RESULTS AND DISCUSSION

Forest composition

In the total 6 ha, we encountered a total of 54 tree species, not including the tree ferns which we recorded as *Cyathea* sp. (Appendix 1). Several of the tree species in the plots are uncommon to rare in American Samoa. These include *Celtis harperi*, *Litsea samoensis*, *Crateva religiosa*, and *Euodia hortensis*. *Dysoxylum samoense* was the most abundant species across all four plots, followed by *Artocarpus altilis* and *Hibiscus tiliaceus*. However, there was substantial variation among plots in terms of composition and diversity.

A total of 18 species were found in the Coastal Plantation. This plot was dominated by *D. samoense*, with *Macaranga harveyana*, *A. altilis*, and *Cocos nucifera* of secondary importance (Appendix 1). In the Coastal Forest, we encountered 16 species. The plot was dominated by *D. samoense*, accounting for about 41% of all trees. Of secondary importance was *Diospyros samoensis*, *Sterculia fanaiho*, and *Pisonia umbellifera* (Appendix 1).

In the Upper Plantation, 26 tree species were recorded. This plot was heavily dominated by *A. altilis* and *D. samoense*, with *Ficus scabra* a distant third in importance (Appendix 1). There were 70 stems of *Morinda citrifolia*, several large *Spondias dulcis* trees, along with one *Carica papaya* stem and one *Syzygium malaccense* tree. In the Upper Forest, a total of 35 species were encountered. *H. tiliaceus* was the most common individual, followed by *Myristica inutilis* (Appendix 1). This plot contained good populations of *Trichospermum richii* and *Pometia pinnata*, both of which were absent from the NPSA plots on Tutuila (Webb and Fa'aumu 1999). This plot also contains *Celtis harperi*, *Litsea samoensis* and *Euodia hortensis*, which were uncommon in American Samoa and absent from the National Park plots on Tutuila.

Of particular interest was the finding of several non-native *Flueggea flexuosa* individuals in the Coastal Plantation and the Upper Forest. To date there have been no formal reports of *F. flexuosa* establishing in natural forest outside of homesteads, so these plots demonstrate that *F. flexuosa* can naturalize in native forests of American Samoa.

Table 2. Diversity indices of the four permanent forest plots, Ta'u.

Diversity Index	**Coastal Plantation**	**Coastal Forest**	**Upper Plantation**	**Upper Forest**
Richness	18	16	26	35
Simpson's λ	0.18	0.21	0.25	0.15
Shannon's H'	2.08	1.99	1.84	2.47
Modified Hill Evenness Ratio	0.65	0.59	0.58	0.51
Stem Density (number / ha)	459	327	588.5	633.5
Basal Area / Ha	23.78	31.42	27.23	29.27

Table 3. Morisita-Horn similarity indices among the four plots.

	Morisita-Horn Index of similarity		
	Coastal Plantation	**Coastal Forest**	**Upper Plantation**
Coastal Forest	0.779		
Upper Plantation	0.702	0.518	
Upper Forest	0.140	0.188	0.163

Diversity indices revealed that in addition to the highest species richness, the Upper Forest was most diverse in terms of Simpson's λ and Shannon's H' (Table 2). On the other hand, the modified Hill Ratio – which approaches zero as one species becomes increasingly dominant in the community – suggests that the species in the Upper Forest were the least evenly distributed. This is probably because of the heavy dominance of *H. tiliaceus* in the Upper Forest. The relatively greater dominance of *H. tiliaceus* over species ranks 2, 3, and 4 than in other plots resulted in a low evenness index.

Morisita-Horn Indices revealed high similarities between the Coastal Plantation and the Coastal forest (0.779) and between the Coastal Plantation and the Upper Plantation (0.702) (Table 3). Moderate similarity existed between the Coastal Forest and the Upper Plantation (0.518), and low similarity was exhibited between the Upper Forest and any of the other three plots (<0.200 for each). Thus, compositional similarities were greatest among the two lowest-diversity plots, with the least similarity between the highest diversity plot and any other plot.

Forest structure

Forest structure varied across the four plots. Tree densities ranged from 327 ha^{-1} in the Coastal Forest to 633.5 ha^{-1} in the Upper Forest (Table 2). The Coastal Plantation and Upper Plantation were intermediate, with 459 trees ha^{-1} and 588.5 trees ha^{-1}, respectively. Basal areas ranged from 23.8 m^2 ha^{-1} in the Coastal Plantation to 31.42 m^2 ha^{-1} in the Coastal Forest. The Upper Plantation and the Upper Forest plots were intermediate, with 27.2 m^2 ha^{-1} and 29.7 m^2 ha^{-1}, respectively. The Coastal Forest had few small trees, resulting in low tree density values, but massive *Dysoxylum* trees that accounted for 24.1 m^2 ha^{-1}, i.e. 76.6% of the total plot basal area (Appendix 1). Species ranks according to total basal area were generally similar to abundance rankings. *D. samoense* was first in three of the four plots, with *H. tiliaceus* ranking first in the Upper Forest.

A total of 372 trees in 31 species were multiple-stemmed (Table 4), which is 11.5% of all individuals, and 57% of the species. The coastal plots had proportionately fewer multiple-stemmed trees, 6.5% and 4.9% in the Coastal Plantation and the Coastal Forest, respectively. In contrast, 13.1% of the trees in the Upper Plantation, and 13.6% of the trees in the Upper Forest were multiple-stemmed. In terms of proportion of species with multiple-stemmed individuals, the numbers were consistent across plots. The Coastal Plantation had 9 species with multiple-stemmed individuals (50% of the total species), the Coastal Forest had 7 species (44%), the Upper Plantation 11 species (42%) and the Upper Forest 15 species (43%). Thus, whereas the number of trees with multiple-stems differed across sites, the proportion of species with multiple-stems did not.

