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Ke'e Lagoon and Reef Flat Users Baseline Study

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Abstract

Ke'e Lagoon is a popular Kauai destination for tourist and resident beach-goers and snorkelers. It is part of the Haena State Park, and is located at the end of Route 56 in Haena, Kauai. Also located at the end of the road is the trailhead to the Kalalau Trail, and an ancient Hawaiian Heiau (ancient Hawaiian religious temple). The area has become extremely popular with visiting tourists in the last few years, and this large amount of usage has prompted this study. The study has been done to conclude whether or not the recent human impact is having a detrimental impact on the lagoon and associated reef.

The survey was done in two parts. The first involved counting the number of people using the beach area, and determining the uses that occurred while these people were at the specific beach park area at the end of the road. One of the impacts of primary concern was the effect of humans walking on the reef flat of the area. The second part of the survey was to monitor the lagoon and reef flat area to detect if the human use had a detrimental effect on the marine life and the reef flat itself.

The first part of the survey was done with volunteers counting the people using the Ke'e beach area, and what the visitors did while they were there. The studies for this survey were done in June and July of 1999, and surveys are continuing by the Hui Maka'ainana O Makana (the local organization in the area committed to community based management).

The total number of visitors to the area has been estimated by the DLNR to be over 1700 per day, with 450 using the Kalalau trail (data from Limu Coalition – Dr. Ray Chuan). This leaves the total users of the lagoon area to be at least 1250 per day. Some casual observations were made of the Ke'e lagoon area by Carl Stepath in August. It appears that the usage is higher during this month, and continued data will be collected by the local Hui will be available on request.

The survey data shows that the peak time for human use during the study period was 4 p.m., with the high level of usage starting at 10 am and lasting until 6:30 p.m. The highest use was sunbathing, with snorkeling and swimming being the important recreational activity of the group. The mean number of people walking on the reef (Figure 8 as seen in appendix) was highest at 1:30 p.m. There did not seem to be any relationship between the tidal stage, and the total number of people at Ke'e, to the number of people walking on the reef. The observations of the data collectors concurred that very few of the people using the beach at Ke'e were residents of Kauai, and many of the local inhabitants seemed to be repulsed by the dense population of tourists at this one

particular spot. There are supposedly no commercial activities in the area, but commercial kayaking operations were witnessed at the very early morning in the lagoon. These kayak groups were transiting from the parking lot to the lagoon, and then kayaking down the coast. They did not return to the lagoon after leaving.

Two zones were surveyed and they bordered on each other (one as a control area). The third zone that is noted on the survey sheet was not used because of a shortage of volunteers. There was a tremendous difference in the usage of the two zones, with the tourist population being limited to the impact zone, and more traditional uses occurring farther down the beach. Only a very few tourists seemed to venture out m 100 m from the congested beach area near the parking lot.

The second survey was done with quadrats placed randomly on the reef flat area, and the percent reef cover was noted. There did seem to be a significant impact because of the tourists walking on the reef. This reef walking to and from the outer edge of the reef to see turtles and other marine life appears to be hurting the health of the reef flat area. This transit corridor has areas that are high in coral cover, and these corals are in danger from the inexperienced tourists and their shoes. The foot traffic appears to be causing the less amount of coral cover in the area as shown in Figures 7 & 8 (as seen in appendix).

This reef walking also poses a cultural problem. The local inhabitants are very upset by it. The Hawaiians use the reef for food collection and feel that the walking and suntan oil use in the area has a negative impact on the limu (algae) and marine life that they collect for food off the reef. This was not specifically studied, but the local residents seem to be convinced that it is true.

This is a single study, at one time of the year, at Ke'e Lagoon and should be used as a baseline for future studies. A fair amount of data was gathered that suggests major changes in the management of the area are needed. In order to effectively manage this area, more studies need to be done in the future, over a longer period of time. Improved facilities and management of the area could be facilitated by performing studies of this type for every season of the year to determine use patterns and populations for the area.

The area is not near to any major hotel, resort area, metropolitan center. Facilities for the tremendously high usage do not exist, and there is no supervision of people using the area. No lifeguards, no park rangers, no park attendants, limited toilet facilities and extremely restricted parking are a few of the problems that need to be worked out in the future. As the demand on these facilities continues to grow with the increased popularity of Ke'e, and the promotion of tourism, these problems will demand attention.

Introduction

Ke'e Lagoon is located on the Northern part of the island of Kauai, at the end of Route 56 in Haena (see map, Figure 1 as seen in appendix). It is located at the very beginning to the beautiful Na Pali Coast, and is a very safe protected place to swim and snorkel, except when there is high surf in the winter. The small-protected lagoon is off a beach at the end of the road and is relatively protected from most wave action by a reef.

“Coral/algal reefs are the largest structures on earth built by plant and animal growth....Corals are usually thought of as the builders of tropical reefs. Although corals are major contributors, stony or coralline algae usually surpass other organisms as the main frame-builders in shallow, surge-swept areas. In fact, the outer-most margin of a reef may harbor few corals. Instead, there may be a ridge of encrusting algae called the “algal ridge” where the greatest force of the waves is concentrated. The encrusting growth of coralline algae binds together the solid and loose fragments of limestone which collect on a reef... Seaweeds are usually the most conspicuous occupants on rock and rubble surfaces of reef flats. Inshore, where water circulation is sluggish, fleshy seaweeds are most common. Where water movement is more vigorous near the reef edge, pastel-colored stony algae (especially Porolithon spp.) are characteristic.” AECOS, Inc., 1979.

“Considered by marine scientists to be the ocean’s version of the rain forests, coral reefs house some of the oldest and most biologically diverse ecosystems on the planet.” Yeomans, M., 1999.

This entire Ke'e lagoon area is part of the Haena State Park, and is managed by the Hawaii Department of Land and Natural Resources. There is no marine protected area here, and no lifeguards or supervisory personnel to manage the thousands of people that visit the area every day.

The Ke'e area consists of a parking lot at the end of Route 56, with six portable toilets, a shower and a beautiful sandy lagoon wedged between the fringing reef and the mountainous Na Pali (Figure 2 as seen in appendix). There is no camping in the area, and no facilities such as picnic tables, food or snorkel concessions.

The reefs are very important to the area, and have been used by the local inhabitants for many centuries. “Reef flats provide shelter for many organisms collected for food, including edible seaweeds (limu), mollusks (octopus or he'e), long-spined sea urchins (wana), sea cucumbers (loli), and fishes... Some organisms (for example, the spaghetti worm, Lanice conchilega) have been collected for use in medical research.” AECOS, Inc., 1979.

The reefs are also an important economic resource. These reefs provide sand for the beautiful white beaches, protection from storms, food to eat, a home for millions of little organisms, and are a wonderful snorkel grounds. A hotel owner in Belize says, “Our

business is completely dependent on the health of the reef...That's primarily why people come here." Yeomans, M., 1999.

Methodology

The surveying was done from June 1 to August 15, 1999. The human use survey data report is from the dates of July 3, 7 and 11, 1999. A copy of the survey form is attached (Ha'ena Marine Use Pattern Survey). Only zones #1 and #2 were used because of the number of volunteers available. Zone 1 was the impact area at Ke'e lagoon and Zone 2 was approximately 200 meters down the beach. Volunteers were selected from the community and Hui, and did the actual counting and entry onto the survey forms. This data set is not large enough to establish anything more than baseline information and more data needs to be collected. The Hui Maka'ainana O Makana is currently collecting more data using the same data sheet. This data will be available upon request.

