A survey of the marine resources of Lawai Bay, Kauai, to support changes in management proposed by the National Tropical Botanical Gardens

Photo: Dave Boyton (deceased)

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Report prepared for:
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Lawai, Hawaii

Summary of marine resource surveys conducted in Lawai Bay, Kauai,

Feb. 9-11, 2007

SUMMARY

Lawai Bay, on the southern coast of Kauai, is approximately 25 acres of mostly sandy bottom (67% of the total area) with coral reef communities colonizing the basalt rock perimeter. This is a high wave energy environment, particularly in summer months, receiving intermittent freshwater and terrestrial sediment/debris input from Lawai Stream. The biological community exhibited relatively healthy herbivore populations (both sea urchins and fish). No alien or invasive algae species were observed, and turf algae were dominant, covering 77% of the hard-bottom habitat. Overall coral abundance was low (15% cover or less) as is typical of high energy environments, dominated by lobe coral (*Porites lobata*, pohaku puna) and cauliflower coral (*Pocillopora meandrina*, koʻa). Forty benthic taxa and 90 fish species were enumerated within the 17 sites surveyed.

Fish species diversity was low owing to the small size of the bay and its limited habitat complexity. Although fish biomass was relatively high, averaging 1.4 tons/hectare, it was dominated (36% of total biomass) by the non-native taʻape (bluelined snapper, *Lutjanus kasmira*). Akule (big-eyed scad, *Selar crumenophthalmus*) and weke ʻula (yellowfin goatfish, *Mulloidichthys vanicolensis)* were the most important fisheries resources utilizing the bay, making up 14% and 10% of the total biomass, respectively; however, the habitat ranges of these species extend outside the bay as well. Uhu (parrotfish, Scaridae) and opihi (*Cellana* spp.) were low in abundance and size, reflecting high harvest pressures in the bay.

Natural stressors to the health of Lawai Bay include high wave energy (as evidenced by a predominance of small and encrusting corals) and periodic stream flooding. The latter is exacerbated by upstream land use, with increased sedimentation, nutrients from fertilizers, and organic debris deposited into the bay. Anthropogenic stressors on the marine ecosystem are fishing activities that lead to overharvesting, as well as a proliferation of derelict fishing gear (lines, weights, and nets) that were observed throughout the bay.

Recommendations

1. Conduct creel surveys and use surveys
2. Establish permanent monitoring and research program
3. Conduct cleanup of fishing gear and other marine debris
4. Survey kupuna knowledge of ahupuaʻa
5. Establish and support community-based management of marine and upland resources
6. Conduct public education and outreach activities

A survey of the marine resources of Lawai Bay, Kauai, to support changes in management proposed by the National Tropical Botanical Gardens

Background

Lawai Bay has been largely protected for the past 200 years due to exclusive land ownership and limited access. Over the past 15 years, the National Tropical Botanical Gardens (NTBG), utilizing the holistic ahupua`a approach to resource management, has become steadily more involved in conserving and protecting the aquatic and marine environments associated with its properties.

Currently, Lawai Bay is a documented green sea turtle nesting site, a refugium for monk seals that haul out frequently, a seldom-used fishery (due to limited access), and a protected habitat for rare coastal plant species. It is steeped in cultural traditions and its sands and cliffs hold both *iwi kupuna* (ancient bones) and historic burials associated with the kuleana tenants who have populated the valley. Since the time of the Great Mahele (1848) when it was awarded to Kanehoa, who in turn gave it to Queen Emma, this ahupua'a has been owned and cared for by individuals who were acutely aware of the sacred site for which they were responsible. This is no different today, and the NTBG takes very seriously its charge to protect the natural and cultural resources of this unique area.

Statement of problem

The National Tropical Botanical Gardens (NTBG) is proposing to preserve Allerton Garden and Lawai Bay by petitioning to change the current State Conservation District designation from "Limited" to "Special". NTBG is preparing an environmental assessment, conservation district use application, and possibly, a natural area reserve application for this project. Therefore, archaeological, cultural, and aquatic studies are needed.

Scope of Work

1. Research on aquatic and marine studies of Lawai Bay. Locate and synthesize available information on aquatic and marine studies of Lawai Bay.
2. Conduct surveys of marine resources in Lawai Bay.
    a. Develop species inventories for fish, coral, algae, and macroinvertebrates.
    b. Conduct quantitative surveys of fish and benthos
3. Develop report in accordance with HRS 343 and "biological surveys, ecosystem impact analysis, and mitigation measures"
4. Coordinate and consult with NTBG, Hawaii Department of Land and Natural Resources, NKN Project Planning, Kauai County Planning Department, and project consultants.

Methodology

1. Species inventories were developed from visual surveys, beach seines, and other sampling gear, as appropriate.
2. Quantitative surveys were conducted on hard bottom habitats only. Sampling locations were randomly assigned into the NOAA benthic habitat map using Arcview 3.1 (Fig. 1). Fish, corals, algae, and macroinvertebrates were sampled along 25m long transects at each random location.

Benthic survey techniques

On completion of the fish survey, benthic cover was assessed along the same 25 m transect line using a 1 m^2 quadrat. Five quadrats were conducted along each transect and randomly located within each 5 m section of the transect. Twenty-five randomly selected intersectionswere marked on the quadrat grid and used for substrate identification within each 5m segment (n = 125 points per transect). Each intersection was identified using substrate categories of sand, coralline algae, turf algae, macroalgae, and coral. Coral and macroinvertebrates were identified to species level. Limitations of *in-situ* methodology precluded taxonomic resolution of algae down to the species level so algae were identified to genera.

To measure reef rugosity or surface relief, a chain of small links (1.3 cm per link) was draped along the full length of the centerline of each transect. A ratio of distance along the reef surface contour (cd) to linear horizontal distance (ld) gave an index of spatial relief or rugosity (r): r = cd/ld.

Fish sampling methodology

Fish assemblages at each location were quantified using standard underwater visual belt transect survey methods. A diver swim a 25 x 5-m transect at a constant speed and identify to the lowest possible taxon all fishes visible within 2.5 m to either side of the centerline (125-m^2 transect area). Total length (TL) of fish was estimated to the nearest centimeter.

Beach Seine

Beach seines were conducted along the sandy shoreline to document juvenile fish nursery habitat. The seine measured 24 x 1.8 m with 1.3 cm mesh. Sampling efforts consisted of seine hauls, in the western, middle, and eastern portion of the beach. Hauls were started at a distance of about 10 m offshore or in a water depth of about 1-1.5 m and pulled directly toward shore. Captured fish were held briefly in barrels, identified, measured, and released.

Marine Surveys

9-11 February 2007: 11 dive surveys at 17 sites and 3 beach seine hauls were conducted.

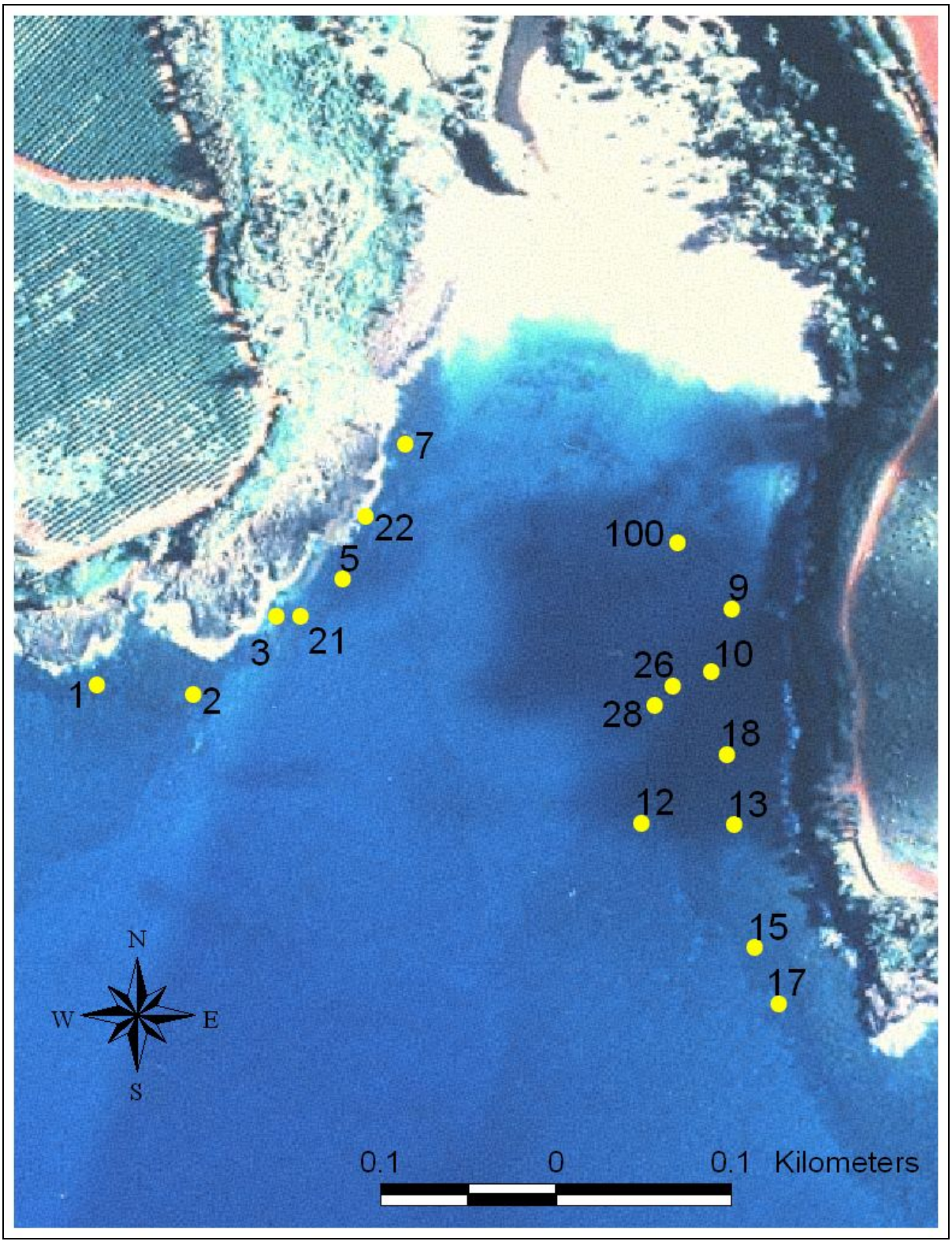

Figure 1. Lawai Bay marine survey sites.

