in the collection with P. mariannus ever since. Andersen (1912) mistakenly associated Peale's record with P. tonganus, the most common species known from Fiji at that time. Gray (1870) described P. nawaiensis and P. vitiensis from Fiji in his catalogue of the collections in the British Museum. Both of Gray's names are synonyms of the earlier named P. samoensis, although nawaiensis is currently recognized as the valid Fiji subspecies, P. samoensis nawaiensis.

Pteropus whitmeei, described by Alston (1874), is also a junior synonym of P. samoensis. Nicoll (1908) used the name P. ruficollis without providing a diagnosis or description, thus rendering it a nomen nudum. In the index of that work, he used the spelling P. rufficollis, also a nomen nudum. As an added complication, his observations make it clear that he had seen both species (P. samoensis and P. tonganus) and assumed them to be the same.

Currently, the accepted name for the Samoan population is Pteropus samoensis samoensis, and for the Fijian population, Pteropus samoensis nawaiensis (Wodzicki and Felten, 1975).

Pteropus samoensis samoensis is known from all the major islands in both American and Western Samoa. We found them on Tutuila, Ofu, Olosega, Ta'u, Savai'i, and 'Upolu. Pteropus samoensis nawaiensis is known from several islands in Fiji--Viti Levu, Vanua Levu, Ovalau, Nauai--and probably occurs on many more.

Pteropus tonganus Quoy and Gaimard, 1830.

Pteropus tonganus Quoy and Gaimard, 1830:74. Type locality Tonga-Tabu.

Pteropus Keraudrenii: Schmeltz, 1864:3. Misidentification (not P. Keraudren Quoy and Gaimard, 1824).

Pteropus flavicollis Gray, 1870:107. Type locality fixed as Moala Island, Fiji, by Andersen (1912).

Pteropus tonganus was described by Quoy and Gaimard (1830) based on specimens obtained by the voyage of the Astrolabe. There are many references in the early literature to P. keraudreni (also spelled keraudrenii and keraudrenius) from Fiji, Samoa, and Tonga, but Pteropus keraudren Quoy and

Gaimard, 1824 correctly belongs in the synonymy of Pteropus mariannus. Andersen (1912) allocated all of the earlier references to the synonymy of P. tonganus, but some may in fact refer to P. samoensis. Pteropus flavicollis Gray (1870) is a junior synonym of P. tonganus.

There are several names available for application to populations of this widespread insular species. However, subspecies limits are so poorly understood that it is beyond the scope of this report to attempt to allocate all of them. In our area of interest, all populations of this species are referable to P. t. tonganus. This nominate form extends from Fiji in the west to the Cook Islands in the east (Wodzicki and Felten 1975; Hill and Beckon 1978). Another well-marked and considerably larger subspecies, P. t. geddiei, is found from New Caledonia north to Rennell Island and the Santa Cruz Islands (Wodzicki and Felten 1981). The westernmost population is P. t. basiliscus on Karkar Island, off the coast of New Guinea (Koopman 1979).

Pteropus tonganus is known from all of the major islands in both American and Western Samoa (Andersen 1912; Sanborn 1931; Cox 1983). We found them on Tutuila, 'Aunu'u, Ofu, Olosega, Ta'u, Savai'i, and 'Upolu. They are also found on many small offshore islets. Amerson et al. (1982) reported them from Nu'utele Islet west of Ofu. In Western Samoa, they have been found on Apolima Island and observed feeding on Manono Island.

#### Description and Morphology

##### Size

Andersen (1912) noted that when two or more species of Pteropus are in sympatry, they generally differ conspicuously in size. This is not true for P. samoensis and P. tonganus. Andersen (1912) listed forearm lengths of 139-150 mm for P. t. tonganus and 140-149 mm for P. s. samoensis. Wodzicki and Felten (1975) listed 133-150 mm (average 141 mm) for P. t. tonganus, 125-143 (average 138) for P. s. samoensis, and 120-135 (average 135) for P. s. nawaiensis. Eleven P. t. tonganus in the National Museum of Natural History measured 114-139 (average 127), and seven P. s. samoensis measured 136-145 (average 141).

The wingspans of both species are about the same. Although Cox (1983:520) stated that P. samoensis "is much larger than P. tonganus and may prove to be the largest bat known to science with a wing span approaching 2 meters (Peale 1848; Anderson [sic] 1912)," we have found no evidence to indicate that P. samoensis reaches this size. In fact, Peale (1848:20) reported the "extent of wings 38 1/2 inches," or 98 cm for a female. Andersen (1912) gave no wingspan measurements. Cassin (1858) gave the wingspan of a male as 40 inches (102 cm). We measured two adult female P. samoensis with wings held tightly outstretched--each had a wingspan of 122 cm, and an adult male P. tonganus had a wingspan of 125 cm.

The skull and dentition differ in several ways between the two species. The rostrum of P. samoensis is considerably shorter than in P. tonganus. The coronoid process of the mandible is higher, broader, and more steeply ascending in P. samoensis. The first pair of lower incisors is much smaller than the second pair in both species, but the disproportion is much greater in P. samoensis. The first premolars, both upper and lower, are reduced and peglike in both species, but are a bit more substantial in P. samoensis.

#### Pelage

The body color of P. samoensis is brown, darker in the nominate form than in P. s. nawaiensis, sometimes with a rusty tinge, sprinkled with grayish white hairs. The mantle is rusty brown, chestnut, or tawny, and the crown varies from buff to silvery gray. The face is sometimes distinctly gray. Wing membranes are dark brown to black.

In P. tonganus, the body is blackish or seal-brown, slightly darker and glossy on the dorsum. The mantle varies from buffy to a very pale cream-buff, and the crown is brownish, similar to the back color. The pale mantle of P. tonganus is characteristic of both young and adult bats (Cox 1983). The wing membranes are dark brown to black.

The fur is longer in P. samoensis than in P. tonganus. In P. tonganus, the longest hairs of the back are 10-13 mm; of the mantle, 12-13 mm in males and 16-17 mm in females; and of the belly, 13-15 mm (Andersen 1912). Pteropus

samoensis has fur about 18 mm long at the middle of the back, 20 mm at the middle of the mantle, and 24 mm at the middle of the belly (Andersen 1912). The slightly shorter fur of P. tonganus imparts a glossy appearance to the pelage. Pteropus samoensis, with its longer fur, has a distinctly shaggy appearance, especially when in hand.

#### Field Identification

Several behavioral and morphological features separate P. samoensis and P. tonganus in the field, and with binoculars, the experienced observer can identify the two species at distances up to 1-2 km. Under optimal viewing conditions the color of the upperparts serves to clearly separate the two species. In P. tonganus the mantle is pale, sometimes nearly white. There is a distinct contrast between the pale mantle and dark back. The crown of the head is dark and contrasts with the paler mantle. In P. samoensis, the mantle is a rusty brown; there is usually only minor contrast between it and the brownish back. The buff or silver-gray crown is paler than the mantle, just the reverse of the color scheme in P. tonganus. Optimally, an animal should be viewed from above to determine mantle color; however, the color of the mantle extends down the sides of the neck and can often be discerned when the animal is viewed clearly from the side. Several other features visible at close range can be used to aid in separating the two species. The snout is blunt in P. samoensis but more pointed in P. tonganus. The facial color usually is grayish in P. samoensis and dark brown or black in P. tonganus.

There is considerable variation in mantle color in both species. The palest mantles of P. samoensis approach the shade of the darkest mantles of P. tonganus. We also noted variation in crown color of P. samoensis. Several that we observed had silvery gray crowns, with the grizzly, nearly white color of the crown extending down and around the face. In contrast, others had only a small buffy patch in an otherwise brownish crown and face.

At a distance, the shape of the wings and body, speed and depth of wingbeats, overall color, and habits distinguish the two species. Pteropus

samoensis has a distinctly stumpier, broader-winged, darker, and often larger appearance than does P. tonganus. Though in the hand P. tonganus is blacker-bodied than Pteropus samoensis, in the air P. samoensis often appears darker than P. tonganus. The wings of P. samoensis typically exhibit a "full" trailing edge without deep indentations. In P. tonganus, the wings appear narrower and have distinct indentations on the trailing edge. Pteropus samoensis has a tail-less or stump-tailed appearance, whereas P. tonganus appears to have a tail (actually the feet extending to the rear, past the wing membranes). The overall shape of P. samoensis in flight is triangular, whereas that of P. tonganus is more of a cross. As a cautionary note, we should add that when flaring, P. tonganus has a broad-winged shape similar to P. samoensis, and that when gliding in a steep descent, P. samoensis has the deep indentations on the trailing edge of the wings, much like P. tonganus.