Zone 2 will not be monitored in the future, because the usage is so small with very little data generated. The exception to this is on windy days with high tide in the summer months when windsurfers use the area. On the day noted (Sunday, July 11) the highest number of windsurfers in the water at one time was 16, and the maximum people on the beach at Ka'ilio Point was 27. This is a seasonal situation, and only happens in the summer, at high tide heights and windy days.

The reef impact work was done by diving the reef with SCUBA and snorkel gear numerous times, and doing transects on the reef flat. The dives were to gather information about the area and make observations, while the transects were to distinguish human impact of walking on the reef flat itself. The transects were done in two areas, an impact area and a control area. A total of ten 10 m transects were set out in both of the areas. Five of these transects were randomly selected in each area and then five points were randomly selected on each transect line. So, five transect lines were selected in each area, and a total of twenty-five 1sq. M quadrats were used to compute percent coverage of coral, algae, and other substrate. See Figure 3 (as seen in appendix) for an outline of the coverage. The quadrat surveying was done at low tide, while the reef was exposed.

The impact area was so designated because it was close to the swimming lagoon and area of the major concentration of people. This concentration of people is close to the parking lot and in front of the small swimming lagoon, this area is noted as Point A in Figure 3. The major flow of people across the reef is from this area to a small indentation in the reef at Point B, and also noted in Figure 3. When people are walking on the reef, the main concentration seems to be in a corridor from Point A to Point B. This is the major impact area as noted in Figure 3 to the left of the line on the graphic. This information has been gathered by observation, and was used to divide the study site. This impact area was studied by percent cover and compared to the control area to the right of the line in Figure 3. Thus these two areas of reef flat were studied, next the results were compared.

The categories looked for in the percent cover on these transect line were turf algae (Turf), coralline encrusting algae (Crust), macro algae (Macro), coral (Coral), sand (Sand) and rubble, and bare substrate or basalt rock (Bare Substrate). The amount of Bare Substrate was negligible

Human Counting Results

The counting results showed that the highest numbers of people were sunbathing with quite a few of them snorkeling and swimming. Snorkeling and swimming appeared to be the only recreational activity for the majority of visitors. They were at the area in the greatest numbers from 10 am to 6 p.m. daily. This information is substantiated by Figure 9 (as seen in appendix), the major human use activities by time of day at Ke'e.

There has been great concern about the people walking on the reef at Ke'e. Figure 4 (as seen in appendix), the Mean number of people walking on the reef at Ke'e shows the highest number of people at one time was eighteen, and happened at 1:30 p.m. This data is not entirely reliable, and needs to be studied more because the amount of data is not sufficient to draw any significant conclusions. However, it can be viewed as a trend to be validated or checked as a baseline for future studies. There appears to be no relationship between the tide and the number of people on the reef as shown in Figure 6 (as seen in appendix). The total number of reef walkers appears to fluctuate greatly (Figure 5 as seen in appendix), and does not seem to be relative to tides or time of day. It was hard to draw any conclusions about the reef-walking profile, because of the limited data and wild fluctuations in behavior. The presence of the reef-walkers has been noted and their behavior can be studied in further detail if necessary.

There is concentrated activity and use in this small area on the North shore of Kauai, and there needs to be more work done to develop a plan to protect this valuable resource. It is obvious that in order to protect this valuable resource there needs to be better facilities and management of the area, especially since it has become such an important and popular tourist destination. Some of the tourists are already beginning to complain about the facilities, and this does not make good economic sense for tourism.

Reef Monitoring Results

The area studied is in a very high surf area for most of the year. The summer months are the only time that the area gets any relief from the pounding surf, so that is when the monitoring was done. "The main factors affecting life on the bottom of this environment of rough and shifting sand are wave energy and bottom topography." PUSPP/CZM, Aug 1978.

Some of the macro-algae found on reef flat included: *Galaxaura rugosa*, *Asparagopsis taxiformis* (limu kohu), *Hydrolithon reinboldii*, *Porolithon onkodes*, *Coralina* sp., *Centroceras clavulatum*, *Pterocladia capillacea*, *Sporolithon erythraeum*, *Hydrolithon breviclavium*, *Amansia glomerata* and *Padina* (sp.). “Due to strong tolerance to sunlight and desiccation and its crustose nature it is extremely successful in occupying high wave energy habitats. *P. onkodes* performs a critical role in the formation and maintenance of the biotic reefs of Hawaii by providing an actively growing reef rim, allowing consolidation and cementation of reef material to occur in protected shoreward areas...” Tissot, 1999. Limu kohu was found in very limited quantities in the control area and none in the impact area, but it mainly blooms in the spring and should be checked at that time. The local people on the reef this time of year are looking for octopus and va’wai’i’ole (sp?).

The corals found on the reef flat included, but are not limited to, *Pocillapora meandrina*, *Montipora patula*, *Montipora capitata* (formerly *M. verrucosa*), *Montipora flabellata* and *Porites lobata*. There were several bleached corals, but this is likely due to the heat of the sun at low tide. (Jokiel, in conversation, 1999)

The reef flat monitoring was done at Ke’e reef flat at low tide on Tuesday, August 10, 1999, and Wednesday, August 11, 1999. The reef flat was divided into two sections that included the impact area and the control area. When the data from the two sections was compared (Figures 7 and 8 as seen in appendix), it became obvious that there is a significant difference in the two areas. The area of particular concern is coral cover, and the average of it is 4.76% in the impact area and 8.92% in the control area. This is a significant difference and was not expected. To establish a statistically valid sampling, more work needs to be done and more data collected. However, a difference has been established. It is hard to definitely say that this difference is due to human impact because of the limitations of this study, but there certainly seems to be a correlation. The area of most concern is the corridor between the beach and the outer reef, where the highest percentages of tourists travel across the reef. At this time there is no control or supervision of the people crossing the reef in this area with coral cover.

Ke’e Beach biological resources and Assessment of fish populations

By Dr. Alan Friedlander (8-13-99)

Site description

Reef flat – This area is shallow, usually less than 5 feet at high tide and exposed at extreme lows. The reef flat off Ke’e Beach is physically divided into two distinct areas. The northwest section off the flat has been undermined by wave action, and subterranean tunnels penetrate the reef through crevices 3 to 10 feet wide. The eastern section of the reef is flat with little variation in relief. Very little rubble or sand occurs on the reef flat.

The only large quantity of sand lies off the beach to the west of the reef flat, where there is a small sandy moat.

Inner lagoon – Less than 10 feet deep with some small rocky outcrops. Minimal marine life present here.

Forereef – Seaward of the reef flat is an area characterized by irregular bottom topography. A series of limestone ridges parallels the shore and extends seaward for more than 1,200 feet. Depth ranges from 10 to 20 feet on the ridge crest to greater than 50 feet in the sand-filled troughs. The shoreward slope of the ridges is ca. 20-45 degrees, but the seaward slope is much steeper and is sometimes vertical. Ridge tops are 50 to 100 feet in width and have deep depressions, crevices, and trenches usually filled with limestone rubble. Very coarse sand accumulates in channels that are 3 to 50 feet and occasionally up to 120 feet wide between the ridges.

Fish populations

Assessment of fish populations

Visual belt transects (25 x 5 m) were conducted in the lagoon and along the reef flat at Ke'e Beach to assess fish abundance in these habitats. Transects were confined to the area inside the reef crest (the area of breaking waves) because the vast majority of snorkeling and other recreational activities were concentrated in the lagoon and along the reef flat. Fish abundance inside the lagoon was very low except for a school of ~ 20 yellow goatfish (weke'ula, *Mulloidichthys vanicolensis*) observed foraging in the sand. These goatfish feed on shrimp, crabs, and other mobile invertebrates that inhabit the sandy lagoon floor.

