The Effects of Cyclone Val on Areas Proposed for Inclusion in the National Park of American Samoa

A Report to the U. S. National Park Service

by

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I. INTRODUCTION

In 1988, the 100th Congress of the United States directed that the nation's newest National Park be established in the Samoan islands, an archipelago approximately 14 south of the equator. The U.S. territory of American Samoa, which includes Tutuila island, the Manu'a group, Swains Island, and Rose Atoll, contains the only paleotropical rain forests on U. S. soil. In both the enabling legislation and the Congressional report by the House Interior Committee, the unique biodiversity of the Samoan islands, including many endemic species of plants, birds, and particularly the flying foxes, was viewed as a key factor meriting protection within the National Park system.

Congress directed that the National Park be established in three different islands: Tutuila, Ta'u, and Ofu. The Tutuila parcel was to include the forests occupying the steep slopes along the north side of the island. The Ta'u parcel was to include the forests on the more gentle slopes of the interior and south coasts, while the Ofu portion was to include the spectacular reef and intertidal communities of the south coast.

Adequate protection of these samples of Samoan natural habitats and their biota requires recognition that these islands are subject to three classes of temporal change, as outlined by Kirch (1991): 1) relatively predictable seasonal rhythms; 2) periodic but less predictable acute events, such as droughts and cyclones; and 3) natural or human-induced long-term directional change. Although Samoa is largely aseasonal, the wet period from December to March is sufficient to trigger flowering in many plant species. Thus seasonal patterns in flowering and fruiting are evident, and result in fluctuations in food availability for the nectarivorous and frugivorous fauna.

Superimposed on these low amplitude, but nonetheless biologically significant variations, are recurrent high intensity cyclonic storms. Samoa experienced six hurricanes (sustained winds over 75 mph) and 42 tropical storms (sustained winds 40-75 mph) between 1840 and 1966 (Craig and Syron in press), and three severe cyclones since 1988. Such storms are visibly, if patchily, devastating to natural communities as well as human infrastructure. While foliage recovery is relatively rapid, some effects persist for years. Storms are part of the evolutionary milieu of tropical oceanic islands, and, while some species may decline in numbers, others (e.g, light gap dependent plants) may benefit.

Cyclone damage and recovery has an irregular, multi-year periodicity, but can been seen as short-term relative to the directional change, resulting primarily from human colonization and land use practices (Kirch 1991) -- especially forest clearing, agricultural conversion, and hunting. While the native flora and fauna have persisted in an environment with seasonal and stochastic (e.g.,typhoons) variation, they are often ill-equipped to deal with the timing and scale of anthropogenic change. Extensive avifaunal extinctions associated with human colonization are known from many south Pacific islands (Steadman 1989). Subsequent to European contact, the scale and pace of change has accelerated (e.g., the introduction of firearms).

In settings like Samoa, extensive anthropogenic change may interact destructively with the ongoing effects of seasonal and storm driven change to threaten the long-term viability of species and natural communities (Pierson and Rainey in press). Thus Cyclone Val highlights the need for the park to monitor and protect native habitat, not only against detrimental anthropogenic change, but also against the interaction of anthropogenic change with seasonal rhythms and stochastic perturbations.

The short and long term effects of cyclonic storms on natural plant and animal populations are poorly understood, even though such effects are potentially highly significant in both ecological and evolutionary terms. Although the impacts of hurricanes have been investigated for some vertebrate species (See Biotropica 23[4a] for a review), most studies have focused on bird populations in the Caribbean (Askins and Ewert 1991, Lynch 1991, Waide 1991a & b, Will 1991). Relatively little information is available for either birds or flying foxes in the Pacific, even though severe tropical storms are a recurring phenomenon throughout much of the region.

Within the last decade, the areas proposed for inclusion within the National Park of American Samoa have been buffeted by three major cyclonic storms. In January 1988, the proposed Ta'u portion of the park was hit by Hurricane Tusi only a few days after the field hearings conducted by the House Interior committee. At the time, enabling legislation was still in a nascent stage, and there was significant concern about the effects of hurricane Tusi on the suitability of the Ta'u portion for inclusion within the Park system. However, a rapid vegetation inventory conducted by Paul Cox and Weseley Teraoka showed there was little cause for alarm. Although the forest was nearly completely defoliated, with the bird and flying fox populations suffering declines, the vegetation rapidly recovered, with canopy closure occurring within 12 months of the onset of the storm, as predicted (Cox and Teraoka, 1988).

In 1990, Hurricane Ofa hit the island of Tutuila. Damage from Ofa was spotty, with some areas being hit worse than others. The effects on wildlife, particularly flying foxes, was very noticeable (Daschbach 1990, Craig et al. MS). Since the south-north trajectory of Samoa carried the eye of the hurricane near Savai'i island, the effects of Ofa were more pronounced in Western Samoa than in American Samoa.

On December 3, 1991, Cyclone Val hit all of the islands of Samoa, on an west to east trajectory. In Tutuila island, wind speeds in excess of 70 m/sec. were recorded. Again, Western Samoa was more severely affected than American Samoa, but significant damage to plant and animal populations occurred.

On December 10, 1991, a proposal was made to the National Park Service for a rapid assessment of the effects of Hurricane Val on natural populations of plants and animals. The proposal had four goals:

1) To make a rapid assessment of cyclone related impacts on indigenous wildlife, particularly the two flying fox species, *Pteropus tonganus* and *Pteropus samoensis*,

2) To make critical observations on the post-cyclone behaviors and foraging patterns of both species of flying foxes within the National Park boundaries,

3) To make an immediate assessment of cyclone related damage to the tropical forest vegetation within the proposed park boundaries.

4) To make an "as needed" effort on wildlife salvage.

A major purpose of this study was to investigate the impact of Cyclone Val on flying fox populations within the proposed boundaries of the American Samoan National Park. The status of these populations was of particular interest, since flying foxes appear to play a keystone role as pollinators and seed dispersers in Pacific island ecosystems (Cox et al. 1991). Collateral observations were made on pigeons and doves, which appear to also function as important seed dispersers.

II. EFFECTS OF CYCLONE VAL ON FLYING FOX POPULATIONS

There are two species of flying foxes in Samoa, the white-necked flying fox (*Pteropus tonganus*), and the Samoan flying fox (*P. samoensis*). Although the two species are of similar size, and show some overlap in activity patterns and feeding behavior, differences between the species are evident.

P. tonganus is widely, if somewhat patchily, distributed throughout the southern Pacific from New Guinea to the Cook islands (Rainey and Pierson, in press). Despite the extensive range, morphological differentiation within the three subspecies suggests that long distance movements among island groups are rare. The species is usually colonial, and primarily nocturnal. Although the animals feed on the fruits and flowers of native forest trees such as *Terminalia catappa* (talie) and *Syzygium inophylloides* (asi), they also frequent plantations and villages, feeding particularly on the fruits of mango (*Mangifera indica* [mago]), and the nectar of coconut (*Cocos nucifera* [niu]) and kapok (*Ceiba pentandra* [vavae]) flowers (Cox, 1983). A summary of biological data on *P. tonganus* is available in the IUCN Fruit Bat Action Plan (Pierson et al. in press).

P. samoensis has a much more limited range with extant subspecies in Samoa (*P. s. samoensis*) and Fiji (*P. s. nawaiensis*). and limited evidence of a related extinct lineage in Tonga (Rainey and Pierson in press). The species is not known to form large colonies and is most often found alone or in small family groups (male, female and young). It is predominantly diurnal, generally showing peaks of activity in early morning and late afternoon. Although often found feeding in secondary or coastal forest, or on the edge of agricultural areas, on such species as *Planchonella torricellensis* [mama lava] or *Cananga odorata* [moso'oi], it is rarely found in plantations, and seems to prefer the native forest, where it is an important pollinator of such species as *Freycinetia reineckei* (Cox, 1984a). A summary of biological data on *P. samoensis* is available in the IUCN Fruit Bat Action Plan (Pierson et al., in press).

There are four species of native doves and pigeons in American Samoa, the Pacific pigeon (*Ducula pacifica*), the crimson-crowned fruit dove (*Ptilinopus porphyraceus*), the many-colored fruit dove (*Ptilinopus perousii*), which are found on all the islands, and the shy ground dove (*Gallicolumba stairi*), found only on Ofu (Amerson et al. 1982, Pratt et al. 1987). The distribution for all four includes other parts of Polynesia, and for *P. porphyraceus* and *D. pacifica*, other parts of the Pacific.

A. Methods

Field surveys were conducted for flying foxes on the islands of Tutuila, Ofu and Ta'u in American Samoa, January 10-18, 1992. Flying fox activity and relative density (# bats observed/unit time) was monitored at five sites on Tutuila, two (Afono Ridge and Amalau Valley) for which pre-cyclone data were available for comparison, a coconut plantation in Leone, Fagasa Pass, and Vatia (at the interface between a coconut plantation, badly damaged forest, and relatively undamaged forest)(see Map 4). Comparable observations were made at three sites along the south coast of Ofu (see Map 5), and five sites along the east coast of Ta'u (see Map 6). Roosting patterns were investigated for *P. samoensis* on Alava Ridge and in Afono Valley, and for *P. tonganus* and *P. samoensis* at Olovalu Crater. All feeding observations were recorded as to locality, time, and the identity of both the bat and the food item.

B. Results

1. Seasonal and Daily Activity Patterns

Observations at a number of sites over a 5 year period suggest that *P. samoensis* is primarily diurnal, and *P. tonganus* primarily nocturnal. Although *P. samoensis* can be observed feeding at all hours of the day, it tends to show a peak of activity in the late afternoon, and relatively little activity after dark. *P.tonganus* can also be found active at all hours of the day, but shows a dramatic increase in activity just prior to dark, as animals travel from roosts to nocturnal feeding areas.

Data collected in 1987 and 1988, prior to both cyclones, indicate that under pre-cyclone conditions there were some seasonal differences in activity patterns, with more diurnal activity in January than in July-August for both flying fox species (see Fig.1A & B). At both times of year, however, *P. samoensis* showed relatively more activity during the day than *P. tonganus*. In January, 1992, 5-6 weeks after Cyclone Val, both species were encountered flying and feeding at all times of day on Tutuila, although *P. tonganus* was still primarily nocturnal.

P. tonganus

Observations of *P. tonganus* at a roost in Olovalu Crater (see Sect.II.B.5 below), between 13:30 and 19:30 on January 17, show some activity in and out of the roost during the entire period, with the majority of the animals departing just prior to dark (see Fig. 2). Out of 967 departures, 413 (42.7%) occurred in a 5.66 hour period between 13:30 and 19:10, and the remaining 554 (57.3%) in the 25 minutes between 19:10 and 19:35.

P. samoensis

P. samoensis was found to be active in the morning hours around probable roost sites on Alava Ridge (see Sect.II.B.5 below). Observations conducted in a foraging area in Amalau Valley show no marked differences for *P. samoensis* activity between early and late afternoon (see Fig. 3). In Afono Valley, a known roosting area for *P. samoensis* (see Sect. II.B.5 below), there was greater activity in the late afternoon (16:30-17:30). Similarly in Olovalu Crater, also a known roosting area, there were more observations of *P. samoensis* activity late in the day (17:30-18:30).

2. Pre- and Post-Cyclone Activity

P. tonganus

On 4 January 1988, there were a total of 161 sightings of *P. tonganus* in Afono Valley between 15:30 and 17:30, whereas during the same time period on 16 January 1992, there were only 4 (see Fig. 4A). The roosting colony which had been present in the valley in 1988 appeared to be gone. In Amalau Valley, the number of sightings of *P. tonganus* during a comparable 1.5 hour period were low for both years with 4 in June 1988 and 12 in 1992 (see Fig. 4A).