Peale (1848:17) gave a good description of the habits of Pteropus in general: "The Pteropi are all more or less gregarious; most active in twilight: and when at rest, hang from the branches of trees with their heads downwards, using their wings as cloaks to shelter their bodies from the wind, rain, and sun; when they fly, as they have no interfemoral membranes, they hold the two hind feet together, which makes them appear to have a tail; they climb with great facility along the under side of the branches, and are very destructive to both wild and cultivated fruits, as they taste and reject until the ripest and best is found; but we never heard them accused of destroying animal life." Later (1848:21), in the original description of P. samoensis, he noted: "It is the least gregarious, and most diurnal, in habits, of any of the genus which we saw; they are frequently abroad at noonday, and fly with the two hind feet together, which makes them appear to have tails." As a comparative trait, this tailed appearance is more applicable to P. tonganus than to P. samoensis. Because Peale was not aware that he was observing two species of bats in Samoa, he may have noticed this feature in P. tonganus and then mistakenly attributed it to P. samoensis.

Wingbeats and flying habits differ between the two species. In Samoa, P. samoensis has slow, shallow wingbeats, and commonly soars. In such instances, it resembles a large, soaring hawk (Cox 1983). The wingbeats of P. tonganus are faster and deeper; individuals sometimes wheel about, especially when descending from upper ridges. At such times, P. tonganus resembles a large, wheeling seabird rather than a bat. Occasionally, when P. samoensis is frightened or flushed, it may fly with deep, fast wingbeats similar to those of P. tonganus.

Habitat use by the two species differs and can sometimes be used as an identification clue but not a reliable indicator, because both species often use the same areas. In general, P. samoensis remains in or near native forest and does not venture out into extensive stands of agricultural forest as often as does P. tonganus. Although mostly found in native forest or in adjacent mixed agricultural forest, P. samoensis is sometimes found well away from native forest and even in villages. Pteropus tonganus commonly roosts in native forest and also forages in it, but it feeds extensively in agricultural forest and in villages and towns.

There is a general pattern of segregation of the two species by activity period and by gregariousness, but again, these are only clues to identification and not distinctive field traits. In most cases, single bats flying during the day or roosting by themselves are P. samoensis. Virtually all the solitary roosting bats we found that could be identified were P. samoensis. Bats moving along a flyway in large numbers in the early morning or at dusk are invariably P. tonganus, although a few P. samoensis occasionally fly among these groups. We found that large groups of bats (more than a dozen) flying about during the day were P. tonganus. These were generally individuals that had been disturbed and flushed from a colony or, in the late afternoon, were leaving a colony to feed.

#### Habits and Ecology

#### Social Organization

Pteropus samoensis is a solitary species that roosts individually or in pairs (Pernetta and Watling 1978; Cox 1983). The great majority of our observations were of single bats, though loose concentrations of up to a dozen individuals were sometimes found at feeding sites. On Savai'i, we found an exceptional site where we counted as many as 41 during a single half-hour census period and saw 9 hanging in the same tree but well spaced. We noticed little interaction between individuals, though on at least two occasions we heard P. samoensis squabbling among themselves. We also sometimes saw one individual following another and occasional chases. We did not collect data on P. samoensis that would confirm or reject pair bonding as suggested by Cox (1983).

Pteropus tonganus is a social species that roosts in colonies, often with several hundred bats in a single tree (Pernetta and Watling 1978; Cox 1983). Amerson et al. (1982) located colonies in American Samoa, some numbering in the thousands. All the P. tonganus that we found roosting were in colonies. The only suggestion that P. tonganus might roost singly is that of Wodzicki and Felten (1975:135): "On Niue P. tonganus has been reported to roost either singly, in pairs, or in larger groups." Presumably, these reports are by local inhabitants, as we know of no published records. Actually, only seven specimens are known from Niue (some 500 km south of Samoa), and five of those are immature (Wodzicki and Felten 1975; Hill 1979). If there are Pteropus roosting singly or in pairs on Niue, the possibility remains that they are P. samoensis, as yet unknown from that island.

We did not notice interactions between P. samoensis and P. tonganus. Ian Gurr (in litt.) found a tree containing both species on Tutuila. Colonies we observed contained all P. tonganus, although on several occasions we saw individual P. samoensis flying in the immediate vicinity of a colony. Away from colonies, we commonly saw the two species flying and foraging in the same general area. Also, there were occasionally a few P. samoensis flying among the P. tonganus moving along a large flyway.

#### Habitat

We found P. samoensis to be more widely distributed than reported by Cox (1983), who considered the species to be restricted to undisturbed rain forest. We found P. samoensis in primary and secondary native forest, in agricultural forest, and sometimes in villages. All types of native forest are used, including cloud forest and montane scrub. We observed P. samoensis from the seacoast to the highest elevations we visited (900 m on Savai'i). On Ta'u, we saw an individual using cloud forest near the top of the island (about 800 m elevation). However, the cloud forest on the higher elevations of Ta'u appears to provide only marginal habitat compared to mature rain forest at lower elevations. On Tutuila, Ofu, and Olosega, which are lower than Ta'u or Savai'i, P. samoensis used both high and low elevations.

In plantation areas, diverse agricultural forest with a variety of food trees is preferred. Pteropus samoensis is not attracted to extensive tracts of homogeneous agricultural forest, such as large coconut plantations. On 'Upolu, P. samoensis is found primarily in the upland interior forest rather than along the coastal plains, which have been largely converted to coconut plantations. On Savai'i, which has native forest along much of the lowlands, the species is found at both lower and higher elevations.

In the interior of 'Upolu, we occasionally found P. samoensis in relatively open pasture land, where individuals roosted high in massive Ficus trees. In 1993, we found that many of the large trees had been destroyed by Hurricane Val in December, 1991, and all of the remaining ones had been defoliated and lost many branches. We saw no sign of bats in these areas in 1993.

We found P. tonganus roosting in primary or secondary forest at inaccessible sites where colonies were protected from human intrusion. Likewise, Amerson et al. (1982) found colonies located in primary or secondary forest, usually in inaccessible areas near mountain tops, on islets, or near cliffs. From these colonies, P. tonganus disperses to forage in agricultural or secondary forests (Cox 1983). We commonly recorded P. tonganus foraging in agricultural forest, often in or around villages. In 1986 and 1989, large

numbers of P. tonganus dispersed to forage over the Tafuna plains, Tutuila. Even well-developed residential areas were used by P. tonganus. We saw and heard P. tonganus squabbling at night in Apia on 'Upolu, Western Samoa; Asau on Savai'i, Western Samoa; and in Pago Pago on Tutuila in American Samoa. Throughout Samoa, we found that we could see P. tonganus flying to and from roosting sites at dawn and dusk from many vantage points. We saw little such regular evening activity during our post-hurricane surveys in 1993. In 1989 we estimated several hundred P. tonganus returning to the roost on the ridge above the airstrip on Ofu, but in 1993 we saw only several dozen at the same spot.

#### Activity Patterns

Cox (1983) reported P. samoensis to be almost strictly diurnal, the peak of activity occurring between 1100 and 1400 h. We observed this species during all of the daylight hours but found it to be most active in the morning until about 1000 h and in the afternoon after 1400 h, with a slight lull in activity around midday. Most census data are difficult to analyze for activity patterns because of variation between sites and seasons. We have two small data sets that address the question directly, and both support a general activity pattern of a slow increase in activity to a midmorning peak around 0900 or 1000 h, a midday lull, and then a steady increase to an overall peak in late afternoon from 1500 to 1700 h.

The first of these we gathered on 28 July 1989, by making half-hour counts beginning every hour on the hour at a site on Savai'i where we had recorded the highest density known to us (41 in a half-hour census). We gathered the second data set from 30 July to 1 August 1989, by making half-hour counts from the summit of Mt. Vaea on Savai'i. We made from one to four counts during each daylight hour and the data represent the average number seen. In contrast, we did eight counts from the runway on Ofu, American Samoa, beginning at 0700, and recorded only a single P. samoensis in each count. From the foraging pattern exhibited there, we suspect it was the same bat using the area all day.