Results

Benthic habitat map

The National Oceanic and Atmospheric Administration (NOAA) acquired and visually interpreted orthorectified aerial photographs from IKONOS satellite imagery and hyperspectral imagery for the near-shore waters (to 25 m depth) for approximately 65% of the main Hawaiian Islands (Coyne et al. 2003).
http://ccma.nos.noaa.gov/products/biogeography/hawaii_cd/index.htm

From these images, general habitat types can be quantified for Lawai Bay (Table 1 and Figure 2). Nearly 67% of the overall area of the bay, mostly within the center, consists of sandy bottom. There is limited coral reef community development (~11% of the total area) on the western side of the bay, with the majority of coral reef community habitat (~22% of the total area) seaward and south of the bay's eastern shoreline.

Additional small patch reefs may occur within the bay, but were too small to be identifiable from the NOAA benthic habitat map (minimum mapping unit = 1 acre [0.4 ha]). We were able to identify and map one patch reef (Site 100) and amend the NOAA benthic habitat map based on surveys conducted during this study.

Table 1. Habitat area within Lawai Bay, Kauai based on NOAA benthic habitat map (Coyne et al. 2003) and assessments from this study.

Location	Area (m^2)	Percentage	Perimeter
West reef	10806.68	10.83	767.16
East reef	21778.53	21.83	868.89
Sand	66684.12	66.84	1537.15
Patch	496.89	0.50	95.67
Total	99766.22	100.00	3268.87

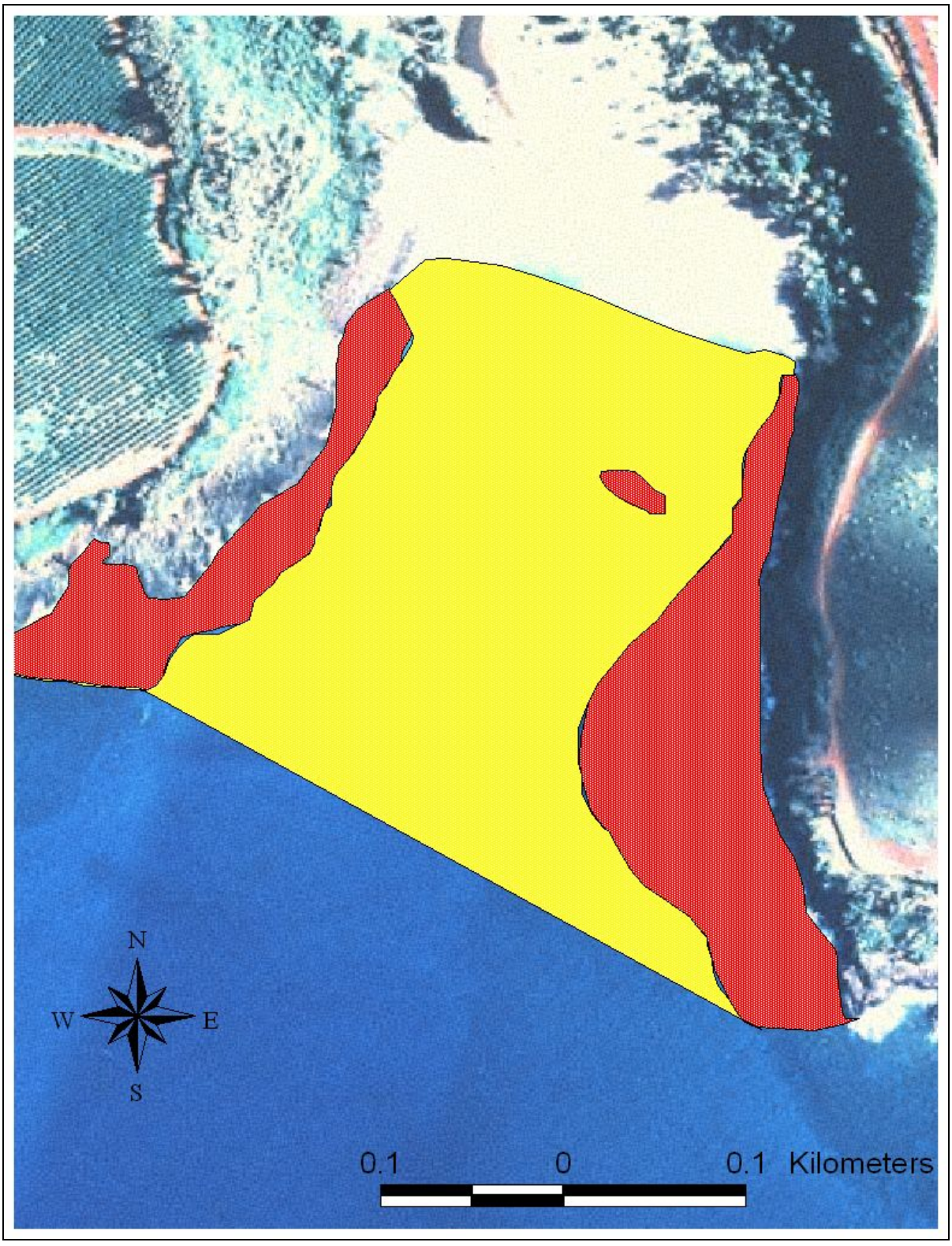

Figure 2. Major habitat types in Lawai Bay, Kauai. Red = colonized volcanic rock, yellow = sand based on NOAA benthic habitat map (Coyne et al. 2003) and assessments from this study.

Habitat characterization:

The overall area inside the Lawai Bay (24.7 acres) was dominated by sandy bottom, reaching to depths of 8-10 m. Coral communities were limited to the bay's perimeter, composed of basalt rock and boulders in the shallows, and basalt and limestone talus at the base (Fig. 3). A total of 40 benthic taxa were enumerated during the surveys.

Dominant corals were lobe coral (*Porites lobata*; pohaku puna) and cauliflower coral (*Pocillopora meandrina*; ko'a) (Table 2 and 3). Although a large (~2 m x 2m x 2 m), long-dead colony of *P. lobata* was seen on the eastern reef edge, most colonies of the species were smaller than 0.5 m in diameter and either encrusting or <0.5 m in height, indicating physical control (wave energy) of coral growth and reef development in the bay.

Areas of highest rugosity (vertical relief) and habitat complexity were at the eastern and western points of the bay (Fig 4). Coral cover was highest at Site 1 (15%), Site 5 (10%), and Site 22 (11%) on the west side, and at Site 17 (10%) on the eastern side of the bay. The red alga, *Melanamansia* sp., was the most common macroalga seen in these surveys, and was a dominant component of the benthos at Sites 1, 2, 3, 5, and 21, on the western side of the bay (Fig. 5). Turf algae dominated most of the hard-bottom substratum at all sites

The soft coral, *Sinularia densa*, a relatively rare species on most Main Hawaiian Island reefs, was seen at Sites 1 and 2, and was abundant at Site 21, all on the western side of the bay.

Five crown-of-thorn seastars (*Acanthaster planci*), ranging in size from 17-40 cm in diameter, were seen feeding on *Pocillopora meandrina* colonies during the 14 survey dives. Many recent coral recruits (both *Porites lobata* and *Pocillopora meandrina*) were noted, particularly at Sites 15, 21, and 22. Anomalous growths (coral "tumors") were seen on *Porites lobata* colonies at Sites 17 and 22.

In the center of the bay were several linear concentrations of terrestrial vegetation (mostly palm fronds, tree branches, decaying leaves, and other organic debris).

Most notably, derelict fishing line, weights, and net were seen fouled on corals at almost every survey site.

Table 2. Percent cover of corals, soft corals, algae, and other benthos (from quadrat surveys).