Overall, fish species richness was low with only 40 species from 15 families observed in the area (Table 1). Wrasses, surgeonfishes, and damselfishes comprised the majority of the species observed in the lagoon and along the reef flat at Ke'e. Fish diversity is much greater on the seaward side of the reef crest and studies conducted nearby off Limahuli Stream and in Hanalei Bay recorded over 160 species of fishes in these areas.

The endemic saddle wrasse, hinalea lau-wili (*Thalassoma duperrey*) was the abundance species observed on visual belt transects in the lagoon and along the reef flat at Ke'e. This species occurred in 83% of all transects and accounted for nearly one half of all fishes observed. Another endemic species, the belted wrasse (omaka, *Stethojulis balteata*) was the second most abundance species observed on transects, accounting for slightly more than 20% of all fishes and also occurring in 83% of all transects. The convict tang, manini (*Acanthurus triostegus sandvicensis*), is regarded as a hawaiian subspecies and was the third most abundant fish species and accounted for just over 9%

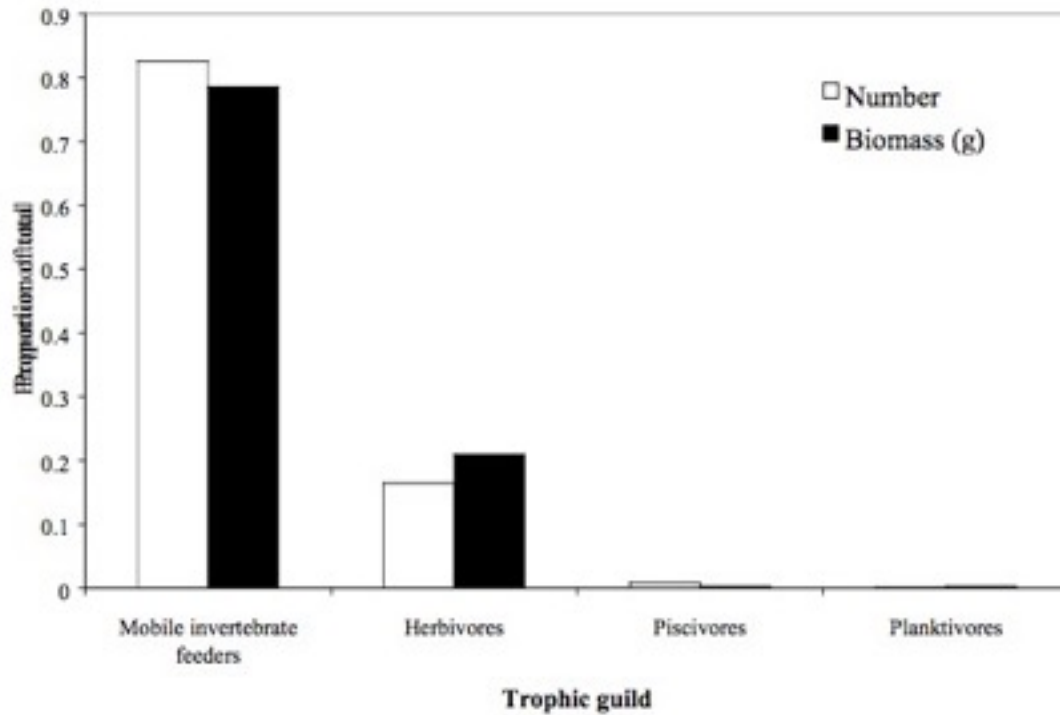
of the fishes observed on transects. Most of the individuals of this species were juveniles in the 4 to 6 cm size range.

Most of the fishes observed at Ke'e were small in size and had a low biomass standing stock. Many of the wrasses and damselfishes are small as adults, usually less than 15 cm in length. This habitat appeared to provide good juvenile habitat for surgeonfishes and wrasses. The saddle wrasse also dominated the fish assemblage by weight accounting for 48.8% of the total reef fish biomass, followed by belted wrasse which accounted for 11.2% of total reef fish biomass. The third most abundant fish by weight (7.7%) was the brown surgeonfish, ma'i'i'i (*Acanthurus nigrofusus*). This was one of the few species that occurred in this habitat as an adult.

Table 1. Fish families and number of species observed in each family observed along Ke'e lagoon and reef flat, Ha'ena State Park, Kauai.

<u>Family</u>	<u>Common name</u>	<u>Number of species</u>
Labridae	<u>Wrasses</u>	9
<u>Acanthuridae</u>	Surgeonfishes	7
Pomacentridae	Damselfishes	5
Kyphosidae	Rudderfishes	3
Mullidae	Goatfishes	3
Balistidae	Triggerfishes	2
Blennidae	Blennys	2
Chaetodontidae	Butterflyfishes	2
Atherinidae	Silversides	1
Carangidae	Jacks	1
Cirrhitidae	Hawkfishes	1
Fistulariidae	Coronetfishes	1
Scaridae	Parrotfishes	1

Fish that feed on mobile invertebrates were the dominant trophic group by weight (78%) and number (82%) (AF_Figure 1). This group was dominated by the wrasses, which feed primarily on small shrimp and crabs. Herbivores accounted for 16% of the total number of individuals and 21% of the total weight of fishes observed on transects. Surgeonfishes were the primary mobile grazers while damselfishes were the resident benthic herbivores.



AF_Figure 1. Trophic comparisons for reef fish assemblage at Ke'e Beach, Kauai.

AF_Table 2 (below). Rank abundance of dominant species observed on transects (25 x 5 m) in the lagoon and along the reef flat at Ke'e Beach. Species are ranked according to Index of Relative Dominance (IRD = Frequency of occurrence x relative abundance).

Family	<u>Species</u>	Common name	Hawaiian name	Frequency of occurrence	Relative abundance	biomass	IRD
Labridae	<i>Thalassoma duperrey</i>	Saddle wrasse	hinalea lau-wili	83.33%	49.44%	48.82%	41.20
Labridae	<i>Stethojulis balteata</i>	Belted wrasse	omaka	83.33%	20.11%	11.19%	16.76
Acanthuridae	<i>Acanthurus triostegus</i>	Convict tang	manini	83.33%	9.08%	2.07%	7.57

Labridae	<i>Thalassoma trilobatum</i>	Christmas wrasse	awela	83.33%	5.31%	7.03%	4.42
Pomacentridae	<i>Plectroglyphidodon imparipennis</i>	Brighteye damselfish		66.67%	5.31%	1.03%	3.54
Pomacentridae	<i>Stegastes fasciatus</i>	Pacific gregory		50.00%	4.19%	6.77%	2.09
Acanthuridae	<i>Acanthurus nigrofusus</i>	Brown surgeonfish	ma'i'i'i	66.67%	2.51%	7.75%	1.68
Fistulariidae	<i>Fistularia commersonii</i>	Cornetfish	nunupeke	50.00%	0.70%	0.22%	0.35
Labridae	<i>Coris venusta</i>	Elegant coris		33.33%	0.84%	0.39%	0.28
Balistidae	<i>Rhinecanthus rectangulus</i>	<u>Reef triggerfish</u>	humuhumunukunuku-a-pua'a	50.00%	0.42%	2.67%	0.21
Labridae	<i>Gomphosus varius</i>	Bird wrasse	aki-lolo	33.33%	0.28%	0.45%	0.09
Acanthuridae	<i>Acanthurus leucopareus</i>	Whitebar surgeonfish	maikoiko	16.67%	0.28%	1.52%	0.05
Mullidae	<i>Mulloidichthys vanicolensis</i>	Yellowfin goatfish	weke'ula	16.67%	0.28%	2.70%	0.05