Andersen (1912:187), referring to the fruit bat population in Tonga, wrote, "Like many other species of the genus, P. tonganus appears sometimes on the wing in the early afternoon in full sunlight, but as dusk comes on it becomes more and more plentiful, and it is probably only those accidentally disturbed or specially driven by hunger that come out before dusk." We found that P. tonganus mostly remained in colonies during the day, departing at dusk to forage at night. We saw and heard individuals throughout the night and saw bats returning to colonies at daybreak. Pteropus tonganus often flies considerable distances as it moves back and forth between roosts and feeding sites. Bats sometimes fly between islands, and we observed one individual flying from 'Aunu'u to Tutuila, a distance of 2 km. On Tutuila at dusk, we regularly saw large numbers move from the mountains down onto the Tafuna Plains. On the south coast of 'Upolu, large numbers were flying across the road near Togitogiga at dusk, presumably from a colony near the coast or on an offshore islet, possibly Nu'usafe'e. On Savai'i, we saw a large flyway of P. tonganus moving across the Tafua Road at 0830-0930 h. We believe these bats were returning to a colony after foraging during the night. During our 1993 surveys, we noticed little dusk or dawn activity by P. tonganus. We saw P. tonganus returning to a roost on Savai'i in the early morning, just south of Fagafau. We also saw about 80 animals returning to a roost above the village of Tula on Tutuila.

We noticed some differences in activity periods for P. tonganus on different islands. On Tutuila, 'Upolu, and Savai'i, P. tonganus was seldom seen flying in large numbers during the day unless a colony had been disturbed or unless bats remained in areas relatively undisturbed by people. Individuals began entering foraging areas in large numbers shortly after dusk (about 1830 h). On 'Aunu'u and Olosega, P. tonganus became active earlier in the afternoon. On these islands, bats were seen leaving colonies to begin foraging as early as 1530 h. This behavioral difference may be due to varying intensities of hunting pressure and other human disturbance. On the larger islands, human disturbance is high, and P. tonganus forages primarily under

the cover of darkness. On 'Aunu'u and Olosega, human disturbance is low, and bats are able to forage with minimal risk during daylight. This behavioral difference might also be due to food availability. On those islands where food is limited, bats may spend additional daylight hours foraging.

#### Foods and Feeding

The genus Pteropus feeds on fruit, nectar, pollen, and, rarely, on other plant material (Marshall 1983). Fruit bats are known to be important pollinators and seed dispersers in tropical forest ecosystems. In Samoa, both species feed on a variety of foods. Both species feed in native and agricultural forest, although P. tonganus appears to forage primarily in agricultural forest, whereas P. samoensis forages more in native forest. The two species undoubtedly have different feeding niches and ecological strategies, but these have yet to be studied. Possibly, P. samoensis focuses on a variety of limited food sources over the year, rather than on an abundant, specific food crop like breadfruit, which may be the strategy of P. tonganus.

Cox (1983) observed P. samoensis taking the fruit of Cupaniopsis samoensis and the inflorescence of Freycinetia reineckei, and he obtained local reports of this species feeding on fruits of various Ficus species and Dysoxylum maota. Kiso So'oto, Edwin Seui, and Fia Tiapula (American Samoa Office of Marine and Wildlife Resources, 1988 report) compiled a list of plants used by P. samoensis that includes Myristica fatua, Persea americana, Carica papaya, Musa paradisiaca, Inocarpus fagiferus, Psidium guajava, Aglaia samoensis, Canarium vitiense, Mangifera indica, Terminalia richii, Cananga odorata, Morinda citrifolia, Artocarpus altilis, Spondias dulcis, Cocos nucifera, Barringtonia asiatica, Grewia crenata, Erythrina variegata, and Syzygium sp.

We recorded P. samoensis foraging on various fruits and flowers. Individuals were attracted to ripening breadfruit in agricultural forest near Amalau, Tutuila. At dusk, a large number of P. tonganus also moved into this general area. Both species could be seen landing in breadfruit trees and

carrying breadfruit pieces in their mouths. On Ofu, we observed a single P. samoensis roosting alongside a partly eaten breadfruit. We also saw P. samoensis landing in breadfruit trees on Olosega and Ta'u. At Leone, Tutuila, two female P. samoensis were shot by hunters as they fed on the flowers of Cananga odorata. In the same area on the previous evening, a male P. samoensis was taken as it fed on the flowers of Ceiba pentandra. We watched 6-10 scattered individuals foraging on the northwest slope of Pioa Mountain, Tutuila, at 360-430 m. Bats appeared to be particularly attracted to scrubby Pandanus trees, in which they landed and moved about with agility as if searching for food. They may be eating flower or leaf buds from the centers of the terminal rosettes of these plants.

Cox (1983) listed breadfruit, papayas, mangos, bananas, Syzygium jambos, and Ceiba pentandra flowers as foods taken by P. tonganus. We observed P. tonganus foraging on breadfruit and on the flowers of Ceiba pentandra, Cananga odorata, Musa paradisiaca, and Cocos nucifera. At Fagamalo, Tutuila, we recorded P. tonganus feeding on the thin outer flesh of Callophyllum inophyllum fruits. We saw individuals feeding on coconut flowers on Viti Levu, Savai'i, and 'Aunu'u.

There are a number of reports of depredation problems posed by fruit bats to agricultural crops (Peale 1848; Cassin 1858; Whitmee 1875; Nicoll 1908; Amerson et al. 1982; Cox 1983). Many types of fruit are said to be taken, but breadfruit is the crop mentioned most often. Most of this damage is probably attributable to the more abundant P. tonganus.

#### Reproductive cycle

Details of the annual reproductive cycle are unknown for both species. We noted several adult female P. samoensis carrying young in January, June, July, and August. Reports from biologists of the American Samoa Office of Marine and Wildlife Resources (K. So'oto and M. Ulugulu, Personal Communication) suggest that young are born throughout the year. The general pattern for pteropodids is one young per year, with one or two seasonal peaks (Martin et al. 1987).

On several occasions, both on Savai'i and on Tutuila, we watched two P. samoensis following each other, flying the same path, and wheeling together. Twice on Tutuila, we saw the animals grapple briefly in flight before separating and continuing to fly. This suggested some type of courtship behavior, but we were unable to sex the animals.

#### Status

#### Former Accounts

There is little reliable information regarding the past status of either species of fruit bat in Fiji and Samoa because most accounts refer collectively to both species. Cassin (1858), citing a journal by Dr. Pickering, recorded that bats were common everywhere in the Manu'a Islands, on Tutuila, 'Upolu, and Savai'i. Whitmee (1875:666) wrote, "Pteropus is very common in Samoa." Nicoll (1908:228) stated that many bats were "seen flying about over the trees even in broad daylight, while at dusk so many of these huge bats came down from the high forests, that we judged there must be a large colony of them at no great distance from Pago-Pago." Many of the bats observed in these accounts were probably the more numerous of the two species, P. tonganus.

Amerson et al. (1982) attempted to quantify the number of bats found in American Samoa, but they, also, were unaware that two species were present. Based on roadside counts and counts made at study plots, they estimated a total population of 140,000 in American Samoa. Their estimate most likely refers primarily to P. tonganus, but the methods used in determining density are not clearly described, and it is not possible to duplicate their study. However, based on our knowledge of forest bird densities in American Samoa, we commonly found their estimates to be up to 10 times higher than those obtained during a 1986 FWS survey.

Cox (1983) reported that P. tonganus was found in large colonies, was considered a pest in agricultural areas, and did not appear to have been severely affected by hunting for local consumption. Conversely, he regarded

P. samoensis as rare and endangered due to loss of forests and the opportunistic shooting of bats by pigeon hunters. He was only able to locate a single breeding pair on Tutuila and only a single individual on Ta'u. He estimated that, in Western Samoa, there were less than 50 remaining individuals on 'Upolu, while Savai'i possibly supported a larger population.

### Survey Results

#### Pteropus samoensis

In 1986, we established and conducted 30-min counts from 53 stations: 29 in American Samoa and 24 in Western Samoa (Table 1; Figs. 1-4). In 1989, we resurveyed 50 of those at about the same time of year and day. In 1993, we re-surveyed those 50 sites during January and February. The numbers recorded during all counts reflected the number of individuals that were observed rather than the number of sightings actually made, which was usually higher.

We recorded P. samoensis on all the major islands visited: Tutuila, Ofu, Olosega, Ta'u, 'Upolu, and Savai'i. We did not record P. samoensis on the small island of 'Aunu'u, although P. tonganus was common there. Pteropus samoensis was observed on 47 of 53 (89%) counts in 1986, and on 41 of 50 (82%) counts in 1989. In 1993, we recorded bats on only 33 of 50 counts (67%) (Table 1). An average of 4.4 individuals was recorded per count in 1986, and 3.1 individuals per count in 1989. In 1993, the comparable figure was 1.3 (Table 2).

We summarized combined data sets for American and Western Samoa, as well as for individual islands and groups (Table 2). The results suggest a serious decline for the entire data set combined, but an island-by-island examination showed that the difference was particularly attributable to a decline on 'Upolu (Table 2). Differences between the three counts indicate a decline for all of the other islands as well (Table 2).