Sites	1	2	3	5	7	9	10	12	13	15	17	18	21	22	26	28	100	Med.
Hard Corals																		
Porites evermanni	0.0	1.6	0.0	5.6	0.0	1.6	0.0	0.0	1.6	0.0	0.0	0.0	1.6	0.8	0.0	0.0	0.0	0.0
Porites lobata	10.4	3.2	1.6	2.4	2.4	2.4	2.4	0.0	3.2	4.8	5.6	4.0	6.4	9.6	0.0	7.2	0.8	3.2
Porites compressa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pocillopora meandrina	4.8	0.8	3.2	1.6	0.0	0.0	0.0	1.6	0.0	3.2	1.6	0.0	0.8	0.0	0.8	0.0	0.0	0.8
Pocillopora eydouxi	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Montipora patula	0.0	0.0	0.0	0.8	0.0	0.0	2.4	0.8	0.0	0.8	3.2	0.0	0.0	0.8	0.0	0.8	0.0	0.0
Hard coral total	15.2	5.6	7.2	10.4	2.4	4.0	4.8	4.0	6.4	8.8	10.4	4.0	8.8	11.2	0.8	8.0	0.8	6.4
Soft corals																		
Palythoa caesia	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.6	0.0	0.8	0.0	0.0	3.2	0.0	0.0
Sarcothelia edmonsonsi	0.0	0.0	0.0	4.0	0.0	4.0	4.0	0.0	3.2	4.0	4.0	0.8	4.0	0.0	0.0	4.8	0.0	0.8
Algae																		
Coralline algae	2.4	3.2	0.8	0.0	0.0	0.8	0.0	3.2	1.6	0.8	1.6	0.0	0.0	2.4	0.0	0.0	0.0	0.8
Turf	64.0	68.0	44.8	51.2	91.2	86.4	75.2	84.0	87.2	83.2	76.8	84.8	27.2	78.4	81.6	74.4	72.8	76.8
Melanamansia sp.	18.4	22.4	44.8	34.4	6.4	0.0	0.0	0.0	0.0	0.0	5.6	2.4	59.2	8.0	1.6	8.8	0.0	5.6
Halimeda sp.	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.0	0.0
Callophycus densa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0
Echinoderms																		
Echinothrix calamaris	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Holothuria atra	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sand	0.0	0.0	0.0	0.0	0.0	1.6	16.0	8.8	0.0	2.4	0.0	8.0	0.0	0.0	15.2	0.0	24.8	0.0

Table 3. Summary of relative abundance of benthic invertebrates and algae at each survey site. (D=dominant, A=abundant, C=common, O=occasional, R=rare).

Summary		Sites	1	2	3	5	7	9	10	12	13	15	17	18	21	22	26	28	100
Corals:																			
Porites	*evermanni*			O	O	O		O			O	O			O	R			
Porites	*lobata*		A	O	O	O	O	O	O		O	O	O	O	O	C	O	O	O
Porites	*compressa*			R						O	R					R	R		R
Pocillopora	*damicornis*		R																
Pocillopora	*meandrina*		C	O	O	O	O	O	O	O		C	O		O		O		O
Pocillopora	*eydouxi*		R	R	O											R			R
Montipora	*capitata*				O	O									O				
Montipora	*patula*			O		O			O	R		O	O		O	O	O	R	
Montipora	*flabellata*							R											
Pavona	*duerdeni*		O																
Leptastrea	*purpurea*					R		C	R			R							
Fungia	*scutaria*						R												
Soft corals:																			
Palythoa	*caesia*		C	O	O	O	O	O	R		O	O	O	R	O		O	O	
Sinularia	*densa*		O	O											A				
Sarcothelia edmonsonsi				O		C	O	O	O	O	O	O	O	O	O	O	O	O	
Zoanthid (unid.)					O					R	O					O			
Algae:																			
Coralline algae			O	O	O	O		R	O	O	O	O	O		O				
Turf			D	D	A	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Melanamansia	*sp.*		C	C	A	A	O						O	O	A	C	R	A	
Heterosiphonia	*sp.*							O											O
Halimeda	*sp.*							O		R	R			R			R	R	
Callophycus	*densa*								R										R

Table 3 continued.

Summary		Sites	1	2	3	5	7	9	10	12	13	15	17	18	21	22	26	28	100
Echinoderms:																			
Tripneustes	*gratilla*				R	O	O				O		O			O			O
Echiniothrix	*calamaris*		O	O	R	O		O		O	O	O		O				R	O
Echinometra	*mathaei*							O	O	O		O					O		
Actinopyga	*mauritiana*				R														
Holothuria	*whitmaei*														R				
Holothuria	*atra*				R			R	O					R	R		R		
Mithrodia	*fisheri*																R		
Acanthaster	*planci*							R					R					O	
Crustaceans:																			
Panulirus	*marginatus*					R									R				
Syllarides	*squammosus*														R				
Stenopus	*earlei*									R									
Encrusting and other organisms:																			
White sponge										O							R		
Black sponge								O		R				O					
Hamigera sp.= subcrusting sponge								O		O						C	R		
White tunicate																		R	
Pseudoceros	*ferrugineus (flatworm)*			R															
Phyllidia	*varicosa (nudibranch)*						R												
TOTAL NUMBER OF SPECIES			11	15	14	14	9	17	11	15	11	11	10	10	16	11	16	10	9
Sand								R	C	O		O	O	O			C		A

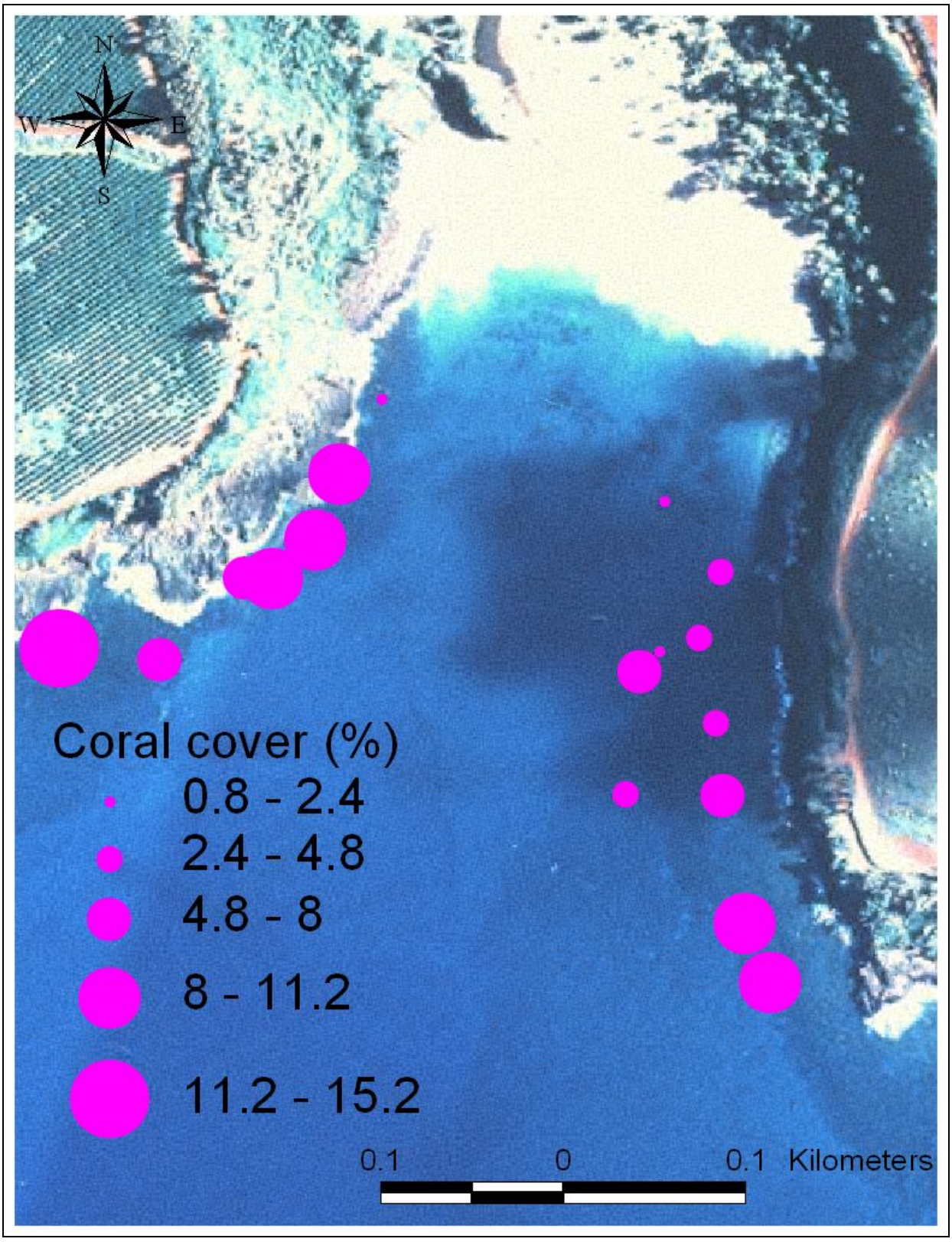

Figure 3. Percent live coral cover at each survey site in Lawai Bay.