Pomocentridae	<i>Abudefduf abdominalis</i>	Hawaiian sergeant	maomao	16.67%	0.14%	0.26%	0.02
Pomocentridae	<i>Abudefduf sordidus</i>	Blackspot sergeant	kupipi	16.67%	0.14%	0.98%	0.02
Acanthuridae	<i>Acanthurus achilles</i>	Achilles tang	paku'iku'i	16.67%	0.14%	0.31%	0.02
Cirrhitidae	<i>Cirrhitops fasciatus</i>	Redbar hawkfish	pili'ko'a	16.67%	0.14%	0.15%	0.02
Labridae	<i>Coris flavovittata</i>	Yellowstripe coris	hilu	16.67%	0.14%	0.05%	0.02
Kyphosidae	<i>Kyphosus species</i>	Rudderfish species	nenu	16.67%	0.14%	1.53%	0.02
Mullidae	<i>Parupeneus porphyreus</i>	Whitesaddle goatfish	kumu	16.67%	0.14%	1.42%	0.02
Blenniidae	<i>Plagiotremus goslinei</i>	Scale eating blenny		16.67%	0.14%	0.04%	0.02
Labridae	<i>Thalassoma purpuraceum</i>	Surge wrasse	hou	16.67%	0.14%	2.67%	0.02

Human impacts

Ke'e lagoon and reef flat, while not a highly diverse area for reef fishes, provides an excellent habitat for juvenile reef fishes. The reef flat provided a good habitat for grazing surgeonfishes as well. Fishing is probably the major human activity that negatively impacts fishes at Ke'e. Indiscriminant use and discard of inexpensive monofilament gillnets has had a major effect of reef fish throughout the state of Hawaii. This method of fishing takes even unwanted species and also leads to habitat destruction. Spear fishing

on SCUBA and excess take of prized resources species has led to severe declines in fish populations. Traditional fisheries management practices in Hawaii and throughout the Pacific relied on a variety of activities to ensure that the resources would be harvested in a sustainable manner (Table 3). There is a need to involve the community and develop a code of fishing conduct that will lead to sustainable fishing practices in the future.

AF_Table 3. Traditional management of fisheries resource in the Pacific

Community reef tenure
Closed areas
Closed seasons
Allow portion of catch to escape
Hold excess catch in enclosures
Ban on small individuals
Lagoon fishing restricted to poor weather conditions
Restrict number of fishing gear

Fish feeding did not appear to be a major concern at Ke'e. The abundance and behavior of fishes that are attracted to feeding activities such as rubberfishes were not substantially higher than observed in other areas. Down the road at Tunnels, a popular snorkeling and diving location, the rudderfishes appeared much more abundant and readily approached divers and snorkelers.

Benthic resources

Low coral cover. Robust reef development.

Seventeen species of coral are recorded, and all but one genera (*Pocillopora*) are of the encrusting type. The predominance of encrusting corals may be an indication that periodic storm waves restrict coral development. *Porites lobata* is relatively common, and abundant on offshore slopes. Algae and the burrowing sea urchin (*Echinometra mathaei*) are relatively abundant on the reef flat. Sea urchins comprise most of the conspicuous macroinvertebrates. Small *Conus* spp. Are also common on the reef flat.

Human impacts

Walking on reef but may be more perception than problem due to nature of reef

Conclusions

The beach and reef area at Ke'e lagoon is a very unique area. It has a beautiful white sand beach; an aquamarine colored safe swimming and snorkeling lagoon, and is surrounded by some of the best natural beauty in the world.

It is no wonder there is so much use of Ke'e beach at the end of the road. Over the years this use has increased, because of the increase popularity and promotion of the area. These tourists are not staying at a nearby hotel or resort and are not paying for any of the facilities at the park. It is all being paid for by the State tax dollars of local residents who are not using the beach park area very much. Some shift of the funding responsibilities seems to be necessary.

There has been a tremendous amount of resources spent for the promotion of tourism, and for some reason very little has been spent on the infrastructure of park facilities such as Ke'e lagoon. These facilities need to be improved and managed in a way that will protect it for future generations.

These visitors are not staying at any local hotels (there are none), and appear to be finding out about Ke'e from travel books, magazines, videos and bus tours. They come and appear to stay between one and two hours, so there is a continual changing of the people there. This information was gathered by interviewing some of the visitors, but can not be substantiated quantitatively.

It appears that if local residents see a lot of people at a beach, they will go somewhere else; while conversely, tourists will go to a beach if they see a lot of people there. This makes Ke'e very crowded, but with very few local people on the beach.

The nearest hotel is about 10 miles away, so the area is not set up for such high use. When one looks across the area and sees the crowds, it feels as if it is at a resort. This beach is one of the remotest on the island, but is very accessible by automobile, and the visitors seem to like the majestic beauty of the surroundings.

It is very difficult to study an area for such a short period of time, and be able to draw any substantial conclusions. "Despite the ecological and economic importance of coral reefs, we have a poor understanding of how this ecosystem responds to human activities..." Hodgson, 1999. Because of the complexity of the coastal marine ecosystems and seasonal variations, it is very difficult to isolate specific impacts. Since this is the first study of its type in the Ke'e area it has to be considered a baseline study, but some conclusions can be inferred, but will need more study in the future.

The coral reef flat data does appear to show harm to the corals on the reef due to the human impact of the tourists in the Ke'e Lagoon area. Humans are impacting the reef area. Because of the limited scope of this study, and the great number of parameters involved, it is very difficult to measure the exact effect. There are differences in the reef

flat area as presented in this paper. These include differences in the beach use, differences in the fish populations, differences in coral cover and differences in the customary uses of the native peoples. "Because of easy access and generally calm waters, reef areas are heavily used.... No doubt certain reef flats are adversely affected by the numbers of people visiting during favorable low tides." AECOS, Inc., 1979.

The reef flat has coral cover in the areas that are not laid bare at low tide. These areas are on the reef flat between the beach and the outer exposed reef area. Because of the location of these coral areas, the tourist foot traffic poses a danger to the coral when people walk to the outer portion of the reef. The tourists transit right through this coral area on their way to dive off the outer portion of the reef, and this poses a threat of damaging or killing the small amount of living coral that does exist at Ke'e reef. The tourists do not really know the habitat, and periodically step on living coral and crush it. As the tourist numbers increase and the area remains unsupervised the threat to these corals will increase. Walking on the reef should be prohibited for tourists.

The main problem is cultural and (subsistence) by the Hawaiian people who reside in the watershed area (Ahupua'a). These people are very concerned by the daily intrusion by thousands of people a day into their beachfront space. A place that they have been fishing and gathering for centuries. These tourists unintentionally intrude into the reef area that is nearly sacred to these Hawaiian people. They feel that they can not go to places that they traditionally have gone all their lives, and that the visitors are trampling and collecting from the reef area that has been their fishing and gathering grounds, their refrigerator. The Hawaiians use the reef for food collection and feel that the walking and suntan oil use in the area has a negative impact on the limu (algae) and marine life that they collect for food off the reef [i.e. *Asparagopsis taxiformis* (limu kohu)]. Although this was not specifically studied it could be in the future.