The apparent decline on 'Upolu is statistically significant and signals the possibility of serious problems for P. samoensis on that island in the near future. Much of the island has been cleared for agriculture, leaving natural forest habitats only on the more inaccessible mountainous areas in the

center of the island. Most of our count sites are in some combination of natural and degraded or agricultural forest, which may represent marginal habitat for this species. When the recent hurricane damage is added to all of this, the remaining habitat for P. samoensis is severely limited. For these reasons, we would caution against the use of our survey data to represent actual population sizes on 'Upolu.

The situation on Savai'i remains mostly unknown, due to the physical features of the island and the difficulty in penetrating to the central undisturbed areas where P. samoensis would be expected to be most numerous. Savai'i is large enough that the central mountainous areas, where relief is sharp, are separated from the island-encircling access road by considerable expanses of gradual slopes that do not afford the ideal field of view for visual counts. The six sites we surveyed in 1986 were hastily chosen and not representative of the island in general. Three were coastal, and three were mountainous, but by 1989 and 1993, all had changed due to growth of roadside vegetation so as to further limit their usefulness. Although we did manage to resurvey four of the six, we had to shift our vantage points to such an extent that we do not believe the data are strictly comparable.

In 1989, we did find several other sites that might be used for visual counts. In the lowlands, 4 such sites that we censused yielded a total of 13 P. samoensis, 1 P. tonganus, and 10 unidentified animals that we believed were most likely P. samoensis. Those numbers are indicative of our general impression of the numbers of P. samoensis seen while exploring several roads through the lowlands of Savai'i. Bats were much more obvious on Savai'i than on 'Upolu. We re-surveyed those sites in 1993, and found 5 P. samoensis, 6 P. tonganus, and 1 unidentified animal that we believed was most likely P. samoensis. This decline paralleled what we found on all of our other count sites.

We located a site on the Vai'a'ata Road on the eastern end of Savai'i that afforded a view across a medium-sized taro field to a rather sharp forest edge, with the forest continuing back on a gradually rising slope to a ridge

about 2 km distant. It did not look like particularly good P. samoensis habitat, but it appeared to be representative and offered a vantage point, so we did a count at 1705 h on 27 August and recorded a remarkable 41 bats, the largest count we have made to date.

We devoted the following day to making 11 additional counts there, 1 per hour on the hour, beginning at 0700 h and ending at 1730 h. The results confirmed that this was an extraordinary site: The lowest number we counted was 17 (at 1200 h) and the highest was 39 (at 1600 h). The nature of the site allowed us to see many individuals roosting simultaneously, another unusual occurrence. The number roosting during each count period ranged from 4 to 17. Most were solitary, although a single tree held as many as nine individuals during some count periods. The number flying, apparently foraging, ranged from 10 to 29. The total number for the day was 298. This of course does not represent 298 separate individuals, but rather some number between 39 and 298. At this site, we know we had repeats of the same individuals during successive counts because we could easily keep track of roosting individuals. In 1993, we found the forest devastated from the previous year's hurricane, and recorded no bats during the same time period that we had counted 35 in 1989.

We discovered a second excellent vantage point for watching P. samoensis alongside the radio tower on the top of Mt. Vaea near the western end of Savai'i. There, we divided the 360° field of view into 3 approximately equal areas, and conducted 26 counts spread across all hours of the day from 0700 to 1750 on 3 consecutive days beginning 30 July. Those counts yielded a total of 227 bats. Once again, this represents some unknown number of individuals between 23 (the highest number recorded during any one count) and 227. However, the behavior of most animals at this site suggested to us that we were actually counting mostly different animals in each count period.

At that site, the bats could be divided into three basic groups, based on activity. By far, the majority was moving inland, uphill, from north to south, gaining altitude by soaring on thermals, and eventually sustaining flapping flight until out of sight. The second most common segment was moving

in the opposite direction, soaring much lower and more rapidly just above the canopy, and working their way downhill until out of sight. The third cohort included individuals foraging in our immediate vicinity, such that we could see them circle repeatedly and occasionally alight in nearby trees.

After watching those bats for 3 days, it was our impression that they use thermals to gain sufficient altitude to make their way inland to the highest peaks in the most energetically favorable manner. Then, they may forage gradually down the mountain slopes, using the terrain to cover maximum territory with minimal outlay of energy for flight. This might help to explain the evolution of soaring behavior in this subspecies, a seemingly useless trait in a frugivore. We did two counts at this site in 1993, and recorded no bats. The surrounding forest had been severely reduced by the hurricanes, both the natural forest and surrounding forestry plantation areas.

Considerably more data exist for American Samoa to fill the gap between 1986 and 1989. Biologists from the American Samoa Office of Marine and Wildlife Resources conducted surveys similar to ours at most of our sites in June and December, 1987 and in January, May, and August, 1988. In all but December 1987, two complete sets of counts were made (Table 3).

To compare all the results, we calculated the mean number of bats per count and multiplied by 21, the number of sites in our 1986 and 1989 surveys. This allowed us to use all surveys, which varied in number of counts from 17 to 50. The totals for Tutuila ranged from lows of 47 (2.2 per count) in May 1988 and January 1993, to a high of 105 (5 per count) in December 1987 (Table 3). The mean was 74.2, variance 349, standard deviation 18.7, and standard error 5.6. The 95% confidence limits were 61.3-87.1, and the coefficient of variation was 25. In 1993, we found a total of 47 and an average of 2.2 per count. This was the lowest total recorded since the May, 1988 counts, and suggests a significant decline.

Data are also available for Manu'a from 1987 and 1988 (Table 4). The pattern there may be related to the effects of Typhoon Tusi, which devastated much of the forest in January 1987. If we accept the earliest available data-

-1986--as the baseline, then the basic pattern is for a decline to about half in 1987, followed by an increase in 1988 and 1989, and a decline again in 1993, after the 1990 and 1991 storms. Residents on Ta'u told us that many bats died as a result of the typhoons and subsequent food shortages. However, the numbers recorded in 1988 and 1989 suggest that the populations there can rebound quickly. To augment the data from our two sites on Ta'u, we also recorded four counts at Lepue Crater on the afternoon of 11 August 1989. We saw three bats in the half hour beginning at 1530 h, two at 1600 h, six at 1630 h, and seven during the final half hour beginning at 1700 h. Although the Manu'a data do suggest a decline, the pattern suggests it is a natural post-hurricane pattern, and that the populations will rebound quickly, barring human disturbance.

#### Pteropus tonganus

This species is much more common than P. samoensis, but because it is basically nocturnal and colonies are remote, it can sometimes be less conspicuous than P. samoensis. The numbers we observed during our counts (Table 1) are quantifiable and comparable, but we do not believe that the data are particularly useful because P. tonganus is primarily nocturnal. We made no effort to visit all the P. tonganus colonies of which we were aware, but incidentally gathered information while in the field. All the population estimates given here are simply our "best guesses." There were probably thousands or tens of thousands of P. tonganus on each of the islands of Tutuila, the Manu'as, 'Upolu, and Savai'i. Even small islands such as 'Aunu'u supported colonies of several hundred.

In many areas bats are heard or seen nightly as they move into and feed in agricultural areas. Amerson et al. (1982) found roosts scattered throughout Tutuila and gave locations of colonies on 'Aunu'u, Ofu, Nu'utele (near Ofu), Olosega, and Ta'u. Several of these colonies probably contained more than a thousand bats each. Amerson et al. (1982) reported a colony of thousands at Fagatele Point on Tutuila. On 25 June 1986, we photographed bats flushed from this colony and counted 3,169 in one photograph. This

represented only a portion of the bats in the colony, and we estimated the roost to number 5,000. This was one of the largest colonies on Tutuila. We are aware of several other colonies and flyways on Tutuila, and we conservatively estimated the population at 12,000 in 1989. Recent islandwide counts conducted by the Department of Marine and Wildlife Resources have yielded estimates of 28,000 ( $\pm$  6,000) in 1987 and 18,000 ( $\pm$  6,000) in 1988. We saw too few animals in 1993 to provide a current estimate, but all indications are that the downward trend has continued.

Based on our incidental observations of flyways and foraging P. tonganus in Western Samoa, we believe that densities are similar to those on Tutuila. We counted 100 in a Terminalia catappa tree near Fagefau on Savai'i in 1989, but they were gone (as was the tree) in 1993). We regularly saw and heard them feeding in trees in Apia on 'Upolu. Considering that Western Samoa has nearly 15 times the land area of American Samoa, we believe the population numbered in the tens of thousands on each of 'Upolu and Savai'i. The total population in Samoa was probably over 100,000 in 1989, but current numbers are impossible to estimate without a much more careful and complete roost survey.