No comparable pre-cyclone data are available for the other areas where observations were made -- Vatia, Leone, and Fagasa pass on Tutuila (see Map 4), Fatuana Pt., S. Toaga and Toaga on Ofu (see Map 5) and Lua, Luamaa, Saua, Judds Crater Creek, and Leusoalii on Ta'u (see Map 6). The number of animals observed at each of these sites is given in Table 1. Engbring (1989) had observations from the south coast of Ofu in July 1986, and observed a total of 6 *P. tonganus* in three 30 minute station counts conducted between 15:20 and 17:50. We observed a total of 12 animals in 40 minutes of observation between 17:00 and 18:00.

P. samoensis

During the same time period (15:30-17:30) on 4 January 1988, there were 69 sightings of *P. samoensis* in Afono Valley, and 34 on 16 January 1992 (see Fig. 4B). Likewise, in Amalau Valley, during a 1.5 hour observation period, 32 P. samoensis were sighted on 2 January 1988, and 19 at the same hours in January 1992 (see Fig. 4B).

As for *P. tonganus*, no comparable pre-cyclone data are available for the other observation sites (see Maps 4,5, & 6). The number of observations made in January 1992 are given in Table 1. During the same 1.5 hours of observation used for *P. tonganus*, Engbring (1989) had 6 sightings of *P. samoensis* on the south coast of Ofu in July. In forty minutes of observation, we had one sighting.

3. Habitat Use

Although both species are often found in the same areas, sometimes feeding in the same trees, *P. samoensis* is more frequently associated with native forest, and *P. tonganus* with highly altered habitats and plantations. During this study, *P. samoensis* was never encountered in the villages, and *P. tonganus* was most commonly seen in coconut plantations, often in close proximity to villages. In Vatia, for example, there were 14 observations of *P.tonganus*, all in association with coconut trees, and 4 observations of *P. samoensis*, all in the forested notch between Siuono and Polauta Ridges. Of the 300 animals that were monitored as they left the Olovalu Crater roost, presumably for foraging areas, 226 (75.3%) departed to the south or southeast, towards the Tafuna Plain, which has a large concentration of coconut plantations. Only 36 (12 %) departed to the north, towards the inland forest, and only 38 (12.7%) headed west.

In fifty minutes of observation at a coconut plantation in Leone near dusk (18:30-19:20, January 11), there were 17 sightings of *P. tonganus* and none of *P. samoensis*. Conversely, in 5 hours on Alava Ridge, (7:30-12:30, January 18),in badly damaged native forest, there were 15 sightings of *P. samoensis* and 4 of *P. tonganus*. In 14 cases the *P. samoensis* appeared to be using the area, and all 4 *P. tonganus* were travelling through.

Likewise on Ofu, 19 of the 20 observations of *P. tonganus* were in association with coconut plantations, and all 4 observations of *P. samoensis* were in the forested area along Leolo Ridge.

4. Feeding Behavior

P. tonganus

During the January 9-18 study period, there were 23 observations of foraging behavior by

P. tonganus (see Table 2). Twenty one (91%) involved nectar feeding, seventeen (74%) at the flowers of coconut (*Cocos nucifera*), three in a small flowering *Polyscias samoensis* tree, and one on a cultivated banana (*Musa paradisiaca*) flower. There was one observation of an animal feeding on a ripe papaya fruit (*Carica papaya*), and one of an immature animal feeding on the leaves of a vine (*Alyxia odorata*). All these observations were made during the daytime. In all instances animals were in plantations or gardens, and in 4 instances (e.g., in Pago Pago, Vatia, and Leone) within 30m of inhabited buildings. The animals feeding on *C. papaya*, *M. paradisiaca*, and *A. odorata* were all within 3m of the ground.

Of those animals that could be observed, the majority, particularly the immatures, appeared underweight.

P. samoensis

From January 9-18, there were 6 observations of feeding behavior by *P. samoensis*, five on breadfruit leaves (*Artocarpus altilis*), and one on the fleshy bracts of the forest liana, *Freycinetia reineckei*, of which it is a major pollinator (Cox 1984a). All observations were made in the daytime.

On 10 January, a female was observed drinking water from a tree scar in Amalau Valley.

All *P. samoensis*, with the exception of one juvenile, which could be observed closely, appeared healthy and of adequate weight. One juvenile was observed to land in the crotch of a tree in Amalau Valley, apparently exhausted. After about a half hour rest, he flew up the valley, and disappeared into the forest.

5. Roosting Behavior

P. tonganus

On 16 January a survey was conducted of three known *P. tonganus* roost sites on Tutuila: Fagatele Bay, where a colony of approximately 5,000 was consistently found prior to Cyclone Ofa; Larsen Cove, where a colony of several hundred was seen a few weeks after Cyclone Val (N. Tuato'o-Bartley, pers. comm.); and Olovalu Crater, another traditional roosting area (and most likely an alternate roosting site for the Fagatele Bay colony). The Fagatele Bay area was almost 100% defoliated, with >50% trees down. There was no suitable roosting habitat left, and no roosting bats were observed. A large, partially refoliated banyan tree (*Ficus obliqua* or *F. prolixa*) in Larsen Cove in which the bat colony had been observed following Cyclone Val, was not occupied. A colony of approximately 1,000 *P. tonganus* was located in Olovalu Crater.

A small colony (100-200 animals) which was known to roost in various localities in Afono Valley and Olo Ridge, was not observed during this study period, and has not been seen since Cyclone Ofa. A small colony (likely <100 animals), which may have been what remained of the Afono Valley colony, was believed to be roosting on Craggy Point in October 1990 and August 1991. No evidence for this colony was found during our survey, but an aggregation of 50-75 animals was observed in late January along the beach in Amalau Valley (D. Cuillard, pers. comm.).

A small colony of *P. tonganus* was found roosting in a *Terminalia catappa* tree on the slope behind the airstrip on Ofu. Thirteen animals were counted in the tree between 6:00-6:30 a.m. on January 13.

P. samoensis

Roosting or roosting-associated behavior (see below) was observed for *P. samoensis* in three areas on Tutuila (Alava Ridge, Olovalu Crater, and Afono Valley) and at one site on the east coast of Ta'u. All three areas on Tutuila were known prior to the storms to contain roost sites for *P. samoensis*. All areas, and especially Alava Ridge, received serious storm damage (see Map 1).

On January 18, on Alava Ridge, between 7:30-12:30, there were 15 sightings of *P. samoensis* between Fagasa Pass and the tower on Alava Mountain. These observations were associated with 7 small peaks along the ridge (see Map 7), and represented at least 8 different individuals. Although no animals were observed roosting, they were generally flying in circles (<200m radius) around these peaks, a behavior characteristically exhibited in the vicinity of roosts.

Observations were conducted inside Olovalu Crater between 13:30 and 19:30 on January 17. There were 20 sightings of *P. samoensis*, mostly on the west and northwest side. On two occasions, animals landed, and remained briefly, in the tallest tree on the rim; on another occasion an animal landed in a tree close to, but distinctly separate from, the roosting area for the *P. tonganus* colony. In most cases, animals entering the crater flew directly towards, and disappeared behind, a large banyan tree at the west end of the crater. Whether they were feeding or roosting there could not be determined. In a brief visit to Olovalu Crater on January 16 at 11:30, a *P. samoensis* was seen roosting on an open limb of a tree on the south side of the crater, about 10m above the crater floor.

Observations made from the crest of the ridge at the east side of Afono Valley (just above Pioa Pass) were consistent with those made in the past, when *P. samoensis* were known to be roosting in trees near the rim of Afono Valley. In two hours of observation (15:30-17:30) on January 16, it was not possible to identify roost sites (known roosting trees had been destroyed in Cyclone Ofa) or the number of individuals using the area. However, characteristic, repetitive circling behavior was observed twelve times. One large male *P. samoensis* roosted briefly in a tree just below the crest of the ridge, within 20m of the observation site.

Individual *P. samoensis* were seen landing in trees near the observable ridge line at two sites on Ta'u, at Lua and ca. 1km N. of Lua, between 14:15 and 17:10 on January 13.

No roosting behavior for *P. samoensis* was observed on Ofu.

C. Discussion

Ecological role of flying foxes.

Pteropodid bats (Chiroptera: Pteropodidae) play a crucial role in the ecology of paleotropical forests (Marshall 1983 & 1985, Fujita and Tuttle 1991). On oceanic islands they are often the only native mammals, and as such, play a keystone role as pollinators and seed dispersers for a number of the forest trees (Cox et al. 1991, Elmqvist et al. 1992). In Samoa, it is likely that at least 30% of the rain forest trees rely, at least partially, on flying foxes for pollination or seed dispersal (Cox et al. in press). These include such important native forest species as various *Syzygium* spp.(Myrtaceae), *Ficus* spp. (Moraceae), (Combretaceae), *Pommetia pinnata* (Sapindaceae), *Diospyros samoensis* (Ebenaceae), *Planchonella costata*, and *P. torricellensis* (Sapotaceae), as well as several important species in the strand community, like *Barringtonia asiatica* (Lecythidaceae) and *Terminalia catappa* (Cox et al. in press). The bats also are pollinators and seed dispersers for a number of introduced and cultivated species of agricultural and cultural importance, such as *Ceiba pentandra* (Bombacaceae) (Elmqvist et al. 1992), *Cocos nucifera* (Palmae), *Carica papaya* (Caricaceae), *Inocarpus fagifer* (Leguminosae), and *Cananga odorata* (Annonaceae).

Population threats.

Flying foxes are facing population declines throughout much of their range, particularly on small islands, due primarily to overhunting and deforestation (Fujita and Tuttle 1991, Pierson and Rainey in press). In recent years additional pressure has been placed on a number of Pacific species by the commercial exploitation of flying foxes for a luxury food market in Guam (Wiles and Payne 1986, Rainey 1990, Pierson and Rainey in press). From 1983-1986, Samoa was the major supplier to the Guam market, with as many as 8,380 animals per year being shipped from Western and American Samoa combined (Bräutigam and Elmqvist 1990). Although legislation banning commercial export was passed in American Samoa in 1986 and in Western Samoa in 1989, and both Samoan species were placed on CITES Appendix I in 1989 (Bräutigam and Elmqvist 1990), populations had already been significantly depleted (Cox 1984b). Populations reduced by commercial hunting were further affected by three high intensity storms in 6 years.

Cyclonic storms pose another significant threat to flying fox populations, even though many species have evolved in a cyclone prone environment, and would thus be expected to have developed survival strategies. In fact, given their long life expectancy (up to 20 or 30 years), individual flying foxes may encounter several severe storms in a lifetime. Nevertheless, there are reports of substantial population reductions following typhoons for *Pteropus rodricensis* on Rodrigues Island (Carroll 1984), *P. niger* on Mauritius (Cheke and Dahl 1981), *P. mariannus* on Guam (Wiles 1987), and *P. tonganus* and *P. samoensis* on Samoa (Daschbach 1990, Craig and Syron in press, Craig et al. in press). All the evidence indicates that direct mortality from storms is minimal, and the primary impacts result from greater vulnerability to human hunting pressure, and the absence of adequate refugia and food resources where forest clearing has reduced total available habitat (Pierson and Rainey in press).

Assessing the Status of *P. tonganus* and *P. samoensis* in Samoa.