Species that had notably high levels of multiple-stemmed trees included *A. altilis*, *Bischofia javanica* and *D. samoense* in the Upper Plantation, and *H. tiliaceus* and *Syzygium inophylloides* in the Upper Forest. However, for *A. altilis* and *D. samoense* it was very difficult to differentiate between multiple-stemmed individuals and genetically unique individuals that had established next to each other. It is most likely that multiple-stemmed trees in the Upper Plantation resulted from historical cutting during plantation management, such as with *B. javanica*.

Table 4. Frequency of individuals with multiple-stems in each plot.

	Coastal Plantation		**Coastal Forest**		**Upper Plantation**		**Upper Forest**		**Total**	
SPECIES	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Alphitonia zizyphoides							2	1.9	2	1.8
Artocarpus altilis	11	18.0			57.0	12.2			68	12.9
Barringtonia asiatica	5	33.3	2	20.0					7	28.0
Barringtonia samoensis					2	11.8			2	11.8
Bischofia javanica					19	26	2	4.3	21	17.6
Cerbera manghas							1	16.7	1	16.7
Diospyros samoensis			2	5.1					2	3.4
Dysoxylum samoense	2	1.3	2	1.5	46	14.6	10	11.9	60	8.7
Elaeocarpus floridanus							1	2.9	1	2.9
Erythrina variegata			2	100.0					2	100.0
Ficus scabra					9	8.3			9	5.5
Ficus tinctoria			1	100.0					1	25.0
Flacourtia rukam							4	13.3	4	12.9
Flueggea flexuosa	1	11.1							1	5.6
Garuga floribunda					2	25.0			2	11.1
Hernandia nymphaeifolia	3	30.0							3	30.0
Hibiscus tiliaceus					3	8.8	121	27.9	124	26.6
Litsea samoensis							1	50.0	1	50.0
Macaranga harveyana	1	1.3							1	1.3
Macaranga stipulosa					2	66.7	1	4.5	3	12.0
Morinda citrifolia	1	14.3			8	11.4			9	10.0
Myristica inutilis							5	3.9	5	3.5
Neonauclea forsteri							4	12.9	4	11.4
Pipturus argenteus					1	5.6			1	4.8
Pisonia grandis	4	19.0							4	10.8
Pisonia umbellifera			5	15.2					5	15.2
Planchonella garberi							1	8.3	1	8.3
Rhus taitensis					5	45.5	6	6.7	11	11.0
Sterculia fanaiho	2	66.7	2	6.1					4	4.9
Syzygium inophylloides							12	12.8	12	12.8
Trichospermum richii							1	4.8	1	4.8
Sum	30		16		154		172		372	
Percent stems	**6.5**		**4.9**		**13.1**		**13.6**			**11.5**
Percent species	**50**		**44**		**42**		**43**			**57**

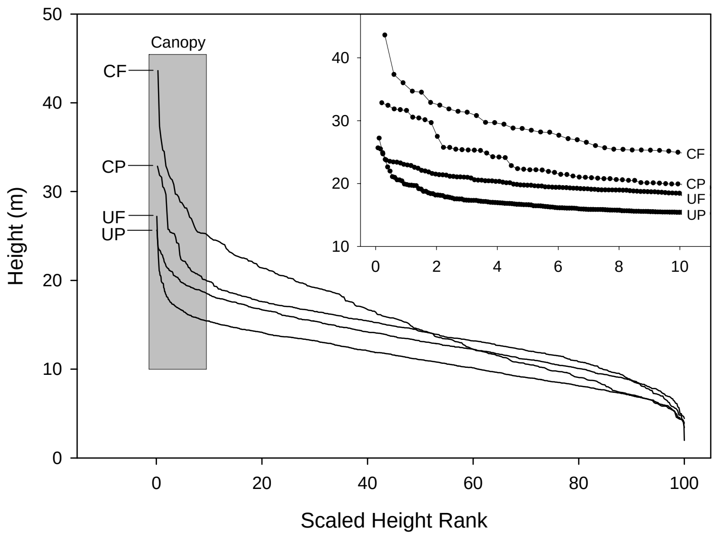


Figure 6. Rank-height diagrams for the four permanent plots, scaled to 0-100. The canopy was defined as the tallest 10% of all trees in the plot. The inset shows the rank height relationship for canopy trees only.

The Coastal Forest had the tallest canopy, which was defined as the tallest 10% of trees in each plot (Figure 6). The top 10% of trees were taller than 25 m in the Coastal Forest, 19.8 m in the Coastal Plantation, 18.3 m in the Upper Forest, and 15.4 m in the Upper Plantation (Figure 6 inset). These figures may not precisely measure the 'canopy height', which is the height of the upper contiguous tree crowns of a forest (Richards 1996). However, they can be considered general estimates of canopy height, and are accurate indicators of the difference in canopy heights among the plots. It is clear that the two coastal plots were taller than the upper plots. This difference becomes more evident if the comparison is made between analogous plots, where the Coastal Forest canopy was about 9.5 m taller than the Upper Forest, and the Coastal Plantation canopy was about 4.5 m taller than the Upper Plantation canopy.