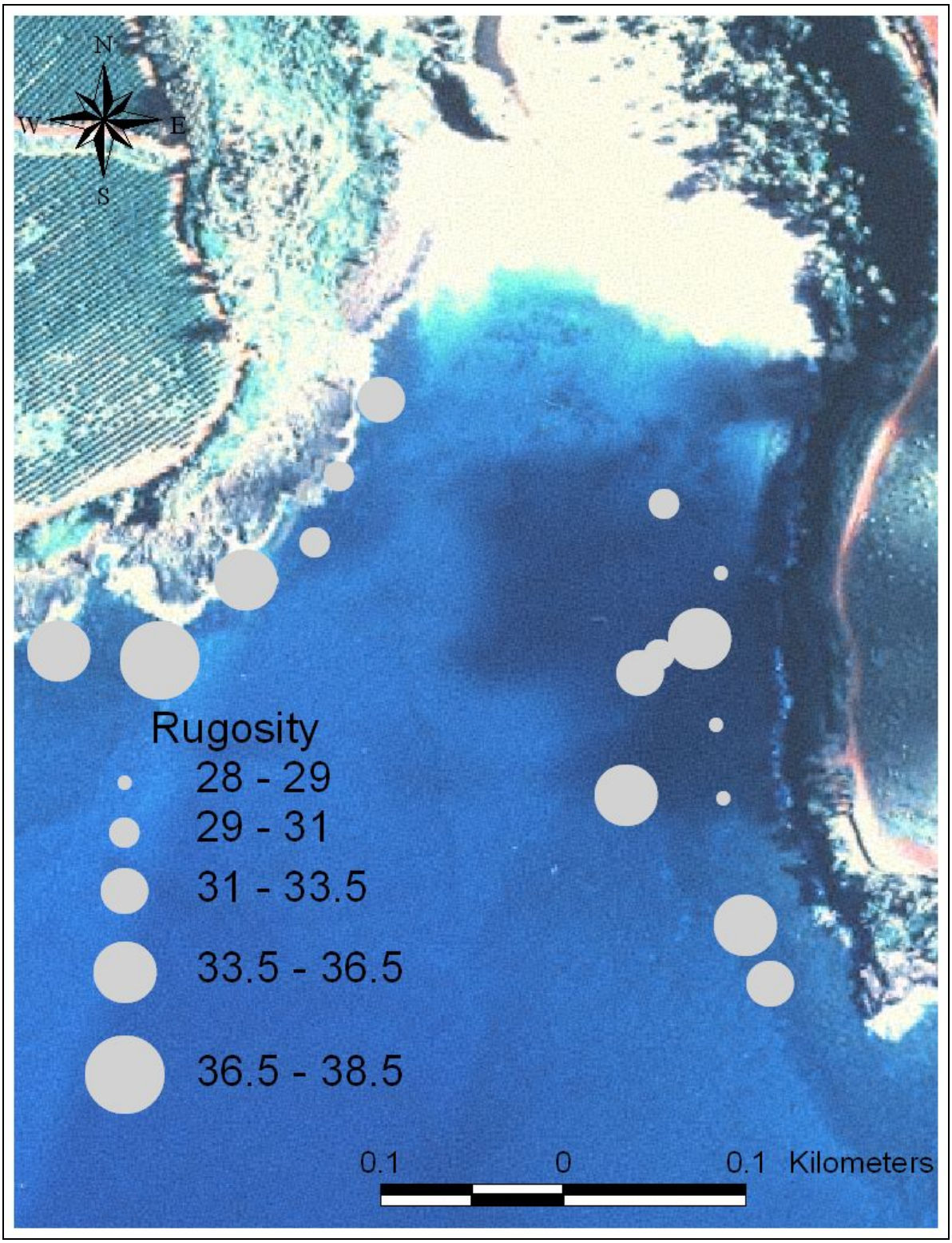

Fig. 4 Relative rugosity (higher numbers indicate higher vertical relief and habitat complexity) for each survey site. Rugosity (r) = cd/ld where cd is surface contour along the linear horizontal distance (ld) of the transect (25 m).

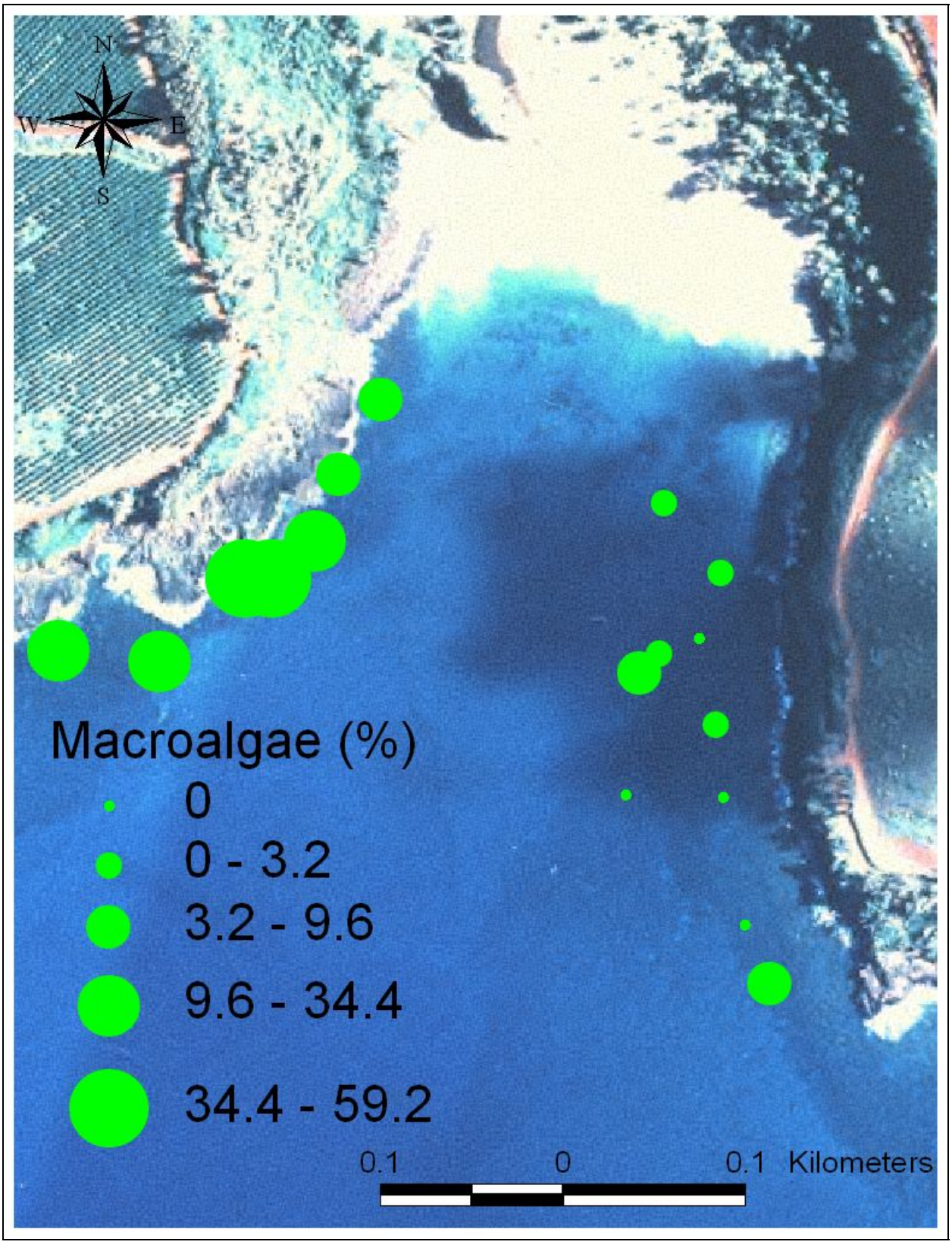

Figure 5. Percent macroalgae cover at each survey site in Lawai Bay.

Fish assemblages

A total of 90 species from 25 families was observed in Lawai Bay during the survey period. Mean fish species richness per transect was 17.24 (± 5.38 sd). This relatively low species richness is due to the small size and limited diversity of habitats found in the bay. The highest richness was found towards the points and the lowest on the small inshore patch reef (Table 4, Fig. 6).

Fish biomass observed on transects (mean = 1.41 t ha^{-1} [± 1.02 sd]) was high but dominated by the introduced ta‘ape (bluelined snapper, *Lutjanus kasmira*) which accounted for 36% of total biomass, followed by akule (14%, bigeye scad, *Selar crumenophthalmus*), weke ula (10%, yellowfin goatfish, *Mulloidichthys vanicolensis*), na‘ena‘e (6%, orangeband surgeonfish, *Acanthurus olivaceus*), and the introduced to‘au (5%, blacktail snapper, *Lutjanus fulvus*) (Table 5). Biomass was highest on the western reef and towards the points (Table 4, Fig. 7).

Similar to the other assemblage measures, total number of individuals was highest towards the points and along the western portion of the bay (Table 4, Fig. 8). Ta‘ape comprised 37% of the total number of individuals, followed by blackfin chromis (17%, *Chromis vanderbilti*), to‘au (10%), and the endemic saddle wrasse (7.8%, hinalea lauwili, *T duperrey*), respectively.

Table 4. Fish assemblage summary statistics

Transect	Species	Number m^2	Biomass (t ha^{-1})	Diversity	Evenness
1	24	3.136	3.08	1.13	0.36
2	27	2.336	2.68	2.12	0.64
3	20	0.720	0.76	2.16	0.72
5	15	2.68	2.80	0.56	0.21
7	20	0.648	0.57	2.45	0.82
9	17	0.560	0.33	2.18	0.77
10	13	0.864	0.43	2.09	0.81
12	22	1.144	0.97	2.26	0.73
13	13	1.208	0.33	1.18	0.46
15	16	1.664	1.74	1.58	0.57
17	16	0.576	0.47	2.36	0.85
18	18	0.320	0.31	2.54	0.88
21	11	0.656	0.19	1.63	0.68
22	23	3.688	6.73	1.39	0.44
26	9	0.256	0.27	1.73	0.79
28	21	1.752	1.69	1.76	0.58
100	8	1.544	0.64	0.91	0.44
Mean	17.24	1.40	1.41	1.77	0.63
Stdev	5.38	1.02	1.67	0.58	0.19

Table 5. Dominant fish species in Lawaii Bay ordered by biomass. Bold denotes endemic species or subspecies.