It has proven difficult to obtain reliable population estimates for two flying fox species in Samoa. The method of choice for *P. tonganus* would be to identify all colonial roost sites, and count all resident animals. This method is currently being tested by the American Samoan Department of Aquatic and Wildlife Resources (DAWR) (P. Craig, pers. comm.). An attempt by DAWR personnel to conduct a post-cyclone roost count from a boat was thwarted twice by bad weather during the time we were in Samoa in January. Thus our assessment relies on data collected at one roost in Olovalu Carter (see below). Although, in general, roost fidelity is quite high among colonial flying foxes, there are a number of records of animals changing roost sites, or altering roost composition, seasonally, and/or in response to disturbance (e.g. hunting or cyclones) (Richards 1990, Pierson and Rainey in press). Thus, ideally, counts should be conducted several times per year, and at the same time year to year.

P. samoensis, because of its dispersed roosting patterns, presents a greater challenge. Our observational data, collected over a number of years, indicate, however, that this species shows strong roost fidelity. Animals with apparently identical color patterns have been seen at the same sites, year to year, and at different months of the year. Roost fidelity is indicated in this survey by the association of animals with severely damaged forest on Alava Ridge. Likewise, in two sites in Western Samoa, *P. samoensis* were found after Cyclone Ofa in previously known, and badly damaged roosting areas. Additionally, this species also has a tendency to roost near ridge tops (unpubl. data), and soar in the daytime (Cox, 1983). These behavioral attributes should make it possible, with repeated and careful observations, to identify the number of animals using an area (which on Tutuila can be conveniently divided into valleys). This is confounded, however, by the tendency of animals to circle an area, thus increasing the risk of duplicate counting.

Station counts have been used extensively by ourselves and others (Engbring 1989, P. Craig pers. comm.). Work by the DAWR has revealed large day to day variation in the numbers of animals observed at the same site (P. Craig, pers. comm). While with repeated observations (which was attempted at Amalau Valley during this survey, but thwarted on several occasions by heavy rain), it may be possible to develop a relative index of abundance, this is not likely to be a reliable method for estimating population size. A primary difficulty with this method is it focuses on foraging animals. Since *P. tonganus* tends to be a flock forager, it is possible to observe large numbers of animals at a site one day, and very few the next. *P. samoensis*, while it does not move in flocks, does aggregate at certain food resources, like fruiting *Planchonella* trees. For other foods, like *Freycinetia reineckei*, however, it tends to feed alone. Thus the number of animals observed during station counts is influenced by the available food resources, which are patchily distributed, show marked seasonal and annual fluctuations in flowering and fruiting, and elicit different feeding behaviors from the animals.

Station counts may prove more useful for assessing *P. samoensis* than *P. tonganus*, especially in areas, like Afono and Amalau Valleys, that are known to contain multiple roost sites. More information (only obtainable by radiotracking) is needed, however, on roosting and movement patterns for both species.

Pre- and Post-cyclone populations of *P. tonganus* and *P. samoensis*.

Prior to Cyclone Ofa in 1990, *P. tonganus* was by far the more abundant species on Tutuila. Although definitive pre-cyclone population estimates are not available, it is likely that the *P. tonganus* population was as high as 10,000 (Engbring 1989; Knowles 1988), and the numbers of *P. samoensis* were fewer than 700 (Engbring 1989), and possibly as low as a few hundred (Cox and Pierson, pers. obs.).

Following Cyclone Ofa there were dramatic declines in *P. tonganus* populations, possibly as great as 90-99% on Savai'i, Western Samoa (unpubl. data). There may have been comparable declines on Tutuila, where bats were killed in large numbers by post-storm hunting (Daschbach 1990), and no colonies larger than a few hundred were found in a June 1990 survey. It is likely that the Olovalu Crater roost, surveyed in January 1992 at about 1,000, represents the survivors of the Fagatele Bay colony, which prior to Cyclone Ofa was estimated at about 5,000 (Engbring 1989). If so, this suggests an approximately 80% population decline. While it is possible that this formerly large colony has dispersed, there is no evidence of this. In fact, fewer small colonies were observed after the storm, and it is likely that the current aggregation, located in one of the few remaining good roosting sites, draws on other colonies (like the one formerly found in Afono Valley), which no longer exist. If so, the declines could be greater than 80%. Since no *P. tonganus* were ever seen roosting alone, it is assumed that this species maintained its colonial behavior after the storm, and an accurate population estimate could be made by identifying and counting all colonies on Tutuila.

It is also likely that *P. tonganus* experienced serious declines in Manu'a. D. Wilson (pers. comm.) describes seeing several hundred flying down from a presumed roost on the cliffs behind the hotel on Ofu at dusk in August 1989. A roost located behind the hotel in January 1992 contained only about a dozen animals -- a reduction in excess of 90%.

While observations in Afono Valley (see Fig. 1A) also suggests a precipitous decline, these data are less reliably interpretable as indicators of population trends. They represent only single sampling episodes, and thus do not allow for day to day variability. Additionally, density differences between 1988 and 1992 could reflect differential response to food availability. In January 1988, *P. tonganus* appeared to be frequenting Afono Valley to feed on *Syzygium* flowers (I. Gurr, pers. comm.), whereas no flowering *Syzygium* was located in January 1992. Coconuts, which were the primary source of food in January 1992, are relatively sparse in Afono Valley. Also, some of the observations in 1988 likely reflected activity around a roost, now abandoned, which was located on Olo Ridge above Afono Valley.

For similar reasons it is also difficult to evaluate the cyclonic impacts on *P. samoensis* populations. In comparing observations made at the same hours in January 1988 and January 1992, there were 51% fewer sightings of P. samoensis in Afono Valley and 41% fewer in Amalau in 1992. Although, day to day variation in number of sightings could obscure a decline as large as that suggested here, it seems unlikely. Prior to Cyclone Val Afono and Amalau Valleys were relatively rich in roosting and foraging habitat, and relatively high numbers of *P. samoensis* could reliably be observed there at all times of year for which we have data (i.e., May, June, July, August, October, November) (unpubl. data). Since these two valleys were among the areas least damaged by Cyclone Val, still had adequate roosting habitat, and some food resources, it would be reasonable to expect an increase in bat activity form a "refugee effect", not a reduction. Thus the data collected in January 1992 are suggestive that decline in *P. samoensis* populations, while not as dramatic as those for *P. tonganus*, were likely significant as well.

Differential consequences of recent cyclones for *P. tonganus* and *P. samoensis* populations.

Given that *P. samoensis* was the rarer species prior to the storms, and the animal of much more limited geographic distribution, with perhaps more specific habitat requirements, we expected that it would be more seriously affected by the storms than *P. tonganus*. The data, however, indicate the reverse. We attribute the higher mortality of *P. tonganus* to behavioral differences between the species.

P. tonganus has a much greater tendency than *P. samoensis* to enter villages, and feed on crop plants, like coconut, papaya and mango, which are often within a few feet of dwellings. In January 1992, we observed *P. tonganus* almost exclusively in plantations and villages, often in very exposed settings (on defoliated branches or close to the ground). All our observations of *P.*

samoensis were in the forest, or in plantations removed from villages. There were numerous local accounts, after Cyclone Ofa, of *P. tonganus* foraging on the ground for fallen fruit (Daschbach 1990). This made the bats extremely vulnerable to hunting by people and to predation by domestic animals (cats, dogs and pigs). In one household alone in W. Samoa, the family cat killed 15 *P. tonganus* (J. Lundgren pers. comm.). This number multiplied by all the households in Samoa with domestic animals could account for a significant mortality. After Cyclone Ofa, one of the main sources of mortality for *P. tonganus* was young boys with slingshots (Daschbach 1990). We were told of similar events occurring on Ofu after Cyclone Val.

Differences in the feeding ecology of the two species also suggest that *P. samoensis* is better adapted to deal with cyclonic storms. First, several observations indicate *P. samoensis* is at least partially folivorous, whereas *P. tonganus* most likely is not; and, second, one of the primary food resources for *P. samoensis* during the cyclone season (December-February), *Freycinetia reineckei*, fared remarkably better than the native foods available to *P. tonganus* at this time.

Since many plants begin to refoliate within days after a storm, folivory is a highly adaptive survival strategy. Thus it is not surprising that the majority of feeding observations for *P. samoensis* in January 1992 involved folivory (see Table 2). Yet, data gathered prior to the storms indicate that leaves, including those of breadfruit (I. Gurr, pers. comm.), are an important component in the normal diet of *P. samoensis*. We also have had observations of feeding on the leaves of *Pometia pinnata*, *Carica papaya*, *Mucuna*, and an epiphytic lily. By contrast, the only observation of folivory for *P. tonganus* was an immature, and clearly weakened, individual on Ofu in January 1992 (see Table 2).

Additionally, data collected prior to the storms suggest that a major food resource for *P. samoensis* during the cyclone season (December-February) is the flowering *Freycinetia reineckei* (Cox 1984a), and for *P. tonganus*, the flowers of *Syzygium*, particularly *S. inophylloides* (unpubl. data). *F. reineckei* survived the storm very well. A number of flowering plants were found, even on totally defoliated trees. By contrast, *S. inophylloides*, along with the majority of the canopy trees, was largely defoliated, and no flowering was seen. *Syzygium*, which is known to be extremely important to *P. tonganus* in other parts of its range (Wodzicki and Felten 1975), may have been limited for *P. tonganus* on Tutuila even prior to the storm. Because *S. inophylloides* is primarily a lowland forest tree its numbers have been declined differentially with the clearing of lowlands. In our experience, *P. tonganus* only feeds on coconut flowers when no better resource is available. In July-August, for example, even though *C. nucifera* is flowering, *P. tonganus* feed primarily on *Ceiba pentandra* (Elmqvist et al. 1992), and is rarely observed in *C. nucifera*. In January, however, *P. tonganus* frequently visits *C. nucifera* (I. Gurr, pers. comm.) suggesting that preferred resources, like *S. inophylloides*, are limited.

Observations in January 1992 suggest that the cyclone was more disruptive of the roosting behavior for *P.tonganus* than for *P. samoensis*. The most important roost site for *P. tonganus* on Tutuila, Fagatele Bay, was completely destroyed, and had been abandoned. *P. samoensis* was still found in all areas known to be roosting areas prior to the storm. Although individual roost trees may have been destroyed, the animals were still found in the vicinity of pre-cyclone roost sites. Even in badly damaged, almost totally defoliated areas, like Alava Ridge, *P. samoensis* appeared to be utilizing pre-cyclone roost areas, suggesting strong site fidelity.

Implication of cyclones for reserve design.

One important consideration for the American Samoan National Park is whether the area proposed provides adequate habitat for flying foxes during periods of resource scarcity. There is marked seasonality to tropical forests, with periods of abundance and scarcity, even under normal conditions (Terborgh 1986). July-August, thanks to the flowering of *Ceiba pentandra*, is known to be a time of food abundance for *P. tonganus* (Elmqvist et al. 1992), but December-January, with the loss of lowland forest, and depletion of *Syzygium* resources, may be a time of food scarcity. When a severe storm, like Cyclone Val, damages 95% of the forest, and eliminates a large proportion of the food base, the survival of the flying fox populations are dependent on the existence of adequate refugia. This may be particularly challenging for *P. tonganus*.

To insure that the proposed park provides adequate habitat for both flying fox species, several steps are recommended for both species: 1) an assessment of what constitutes a viable population size; 2) the identification of key seasonal food resources and roosting habitat; and 3) an identification of habitat that includes adequate refugia for maintaining viable flying fox populations during storms of the severity of Cyclone Val.

III. OBSERVATIONS ON THE STATUS OF SAMOAN BIRDS

Tutuila, American Samoa.

Prior to Cyclone Ofa, *D. pacifica*, *P. porphyraceus* and *P. perousii* were seen regularly in the forests of Tutuila. Although, *P. perousii* was the least common, it was reliably observed on any day in Afono Valley, the primary study site for pre-cyclone observations.