The decline of the scaled-rank-height curves for the subcanopy was parallel for the Coastal Plantation, Upper Forest and Upper Plantation plots (Figure 6). This suggests that the plots had similar proportions of trees across the height spectrum. Vertical structural complexity of those three plots was therefore similar. However, the Coastal Forest curve declined at a faster rate than the other three plots. This indicates that the Coastal Forest had fewer mid-story trees relative to the other plots, suggesting a more simplified vertical structure than the other three plots. The simplified vertical structure was also evident with a lower proportion of trees with multiple stems (Table 4).

Table 5. The tallest 20 trees in each plot. In order to save space, the species coding system uses the first three letters of the genus name and the first three letters of the species name.

	Coastal Plantation			Coastal Forest			Upper Plantation			Upper Forest		
Rank	Species	DBH (cm)	Ht (m)	Species	DBH (cm)	Ht (m)	Species	DBH (cm)	Ht (m)	Species	DBH (m)	Ht (m)
1	PISGRA	100.5	32.8	DYSSAM	101.3	43.6	SPODUL	54.8	25.7	ALPZIZ	37.4	27.2
2	PISGRA	134.3	32.4	DYSSAM	63.7	37.3	SPODUL	67.2	25.5	SYZINO	38.0	24.9
3	DYSSAM	79.0	31.8	DYSSAM	84.5	36.0	SPODUL	53.2	24.7	PLAGAR	52.3	23.7
4	PISGRA	109.9	31.7	DYSSAM	93.5	34.7	ALPZIZ	39.0	23.8	SYZINO	45.4	23.5
5	DYSSAM	57.0	31.6	DYSSAM	71.8	34.5	SPODUL	67.7	22.6	DYSSAM	65.7	23.4
6	DYSSAM	54.8	30.5	DYSSAM	94.0	32.9	ALPZIZ	33.9	22.0	ALPZIZ	14.4	23.4
7	DYSSAM	77.5	30.4	DYSSAM	84.5	32.4	SPODUL	76.7	21.1	DYSSAM	44.0	23.3
8	DYSSAM	80.5	30.1	DYSSAM	98.9	31.8	DYSSAM	32.3	20.9	ALPZIZ	27.7	23.0
9	FICOBL	n/a	29.7	DYSSAM	93.7	31.5	ALPZIZ	49.4	20.6	SYZINO	57.8	22.9
10	DYSSAM	30.6	27.5	DYSSAM	97.7	31.3	SPODUL	41.7	20.6	ALPZIZ	33.6	22.9
11	DYSSAM	63.6	25.7	DYSSAM	65.9	30.8	ALPZIZ	15.0	20.4	SYZINO	54.1	22.6
12	HERNYM	57.4	25.7	DYSSAM	31.0	29.7	CANODO	39.8	19.9	ALPZIZ	22.6	22.4
13	ARTALT	40.7	25.4	DYSSAM	110.9	29.7	SPODUL	50.0	19.8	SYZINO	40.3	22.1
14	DYSSAM	57.6	25.4	DYSSAM	89.9	29.4	RHUTAI	34.7	19.7	ALPZIZ	39.6	22.0
15	DYSSAM	48.9	25.3	DYSSAM	62.3	28.8	DYSSAM	40.3	19.7	ALPZIZ	38.0	21.8
16	DYSSAM	31.4	25.3	DYSSAM	59.4	28.7	DYSSAM	35.4	19.7	RHUTAI	27.6	21.6
17	ARTALT	25.4	25.2	DYSSAM	73.6	28.5	DYSSAM	28.1	19.6	ALPZIZ	47.0	21.5
18	DYSSAM	34.2	24.8	DYSSAM	99.5	28.2	RHUTAI	61.3	19.2	ALPZIZ	37.3	21.4
19	ARTALT	40.5	24.2	DYSSAM	68.2	28.1	DYSSAM	38.0	19.1	STEFAN	21.8	21.3
20	DYSSAM	37.7	24.2	DYSSAM	93.2	27.7	ARTALT	26.6	18.7	ALPZIZ	20.9	21.3

The Coastal Forest contained the tallest tree of the 6 ha (43.6 m), and there were no other trees >40 m in the 6 ha (Table 5). This single tree could be considered the only true emergent tree in the 6 ha surveyed, because it was more than 5 m taller than the second tallest tree in the plot (Table 5). The set of the eight tallest trees in the Coastal Plantation were not emergents since their heights (30.1 – 32.8 m) were canopy height for the Coastal Forest only 50 m away, and this forest would be expected to revert to a *Dysoxylum*-dominated coastal forest in time. There were no emergent trees in the short-statured upper forest plots.