#### Cultural and Resource Significance

Fruit bats play an important role in the ethnobiology of Samoa (Cox 1983). Samoans, though generally aware of the morphological and behavioral differences between Pteropus samoensis and P. tonganus, are often not aware that there are two different species. When we asked residents about the two color types, they variously replied that this was due to a difference in age, sex, or possibly species. Knowledgeable residents know the two types of bats by different names. For P. samoensis, the common name we were given was "pe'a vao" (fruit bat of the forest); for P. tonganus, "pe'a fanua" (fruit bat of settled lands). For P. samoensis, Cox (1983) gave "pe'a vao", and for P. tonganus, "pe'a fai taulaga pe'a" (flying fox which makes flying fox towns). Whitmee (1875) listed "manu lagi" (animal of the heavens) as a local name for P. samoensis, after its habit of soaring high in the sky. There is a difference of opinion about the value of fruit bats in Samoa. Some Samoans

consider fruit bats to be a unique and aesthetically valuable part of the environment; others see them as agricultural pests.

Fruit bats play an equivalent role in Fiji, where "beka" is the name applied to both species. An ancient Fijian fable asserts that fruit bats obtained their wings by stealing them from the rat, who as a consequence tries to eat young fruit bats at every opportunity; this explains why one frequently sees fruit bats carrying their young. Fruit bats are considered an important part of the environment by some Fijians, a food source by others, and an agricultural pest by some small farmers.

### Hunting

#### Subsistence Harvest

Fruit bats have long been used as a source of food in Samoa (Whitmee 1875; Cox 1983). Whitmee wrote that during the breadfruit season a good many bats were killed for food, and that Samoans even preferred bats over fowl. Whitmee (1875:667) reported, "At the present time they often shoot them: but the more common mode of catching them is to fasten a prickly bush on a long bamboo or light pole; with this they approach the tree on which a Bat is feeding, and by a dexterous movement manage to strike a wing with a thorn of the bush as the animal takes to flight; the wing is thus torn by the thorns and the Bat disabled."

Although still occasionally used as a source of food today, fruit bats are not sought for consumption as intensively in Samoa as on certain other Pacific islands, such as the Marianas. While some Samoans consider fruit bat to make a fine meal, others refuse to eat it. Use of fruit bats as food is more prevalent in Western Samoa than in American Samoa. Several hunters with whom we spoke indicated that the Pacific Pigeon (Ducula pacifica) was the select quarry, and that fruit bats were taken incidental to pigeon hunting. The high cost of shotgun shells partly deters their liberal use on the less desirable bats.

In American Samoa, we observed subsistence hunters on several evenings in 1986. Hunters stationed themselves on a flyway or in agricultural forest

where bats were coming to feed. Shotguns or .22-caliber rifles were used, and bats were taken on the wing or while roosting. Pteropus tonganus appeared to be the species commonly taken. Of 15 bats that we examined, 12 (80%) were P. tonganus and 3 (20%) were P. samoensis. Pteropus samoensis may be taken regularly by pigeon hunters during the day (Cox 1983). In 1989, we obtained an albinotic specimen of P. samoensis that had been shot earlier by hunters. We found no evidence of hunting in 1993, perhaps due to a government-imposed moratorium. We also noted a significant increase in knowledge about the plight of the bats on the part of the local people, attesting to the successful efforts at education by various groups, including the Department of Marine and Wildlife Resources.

#### Commercial Harvest

Virtually all bats harvested for commercial purposes in Samoa have been exported to Guam or Saipan in the Marianas. An estimate of the number of bats shipped to Guam, where most are sent, is available from information collected by customs agents on Guam (Wiles and Payne 1986). The percentage of P. samoensis and P. tonganus in each shipment is not known, nor is the number of bats shipped to Saipan. Relatively small numbers of fruit bats entered Guam from American Samoa from 1980 to 1983, averaging 210 animals per year (Wiles and Payne 1986). In 1984, imports to Guam from American Samoa increased to about 1,630 bats. In 1985, about 1,000 were imported into Guam. Numbers dropped about 50% in 1986, and in November 1986, all commercial exports from American Samoa were banned. There have been no commercial shipments since then, although bats may be exported for personal use. No export permit has been required for bats shipped from American Samoa.

In American Samoa, commercial hunting of bats was more of a sport than a lucrative business enterprise. Commercial hunting was generally done by small parties of hunters that "pass shot" along flyways at dusk. Because the vegetation is dense and the light usually poor, many bats were crippled and lost (W. Knowles, American Samoa Office of Marine and Wildlife Resources and P. Cox, Brigham Young University, personal communication). Bats were frozen

whole and stored until a sufficient number had accumulated for a shipment. We interviewed a local exporter who made five or six shipments in 1985, each with an average of about 200 bats (D. Spencer, personal communication). The exporter received \$6.50 (U.S.) per pound for the bats from the Guam dealer. On Guam, bats were selling for about \$14.00 per pound (G. Wiles, Guam Division of Aquatic and Wildlife Resources, personal communication). Bats with the "white" mantle (P. tonganus) made up the bulk of the harvest. After calculating the cost of shotgun shells and shipping, sale of bats was deemed to be only marginally profitable (D. Spencer, personal communication).

Commercial sale of fruit bats from Western Samoa began in 1981 (Wiles and Payne 1986). From 1981 to 1984, 18,750 were exported to Guam. During 1983 and 1984, Western Samoa was the most important supplier of bats to Guam, with about 8,350 and 6,650 imported in these two years. In 1985, about 7,000 bats were exported to Guam from Western Samoa and about 5,000 in 1986. Then, in the fall of 1986, exports from Western Samoa dropped significantly and remained low throughout 1987 and 1988. In 1988, 360 were imported into Guam from Western Samoa (G. Wiles, personal communication). This decline is believed to have resulted from one of the importers on Guam going out of business. For each shipment of bats from Western Samoa, a certificate of export is required from the Department of Agriculture. In 1987, both species of fruit bats found in Western Samoa were included on the Convention on International Trade in Endangered Species (CITES) Appendix II list, and in 1989, were upgraded to Appendix I. Thus, it is now illegal to commercially export bats from Western Samoa to Guam.

In Western Samoa, where wages are low, commercial hunting of fruit bats was formerly viewed as a viable enterprise. There were evidently several major exporters that collected bats from a number of independent hunters. In the mid-1980's, one hunter on 'Upolu was given shotgun shells by an exporter and was paid (in Western Samoan) \$3.00-\$4.00 (U.S. \$1.50-\$2.00) for each bat (B. Emsley, American Samoa Office of Marine and Wildlife Resources, personal communication). Because shotgun shells are expensive and each bat represented

a valuable commodity, there was probably less pass shooting and more hunting of roosting bats in Western Samoa than in American Samoa--thus, it is probably that a lower percentage of bats were crippled and lost in Western Samoa.

#### Management Recommendations

##### Threats to Population

With the possible exception of the Barn Owl (Tyto alba), which may take a few bats, there are few natural predators in Samoa. The primary threat to both species of fruit bats in both American and Western Samoa is the loss of habitat.

Hunting for local consumption has evidently never threatened either species in the past; it is the recent commercial exploitation of fruit bats that could excessively depress populations. The large numbers of bats shipped to the Marianas in the 1980's suggest that populations of both species have been subjected to increased hunting pressure, and several residents with whom we spoke indicated that bats were less common since the export trade became established. It is difficult to say how much of this decline is due to a reduction in bat numbers or to increasing secrecy of bats; the actual reduction in numbers cannot be determined without continuing systematic and comprehensive surveys. Commercial use of fruit bats is a threat that can be controlled, and was banned by local regulation in American Samoa in 1986. Western Samoa issued regulations in August 1989 directing the Comptroller of Customs to ensure and enforce the control of exportation of fruit bats and empowering the Chief Agricultural Quarantine Officer to search, seize, or refuse export of any fruit bats from any aircraft or vessel.

The loss of habitat due to logging and a growing human population will be more difficult to ameliorate. Timber is listed as the only natural resource in Western Samoa; it is listed as the number four agricultural product, number one industry, and number four export (Adams 1985b). In Western Samoa, commercial logging has been an important source of revenue in recent years. Much of the interior of 'Upolu has been commercially logged and converted to

pasture and other agricultural land. On Savai'i, logging is an even more important industry, although many of the logged areas are replanted or otherwise allowed to return to forest.