After Cyclone Ofa, there were marked declines for all three species, but particularly for *P. perousii*. Individual *P. perousii* were observed, however, in both Afono and Amalau Valleys in November, 1990, and in Amalau Valley in August, 1991.

Observations in January, 1992, 5-6 weeks after Cyclone Val, suggest that pigeon and dove populations, which had not yet recovered from the effects of Cyclone Ofa, were further reduced. In 31.58 hours of observation on Tutuila, 22.25 within park boundaries (7 in Amalau Valley, 9.75 on Alava Ridge, 2 in Afono Valley, 3 in Vatia, and 0.5 at Fagasa Pass) and 9.33 outside, no *P. perousii* were observed. Within the Park, there were only three sightings of *D. pacifica* (one in Afono Valley and 2 on Alava Ridge), and 4 of *P. porphyraceus* (1 on Alava Ridge, and 3 in Afono Valley).

Most *D. pacifica* and *P. porphyraceus* appeared to have abandoned the forest where fruit supplies were very low, and were concentrated in coastal Vaitogi, where they were feeding on the berries of *Scaevola taccada*, and possibly on the fruits of *Pandanus tectoris*. At this site, mid-day on January 16, 1992, 4 *D. pacifica* and 6 *P. porphyraceus* were observed in a five minute period. At this site, close to human dwellings, the birds were extremely vulnerable to being shot. Also, in 5.5 hours of observation in Olovalu Crater, a privately owned site protected from hunting, *D. pacifica* were observed 5 times, and *P. porphyraceus* twice.

Wattled honeyeaters, *Foulehaio carunculata*, the Samoan starling, *Aplonis atrifuscus*, and the white-collared kingfisher, *Halcyon chloris*, all appeared to be still quite common after Cyclone Val. Also, the blue-crowned lory, *Vini australis*, rarely seen on Tutuila, was observed in Afono

Valley and on Alava Ridge.

Ofu and Tau, Manua Islands, American Samoa.

No pigeons or doves of any species were observed on Ofu or Tau in 3.25 and 8 hours of observation, respectively.

IV. EFFECTS OF CYCLONE VAL ON VEGETATION

Our experience of Hurricane Tusi in Manu'a and Hurricane Ofa in Savai'i strongly indicated that damage to Samoan vegetation from cyclone Val would be temporary in nature; i.e. that despite significant defoliation and even some structural damage, Samoan primary forest would recover within a matter of months. However, such recovery patterns, even though rapid, can be slow enough to be extremely deleterious to phytophilic animals, such as pollinators and seed dispersers. Subsequent reduction of, or loss of pollinators, can in turn have a deleterious effect on long-term seed production and seedling recruitment within primary forest. Thus, even though apparent structural recovery of the forest may be rapid, if production of fruit, nectar, and leaves is sufficiently delayed to cause pollinator or seed disperser extirpation or extinction, long-term demographic effects on primary forest may be extremely severe. This is particularly true in tropical forests, which, unlike most temperate forests, are dominated by taxa which require animal pollination (Cox 1991).

Thus any report on cyclone-induced damage on vegetation cannot be considered in isolation from analysis of pollinator and seed disperser mortality.

A. Methods

Intensive but rapid surveys were made of all vegetation areas within the National Park boundaries on Tutuila, Ofu, and Ta'u islands. Three different methods were used to (1) estimate vegetation damage due to Cyclone Val; and (2) provide a baseline for future analysis of vegetation recovery patterns:

(a) Areas within the proposed park boundaries were inspected and assigned to four different damage classes:

1. Intact
2. Some canopy damage visible
3. Canopy completely defoliated, but few trees down
4. Canopy completely defoliated, and many trees down

All assignations to a damage class were made by the consensus of two independent observers. Survey data were entered directly onto topographic maps, with all proposed park areas except for some interior portions of Ta'u island (which were inaccessible) being so mapped.

(b) Vegetation cover with representative areas of the different damage classes was estimated by using a relascope (Bitterlich 1984) and a point survey method.

(c) Overpasses by a French satellite was arranged with infrared photographs taken of the proposed park areas for later interpretation.

B. Results

Forest damage is mapped as damage classes on the topographic maps of Ofu, Ta'u, and Tutuila as attached (Maps 1-3). There is clearly a strong directionality to the damage. The south and west sides of the proposed Tutuila park parcel were far more damaged than the north and east sides. For example, in the protected western side of the Afono valley, no canopy damage was observable. The pronounced high ridge system of Tutuila island thus served as a natural wind-break to Cyclone Val, with vegetation on the lee (eastern) sides of the ridges receiving only moderate canopy damage, while the windward (western) ridges suffered complete canopy destruction with some trees downed. Since the southern slope of the proposed park parcel was relatively unprotected, damage was more severe. Of local interest was a large fault system exposed on the southern side of Pago ridge; local opinion was divided as to whether the fault was a consequence of the cyclone, or whether it was pre-existing and merely made visible due to the vegetation removal.

In the eastern part of the archipelago, damage was somewhat less than in Tutuila. For example, on the southern slope of Ofu (Map 2) which forms the watershed for the proposed underwater parcel of the park, damage was slightly less than the south part of the proposed Tutuila parcel, even though the topography is nearly identical. The south slope of Ta'u (Map 3), however, seemed to have equal damage as the proposed Tutuila parcel except in the extensive Liu bench area from 1400 ft.-3000 ft. level which suffered only moderate canopy damage. Unfortunately, Tufu point and Saua were extensively damaged. Over 95% of each island's park parcel received some damage from the Cyclone Val as shown below:

Approximate Percentage of Park Parcel per Damage Class

Damage Class	Tutuila	Ofu	Ta'u
1	5%	5%	5%
2	20%	25%	45%
3	70%	60%	40%
4	5%	10%	10%

Field study of tree architecture showed that most class 2 and 3 damage was due to defoliation, with axillary buds already (January 1992) beginning renewal growth for damaged axes. We can therefore with confidence predict canopy closure in damage class areas 1,2, and some areas with damage 3 within 12 months. Damage class 4 areas, however, may require several decades to regain the structural character of the original forest. Yet this also is inevitable since none of the proposed park parcels suffered significant wave incursion, which appear to be largely limited to a single area on Olosega island. There are legitimate concerns, though about slope and soil stability in areas of damage class 4, most of which occurred on areas of high slope.

Relascope data are summarized in Table 3 in the Appendix. There is a good correlation between our subjective estimates of canopy damage, and percentage cover as estimated by the relascope for representative areas: Table 3

Damage Class	Appearance	Relascope Percent Cover
1	Intact	83%-95%
2	Some canopy damage visible	87%-98%
3	Canopy completely defoliated, but few trees down	13%-50%
4	Canopy completely defoliated, and many trees down	5-8%

As expected there is some overlap between percentage cover for damage class # 1, and #2 for several reasons. First, our damage class estimates included not only cover (as estimated by the relascope) but also structural damage. Intact forest naturally varies in percentage cover because of natural gaps in the canopy, and thus there is expected variation even within damage class 1 (intact vegetation). Furthermore, relascope calibrations for Damage Class 1 were made only in the Vatia notch, which is likely atypical of other primary vegetation. In retrospect, relascope readings in the only other undamaged forest on Tutuila, ie. in the Western side of Afono Ridge (see map #1) would have been useful.

Perhaps a far more profound factor from a ecological point of view is the cyclone-induced loss of fruit and nectar as flying fox and bird forage. Only a few *Ficus tinctoria* and several *Araliopanax* (which is anemophilous) were observed in fruit or flower in the damaged areas. *Freycinetia reineckei*, which is an important forage plant for *Pteropus samoensis* was just beginning to flower.

V. MANAGEMENT RECOMMENDATIONS

In light of the apparently severe reductions in flying fox and pigeon/dove populations in American Samoa as a result of Cyclone Val, we make the following recommendations:

1. that all hunting of flying foxes and pigeons/doves be banned until assessments indicate that populations have recovered adequately to support a controlled harvest;

2. that ecological studies be undertaken for both the flying foxes and birds to define seasonal patterns of food abundance and scarcity, and to identify any limiting food and other habitat resources;

3. that radiotracking studies be conducted on the flying foxes to gain a better understanding

of roosting and foraging patterns;

4. that roosting patterns for both flying fox species be thoroughly understood before any trail system is developed. It may be particularly important for example to protect the *P. samoensis* roosting habitat along Alava Ridge, and the foraging habitat in Amalau Valley;

5. that a monitoring program be initiated to document the status of the flying fox and pigeon/dove populations over time;

6. that given the disturbed nature of the forests, all possible efforts be taken to prevent the introduction of any exotic species, and that any attempt at reforestation or reseeding be precluded,

7. that given the lack of soil stability on steep, highly damaged slopes, that no heavy equipment be introduced into proposed park areas, and that fire breaks not be constructed.

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Table 1. Observations of *P. tonganus* and *P. samoensis* at observation stations on Tutuila, Ofu and Ta'u, January 1992.

Locality	Date	Time	# *P. tonganus*	# *P. samoensis*	# Unknown
Tutuila					
Afono	1/16	1530-1730	4	34	4
Amalau	1/10	1350-1450	3	1	1
Amalau	1/10	1755-1905	14	9	2
Amalau	1/14	1555-1705	15	11	0
Fagasa Pass	1/10	1820-1900	2	1	3
Leone	1/11	1830-1920	17	0	0
Vatia	1/15	1520-1620	3	1	1
Ofu					
Toaga	1/12	1700-1710	3	0	0
S. Toaga	1/12	1720-1730	3	1	0
Fatuana Pt.	1/12	1740-1800	6	0	0
Ta'u					
Lua	1/13	1610-1630	1	1	0
Luamaa	1/13	1645-1705	1	3	0
Saua	1/13	1735-1755	4	0	0
Judds Creek	1/13	1810-1820	3	0	0
Leusoalii	1/13	1830-1840	4	0	0

Table 2. Feeding Observations for two species of flying foxes, American Samoa, January 9-18, 1992.

Date	Food Item	Plant Part	# Observations	Locality
P. samoensis				
1/9	*Freycinetia reineckei*	Bract	1	Alava Ridge
1/14	*Artocarpus altilis*	Leaf	3	Amalau Valley
1/16	*Artocarpus altilis*	Leaf	2	Amalau Valley
P. tonganus				
1/10	*Carica papaya*	Fruit	1	Pago Pago
	Cocos nucifera	Flower	2	Vatia
	Cocos nucifera	Flower	1	Amalau
	Polyscias samoensis	Flower	3	Amalau
1/11	*Cocos nucifera*	Flower	1	Leone
1/12	*Cocos nucifera*	Flower	9	Ofu
	Alyxia odorata	Leaf	1	Ofu
1/14	*Cocos nucifera*	Flower	1	Amalau Valley
	Musa paradisiaca	Flower	1	Amalau Valley
1/15	*Cocos nucifera*	Flower	1	Vatia
1/17	*Cocos nucifera*	Flower	2	Olovalu Crater

Table 3
Cover Data for Subjective Plots after Cyclone Val

Damage Class	Locality	Realascope	Percent Cover
1	Vatia Notch	20	83%
	Vatia Notch	18	95%
2	Amalau W.	23	87%
	Afono-olo	26	97%
	Facing Afono	14	98%
	Olo Ridge	28	93%
3	Amalau stream	13	50%
	~~Amalau stream~~	16	41%
	Olo Ridge	20	13%
	Olo Ridge	19	16%
	Facing Amalau	16	23%
	Amalau below stream	21	23%
4	Siu Pt, Tau	19	5%
	Vatia	10	8%

Damage Class Key:

Class	Appearance
1	Intact
2	Some canopy damage visible
3	Canopy completely defoliated, but few trees down
4	Canopy completely defoliated, and many trees down