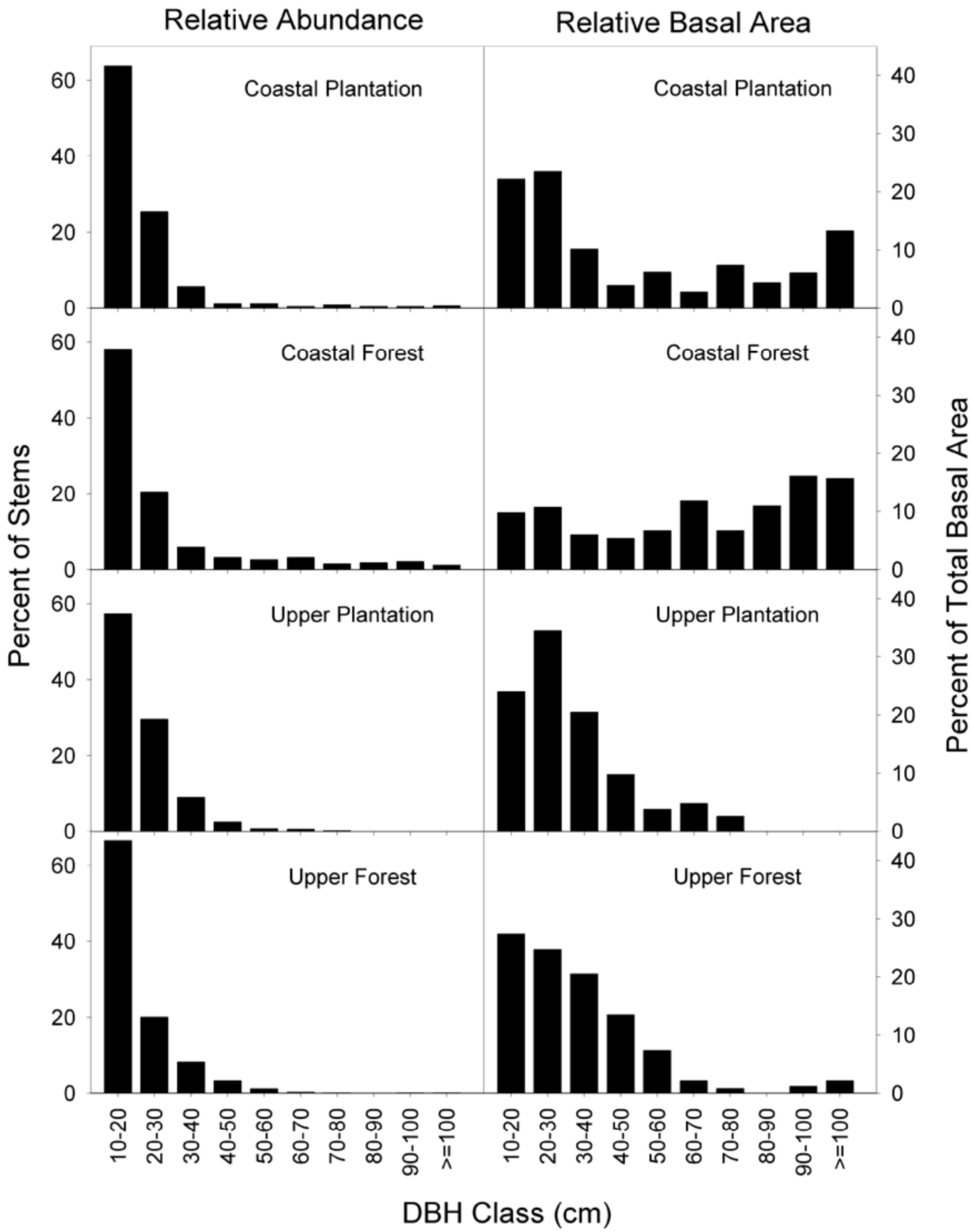
The species composition of the tallest tree group differed among the four plots (Table 5). *D. samoense* contributed greatly to the upper canopy composition of both coastal plots, and was the only species found in the upper canopy of the Coastal Forest. *Pisonia grandis* was an important feature of the upper canopy composition in the Coastal Plantation. In contrast, the tallest trees in the Upper Plantation consisted of the agroforestry species *S. dulcis* and the secondary species *A. zizyphoides*. Only one *D. samoense* tree was among the ten tallest trees in the Upper Plantation. The upper stratum of the Upper Forest canopy consisted primarily of *A.*

zizyphoides and *S. inophylloides*, with *D. samoense* contributing a minor component. Of the six *Planchonella garberi* trees in the Upper Forest, one was among the three tallest trees at that site.

In Figure 7 we compare the size class distributions of the tree communities across the four sites. In general the distribution of size classes was similar across sites, with the exception of the larger tree size classes in the Coastal Forest. In that plot, there was a higher proportion of large trees than in the other three plots. In contrast, the basal area class distributions varied substantially across the four plots (Figure 7). In the Coastal Plantation, the three basal area classes with the greatest contribution to overall basal area were 10 – 20 cm, 20 – 30 cm, and ≥100 cm dbh. In the Coastal Forest, the majority of basal area was contained in trees ≥80 cm dbh, with each class <80 cm dbh contributing similarly. In the Upper Plantation most of the basal area was in trees 10 – 40 cm dbh, and peaking in the 20 – 30 cm dbh class (about 35% total in that class). With no trees above 80 cm dbh in the Upper Plantation, there was no contribution of trees ≥80 cm dbh to plot basal area. The Upper Forest was similar to the Upper Plantation in that the three smallest size classes contributed the greatest to total community basal area, but the 10 – 20 cm dbh class contributed the most to basal area (about 27%). With only two trees ≥80 cm dbh, the contribution of large trees to total community basal areas was minimal.

There was variability in the size class distributions for six common species in the coastal plots (Figure 8). The only species that had similar size class distributions in both coastal sites was *F. scabra*, but this is not surprising because that species rarely achieves large dimensions. It is interesting to note, however, that in the Coastal Forest, we encountered one relatively large *F. scabra* tree of 31.4 cm dbh. The other five species, however, had substantial differences in their size class distributions between the two plots. *Barringtonia asiatica*, *D. samoense*, and *P. grandis* all showed higher numbers of trees 10 – 20 cm dbh in the Coastal Plantation. Moreover, in comparison with the Coastal Forest, *B. asiatica* and *D. samoense* had fewer large trees in the Coastal Plantation. In contrast, *Diospyros samoensis* and *S. fanaiho* had higher numbers of trees 10 – 20 cm dbh in the *Dysoxylum* coastal plot, in addition to greater abundances of larger trees, than in the Coastal Plantation.