In American Samoa, commercial logging is not a viable industry, but in recent years much of the native forest has been removed and planted in taro and other crops. The loss of native forests and diverse agricultural forests will eventually limit the habitat available, especially for Pteropus samoensis. Conversion of native forest to diverse agricultural forests may not be detrimental to foraging habitat for P. tonganus, although a growing human population will probably increasingly disturb the remote areas where P. tonganus is currently able to roost.

On the positive side, viable populations of both species should be able to remain in Samoa; extinction for either species does not appear to be an imminent threat, although the reduced numbers are certainly cause for concern. The islands have a diversity of habitat types, often with rugged terrain. Much of this habitat is not easily accessed, making it difficult to eliminate fruit bats by hunting. About half of American Samoa remains in rain forest, ridge forest, and secondary forest, and much of this forest is too steep or otherwise unsuitable for development. Only about 20% of American Samoa is considered developable in the sense of having a slope of less than 30% (Amerson et al. 1982). On other islands in American Samoa, such as Ta'u, there has been minimal development, and formerly cultivated areas have returned to native forest. In Western Samoa, native forests cover about half of the land area; about one-third on steep terrain where their function must be protective rather than productive (M. Iakopo, Western Samoa Forest Service, 1985 report). While conversion of native forest to pasture land or homogeneous coconut or cacao plantations may effectively eliminate habitat for fruit bats, conversion to diverse agricultural forest may not be so detrimental. Nonetheless, because little is known about fruit bat ecology and population dynamics, and because of the threats posed by the loss of habitat

and commercial hunting, a conservative approach is recommended for fruit bat management in Samoa and Fiji.

#### Recommendations

There have been only limited studies and surveys of fruit bats in Samoa, and there are few data on which to base management decisions. Because of its naturally lower population density, P. samoensis is probably the more vulnerable of the two species. It may be possible to implement regulations that selectively protect P. samoensis. Our recommendations include the following:

1. Establish parks and reserves. With an expanding human population and an increasing demand for land, it is important that certain areas be established as parks or reserves. A large national park, O le Pupu, has been set aside in Western Samoa on the south side of 'Upolu. This exemplary park preserves a tract of native forest that is inhabited by P. samoensis. More recently, a national park has been established in American Samoa.

2. After hurricanes, a moratorium on hunting should be enforced until populations have a chance to recover. Once populations recover, then the following hunting regulations are recommended:

- Protect colonies of P. tonganus. Hunting should not be allowed in fruit bat colonies, and the isolated mountain peaks, offshore islets, and craggy points that harbor colonies should be set aside as reserves. Major flyways should also be protected, if possible.

- Prohibit hunting of fruit bats during the daytime. If the hunting of fruit bats was allowed only from sunset to sunrise, a larger percentage of the harvest would consist of P. tonganus, the more common of the two species. Also, P. tonganus colonies would be protected to some extent because most bats are away from colonies at night.

- Establish a bag limit on fruit bats taken for subsistence. Any export of fruit bats for personal use should be limited to the daily bag limit. Special provision should be made for the taking of bats that are causing agricultural problems and for scientific research. Western Samoa has already

added fruit bats to the list of "partially protected birds," thereby closing the hunting season from 1 April to 1 October each year.

3. Continue surveys and begin life history studies. This report represents preliminary information only, and many biological and ecological studies must be conducted before sound management practices can be implemented, including: marking or radio-tagging bats to determine home ranges, movement patterns, and population sizes; locating and visiting P. tonganus colonies to determine population size and social structure; analyzing food habits and foraging ecology; and questioning hunters about numbers harvested and other lore.

4. Map habitat types and vegetative communities. The amount of habitat available for fruit bats and other wildlife, and the rate at which it is being lost, is not well known, especially in Western Samoa. Accurate vegetation mapping would provide this information. New aerial photos and maps are particularly urgent to assess the effects of the recent hurricanes.

5. Conduct a public education program. Regardless of the number of environmental regulations passed, enforcement of such laws will be difficult and only partially successful without an active public education program. The increased awareness we found on tutuila in 1993 attest to the success of such programs.

#### ACKNOWLEDGMENTS

Our surveys were conducted in cooperation with the Division of Forestry, Western Samoa, and the Office of Marine and Wildlife Resources, American Samoa. Their assistance is greatly appreciated, especially that of M. Iakopo, Assistant Director of the Western Samoan Division of Forestry, and R. Tulafono, Director of the American Samoan Office of Marine and Wildlife Resources. In Western Samoa, T. Taogaga and V. Harris of the Division of Forestry were especially helpful, and T. E. J. Thomsen kept us apprised of recently enacted wildlife legislation. In American Samoa, assisting staff from the Office of Marine and Wildlife Resources included B. Emsley, P. Ili, D. Itano, P. Langford, F. Niumata, E. Seui, K. So'oto, and W. Syron, and P. Trail. P. Cox of Brigham Young University spent time in the field with us, and we thank him. Niumata, from Ta'u, and T. Sagale, from 'Aunu'u, were both generous hosts whose kindness is much appreciated, and F. Matagi assisted us logistically. J. Culliny, E. Eckhoff, J. Masalino, and D. Spencer supplied information about status and commercial harvest. I. Gurr spent a day in the field with us and shared his extensive knowledge of the natural history of fruit bats on Tutuila. P. Ashman, R. Banks, D. Blockstein, P. Cox, A. Gardner, W. Knowles, E. Pierson, P. Pyle, M. Tuttle, and G. Wiles read earlier versions or portions of the manuscript and offered a number of useful suggestions. United States Fish and Wildlife Service biologists who assisted with the 1986 survey were C. Aguon, P. Ashman, and P. Pyle. C. Dane of the United States Fish and Wildlife Service Office of Scientific Authority provided the impetus and partial funding for the 1989 surveys.

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Table 1. Pteropus recorded at 50 stations in Samoa, 1986 and 1989. 30-min counts were conducted on Tutuila (21 sites), Ofu (3), Olosenga (3), Ta'u (2), 'Upolu (17), and Savai'i (4).

| Station        | Date    | Time | <u>P. samoensis</u> | <u>P. tonganus</u> | Unidentified | Total |
|----------------|---------|------|---------------------|--------------------|--------------|-------|
| <u>Tutuila</u> |         |      |                     |                    |              |       |
| Leone          | 7-3-86  | 1645 | 3                   | 1                  | 0            | 4     |
|                | 8-6-89  | 1652 | 5                   | 1                  | 2            | 8     |
|                | 1-23-93 | 1815 | 3                   | 0                  | 0            | 3     |
| Asili          | 7-3-86  | 1726 | 10                  | 17                 | 2            | 29    |
|                | 8-6-89  | 1608 | 5                   | 1                  | 2            | 8     |
|                | 1-23-93 | 1740 | 1                   | 0                  | 0            | 1     |
| Tuigaava       | 7-3-86  | 1700 | 3                   | 0                  | 2            | 5     |
|                | 8-4-89  | 1714 | 9                   | 0                  | 0            | 9     |
|                | 1-23-93 | 1645 | 2                   | 0                  | 0            | 2     |
| Fagalii        | 7-3-86  | 1742 | 2                   | 6                  | 6            | 14    |
|                | 8-4-89  | 1636 | 8                   | 2                  | 1            | 11    |
|                | 1-23-93 | 1605 | 2                   | 0                  | 0            | 2     |
| Ogefao         | 7-7-86  | 0850 | 2                   | 0                  | 1            | 3     |
|                | 8-5-89  | 0934 | 4                   | 1                  | 0            | 5     |
|                | 2-3-93  | 0701 | 1                   | 0                  | 0            | 1     |
| Onenoa         | 7-7-86  | 0937 | 5                   | 0                  | 0            | 5     |
|                | 8-5-89  | 1013 | 4                   | 5                  | 1            | 10    |
|                | 2-3-93  | 0752 | 1                   | 0                  | 0            | 1     |
| Tula           | 7-7-86  | 1020 | 0                   | 0                  | 0            | 0     |
|                | 8-5-89  | 0848 | 4                   | 4                  | 1            | 9     |
|                | 2-3-93  | 0615 | 2                   | 80                 | 0            | 82    |
| Masefau        | 7-8-86  | 0800 | 3                   | 0                  | 0            | 3     |
|                | 8-5-89  | 1545 | 4                   | 0                  | 0            | 4     |
|                | 2-2-93  | 1717 | 2                   | 0                  | 0            | 2     |
| Talaloa        | 7-8-86  | 0843 | 2                   | 1                  | 0            | 3     |