Taxon name	Common name	Hawaiian name	Freq	Biomass (t ha^{-1})	Number m^2
Lutjanus kasmira	Bluestripe Snapper	ta'ape	58.8%	8.74	8.88
Selar crumenophthalmus	Big-Eyed Scad	akule	5.9%	3.48	0.40
Mulloidichthys vanicolensis	Yellowfin Goatfish	weke 'ula	35.3%	2.34	0.57
Acanthurus olivaceus	Orangeband Surgeonfish	na'ena'e	47.1%	1.46	0.40
Lutjanus fulvus	Blacktail Snapper	to'au	47.1%	1.19	2.38
Parupeneus multifasciatus	Manybar Goatfish	moano	76.5%	0.80	0.38
Acanthurus leucopareius	Whitebar Surgeonfish	ma¯ikoiko	17.6%	0.62	0.20
Acanthurus nigrofuscus	Brown Surgeonfish	ma¯i'i'i	88.2%	0.61	1.12
Sufflamen frenatus	Bridled Triggerfish	humuhumumimi	35.3%	0.55	0.06
Caranx melampygus	Blue Trevally	'omilu	17.6%	0.52	0.36
Naso unicornis	Bluespine Unicornfish	kala	17.6%	0.38	0.06
Abudefduf vaigiensis	Indo-Pacific Sargent	mamo	17.6%	0.36	0.30
Thalassoma duperrey	**Saddle Wrasse**	**hi¯na¯lea lauwili**	**100.0%**	**0.28**	**1.86**
Acanthurus dussumieri	Eye-stripe Surgeonfish	palani	41.2%	0.26	0.10
Mulloidichthys flavolineatus	Yellowstripe Goatfish	weke	5.9%	0.24	0.10
Kyphosus species	Lowfin Chub	nenue	17.6%	0.21	0.06
Rhinecanthus rectangulus	Reef Triggerfish	humuhumunukun ukuapua'a	47.1%	0.20	0.10
Zanclus cornutus	Moorish idol	kihikihi	35.3%	0.17	0.12
Bodianus bilunulatus	**Hawaiian Hogfish**	**'a'awa**	11.8%	**0.15**	**0.02**
Acanthurus triostegus	**Convict Tang**	**manini**	**64.7%**	**0.14**	**0.13**

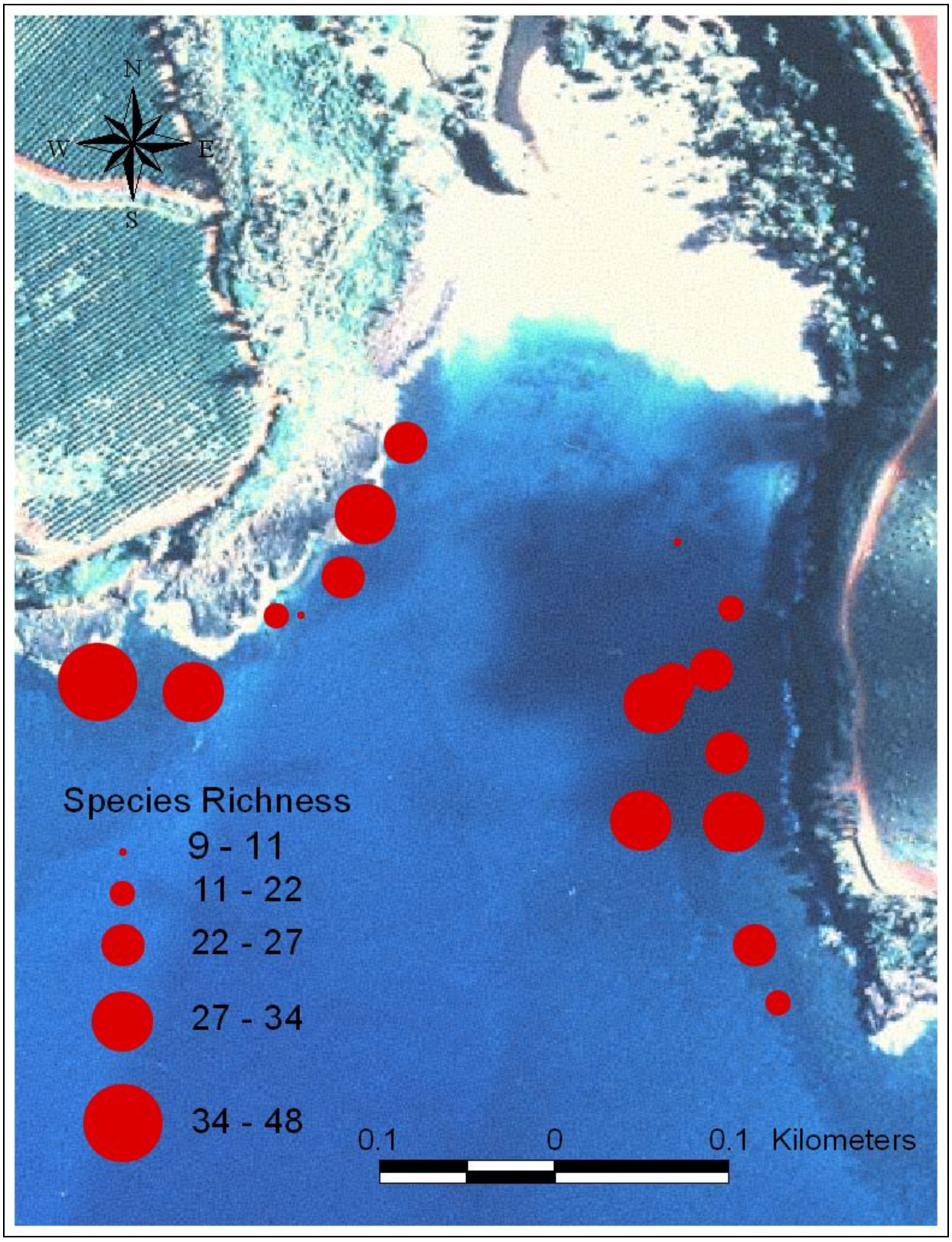

Figure 6. Mean fish species richness in Lawai Bay based on *in situ* quantitative 25 x 5 m transects.

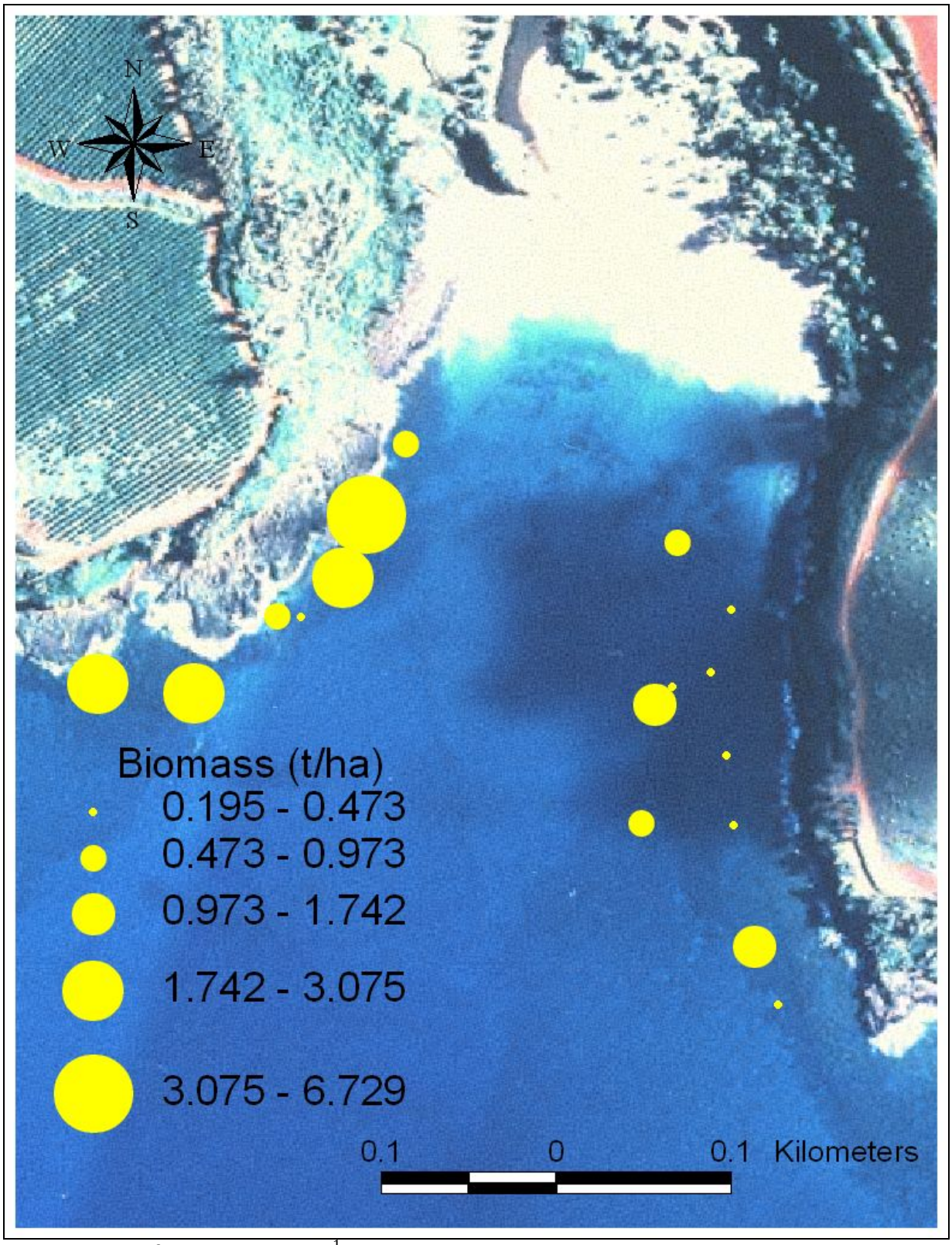

Figure 7. Mean fish biomass (t ha^{-1}) in Lawai Bay based on *in situ* quantitative 25 x 5 m transects.