Figure 7. Diameter and basal area class distributions for the trees communities of the four permanent forest plots, Ta'u.



Diospyros samoensis is known to be a shade-tolerant and slow growing species that requires long periods of time to reach 10 cm dbh. Our observations have been that seedlings have the capacity to survive in low light levels, and with very slow growth rates. Growth rate data for adult *D. samoensis* trees show that its growth rates are among the slowest of any species in American Samoa (E. Webb, unpublished data). Thus, the recruitment of seedlings into the 10 – 20 cm dbh class takes many years. The higher numbers of *D. samoensis* trees in all size classes in the Coastal Forest therefore suggests that the understory of the Coastal Forest had been subjected to lower intensities of disturbance, and may have had longer to recover from agricultural practices, than the Coastal Plantation.

One rather puzzling result is the difference in size class distributions of *S. fanaiho* between the two coastal plots. It is generally recognized that the Sterculiaceae, along with the closely related Tiliaceae, contain a high proportion of species that can be found in open to disturbed forests. Notwithstanding the fact that Webb and Fa'aumu (1999) found no difference in abundances of *S. fanaiho* among three forest plots on Tutuila (low sample sizes), we would have expected to see higher abundances of *S. fanaiho* in the Coastal Plantation, where light levels were higher. Lack of agreement with our expectation leads us to question whether *S. fanaiho* is an early-successional species that establishes in recently-disturbed forest, or whether it requires a closed secondary forest to be established before seeds can germinate and compete with other species. The fact that large *S. fanaiho* trees can be found in older-growth forest suggests that it is a 'persistent secondary' species. Alternatively, it is possible that seeds are being dispersed into the Coastal Plantation at slower rates than in the Coastal Forest. This could come about as a result of a lack of local seed source or fewer seed deposition events by dispersers (i.e. preference of birds for the Coastal Forest habitat over the Coastal Plantation habitat). Research needs to evaluate the germination and survival requirements of the species.

Six of eight species in the Upper Forest had higher levels of regeneration than the Upper Plantation (Figure 9). *Alphitonia zizyphoides*, *Cananga odorata*, *H. tiliaceus*, *Macaranga stipulosa*, *Rhus taitensis*, and *S. inophylloides* all showed higher numbers of trees in the 10 – 20 cm dbh class than the Upper Plantation. Of those species, all except *Cananga odorata* had more trees in all size classes; 30 – 50 cm dbh *C. odorata* trees were more abundant in the Upper Plantation. In contrast, *B. javanica* and *D. samoense* had more robust populations, with higher levels of 10 – 20 cm dbh trees, in the Upper Plantation than in the Upper Forest.

Figure 8. Size class distributions for important species in the two coastal plots.

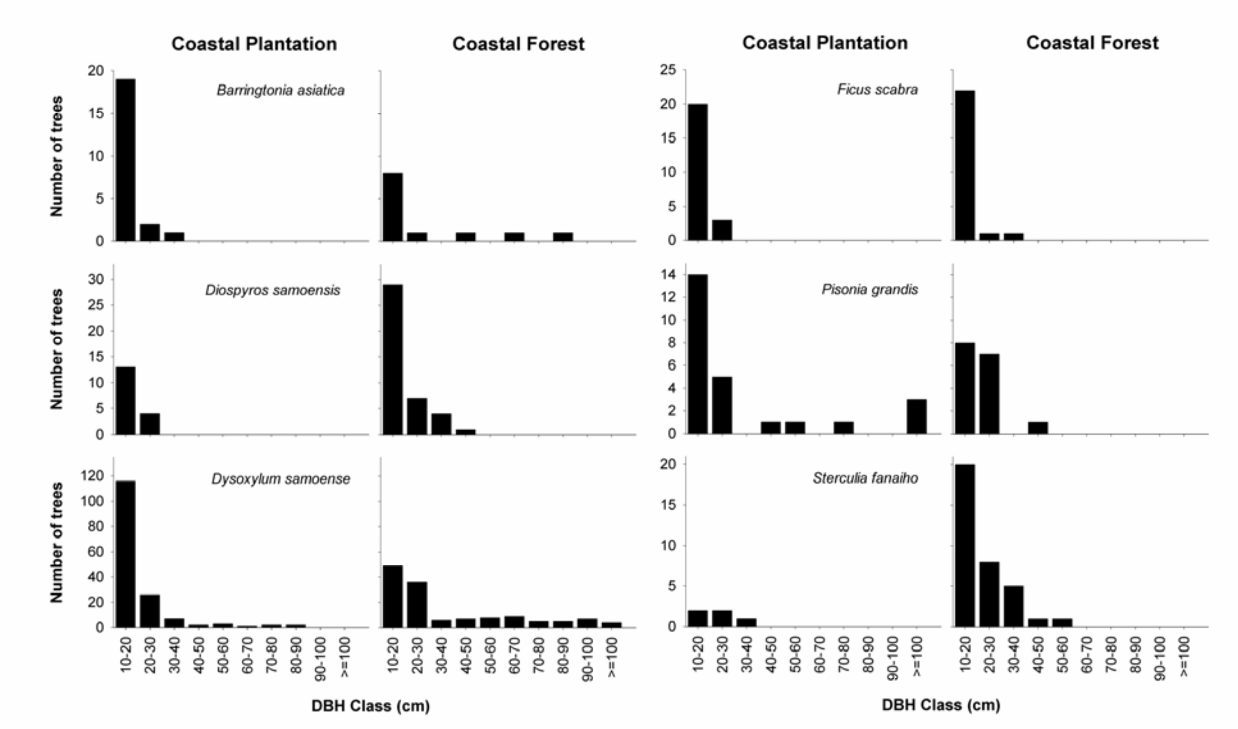


Figure 9. Size class distributions for important species in the two upper plots.