P. samoensis sightings, Afono Valley, July 1987 and January 1988

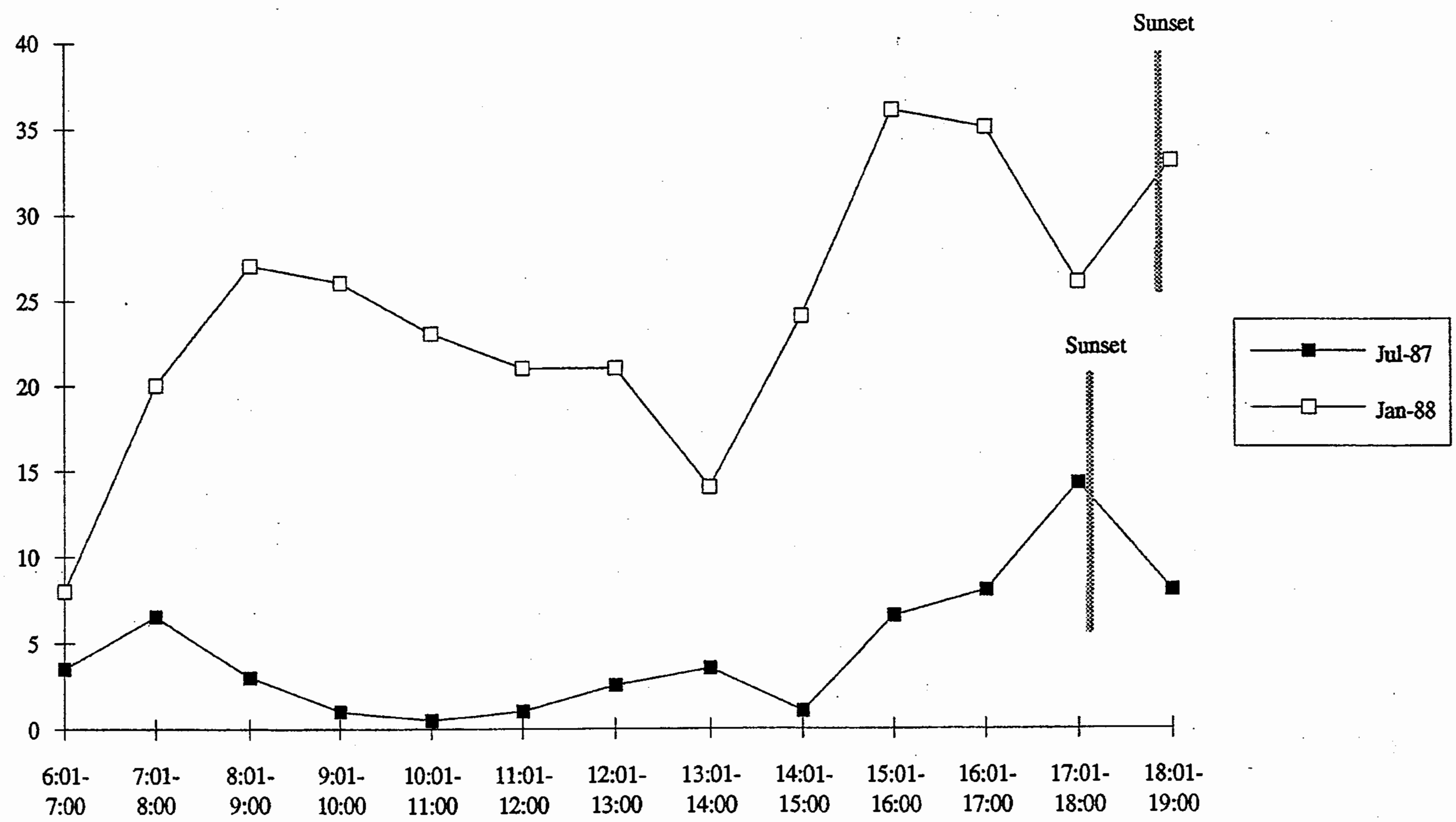


Figure 1A

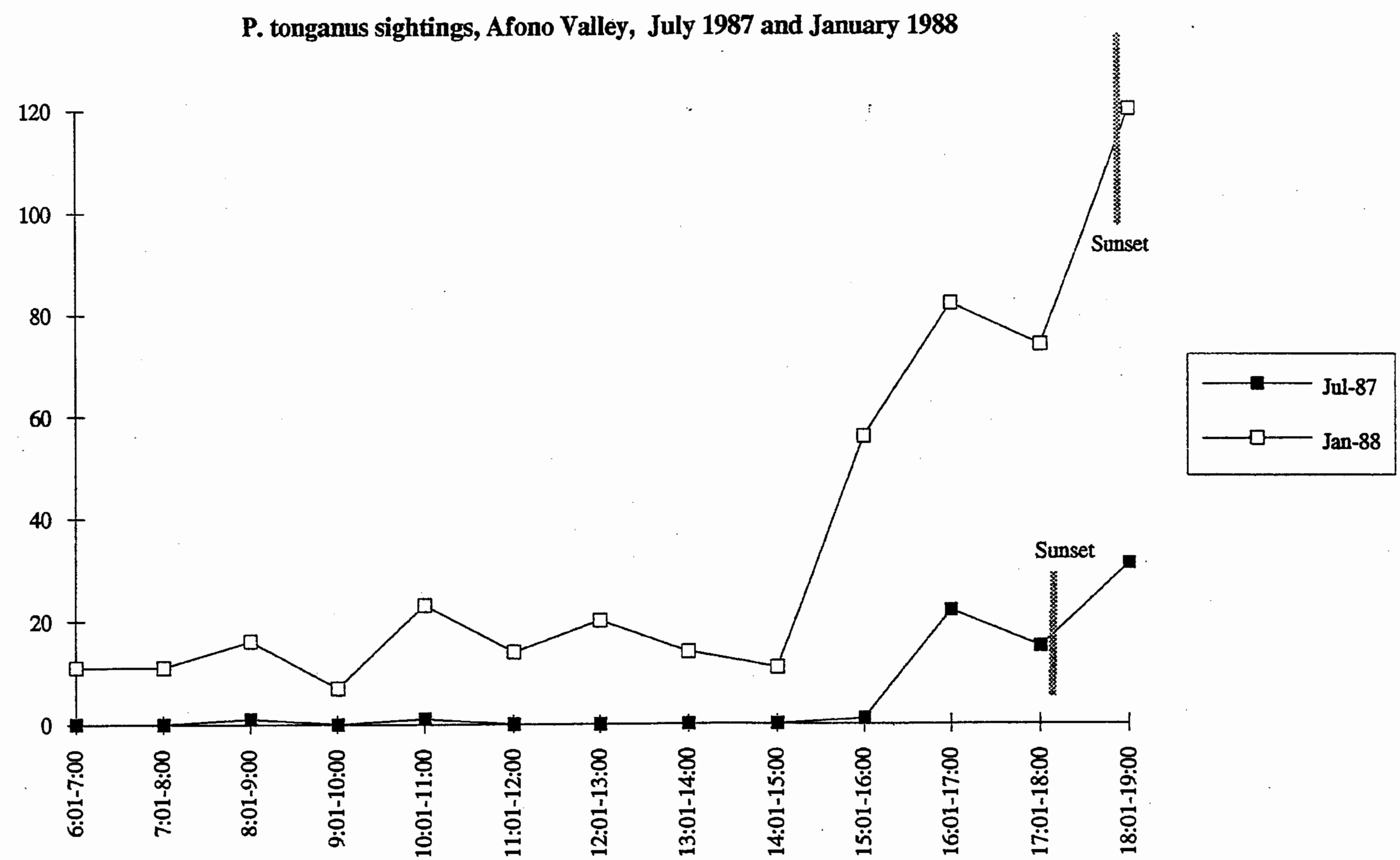

P. tonganus sightings, Afono Valley, July 1987 and January 1988
120
100
80
60
40
20
0
6:01-7:00
7:01-8:00
8:01-9:00
9:01-10:00
10:01-11:00
11:01-12:00
12:01-13:00
13:01-14:00
14:01-15:00
15:01-16:00
16:01-17:00
17:01-18:00
18:01-19:00
Sunset
Sunset
Jul-87
Jan-88