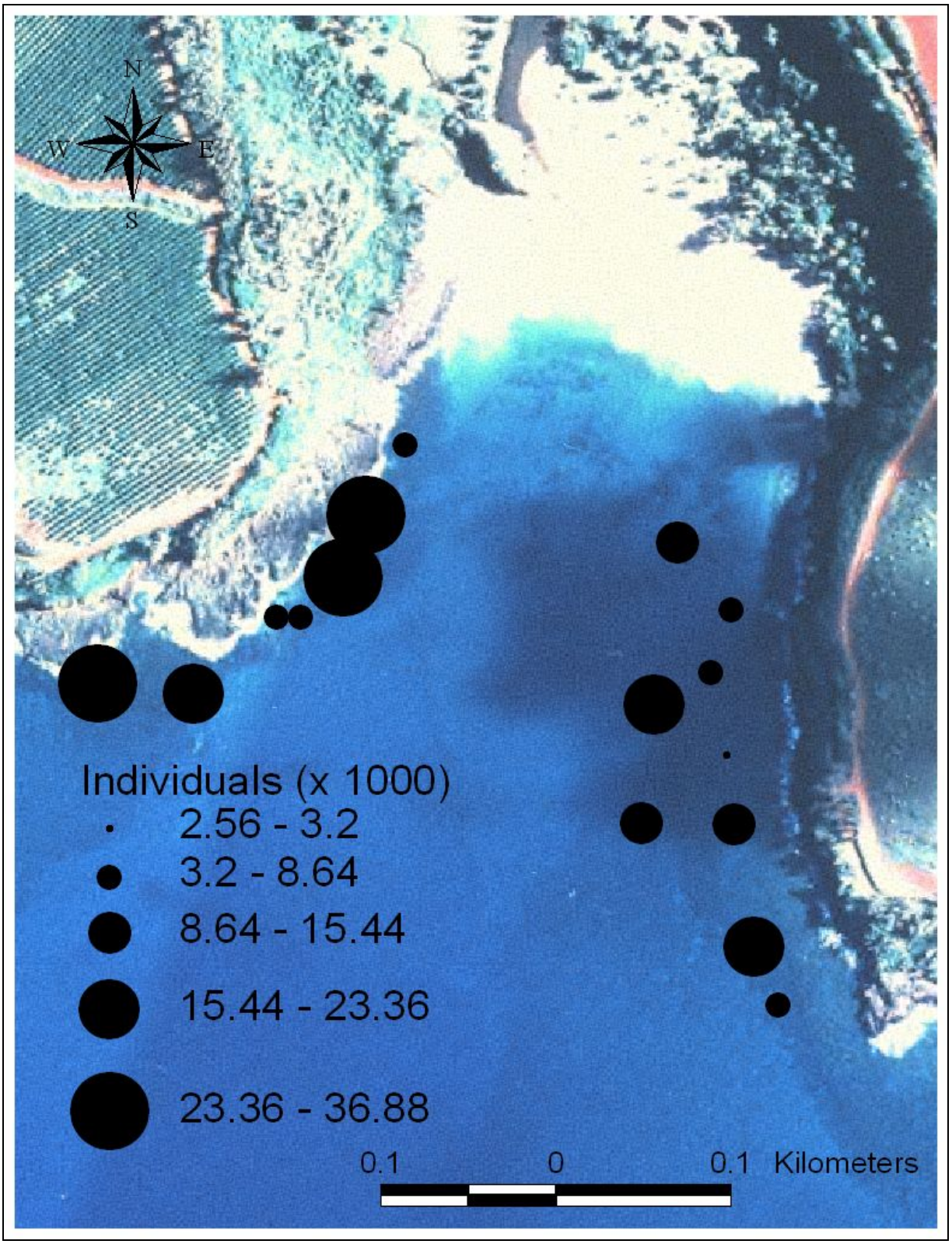

Figure 8. Mean number of individual fishes (x 1000) per hectare in Lawai Bay based on *in situ* quantitative 25 x 5 m transects.

Sand-associated species

The extensive sandy areas and adjacent estuarine habitat makes Lawai Bay a important nursery habitat for several nearshore fish species. Papio (jacks) and aholehole (*Kuhlia* spp.) were observed along the shoreline in the surf zone. Further offshore, small schools (<100 individuals each) of opelu (*Decapterus* spp.) and akule (*Selar crumenophthalmus*) were observed on several occasions and commercial harvest of akule is reported from the bay on an annual basis.

Goatfishes, primarily weke ula (*Mulloidichthys vanicolensis*) and weke ‘a (*M. flavolineatus)*, were observed feeding over the deeper (>5 m) sandy areas of the bay. One large (~ 60 cm disk width) broad stringray (lupe, *Dasyatis latus*) was noted feeding in the sand in 8 m of water off the eastern portion of the bay. This species is known only from Hawaii and Japan and is not often seen in Hawaiian waters (Randall 1996).

Beach seines

We conducted beach seines (Fig. 9) along the sandy shoreline to further assess the surf zone fish assemblage. A total of 41 Moi li‘i (juvenile *Polydactylus sexfilis*) was captured in beach seines (Mean = 13.7, ± 5.5 sd) per haul (Fig. 10 and 11). The average size of these moi li‘i was 14.4 FL cm (±1.5 sd), is equivalent to 142 days in age (Table 6). The largest individual recorded in the seine hauls was 20 FL cm (208 day) and the smallest was 9.9 FL cm (91 days in age). No other species were taken or observed during beach seine activities.

Figure 9. Beach seine (24 x 1.8 m with 1.3 cm mesh) used to survey surf zone fish assemblage.

Table 6. Size of moi li‘i captured in beach seines.

	Length FL (cm)
MEAN	14.4
SD	1.5
MIN	9.9
MAX	20.0

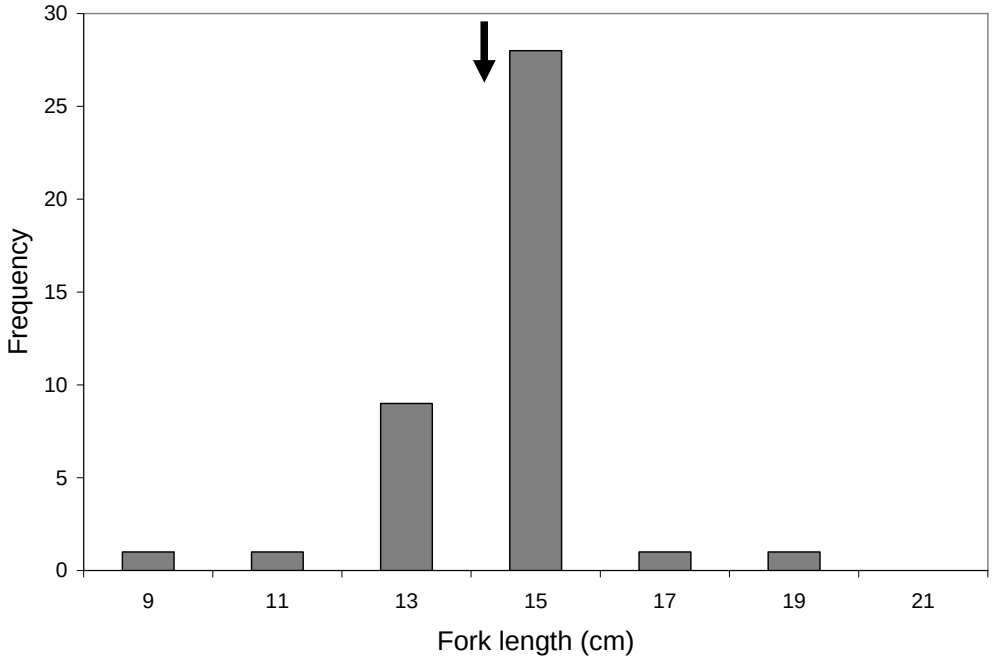

Figure 10. Length frequency distribution of moi li‘i captured in beach seines along shoreline at Lawai Bay. Arrow denotes mean size.

Figure 11. Moi li‘i (juvenile Pacific threadfin, *Polydactylus sexfilis*) captured in beach seine.

Rare and unique fish species

We observed a few rare or unique fish species in Lawai that are worthy of note. One hybrid fivestrip wrasse (T. *quinquevittatum*) was noted on the western reef in 14 ft. of water at station 22 on 11 Feb 07. This species is rare in Hawaii but is known to hybridize with the endemic saddle wrasse (hinalea lauwili, *T duperrey*) (Randall 1996).

At this same location, we found a large (55 TL cm) spotted knifejaw (*Oplegnathus punctatus*, Fig. 12). This species is also rare in the main Hawaiian Islands but not uncommon in the NWHI (Randall 1996). This family (single genus = *Oplegnathus*) has an antitropical distribution with species found in South Africa, southern Australia, Japan, Hawaii, and from the Galapagos Islands south to Chile (Randall 1996). It is an highly valued food fish in Japan. These two species present a contrast in that the fivestripe wrasse is more common the tropical Indo-Pacific while the spotted knifejaw is more typically found in colder tropical and sub-tropical waters.