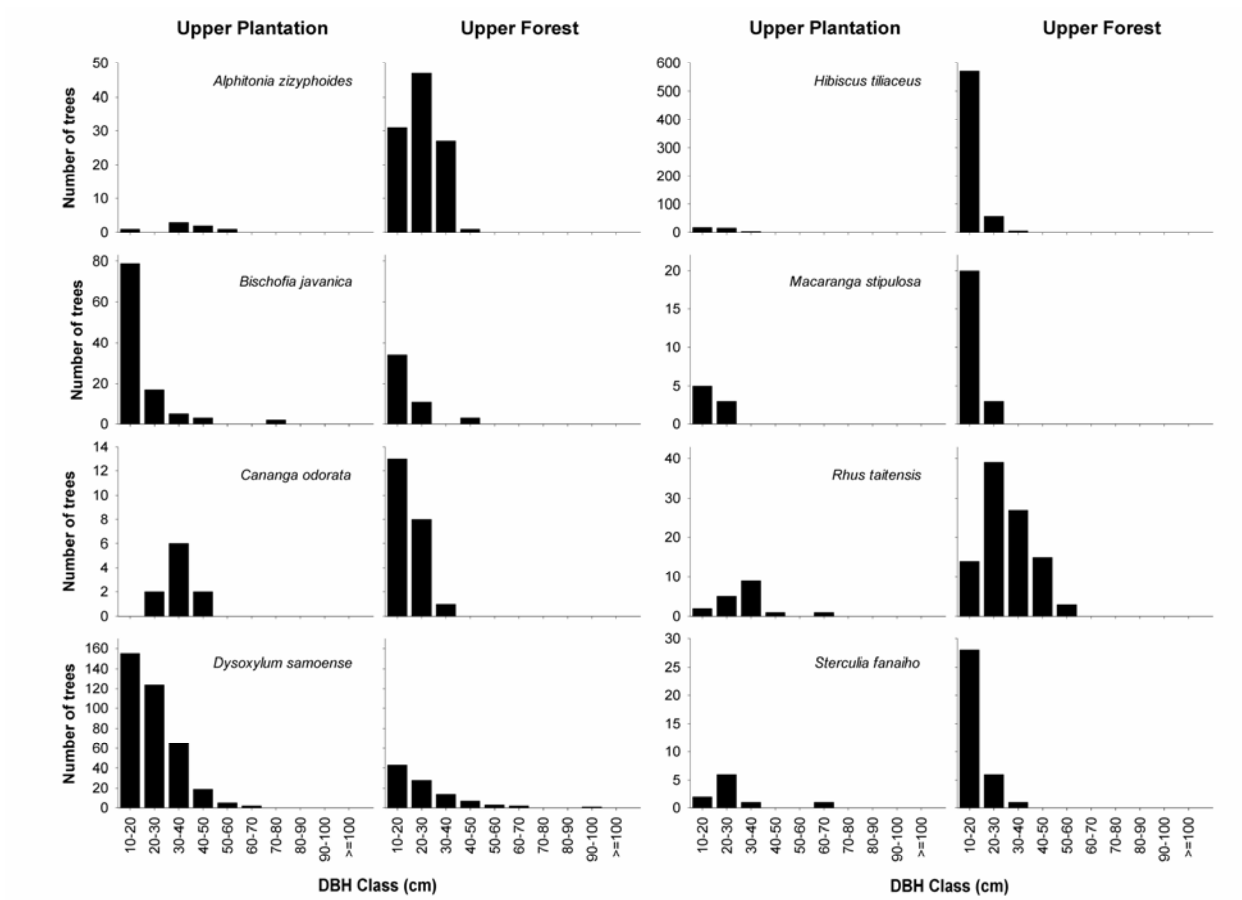


Table 6. Results of spatial analysis calculating Ripley's K for the most abundant species in each plot. The numbers in parentheses indicate the lag distances (m) at which the species exhibited clumping in that plot.

Rank	**Coastal Plantation**	***Dysoxylum* Coastal Forest**	**Upper Plantation**	**Upper Forest**
1	*D. samoense* (>1)	*D. samoense*	*A. altilis* (>0)	*H. tiliaceus* (>0)
2	*M. harveyana* (>0)	*D. samoensis*	*D. samoense* (>0)	*M. inutilis*
3	*A. altilis* (>1)	*S. fanaiho* (3-15)	*F. scabra* (1-4)	*A. zizyphoides* (1-30)
4	*C. nucifera*	*P. umbellifera*	*B. javanica* (>9)	*S. inophylloides* (15-35)
5	*F. scabra* (>5)		*M. citrifolia* (>13)	*R. taitensis* (5-25)
6				*D. samoense* (13-32)

These results are different than our expectation based on apparent intensity of disturbance and forest physiognomy in the upper plots. On Tutuila, Webb and Fa'aumu (1999) found higher abundances of *A. zizyphoides*, *B. javanica*, *C. odorata*, *H. tiliaceus*, *M. stipulosa*, and *R. taitensis* in a regenerating forest (Alava) than in mature forest (Amalau or Vatia). On Ta'u, what we considered to be more mature forest had higher abundances of all those species except for *B. javanica*.