Recommendations

1) It appears to be very important to make Ke'e a marine protected area for subsistence and sustainable fisheries management. "Important parts of the sea must be set aside in marine reserves and safeguarded from as many threats as possible, because future generations deserve to inherit some portion of the natural ecosystems that exist today. Marine reserves provide protection from the harmful effects of overfishing... Marine reserves provide an excellent opportunity for public education... Marine reserves would be expected to increase economic activities that depend on healthy natural resources... Marine reserves can be effectively enforced." Fujita, 1999

2) It is necessary to improve restroom facilities, and make sure that the sewage is treated before going into the ocean. The portable toilets are good in the respect that they remove the excrement from the area, whereas a septic system would release it into the immediate

ocean environment. The extremely high use of the area by visitors makes it important to clean up the unsightly and unpleasant situation there now.

- 3) Redesign park so that parking is next to park entrance.
- 4) Hire staff to monitor park, while managing and controlling people. These people could educate visitors about the reef and cultural significance of the surrounding area.
- 5) Begin environmental education programs for visitors. Pamphlets could be designed to distribute to the visitors, so they would learn about the qualities of the reef and the rest of the area.
- 6) Charge admission for tourists to pay for improvements and staffing. "On Bonaire, one successful marine park – financed wholly by divers' fees – has been in operation for 20 years." Yeomans, M., 1999.
- 7) Work with residents to incorporate community based management.
- 8) Study the effect of suntan lotion on the reef and other marine organisms in the area.

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Appendix

Appendix I. List of fish species observed in the lagoon and on the reef flat at Ke'e Lagoon, Ha'ena State Park, Kauai. Species are listed in phylogenetic order.

Family	Species	COMMON	Hawaiian
Atherinidae	<i>Atherinomorus insularum</i>	Hawaiian silverside	'iao
Fistulariidae	<i>Fistularia commersonii</i>	Cornetfish	nunupeke
Serranidae	<i>Cephalopholis argus</i>	Blue spotted grouper	roi
Carangidae	<i>Caranx Melampygus</i>	Blue jack	omilu
Mullidae	<i>Parupeneus porphyreus</i>	Whitesaddle goatfish	kumu
Mullidae	<i>Mulloidichthys vanicolensis</i>	Yellowfin goatfish	weke'ula
Mullidae	<i>Parupeneus multifasciatus</i>	Manybar goatfish	moana
Kyphosidae	<i>Kyphosus species</i>	Rudderfish	nenu
Kyphosidae	<i>Kyphosus bigibbus</i>	Brown chub	nenu
Kyphosidae	<i>Kyphosus vaigiensis</i>	Lowfin chub	nenu
Chaetodontidae	<i>Chaetodon unimaculatus</i>	Teardrop butterflyfish	lau-hau
Chaetodontidae	<i>Chaetodon lunula</i>	Raccoon butterflyfish	kikakapu
Pomacentridae	<i>Plectroglyphidodon imparipennis</i>	Brighteye damselfish	
Pomacentridae	<i>Stegastes fasciolatus</i>	Pacific gregory	
Pomacentridae	<i>Abudefduf abdominalis</i>	Hawaiian sergeant	maomao

Pomocentridae	<i>Abudefduf sordidus</i>	Blackspot sergeant	kupipi
Pomocentridae	<i>Plectroglyphidodon sindonis</i>	Rock damselfish	
Cirrhitidae	<i>Cirrhitops Fasciatus</i>	Redbar hawkfish	pili'ko'a
Labridae	<i>Thalassoma trilobatum</i>	Christmas wrasse	awela
Labridae	<i>Coris flavovittata</i>	Yellowstripe coris	hilu
Labridae	<i>Gomphosus varius</i>	Bird wrasse	aki-lolo
Labridae	<i>Stethojulis balteata</i>	Belted wrasse	omaka
Labridae	<i>Thalassoma Duperrey</i>	Saddle wrasse	hinalea lau-wili
Labridae	<i>Coris venusta</i>	Elegant coris	
Labridae	<i>Thalassoma Purpureum</i>	Surge wrasse	hou
Labridae	<i>Labroides phthirophagus</i>	Hawaiian cleaner wrasse	
Labridae	<i>Thalassoma Ballieui</i>	Blacktail wrasse	hinalea luahine
Scaridae	<i>Calotomus carolinus</i>	Stareye parrotfish	ponuhunuhu
Blennidae	<i>Plagiotremus gosline</i>	Scale eating blenny	
Blennidae	<i>Cirripectes vanderbilti</i>	Scarface blenny	
Acanthuridae	<i>Acanthurus nigrofuscus</i>	Brown surgeonfish	ma'i'i'i
Acanthuridae	<i>Acanthurus triostegus</i>	Convict tang	manini
Acanthuridae	<u>Acanthurus achilles</u>	Achilles tang	paku'iku'i

Acanthuridae	<i>Acanthurus leucopareius</i>	Whitebar surgeonfish	maikoiko
Acanthuridae	<i>Acanthurus guttatus</i>	Whitespotted surgeonfish	'api
Acanthuridae	<i>Naso unicornis</i>	Bluespine unicornfish	kala
Acanthuridae	<i>Acanthurus blochii</i>	Ringtail surgeonfish	pualu
Balistidae	<i>Rhinecanthus rectangulus</i>	Reef triggerfish	humuhumu-nukunuku-a-pua'a
Balistidae	<i>Melichthys niger</i>	Black durgon	humuhumu-'ele'ele
Tetraodontidae	<i>Canthigaster amboinensis</i>	Ambon toby	

AF_Table 1. Fish families and number of species observed in each family observed along Ke'e lagoon and reef flat, Ha'ena State Park, Kauai.

Family	<u>Common name</u>	<u>Number of species</u>
Labridae	<u>Wrasses</u>	9
<u>Acanthuridae</u>	Surgeonfishes	7
Pomocentridae	Damselfishes	5
Kyphosidae	Rudderfishes	3
Mullidae	Goatfishes	3
Balistidae	Triggerfishes	2
Blennidae	Blennys	2
Chaetodontidae	Butterflyfishes	2
Atherinidae	Silversides	1
Carangidae	Jacks	1

Cirrhitidae	Hawkfishes	1
Fistulariidae	Coronetfishes	1
Scaridae	Parrotfishes	1
Serranidae	Groupers	1
Tetraodontidae	Pufferfishes	1
Grand Total		40