Figure 1B

P. tonganus activity at Olovalu Crater roost, 17 January 1992

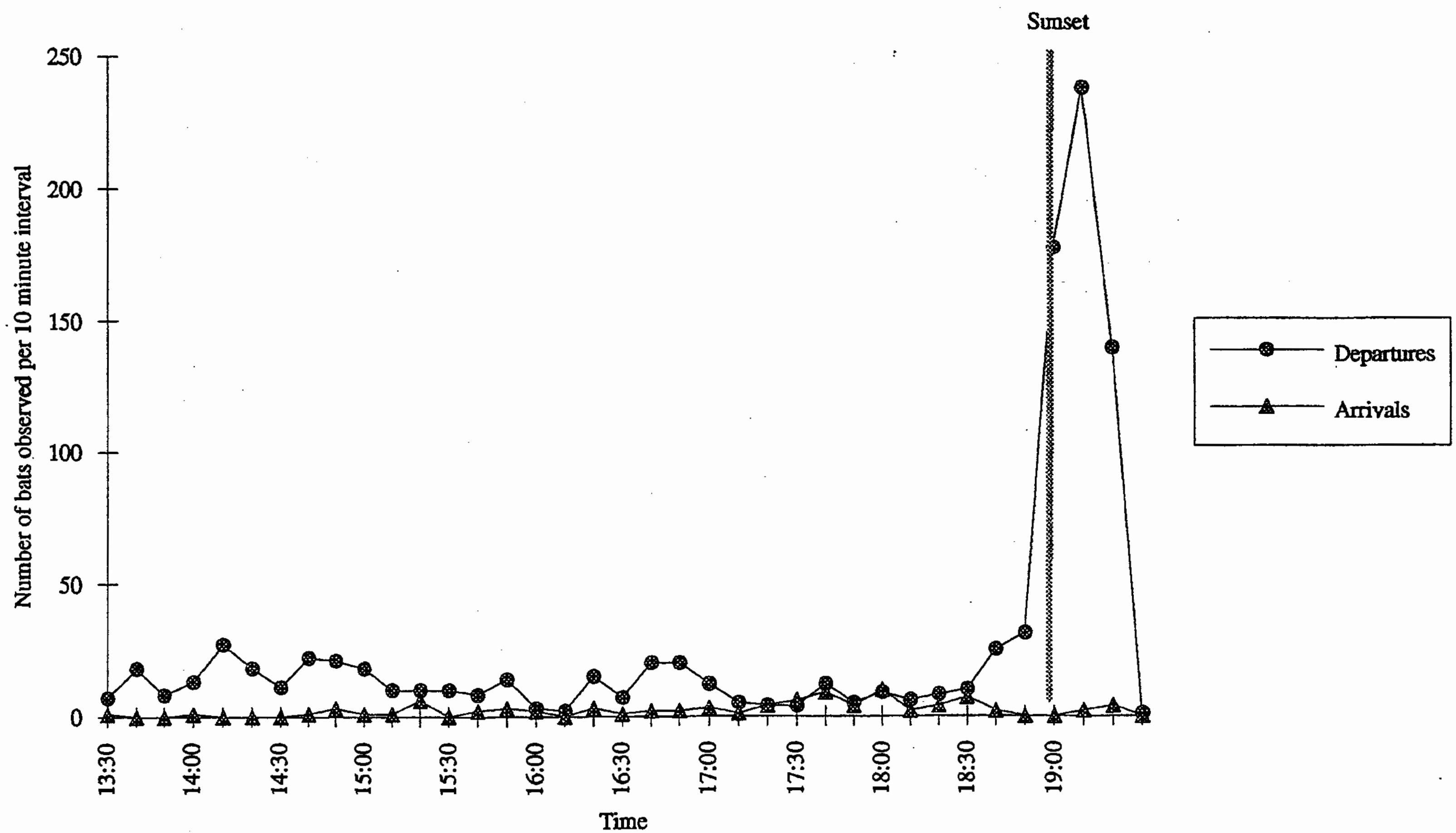


Figure 2

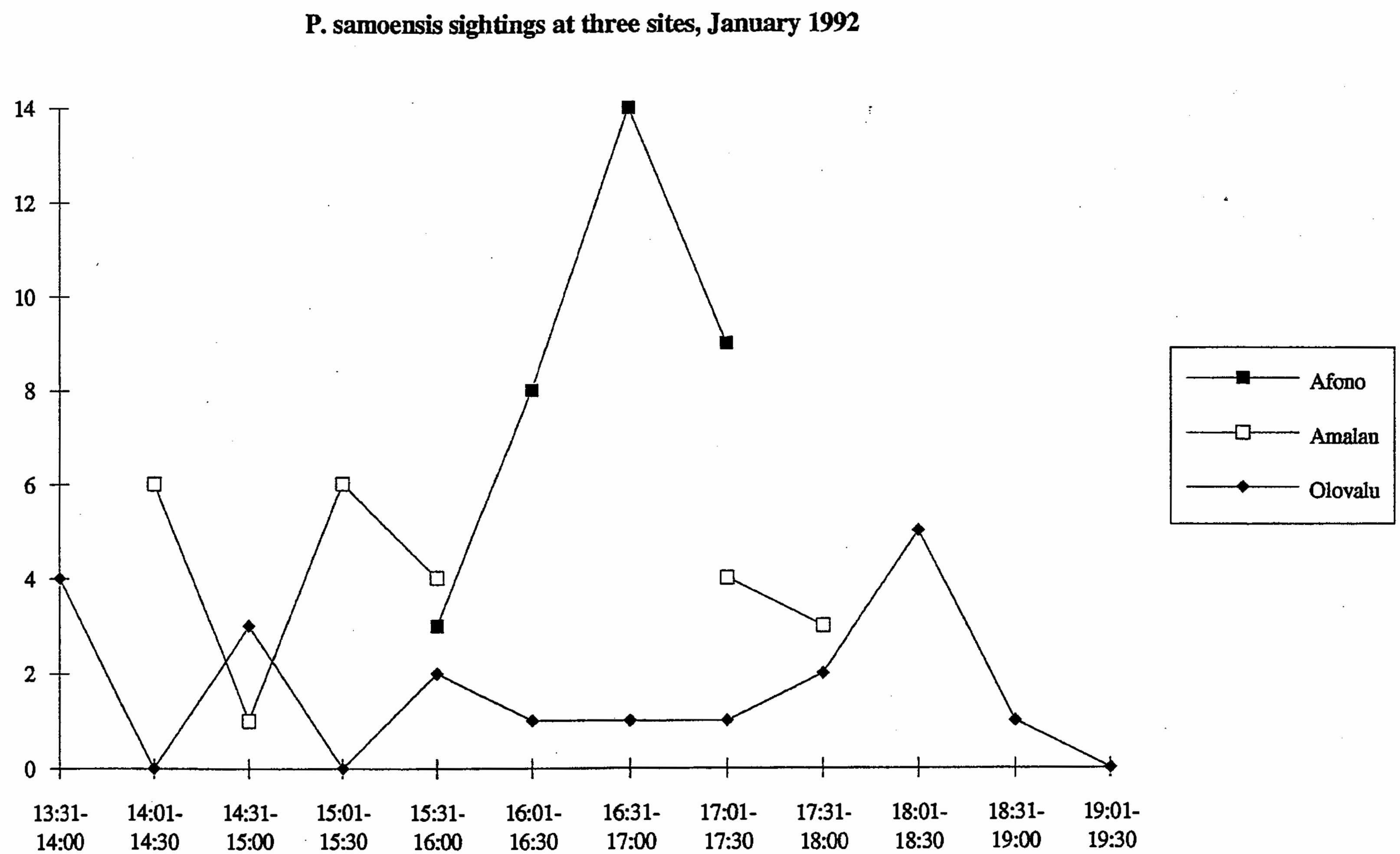

P. samoensis sightings at three sites, January 1992
14
12
10
8
6
4
2
0
13:31-
14:00
14:01-
14:30
14:31-
15:00
15:01-
15:30
15:31-
16:00
16:01-
16:30
16:31-
17:00
17:01-
17:30
17:31-
18:00
18:01-
18:30
18:31-
19:00
19:01-
19:30
Afono
Amalau
Olovalu