Tree dispersion patterns

There was substantial variation between the two coastal plots in the spatial distributions of important species (Table 6, Appendix 2). In the Coastal Plantation, four of the five most common species exhibited clumping at all lag distances (except *F. scabra*, which was not clumped for 1 – 5 m lag distances). In contrast, only *S. fanaiho* exhibited clumping in the Coastal forest, at 3 – 15 m lag distances.

The spatial distribution of abundant species also varied across the two upper plots. In the Upper Plantation, all five of the abundant species were clumped, and the minimum lag distance of clumping increased with species rank (Table 6). In contrast, in the Upper Forest *M. inutilis* exhibited no clumping; however aside from that species a similar trend of increasing minimum lag distance was apparent.

Table 7. Height class distribution of Cyathea *spp. tree ferns in the two upper plots.*

Height (m)	Upper Plantation	Upper Forest
<2.0	0	4
2.0-2.9	1	72
3.0-3.9	1	95
4.0-4.9	0	116
5.0-5.9	0	50
6.0-6.9	1	10
7.0-7.9	0	2
8.0-8.9	0	8
9.0-9.9	3	5
10.0-10.9	2	3
11.0-11.9	0	5
12.0-12.9	1	4
13.0-13.9	0	2
14.0-14.9	0	2
Total	9	378

Tree fern community

Tree ferns were only found in the two upper plots. A total of 388 tree ferns were encountered, of which 379 were in the Upper Forest. In the Upper Plantation, the nine tree ferns ranged in heights, with six of the nine tree ferns greater than 9.0 m. In contrast, of the 378 tree ferns in the Upper Forest, the vast majority was less than 6.0 m tall (Table 7).

The finding that no tree ferns were present in the Coastal Forest was probably due to the substratum in the coastal plots, which was most likely not suitable for *Cyathea*. The large difference in tree fern densities between the Upper Plantation and the Upper Forest plots may have been due to substrata differences, disturbance differences, or a combination of the two. A visual comparison of the spatial maps of *Cyathea* and *H. tiliaceus* in the Upper Forest suggested that there may be a negative association between those two species. Assuming that *H. tiliaceus* is an indicator of past disturbance, then the hypothesis could be generated that *Cyathea* populations are associated with less disturbed forest patches, and therefore less overall-disturbed forests. Further investigation of the tree fern – forest disturbance association should be undertaken in the future.

Forest history, disturbance and condition

The Upper Forest canopy was dominated by *S. inophylloides*, *R. taitensis*, *D. samoense*, and *A. zizyphoides*. *R. taitensis* and *A. zizyphoides* are considered to be dominant early-successional trees (Drake *et al.* 1996, Franklin *et al.* 1999), but *S. inophylloides* is a late-successional species. Thus, despite the lack of evidence for agricultural disturbance, this result confirmed earlier observations (Whistler 1992) that the forests along the eastern slope of Ta'u have been strongly impacted by disturbance and are in a state of succession. The presence of *S. inophylloides* indicates that if left undisturbed, the plot will mature into *Syzygium*-dominated mixed lowland forest (Whistler 1992). Increasing dominance of *S. inophylloides* in later-successional forests may be due to the dense wood of the species, which presumably allows it to persist in hurricane-disturbed forest relatively more successfully than other species (Whistler 1992, Webb *et al*. 1999). Over time, resistance of *S. inophylloides* to hurricanes, when other species would be uprooted, snapped or severely damaged, would allow them to attain canopy stature and become an important canopy component. Given a long enough period of recovery after a cyclone (in this case since Tusi in 1987), structure and diversity could return to more mature-phase conditions.

Variability in composition and structure of the plots reflects the agricultural histories we were able to ascertain from interviews. In the Coastal Plantation, nearly 25% of the relative abundance and relative basal area consisted of *A. altilis* and *C. nucifera*, and in the Upper Plantation *A. altilis* alone comprised 40% of the relative abundance and 32% of the relative basal area. Prolific regeneration of *A. altilis*, which was evident during our field research, served to maintain dominance of this important agroforestry species in former plantations. Monitoring the two plantation plots will reveal the dynamics and compositional changes associated with succession in abandoned plantations (see also Franklin *et al.* 1999).

Cyclones are an important factor in shaping forests of Samoa and Polynesia in general (Elmqvist *et al.* 1994, Elmqvist *et al*. 2001, Hjerpe *et al.* 2001, Franklin *et al.* 2004). Webb *et al.* (1999) found significant differences in canopy height as a function of topography on Tutuila, with well-protected valley forests being significantly taller than exposed ridge forest. The escarpment between the coastal plots and the upper plots is an obvious topographical feature, and could potentially affect the amount of damage sustained by forests during catastrophic events. For example, in Fiji, 72% of the 50 recorded tropical storms (including cyclones) that passed within 180 nautical miles of Lautoka (Viti Levu) came from the northwest (Brand 2003). Storm trajectory will affect both directionality and force of the winds striking a particular point. In the case of Ta'u it is possible that the coastal plots, which were taller than the upper plots, have been more protected from wind disturbance in the recent past than the upper plots.