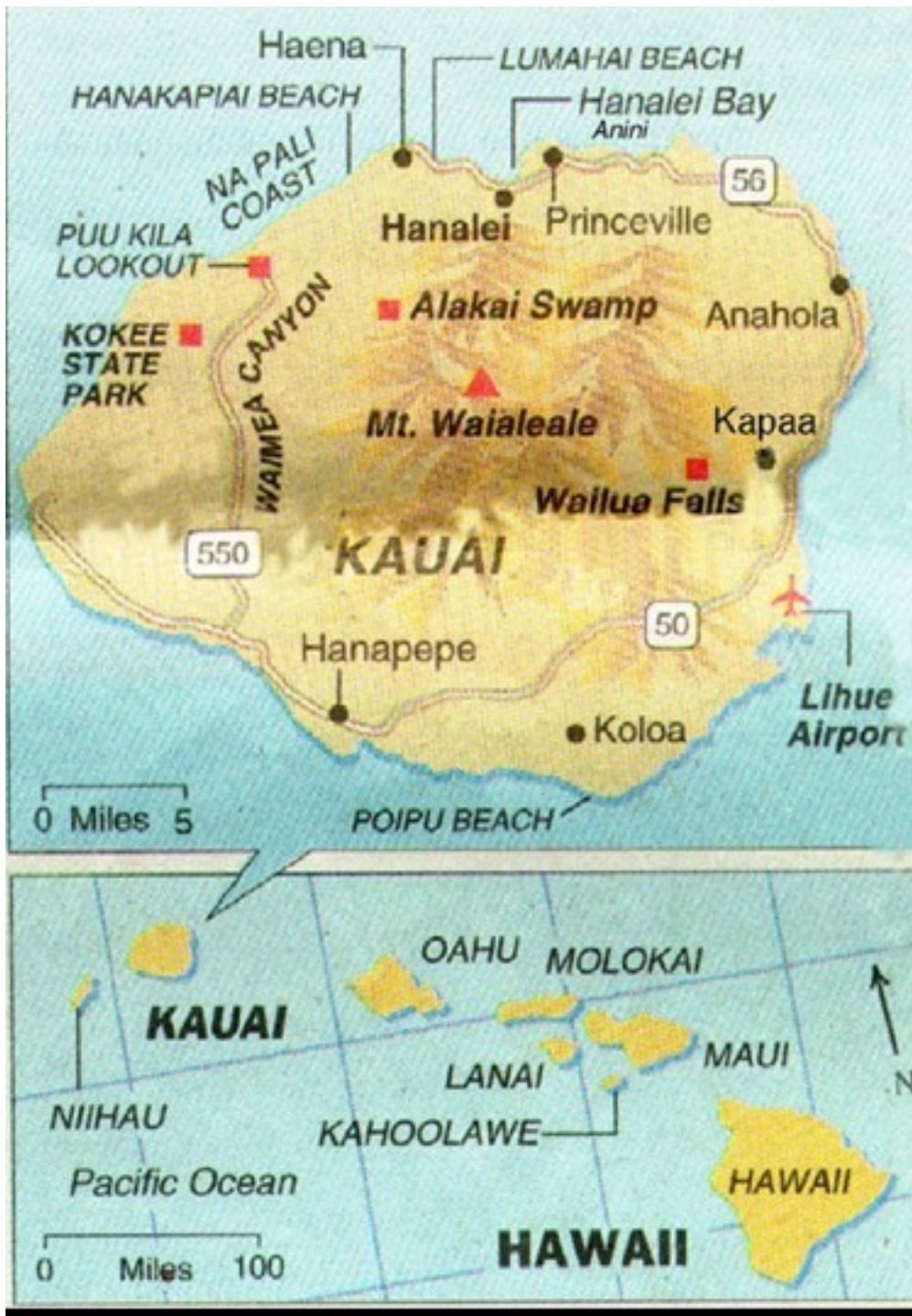


Figure 1, Map of Kaua'i and Location of Haena.