Figure 12. Spotted knifejaw (*Oplegnathus punctatus*) (Photo: Randall 1996).

Resource species

The lack of numerous or large resource species in Lawai Bay was noted and may reflect a combination of factors including: limited habitat available, moderate to heavy fishing pressure, and poor water quality from upland sources. Although ta‘ape is the dominant biomass of fishes in the bay, it is rarely targeted by fishers despite it importance as a food fish in other parts of the Indo-Pacific. A large school of >1000 small (16-18 TL cm) was observed on the inshore western portion of the bay. Akule was second in total weight of fishes observed in Lawai but only occurred in 6% of the surveys. This species forms annual migrations around the islands and large commercial catches have been reported from Lawai in the past. The most important resident resource species, based on quantitative transect data, was weke ula which were observed in schools of up to 50 individuals in the 30-35 TL cm size range. These schools also likely move in and out of the bay during feeding excursions and management measures aimed at this species needs to take this into consideration.

One of the most striking observations was the lack of any large parrotfishes in the bay. Only 3 palukaluka (redlip parrotfish, *Scarus rubroviolaceus*) and one ponuhununuhu (stareye parrotfish, *Calotomus carolinus*) were noted during the survey period. These species are frequently targeted by spear fishers and there low numbers and small size might reflect high fishing pressure.

Protected species

Honu (green sea turtle, *Chelonia mydas*) were seen at 4 stations (24% of total) and averaged 107 cm carapace length (± 25.8 sd). The bay has been reported as a nesting beach in the past but NOAA fisheries thought that this consisted of a single female and nesting has not occurred in several years (Balaz, pers. comm.). On June 1, 2007 Rick Hanna (NTBG) documented a green sea turtle nesting at Lawai Bay (Fig. 13). The female came out of the water between 12:30 and 3:30 and dug three nests. Two of the nests had eggs and one was aborted after she dug into some buried drift wood. A total of 6 nests were dug by three turtles between 1 and 3 June 2007 (2 nest were aborted and 4 had eggs) (Fig. 14).

The Hawaiian monk seal (*Monachus schauinslandi*) is the only endangered pinniped occurring entirely within U.S. waters. Its current population is estimated at 1,300 seals, a decrease of about 60% since the 1950s (Antonelis et al. 2006). Monk seals have been reported to haul out on the beach at Lawai and activities should attempt to minimize negative interactions with this critically endangered species. Spinner dolphins (*Stenella longirostris*) likely utilize the bay as a foraging and resting area and humpback whales (*Megaptera novaeangliae*) can be found offshore during the winter months.

Figure 13. Green sea turtle nesting at Lawai Bay on June 1, 2007 (photos: Rick Hanna, NTBG).

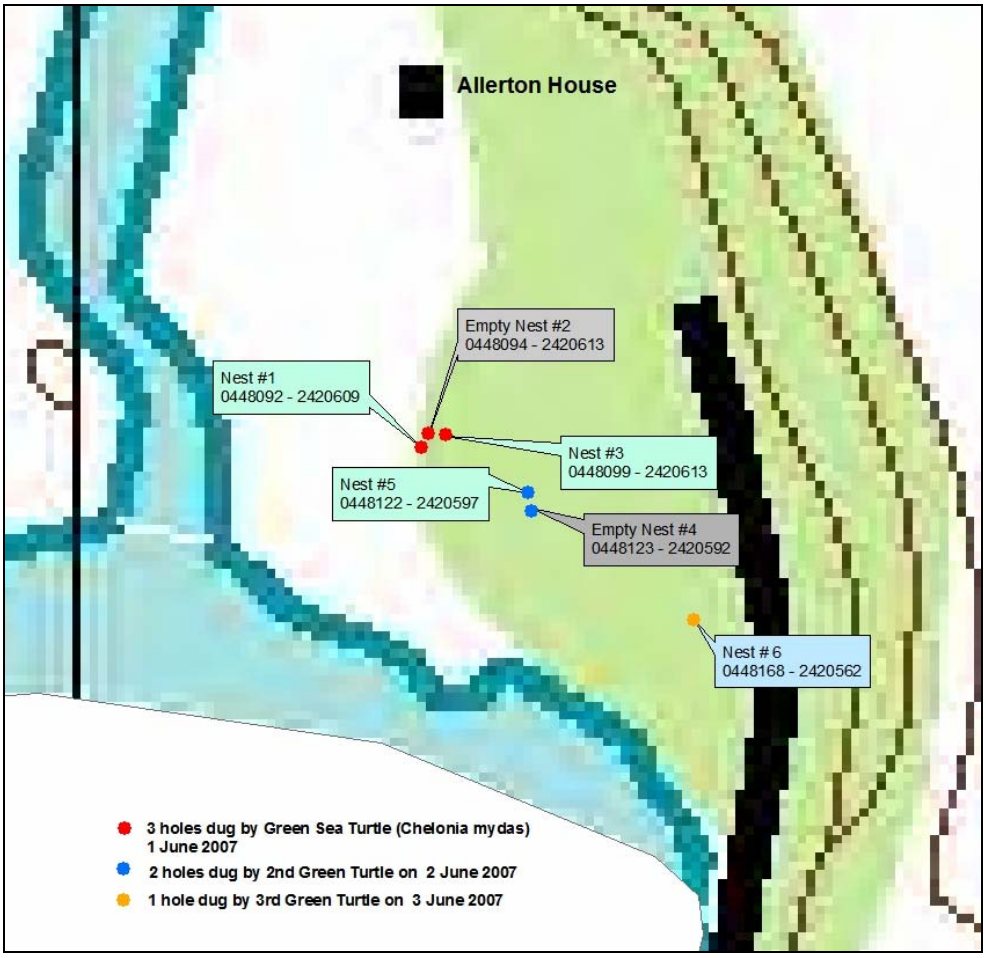

Figure 14. Locations of turtle nesting site at Lawai Bay from 1-3 June 2007. Data and figure provided by NTBG.

Invasive species

The introduced ta‘ape was the dominant species in the bay by weight. Although it has been reported by fishers to have a negative impact on native fish populations, recent studies have found this not to be the case. If reduction of the size of ta‘ape in Lawai Bay is determined to be a management goal, then the targeted harvest of this species would be effective strategy. The other introduced fish species of mention is to‘au, which comprised 5% of the total fish biomass in the bay and was present at 47% of the stations surveyed.

No alien limu (seaweed) was observed during the survey period and the relatively high biomass of herbivorous fishes (primarily surgeonfishes) and sea urchins may be helping to control alien limu but a management plan should be in place to monitor and deal with the potential introduction of invasive species. Several locations in Hawaii have suffered negative ecological as well as socio-economic consequences as a result of the spread of invasive algae (Hunter and Evans 1995, Smith et al. 2002)

Fishing effort

During the three days of the survey, a modest amount of fishing effort was noted in the bay. Pole-and-line fishing was observed on all three days and on both sides of the bay (Fig. 15). Three spear fishers were observed on Saturday 10 Feb 07 and one opihi (*Cellana* spp.) picker was seen on Sunday the 11th of Feb 07. Harvest of opihi did not appear to be size selective and a number of undersized animals (<1.25 in. shell diameter) were observed being collected. Fishing effort and catch need to be monitored using a more rigorous and systematic approach to protect the limited resources and habitat within the bay.

Fishing activities observed in Lawai Bay, 9-11 February 2007
Friday – 9 Feb 07--2 people, 3 rods, western reef
Saturday – 10 Feb 2007 – 3 spearfishers, 2 pole fishers, eastern reef
Sunday 11 Feb 07 – 2 pole fishers, kayakers with 4 poles on eastern reef, one opihi picker on western shore.

Figure 15. Pole-and-line fishing off the western point of Lawai Bay on 9 Feb. 07.

Other marine-related activities

Lawai Bay receives a number of marine-related activities owing to its relative close proximity to Poipu Beach, a major tourist area on Kauai. Kayakers frequent the bay (Fig. 16) and tourist boats (Fig. 15) from the Poipu area stop at Lawai on a regular basis. The current level of these activities appears sustainable but a management plan for Lawai Bay should include provisions for managing and monitoring these and other uses.

Figure 16. Kayakers and tourist boats frequent Lawai Bay on a regular basis owing to the close proximity to Poipu Beach.

Stressors

There are a number of natural and human-induced stressors that impact the marine environment in Lawai Bay. Lawai has a southern exposure that receives large surf during the spring, summer, and fall months from storms generated in the southern hemisphere. The coral growth forms in the bay (encrusting or robust branching) are indicative of a high wave energy environment. The bay receives sediment input from the adjacent stream, which is likely considerable during heavy rain events.

Human impact can have both direct and indirect effects on the health of Lawai Bay. The primary direct influence is through resource extraction. The small size of the bay and the limited available habitat makes the bay unsuitable for large-scale commercial harvest. Several resource species such as uhu and opihi are in low abundance and small is size, reflecting possible overfishing conditions

An indirect effect of these activities is the relatively large amount of marine debris found on the reef during the survey period. This debris consisted primarily of discarded fishing line (Fig. 17) and nets and derelict gear was found at almost every survey station. Efforts should be made to remove and prevent additional debris from accumulating in the bay. The indirect effects from sedimentation and pollutants from the adjacent stream are unknown but efforts should be made to examine the potential linkages between the marine, fresh water, and terrestrial environments within the ahupua`a.