Successional development generally results in older forests having greater basal area than younger forests but not necessarily fewer stems (Aide *et al.* 1995, Guariguata and Ostertag 2001, Franklin 2003). In this study, basal area was greater in both forest plots than their corresponding plantation plots. Stem density in the Coastal Plantation was greater than the Coastal Forest, while the Upper Forest had greater stem densities than the Upper Plantation. The high stem densities in the plantations are due to the fact that trees such as *A. altilis*, and *C. nucifera* were already present at the time of abandonment. Indeed, calculating total stem density and basal area in each plot without including those two species dramatically reduces those values. In the Coastal Plantation, stem densities and basal area would be reduced to 348 trees ha^{-1} and 18.2 m^2 ha^{-1}, while the Upper Plantation would be reduced to 353 trees ha^{-1} and 18.3 m^2 ha^{-1}.

Greater overall canopy heights in the forest plots than their corresponding plantation plots may reflect the land management techniques of clearing large trees in heavily disturbed plantation areas. Large trees would be removed for plantations because the root systems and wide crowns would reduce agricultural output. Long-term monitoring of the compositional and structural changes of these plots will reveal the rate at which structural features change over time.

Exotic species in NPSA

Introduced species have become a common feature in the forests of American Samoa, but as yet they are not as threatening to native biodiversity as is the case in other island systems (e.g. Meyer and Florence 1996). Although 99% of all non-native stems in these plots were of species considered not to be a major threat to American Samoa, monitoring and proactive action must take place. For example, we found mature *F. flexuosa* trees in both coastal and upland forest on Ta'u. This species has been widely promoted as a potentially valuable tree in American Samoa for use as building material. The fruits of *F. flexuosa* are favored by several species of birds, including purple-capped fruit doves (*Ptilinopus porphyraceus*) and Pacific pigeons (*Ducula pacifica*) (J. Seamon, Department of Marine and Wildlife Resources, unpublished data).

Therefore, while it is not surprising that *F. flexuosa* escaped into natural forest, it is important to recognize it as a potentially invasive species. Other tree species in American Samoa have been introduced only to naturalize and become aggressive invasives, notably *Adenanthera pavonina*, *Castilla elastica* Cerv., and *Paraserianthes falcataria* (L.) I. Neilsen, the latter of which has been the focus of an intensive eradication program within the National Park of American Samoa. As of yet, there have been no reports of *P. falcataria* on Ta'u, but *C. elastica* has already arrived (E. Webb personal observation). We recommend that *F. flexuosa* be included in the list of potential invasive species for American Samoa. While the plots for this study will give a small sample size of trees to estimate growth rates and possibly localized regeneration, more thorough studies of the growth and regeneration of *F. flexuosa* in native forest of American Samoa are necessary to determine the level of threat posed by this species. At present, the low density of *F. flexuosa* does not make it a high priority for eradication efforts; monitoring of its presence in the forest would, however, be advisable.

Benefits of long-term monitoring for NPSA

Permanent forest plots allow research on the response of vegetation communities to natural disturbances such as hurricanes and human-induced disturbances (e.g. clearing for plantation). The plots we have established, particularly the two plantation plots, will provide unique data on the processes of succession following intensive agriculture and agroforestry activities. These can be compared to the dynamics of the apparently less-disturbed plots of the *Dysoxylum* coastal plot and the Upper Forest. Medium to long-term comparative data could lead to important management recommendations to reduce the level / impact of non-native plantation species in regenerating forest, improve the regeneration of native tree species, or ameliorate negative impacts of potentially invasive species.

Another important benefit of long-term vegetation data is the ability to evaluate forest dynamics within a changing environment. Cyclical changes in weather patterns (such as El Niño) are well documented, and long-term changes in regional weather patterns may also be taking place. Several papers have determined that long-term changes in weather patterns are having measurable impacts on ecosystems. For example, a recent report highlighted the impact of a changing regional climate on the phenology of forest trees in Uganda (Chapman *et al.* 2005). Although American Samoa is a remote island system in the South Pacific, it will not be immune to climate changes, and is impacted strongly by El Niño. Thus, the plots we have established can contribute to a better understanding of the impacts of climate change on terrestrial ecosystems.

Long-term ecological processes and changes in processes associated with climate change are best measured at the seedling and sapling size classes. Changes in habitat leading to favorable or unfavorable regeneration conditions will first be seen in changes in tree species regeneration. In the plots we established in this project, we only surveyed trees ≥10 cm dbh. It takes decades for small environmental changes to be reflected in changes in the tree community. However, it may take only several years to measure differences in recruitment rates that might be associated with environmental parameters such as an increase or decrease in rainfall. Thus, smaller plots should be established within the larger permanent plots to monitor the regeneration of tree communities from the seed and seedling stage. This will be much more labor-intensive than monitoring the tree community, but will reveal crucial information on the dynamics of the smaller size classes. This could serve as an early-warning system to park management.

ACKNOWLEDGMENTS

This research was supported by project number CA 8022-AO-001 of the Pacific Cooperative Studies Unit at the University of Hawaii. Field work was accomplished with the assistance of Saifoi Fa’aumu, Rachel Conejos, Vitale So’oto, Jr and Chey Auelua. Technical and logistical assistance was generously provided by Doug Neighbor and Peter Craig of the NPSA, and Ufagafa Ray Tulafono, Joshua Seamon and Ruth Utzurrum of the Department of Marine and Wildlife Resources, Government of American Samoa. Art Whistler provided assistance with species identification. Janet Franklin provided very helpful comments on an early version of this report. Satellite image processing was accomplished by Thiha. We especially thank High Chief Paopao and family, along with other residents of Fitiuta village, who provided oral histories.

The main field team in the Upper Forest plot. From left to right: Rachel Conejos, Edward Webb, Siaifoi Fa'aumu, Martin van de Bult, Md. Enamul Kabir, Wanlop Chutipong.