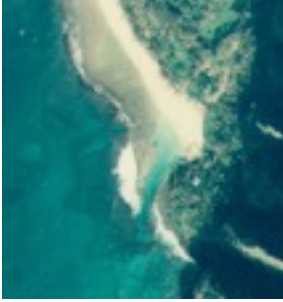


Figure 2, Aerial photo of Ke'e Lagoon, Haena, Kaua'i

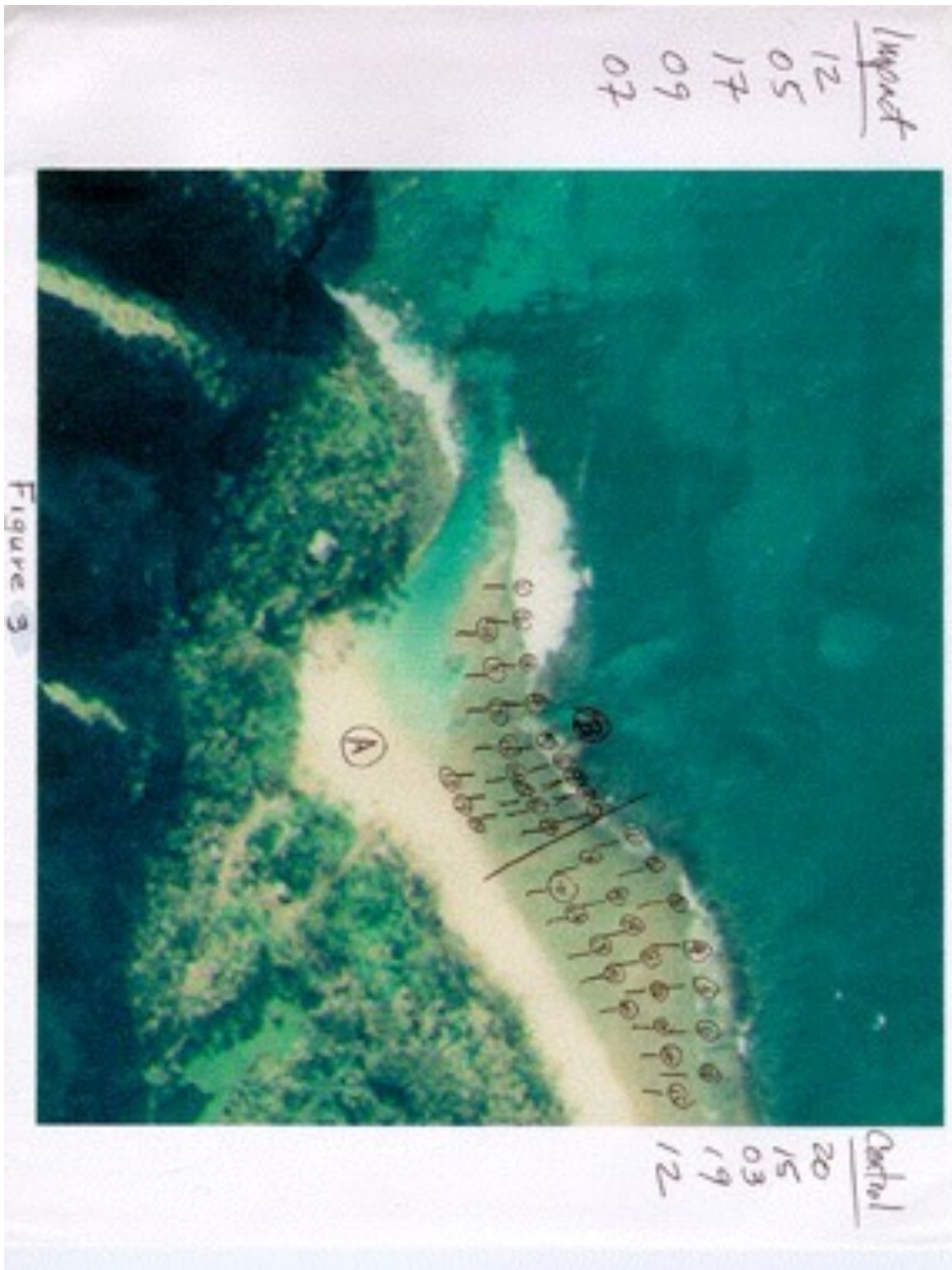


Figure 3, Aerial view of Quadrat location along Ke'e Reef

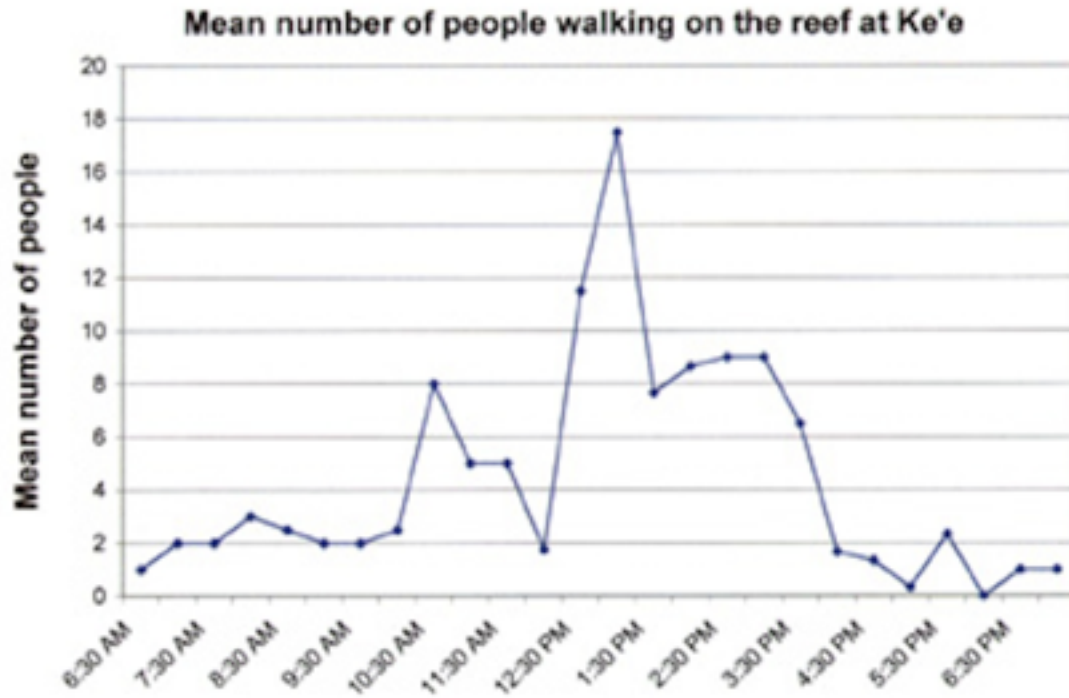


Figure 4, Mean number of people walking on Ke'e reef during different times of day

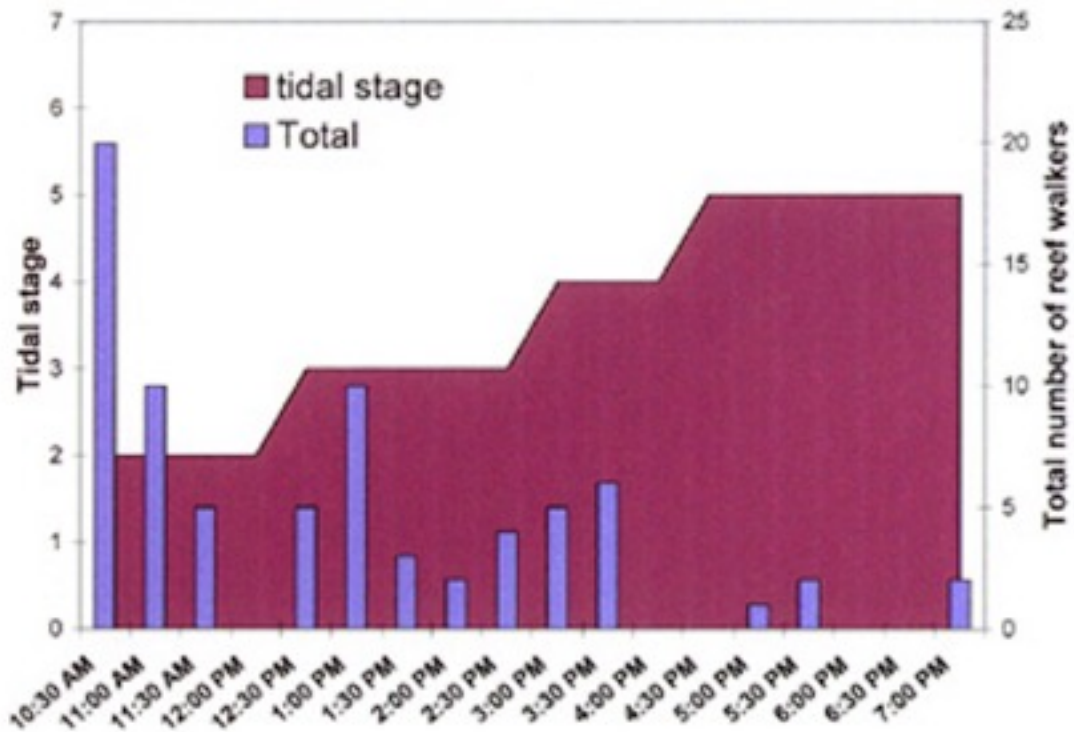


Figure 5, Number of reef walkers at different times and stages of tidal height at Ke'e reef

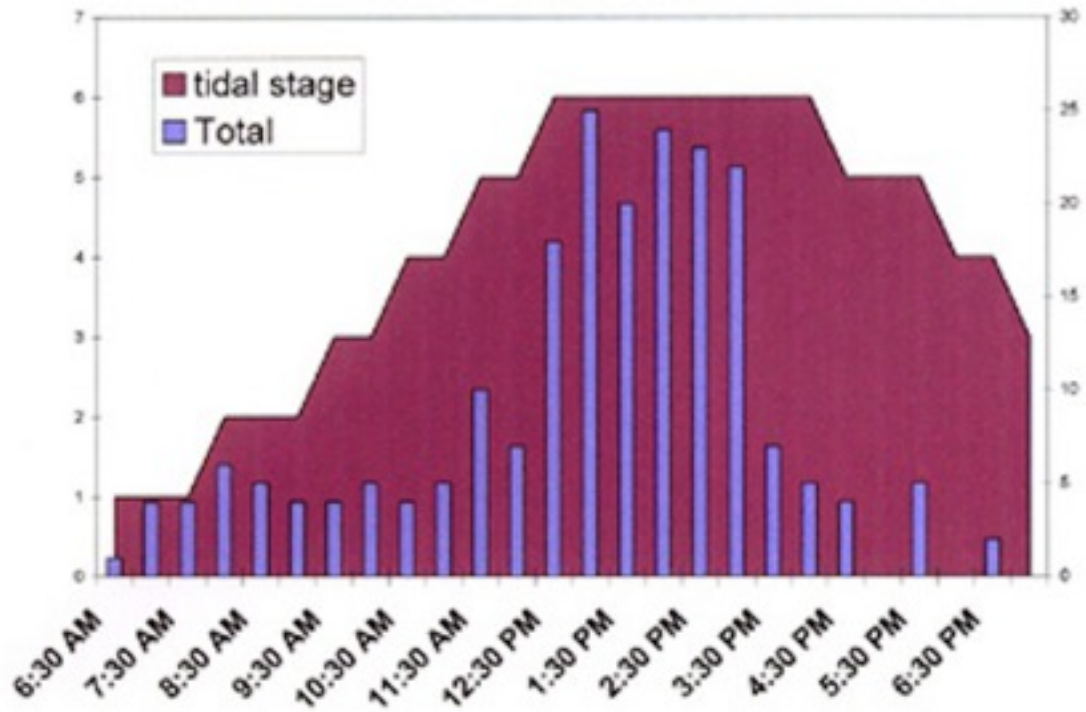


Figure 6, Tidal stage change versus time of day and total number of reef walkers at Ke'e