Figure 3

Total number of bat observations, 15:30- 17:00, January 1988 and 1992

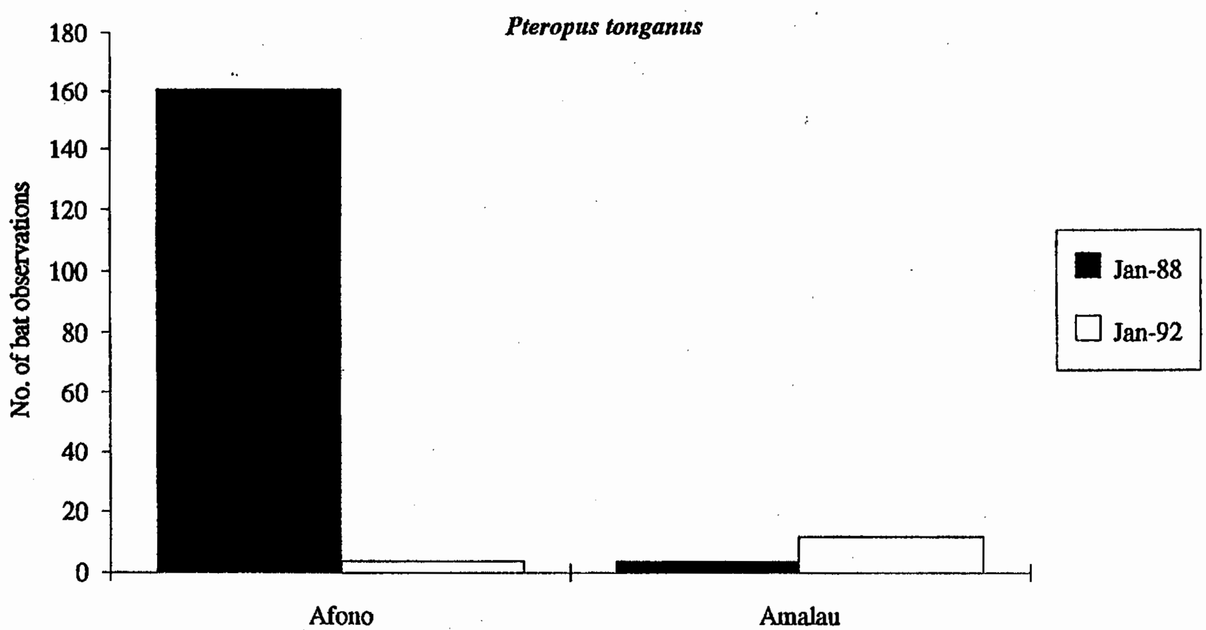


Figure 4A

Total number of bat observations, 15:30- 17:00, January 1988 and 1992

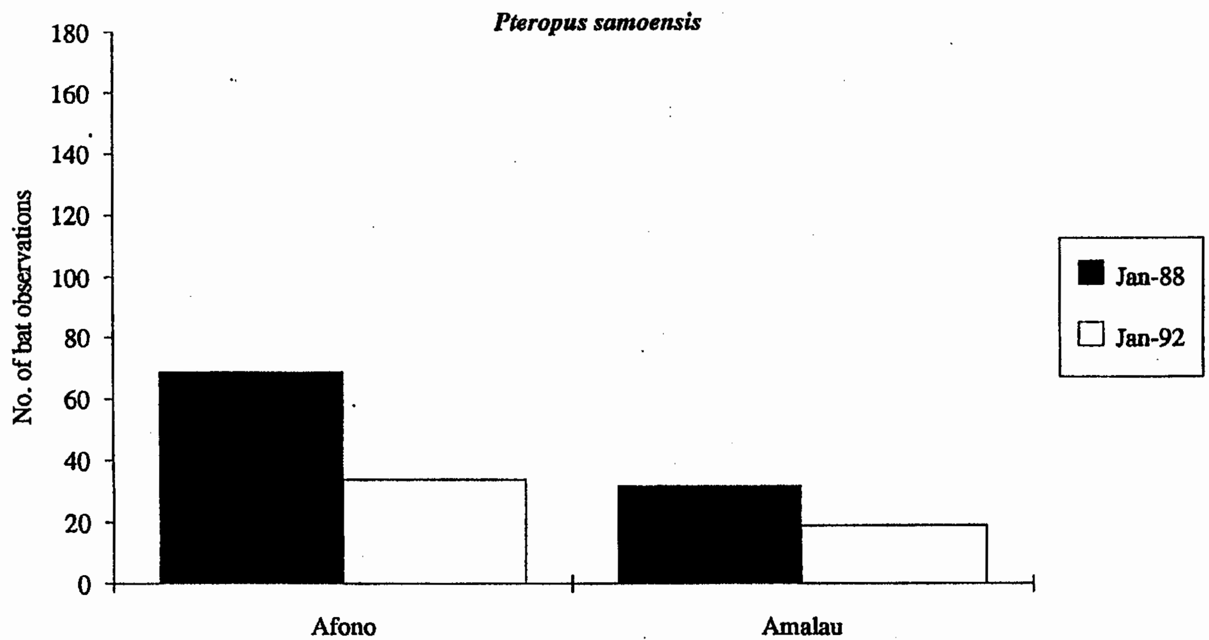
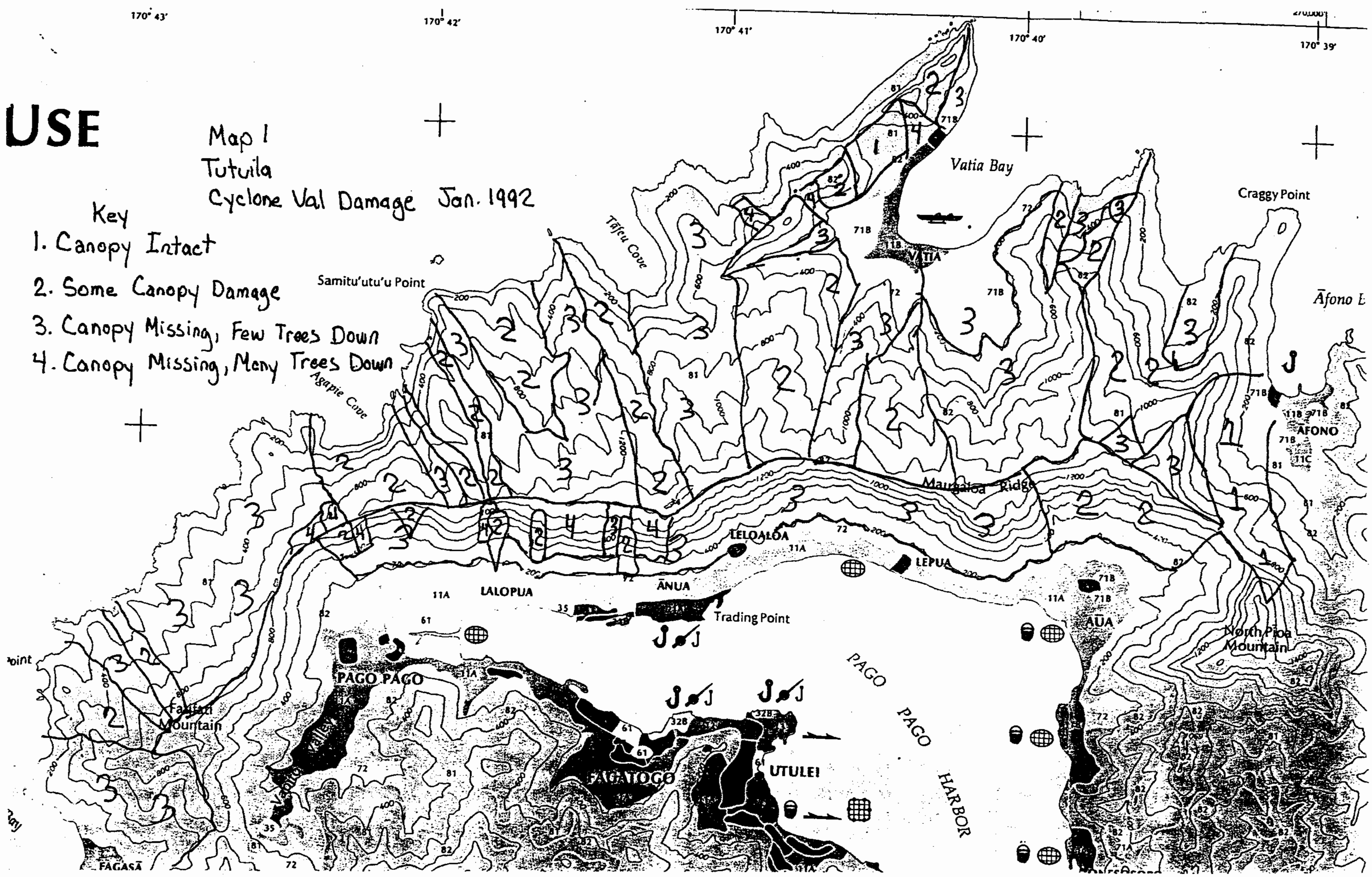
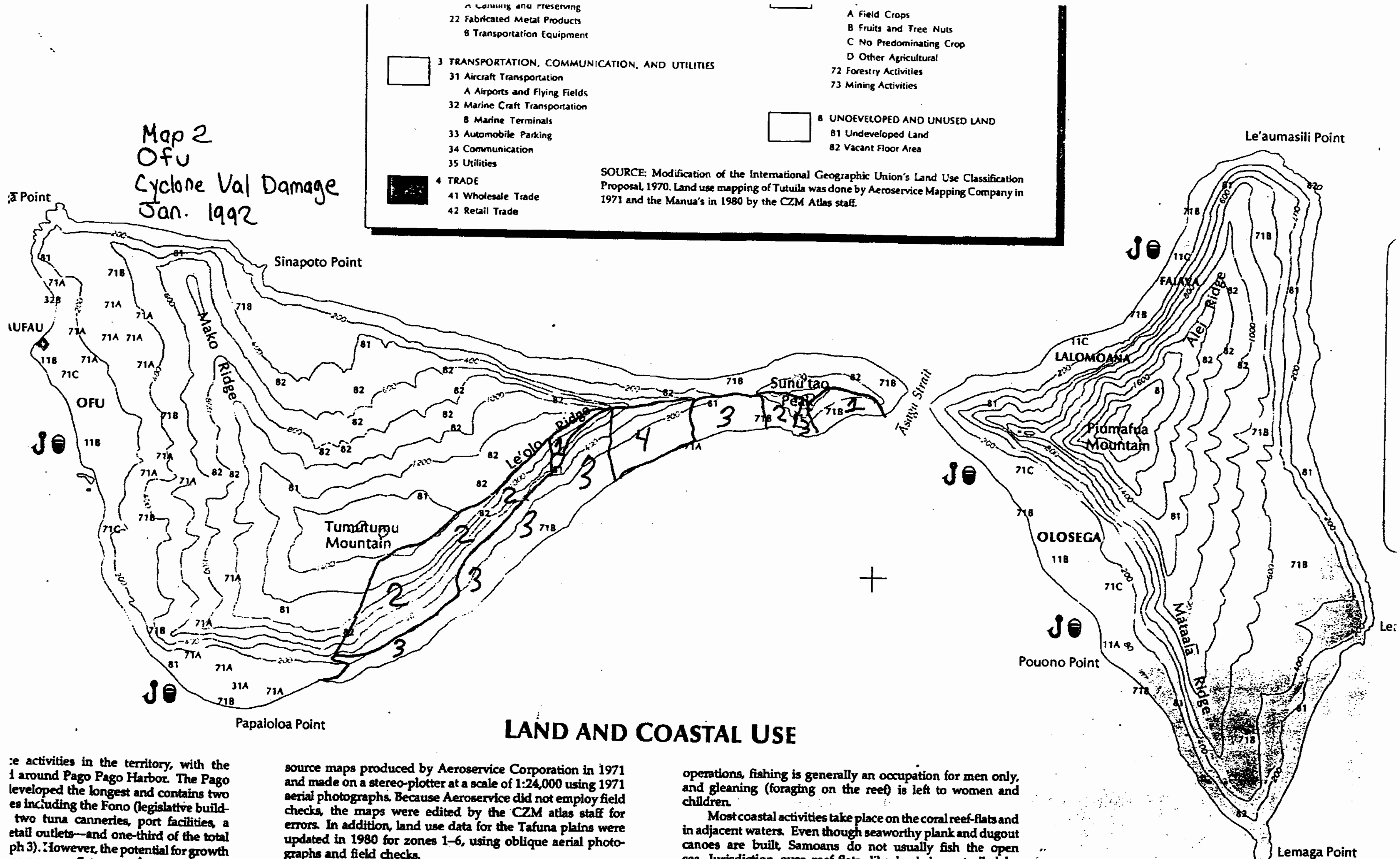


Figure 4B



USE
Map 1
Tutuila
Cyclone Val Damage Jan. 1992
Key
1. Canopy Intact
2. Some Canopy Damage
3. Canopy Missing, Few Trees Down
4. Canopy Missing, Many Trees Down
170° 43'
170° 42'
170° 41'
170° 40'
170° 39'
Samitu'utu'u Point
Agapie Cove
Tāfeu Cove
Vatia Bay
VATIA
Craggy Point
Āfono
AFONO
Maugaloa Ridge
LELOALOA
LEPUA
LALOPUA
ĀNUA
Trading Point
ĀUA
North Pioa Mountain
PAGO PAGO HARBOR
PAGO PAGO
FAGATOGO
UTULEI
Fagatele Mountain
FAGASĀ



LAND AND COASTAL USE

...e activities in the territory, with the ...1 around Pago Pago Harbor. The Pago ...leveloped the longest and contains two ...es including the Fono (legislative build- ... two tuna canneries, port facilities, a ...etail outlets—and one-third of the total ...ph 3). However, the potential for growth ...se no more flat or gently sloping land is ...ment. Therefore, most new growth is

source maps produced by Aeroservice Corporation in 1971 and made on a stereo-plotter at a scale of 1:24,000 using 1971 aerial photographs. Because Aeroservice did not employ field checks, the maps were edited by the CZM atlas staff for errors. In addition, land use data for the Tafuna plains were updated in 1980 for zones 1–6, using oblique aerial photographs and field checks.

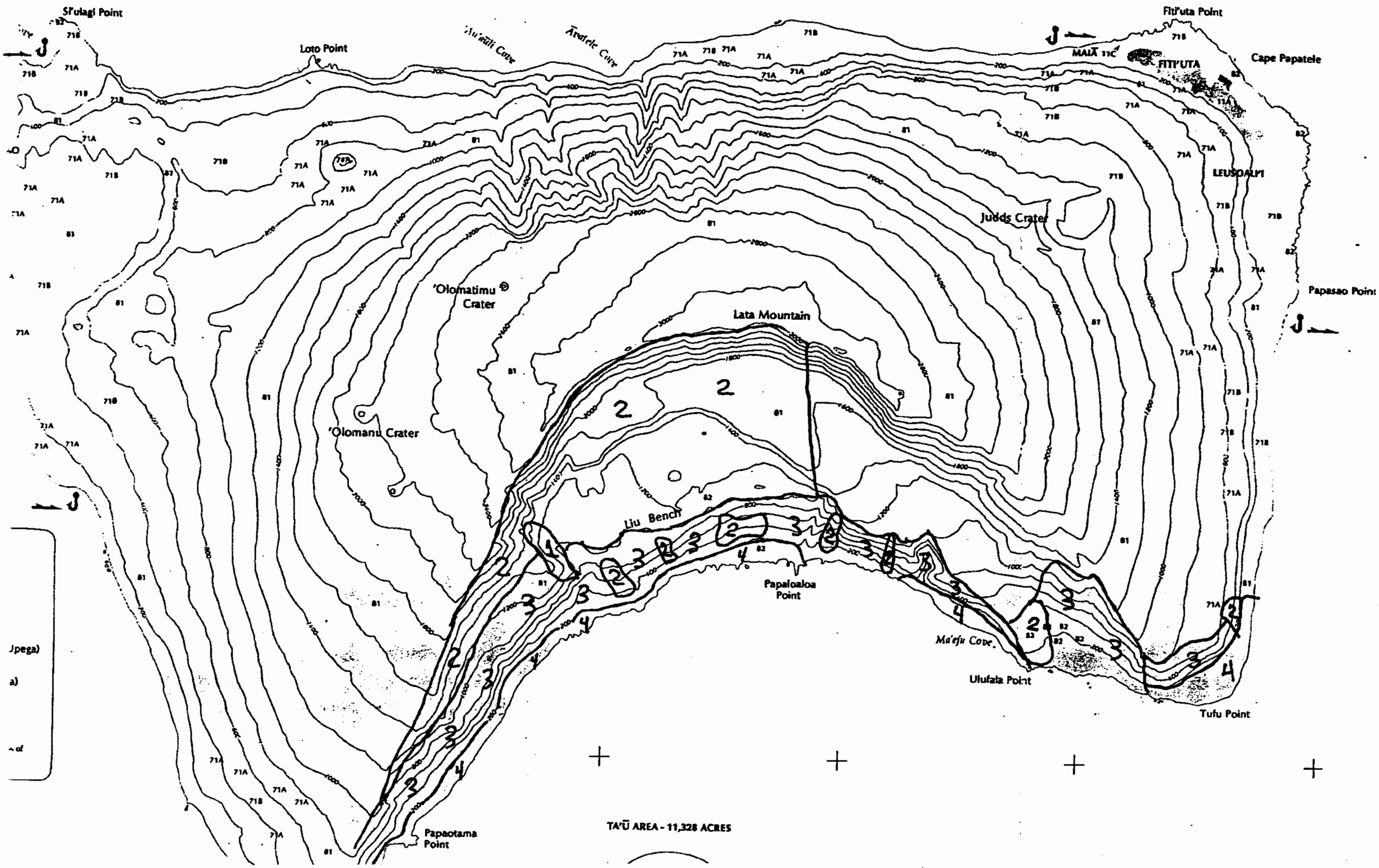
Prior to this project, land use maps were not available for ...