|            |         |      |   |    |   |    |
|------------|---------|------|---|----|---|----|
|            | 8-5-89  | 1509 | 7 | 1  | 1 | 9  |
|            | 2-2-93  | 1635 | 9 | 0  | 0 | 9  |
| Masausi    | 7-8-86  | 0940 | 1 | 0  | 0 | 1  |
|            | 8-5-89  | 1627 | 7 | 8  | 0 | 15 |
|            | 2-2-93  | 1758 | 5 | 0  | 0 | 5  |
| Fagaitua   | 7-8-86  | 1028 | 0 | 0  | 0 | 0  |
|            | 8-6-89  | 0742 | 3 | 3  | 2 | 8  |
|            | 1-24-93 | 0647 | 3 | 0  | 0 | 3  |
| Nu'uuli    | 7-12-86 | 1425 | 7 | 7  | 3 | 17 |
|            | 8-6-89  | 1519 | 7 | 10 | 4 | 21 |
|            | 1-23-93 | 0828 | 3 | 0  | 0 | 3  |
| Vaitanoa   | 7-12-86 | 1515 | 5 | 5  | 1 | 11 |
|            | 8-13-89 | 0839 | 2 | 0  | 0 | 2  |
|            | 1-23-93 | 0740 | 3 | 0  | 0 | 3  |
| Fagaalu    | 7-12-86 | 1604 | 0 | 0  | 0 | 0  |
|            | 8-7-89  | 0826 | 0 | 0  | 0 | 0  |
|            | 1-23-93 | 0705 | 0 | 0  | 0 | 0  |
| Faganeanea | 7-12-86 | 1647 | 7 | 11 | 3 | 21 |
|            | 8-6-89  | 1415 | 8 | 0  | 0 | 8  |
|            | 2-3-93  | 1610 | 1 | 0  | 0 | 1  |
| Sagamea    | 7-12-86 | 1727 | 7 | 8  | 2 | 17 |
|            | 8-6-89  | 1453 | 7 | 0  | 0 | 7  |
|            | 1-23-93 | 0610 | 3 | 0  | 0 | 3  |
| Alega      | 7-12-86 | 1448 | 4 | 0  | 1 | 5  |
|            | 8-6-89  | 0859 | 0 | 9  | 3 | 12 |
|            | 1-24-93 | 0610 | 3 | 0  | 0 | 3  |
| Amaua      | 7-12-86 | 1526 | 1 | 0  | 1 | 2  |
|            | 8-6-89  | 0821 | 4 | 2  | 0 | 6  |
|            | 2-2-93  | 1547 | 2 | 0  | 0 | 2  |
| Alofau     | 7-12-86 | 1601 | 3 | 2  | 2 | 7  |
|            | 8-5-89  | 1706 | 4 | 8  | 1 | 13 |

|                |         |               |     |    |    |     |
|----------------|---------|---------------|-----|----|----|-----|
|                | 2-3-93  | 0827          | 1   | 0  | 0  | 1   |
| Pioa Mt.       | 7-12-86 | 1652          | 7   | 0  | 1  | 8   |
|                | 8-6-89  | 0949          | 2   | 0  | 0  | 2   |
|                | 1-24-93 | 0742          | 1   | 0  | 0  | 1   |
| Maugaloa       | 7-12-86 | 1623          | 10  | 4  | 1  | 15  |
|                | 8-6-89  | 1019          | 7   | 0  | 0  | 7   |
|                | 1-24-93 | 0814          | 1   | 0  | 0  | 1   |
| Tutuila Totals |         | <u>counts</u> |     |    |    |     |
|                | 1986    | 21            | 82  | 62 | 26 | 170 |
|                | 1989    | 21            | 101 | 55 | 18 | 174 |
|                | 1993    | 21            | 47  | 80 | 0  | 127 |
| <u>Ofu</u>     |         |               |     |    |    |     |
| Runway         | 7-17-86 | 1520          | 2   | 0  | 0  | 2   |
|                | 8-7-89  | 1608          | 2   | 0  | 1  | 3   |
|                | 1-26-93 | 0610          | 0   | 18 | 0  | 18  |
| Toaga          | 7-17-86 | 1631          | 3   | 2  | 0  | 5   |
|                | 8-7-89  | 1654          | 2   | 0  | 1  | 3   |
|                | 1-25-93 | 1805          | 0   | 5  | 0  | 5   |
| Leolo          | 7-17-86 | 1721          | 1   | 4  | 1  | 6   |
|                | 8-8-89  | 1552          | 1   | 0  | 0  | 1   |
|                | 1-25-93 | 0907          | 0   | 0  | 0  | 0   |
| <u>Olosega</u> |         |               |     |    |    |     |
| Tumatolu       | 7-17-86 | 1535          | 3   | 10 | 0  | 13  |
|                | 8-8-89  | 0814          | 8   | 0  | 0  | 8   |
|                | 1-25-93 | 1636          | 3   | 0  | 0  | 3   |
| Sili           | 7-17-86 | 1616          | 6   | 15 | 0  | 21  |
|                | 8-8-89  | 0904          | 5   | 0  | 0  | 5   |
|                | 1-25-93 | 1555          | 3   | 0  | 0  | 3   |
| Olosega        | 7-17-86 | 1717          | 9   | 27 | 0  | 36  |
|                | 8-8-89  | 1446          | 1   | 0  | 1  | 2   |

|                       |         |               |     |     |    |     |
|-----------------------|---------|---------------|-----|-----|----|-----|
|                       | 1-25-93 | 1719          | 5   | 0   | 1  | 6   |
| <u>Ta'u</u>           |         |               |     |     |    |     |
| Lepula                | 7-23-86 | 1449          | 5   | 17  | 0  | 22  |
|                       | 8-10-89 | 0840          | 3   | 2   | 2  | 7   |
|                       | 1-24-93 | 1600          | 4   | 0   | 0  | 4   |
| Letula                | 7-23-86 | 1453          | 1   | 12  | 1  | 14  |
|                       | 8-9-89  | 1715          | 1   | 10  | 0  | 11  |
|                       | 1-24-93 | 1642          | 3   | 0   | 0  | 3   |
| Manu'a Totals         |         | <u>counts</u> |     |     |    |     |
|                       | 1986    | 8             | 30  | 87  | 2  | 119 |
|                       | 1989    | 8             | 23  | 12  | 5  | 40  |
|                       | 1993    | 8             | 18  | 23  | 1  | 42  |
| American Samoa Totals |         |               |     |     |    |     |
|                       | 1986    | 29            | 112 | 149 | 28 | 289 |
|                       | 1989    | 29            | 124 | 77  | 23 | 214 |
|                       | 1993    | 29            | 64  | 103 | 1  | 168 |
| <u>'Upolu</u>         |         |               |     |     |    |     |
| Mt. Vaea              | 7-30-86 | 1632          | 2   | 0   | 0  | 2   |
|                       | 8-3-89  | 1704          | 1   | 0   | 0  | 1   |
|                       | 2-1-93  | 0839          | 0   | 0   | 0  | 0   |
| Tiavi                 | 7-30-86 | 1643          | 7   | 0   | 1  | 8   |
|                       | 8-3-89  | 1536          | 0   | 0   | 0  | 0   |
|                       | 2-1-93  | 0658          | 0   | 0   | 0  | 0   |
| Afiamalu              | 7-30-86 | 1734          | 3   | 2   | 1  | 6   |
|                       | 8-3-89  | 1613          | 2   | 0   | 2  | 4   |
|                       | 2-1-93  | 0744          | 0   | 0   | 0  | 0   |
| Falefa                | 7-31-86 | 1622          | 0   | 0   | 1  | 1   |
|                       | 7-26-89 | 0654          | 0   | 0   | 0  | 0   |
|                       | 2-1-93  | 1600          | 1   | 0   | 0  | 1   |