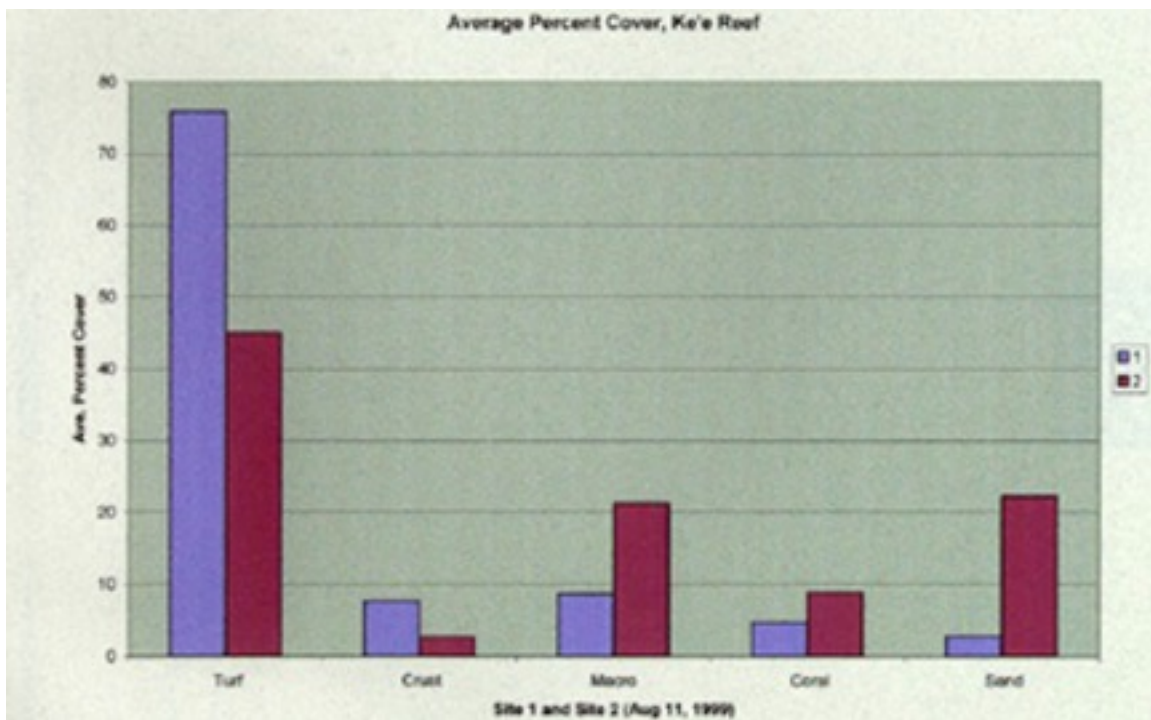


Figure 7, Average percent coral cover between sites 1 and 2 on Aug 11, 1999 at Ke'e reef

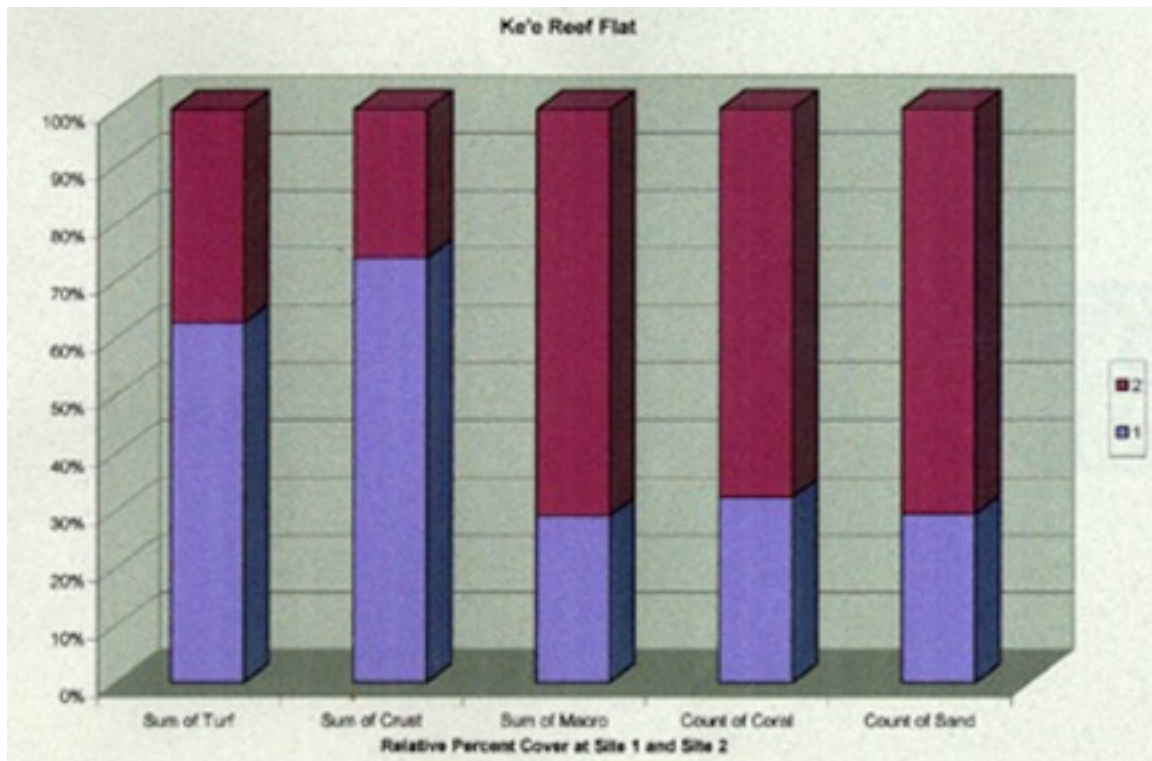


Figure 8, Relative percent of coral cover at sites 1 and 2 at Ke'e Reef Flat

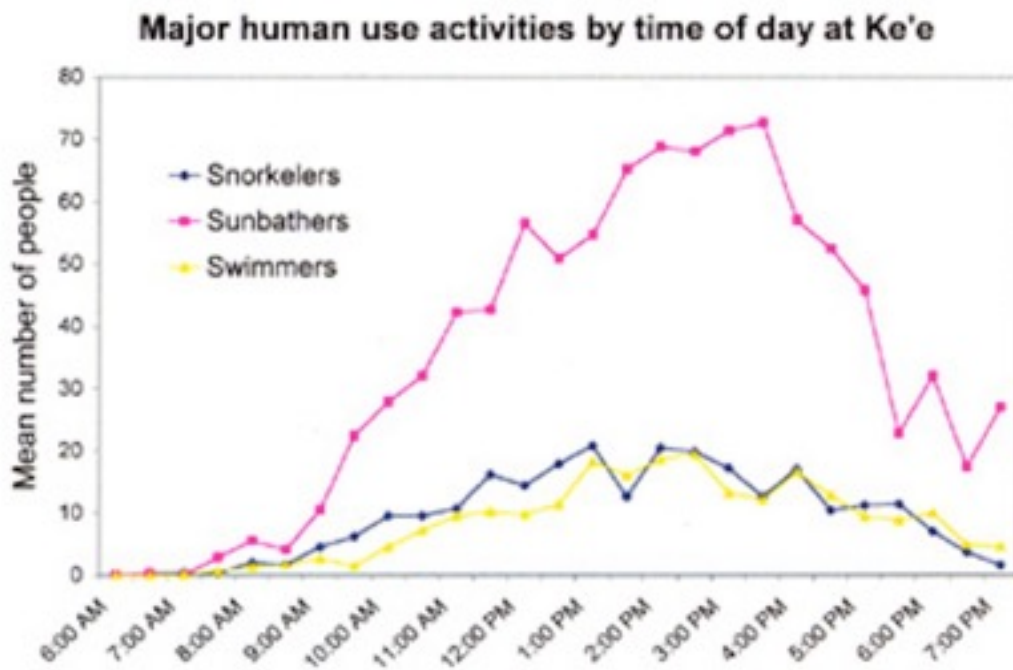


Figure 9, Major human use activities at different times of day at Ke'e Lagoon and Reef