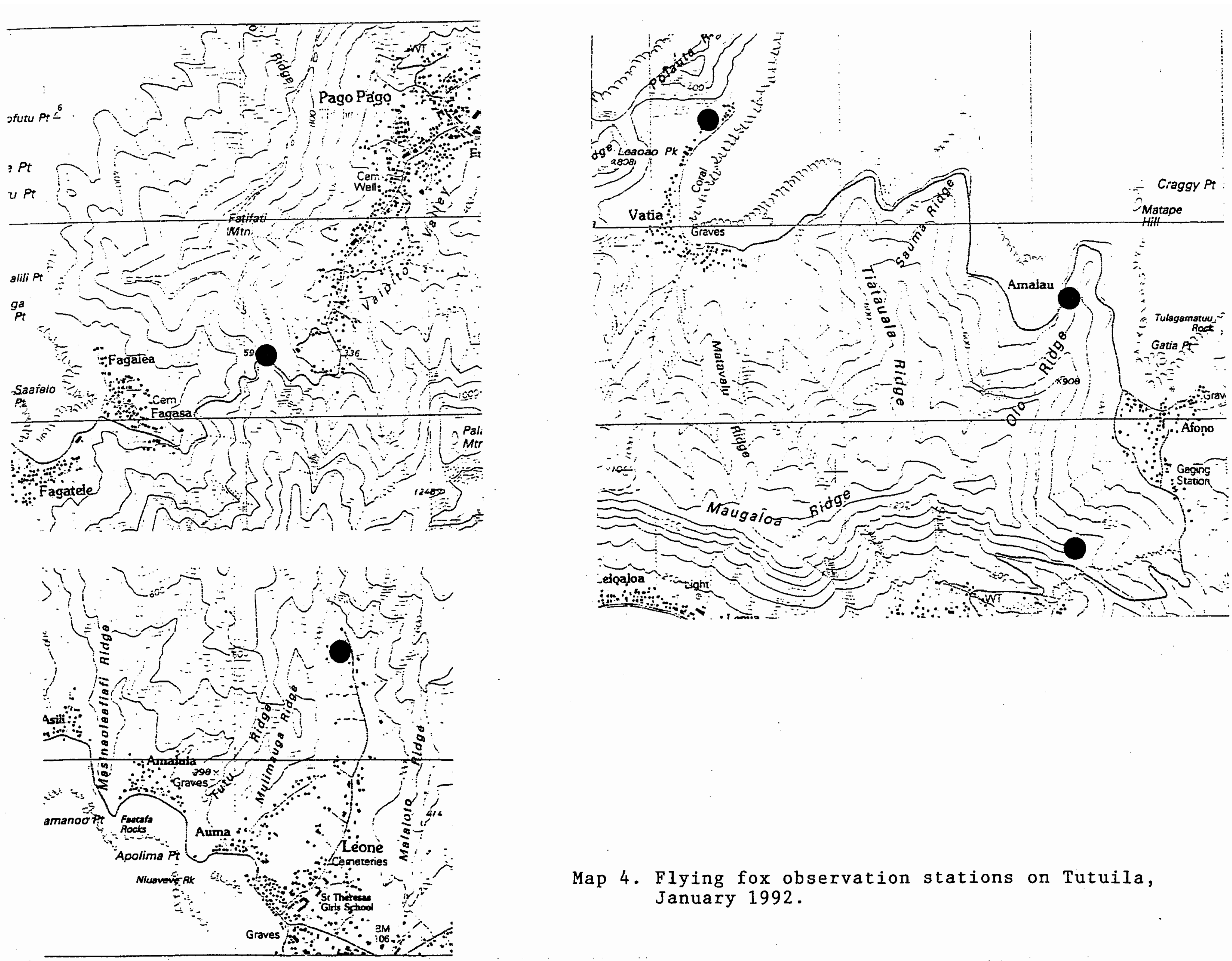
operations, fishing is generally an occupation for men only, and gleaning (foraging on the reef) is left to women and children.

Most coastal activities take place on the coral reef-flats and in adjacent waters. Even though seaworthy plank and dugout canoes are built, Samoans do not usually fish the open sea. Jurisdiction over reef-flats, like land, is controlled by village matais. In traditional Samoa, marine resources were

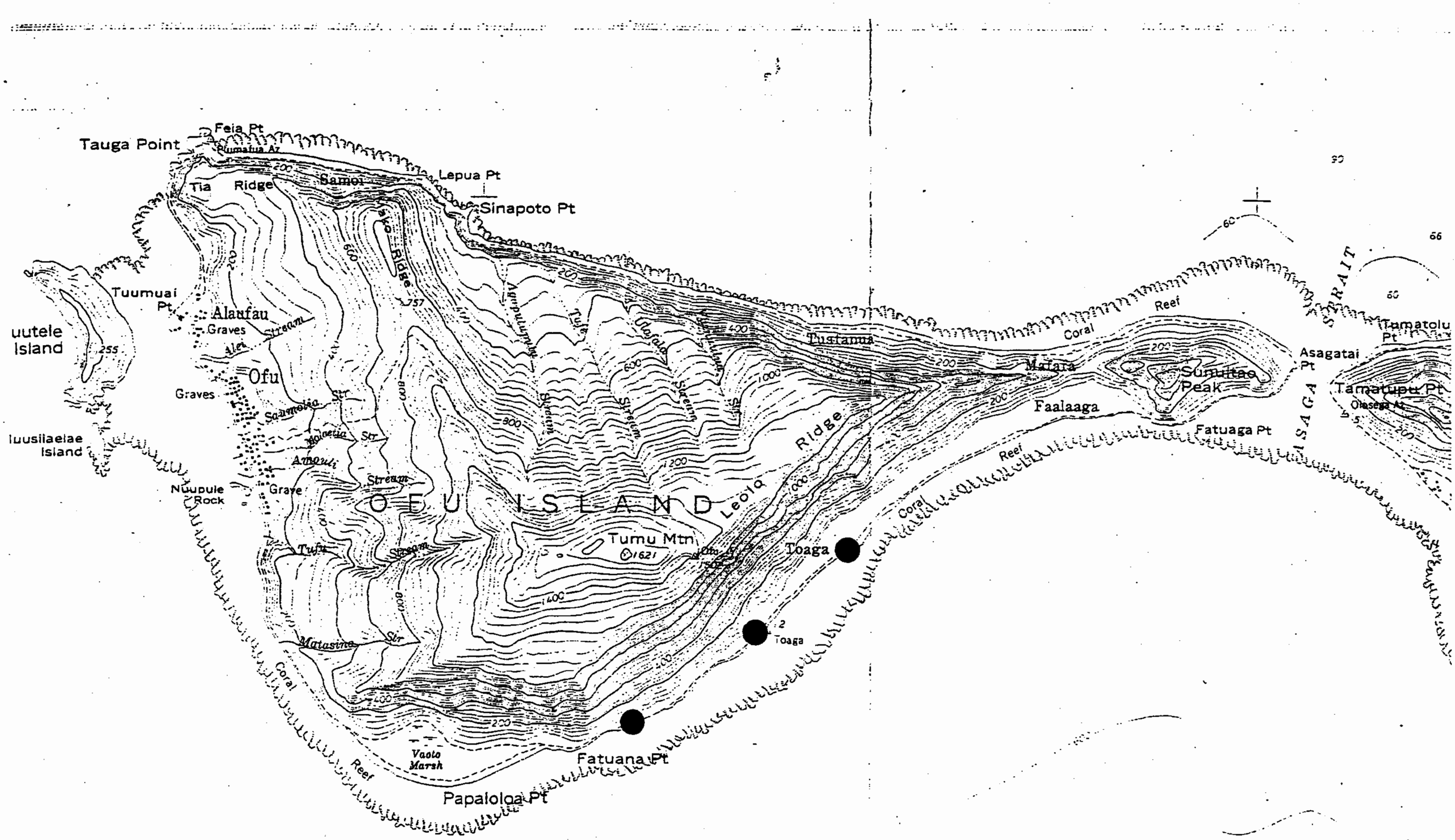
TA'Ū MAP 3
Cylcone Val Damage Jan. 1992

... was especially difficult. For further details refer to the main text.

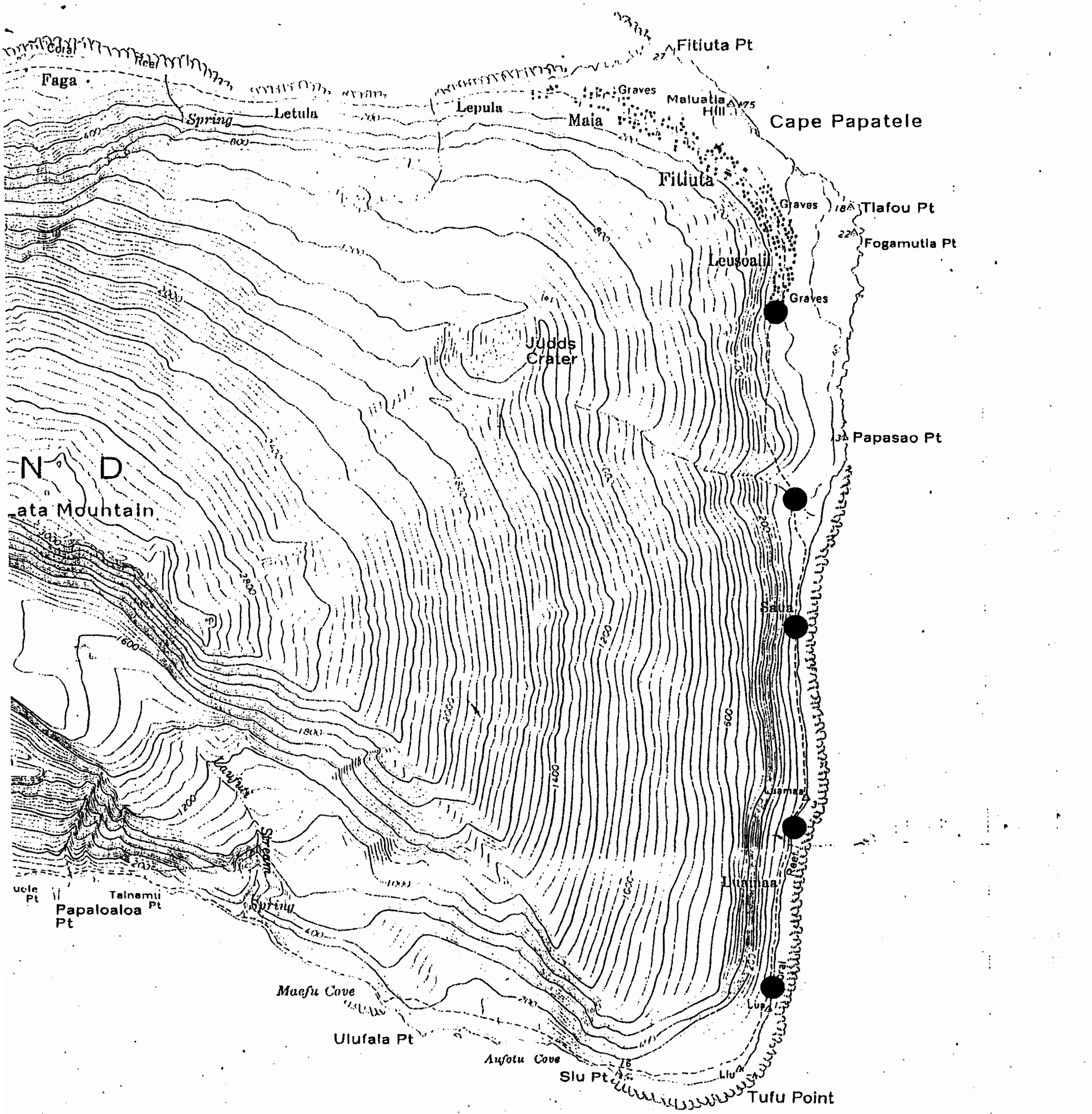




Map 4. Flying fox observation stations on Tutuila, January 1992.



Map 5. Flying fox observation stations on Ofu, January 1992



Map 6. Flying fox observation stations on Ta'u, January 1992.

Map 7. Probable P. samoensis roosting sites on Alava Ridge, January 1992.