|              |         |      |    |   |   |    |
|--------------|---------|------|----|---|---|----|
| Falevao      | 7-31-86 | 1609 | 0  | 0 | 0 | 0  |
|              | 7-26-89 | 1716 | 3  | 0 | 0 | 3  |
|              | 1-27-93 | 0844 | 0  | 0 | 0 | 0  |
| Lemafa       | 7-31-86 | 1651 | 7  | 1 | 0 | 8  |
|              | 7-26-89 | 0750 | 3  | 0 | 0 | 3  |
|              | 1-27-93 | 0810 | 1  | 0 | 0 | 1  |
| Mt. Poutavai | 7-31-86 | 1730 | 5  | 0 | 1 | 6  |
|              | 7-26-89 | 0826 | 1  | 0 | 0 | 1  |
|              | 1-27-93 | 731  | 0  | 0 | 0 | 0  |
| Mt. Tafua N. | 8-1-86  | 1455 | 0  | 0 | 4 | 4  |
|              | 8-2-89  | 1618 | 1  | 0 | 3 | 4  |
|              | 1-31-93 | 1752 | 0  | 0 | 0 | 0  |
| Mt. Tafua S. | 8-1-86  | 1442 | 4  | 0 | 0 | 4  |
|              | 8-2-89  | 1536 | 2  | 0 | 2 | 4  |
|              | 1-31-93 | 1744 | 1  | 0 | 0 | 1  |
| Faleaseela   | 8-1-86  | 1555 | 10 | 1 | 1 | 12 |
|              | 7-25-89 | 1600 | 5  | 0 | 0 | 5  |
|              | 1-31-93 | 1645 | 2  | 0 | 0 | 2  |
| Mt. Tiatala  | 8-2-86  | 1555 | 4  | 0 | 0 | 4  |
|              | 8-3-89  | 1012 | 0  | 0 | 0 | 0  |
|              | 1-26-93 | 1705 | 0  | 0 | 0 | 0  |
| Mt. Savaii   | 8-2-86  | 1638 | 6  | 0 | 0 | 6  |
|              | 8-3-89  | 0820 | 0  | 0 | 0 | 0  |
|              | 1-26-93 | 1745 | 0  | 0 | 0 | 0  |
| Vaipu        | 8-2-86  | 1730 | 9  | 0 | 0 | 9  |
|              | 7-26-89 | 0913 | 1  | 0 | 0 | 1  |
|              | 1-27-93 | 0655 | 0  | 0 | 0 | 0  |
| Richardson-1 | 8-2-86  | 1550 | 8  | 0 | 0 | 8  |
|              | 8-3-89  | 0935 | 1  | 0 | 0 | 1  |
|              | 1-27-93 | 0614 | 0  | 1 | 0 | 1  |
| Richardson-2 | 8-2-89  | 1637 | 9  | 0 | 2 | 11 |

|                      |         |               |    |   |    |     |
|----------------------|---------|---------------|----|---|----|-----|
|                      | 8-3-89  | 0855          | 0  | 0 | 0  | 0   |
|                      | 1-26-93 | 1821          | 0  | 0 | 0  | 0   |
| Richardson-3         | 8-2-86  | 1725          | 7  | 0 | 1  | 8   |
|                      | 8-3-89  | 1100          | 1  | 0 | 1  | 2   |
|                      | 2-1-93  | 1710          | 0  | 0 | 0  | 0   |
| Tiavi Falls          | 8-5-89  | 1702          | 8  | 0 | 0  | 8   |
|                      | 8-3-86  | 1457          | 2  | 0 | 0  | 2   |
|                      | 2-1-93  | 0620          | 0  | 0 | 0  | 0   |
| 'Upolu Totals        |         | <u>counts</u> |    |   |    |     |
|                      | 1986    | 17            | 89 | 4 | 12 | 105 |
|                      | 1989    | 17            | 23 | 0 | 8  | 31  |
|                      | 1993    | 17            | 5  | 1 | 0  | 6   |
| <u>Savai'i</u>       |         |               |    |   |    |     |
| Asau-1,500m          | 8-4-86  | 1618          | 9  | 2 | 1  | 12  |
|                      | 7-29-89 | 1638          | 4  | 0 | 1  | 5   |
|                      | 1-29-93 | 0746          | 4  | 0 | 0  | 4   |
| Asau-750m            | 8-4-86  | 1726          | 5  | 5 | 0  | 10  |
|                      | 7-29-89 | 1728          | 0  | 0 | 5  | 5   |
|                      | 1-29-93 | 0624          | 0  | 0 | 0  | 0   |
| Asau-2,250m          | 8-4-86  | 1630          | 3  | 0 | 1  | 4   |
|                      | 7-29-89 | 1547          | 3  | 0 | 1  | 4   |
|                      | 1-29-93 | 0901          | 1  | 0 | 0  | 1   |
| Mauga                | 8-5-86  | 1607          | 3  | 0 | 0  | 3   |
|                      | 7-27-89 | 1534          | 0  | 0 | 0  | 0   |
|                      | 1-27-93 | 1751          | 1  | 0 | 0  | 1   |
| Savai'i Totals       |         | <u>counts</u> |    |   |    |     |
|                      | 1986    | 4             | 20 | 7 | 2  | 29  |
|                      | 1989    | 4             | 7  | 0 | 7  | 14  |
|                      | 1993    | 4             | 6  | 0 | 0  | 6   |
| Western Samoa Totals |         |               |    |   |    |     |

|      |    |     |    |    |     |
|------|----|-----|----|----|-----|
| 1986 | 21 | 109 | 11 | 14 | 134 |
| 1989 | 21 | 30  | 0  | 15 | 58  |
| 1993 | 21 | 11  | 1  | 0  | 12  |

Samoa Grand Totals

|      |    |     |     |    |     |
|------|----|-----|-----|----|-----|
| 1986 | 50 | 221 | 160 | 42 | 423 |
| 1989 | 50 | 154 | 77  | 23 | 267 |
| 1993 | 50 | 75  | 104 | 1  | 179 |

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Table 3. Pteropus samoensis recorded during 12 surveys on Tutuila, 1986-93.  
Adjusted total is the mean multiplied by 21, to standardize data to the  
initial and final surveys. Of the 246 counts, the initial and final 21 were  
30-minute counts, and all of the intervening ones were 20-minute counts.

| Date          | # Bats | # Counts | Mean | Adjusted Total |
|---------------|--------|----------|------|----------------|
| July 1986     | 82     | 21       | 3.9  | 82             |
| June 1987     | 70     | 20       | 3.5  | 74             |
| June 1987     | 86     | 20       | 4.3  | 90             |
| December 1987 | 85     | 17       | 5.0  | 105            |
| January 1988  | 73     | 25       | 2.92 | 61             |
| January 1990  | 71     | 25       | 2.84 | 60             |
| May 1988      | 56     | 25       | 2.24 | 47             |
| May 1988      | 68     | 25       | 3.40 | 71             |
| August 1988   | 83     | 25       | 3.32 | 70             |
| August 1988   | 63     | 24       | 2.63 | 55             |
| July 1989     | 101    | 21       | 4.8  | 101            |
| January 1993  | 47     | 21       | 2.2  | 47             |

Table 4. *Pteropus samoensis* recorded during five surveys in Manu'a, 1986-89. Adjusted total is the mean multiplied by 1986 count number, to standardize data to the initial survey. Of the 86 counts, the initial and final ones were 30-minute counts and the intervening ones were 20-minute counts.

| Date           | # Bats | # Counts | Mean | Adjusted Total |
|----------------|--------|----------|------|----------------|
| <u>Ofu</u>     |        |          |      |                |
| July 1986      | 6      | 3        | 2    | 6              |
| July 1987      | 3      | 9        | 0.3  | 1              |
| May 1988       | 13     | 9        | 1.4  | 4              |
| September 1988 | 12     | 8        | 1.5  | 5              |
| July 1989      | 5      | 3        | 1.7  | 5              |
| January 1993   | 0      | 3        | 0    | 0              |
| <u>Olosega</u> |        |          |      |                |
| July 1986      | 18     | 3        | 6    | 18             |
| July 1987      | 33     | 6        | 5.5  | 17             |
| May 1988       | 19     | 7        | 2.7  | 8              |
| August 1988    | 29     | 7        | 4.1  | 12             |
| July 1989      | 14     | 3        | 4.7  | 14             |
| January 1993   | 11     | 3        | 3.7  | 11             |
| <u>Ta'u</u>    |        |          |      |                |
| July 1986      | 6      | 2        | 3    | 6              |
| May 1988       | 53     | 10       | 5.3  | 11             |
| August 1988    | 47     | 10       | 4.7  | 9              |
| July 1989      | 22     | 6        | 3.7  | 7              |
| January 1993   | 7      | 2        | 3.5  | 7              |

Ofu-Olosega (combined)

|              |    |    |     |    |
|--------------|----|----|-----|----|
| July 1986    | 24 | 6  | 4.0 | 24 |
| July 1987    | 36 | 15 | 2.4 | 14 |
| May 1988     | 32 | 16 | 2.0 | 12 |
| August 1988  | 41 | 15 | 2.7 | 16 |
| July 1989    | 19 | 6  | 3.2 | 19 |
| January 1993 | 11 | 6  | 1.8 | 11 |

Manu'a total

|              |    |    |     |    |
|--------------|----|----|-----|----|
| July 1986    | 30 | 8  | 3.8 | 30 |
| July 1987    | 36 | 15 | 2.4 | 14 |
| May 1988     | 85 | 26 | 3.3 | 26 |
| August 1988  | 88 | 25 | 3.5 | 28 |
| July 1989    | 41 | 12 | 3.4 | 27 |
| January 1993 | 19 | 8  | 2.4 | 19 |

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