Figure 17. Diver (Linda Kosen) removing fishing line from coral head.

Overall condition

The marine environment of Lawai Bay consists of a small sandy bay that receives natural stressors from surf and sediment and moderate human use through both extractive and non-extractive activities. Coral cover and growth forms are typical of this type of environment in Hawaii, although some coral disease was observed. The absence of invasive limu is very positive and efforts should be made to manage this potential threat through monitoring and through the maintenance of healthy herbivore populations. The small size of the bay precludes intensive commercial harvest of resources and several resource species appear to low in abundance and small in size. One of the obvious stressors is currently marine debris and removal and management of this problem should be a priority.

Recommendations

1. Conduct creel surveys and use surveys – To better understand the spatial and temporal patterns of human use (both extractive and non-extractive) within Lawai Bay, a rigorous stratified random survey should be conducted over one or more annual cycles. This information will help determine potential carrying capacity and identify user conflicts.

2. Establish permanent monitoring and research program – Continued monitoring of marine resources (fishes and benthic community) is important to help examine trends over time and to identify any potential problems such as invasive species or declines in species abundance. Important research questions such as circulation patterns and movement of sediment needs to be assessed.
3. Conduct cleanups of fishing gear and other marine debris – The debris possesses a continuing threat to the benthic community and removal could be achieved with a moderate amount of effort. This activity should be community-based to encourage better practices in the future.

4. Survey of kupuna knowledge – The knowledge held by kupuna and others within the community is the most valuable resource available for wise use of Lawai Bay. Information needs to be collected on past and present activities as well as assessments of changes and potential reasons for these changes.

5. Establish and support community-based management – The community needs to have all the necessary information in order to make wise management decisions. Interactions between community members, resource managers, and scientists are critical to developing pono practices.

6. Conduct public education and outreach – Information on the value and pono practices related to Lawai Bay should be developed and distributed in a variety of media.

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Appendix I – List of fish species observed in Lawai Bay, Kauai. * = Tahitian names for introduced species.

Family	TaxonName	Common Name	Hawaiian Name
Dasyatidae	Dasyatis latus	Broad stingray	lupe
Muraenidae	Gymnothorax eurostus	Stout Moray	pu¯hi
Muraenidae	Gymnothorax meleagris	Whitemouth Moray	pu¯hi o¯ni'o
Synodontidae	Saurida flamma	Orangemouth Lizardfish	'ulae
Fistulariidae	Fistularia commersonii	Cornetfish	
Holocentridae	Myripristis berndti	Bigscale soldierfish	‘u‘u
Scorpaenidae	Sebastapistes coniorta	Speckled Scorpionfish	
Serranidae	Cephalopholis argus	Blue-spotted Grouper	roi*
Carangidae	Caranx melampygus	Blue Trevally	'omilu
Carangidae	Decapterus species	Mackerel Scad	'opelu
Carangidae	Scomberoides lysan	Leatherback	lai
Carangidae	Selar crumenophthalmus	Big-Eyed Scad	akule
Lutjanidae	Lutjanus fulvus	Blacktail Snapper	to'au*
Lutjanidae	Lutjanus kasmira	Bluestripe Snapper	ta'ape*
Polynemidae	Poldyactylus sexfilis	Pacific threadfin	moi
Mullidae	Mulloidichthys flavolineatus	Yellowstripe Goatfish	weke
Mullidae	Mulloidichthys vanicolensis	Yellowfin Goatfish	weke 'ula
Mullidae	Parupeneus insularis	Doublebar Goatfish	munu
Mullidae	Parupeneus cyclostomus	Blue Goatfish	moano kea
Mullidae	Parupeneus multifasciatus	Manybar Goatfish	moano
Mullidae	Parupeneus pleurostigma	Sidespot Goatfish	malu
Mullidae	Parupeneus porphyreus	Whitesaddle Goatfish	ku¯mu¯
Kyphosidae	Kyphosus cinerascens	Highfin Chub	nenue
Kyphosidae	Kyphosus species	Lowfin Chub	nenue
Chaetodontidae	Chaetodon auriga	Threadfin Butterflyfish	ki¯ka¯kapu
Chaetodontidae	Chaetodon fremblii	Bluestripe Butterflyfish	ki¯ka¯kapu
Chaetodontidae	Chaetodon lunula	Racoon Butterflyfish	ki¯ka¯kapu
Chaetodontidae	Chaetodon miliaris	Milletseed Butterflyfish	lauwiliwili
Chaetodontidae	Chaetodon multicinctus	Multiband Butterflyfish	ki¯ka¯kapu
Chaetodontidae	Chaetodon quadrimaculatus	Fourspot Butterflyfish	lau hau
Chaetodontidae	Chaetodon unimaculatus	Teardrop Butterflyfish	lau hau
Pomacanthidae	Centropyge potteri	Potter's Angelfish	
Oplegnathidae	Oplegnathus punctatus	Spotted Knifejaw	
Pomacentridae	Abudefduf abdominalis	Sargent Major	mamo
Pomacentridae	Abudefduf sordidus	Blackspot Sargent	ku¯pi¯pi¯
Pomacentridae	Abudefduf vaigiensis	Indo-Pacific Sargent	mamo
Pomacentridae	Chromis ovalis	Oval Chromis	
Pomacentridae	Chromis vanderbilti	Blackfin Chromis	
Pomacentridae	Plectroglyphidodon imparipennis	Brighteye Damselfish	
Pomacentridae	Plectroglyphidodon johnstonianus	Blue-eye Damselfish	
Pomacentridae	Plectroglyphidodon sindonis	Rock Damselfish	
Pomacentridae	Stegastes fasciolatus	Pacific Gregory	
Cirrhitidae	Cirrhitops fasciatus	Redbar Hawkfish	pili ko'a
Cirrhitidae	Cirrhitus pinnulatus	Stocky Hawkfish	po'o pa'a

Appendix I continued.

Family	TaxonName	Common Name	Hawaiian Name
Cirrhitidae	Paracirrhites arcatus	Arc-eye Hawkfish	pili ko'a
Cirrhitidae	Paracirrhites forsteri	Blackside Hawkfish	hilu pili ko'a
Labridae	Bodianus bilunulatus	Hawaiian Hogfish	'a'awa
Labridae	Coris flavovittata	Yellowstrip coris	hilu
Labridae	Coris gaimard	Yellowtail Coris	hi¯na¯lea 'akilolo
Labridae	Coris venusta	Elegant Coris	
Labridae	Gomphosus varius	Bird Wrasse	hi¯na¯lea 'i'iwi, 'akilolo
Labridae	Halichoeres ornatissimus	Ornate Wrasse	'o¯hua
Labridae	Labroides phthirophagus	Hawaiian Cleaner Wrasse	
Labridae	Macropharyngodon geoffroy	Shortnose Wrasse	
Labridae	Pseudocheilinus octotaenia	Eightline Wrasse	
Labridae	Pseudocheilinus tetrataenia	Fourline Wrasse	
Labridae	Stethojulis balteata	Belted Wrasse	'o¯maka
Labridae	Thalassoma ballieui	Blacktail Wrasse	
Labridae	Thalassoma duperrey	Saddle Wrasse	hi¯na¯lea lauwili
Labridae	Thalassoma purpureum	Surge Wrasse	hou
Labridae	Thalassoma quinquevittatum	Fivestripe Wrasse	
Labridae	Thalassoma trilobatum	Christmas Wrasse	a¯wela
Scaridae	Calotomus carolinus	Stareye Parrotfish	
Scaridae	Scarus rubroviolaceus	Redlip Parrotfish	pa¯lukaluka
Blenniidae	Plagiotremus goslinei	Scale-eating Blenny	
Acanthuridae	Acanthurus achilles	Achilles Tang	pa¯ku‘iku‘i
Acanthuridae	Acanthurus blochii	Ringtail Surgeonfish	pualu
Acanthuridae	Acanthurus dussumieri	Eye-stripe Surgeonfish	palani
Acanthuridae	Acanthurus leucopareius	Whitebar Surgeonfish	ma¯ikoiko
Acanthuridae	Acanthurus nigrofuscus	Brown Surgeonfish	ma¯i'i'i
Acanthuridae	Acanthurus nigroris	Bluelined Surgeonfish	maiko
Acanthuridae	Acanthurus olivaceus	Orangeband Surgeonfish	na'ena'e
Acanthuridae	Acanthurus triostegus	Convict Tang	manini
Acanthuridae	Acanthurus xanthopterus	Yellowfin Surgeonfish	pualu
Acanthuridae	Ctenochaetus strigosus	Goldring Surgeonfish	kole
Acanthuridae	Naso lituratus	Orangespine Unicornfish	umaumalei
Acanthuridae	Naso unicornis	Bluespine Unicornfish	kala
Zanclidae	Zanclus cornutus	Moorish idol	kihikihi
Monacanthidae	Cantherhines dumerilii	Barred Filefish	'o¯'ili
Monacanthidae	Cantherhines sandwichiensis	Squaretail Filefish	'o¯'ili lepa
Balistidae	Melichthys niger	Black Durgon	humuhumu'el'ele
Balistidae	Melichthys vidua	Pinktail Durgon	humuhumuhi'ukole
Balistidae	Rhinecanthus rectangulus	Reef Triggerfish	humuhumunukunuku apua'a
Balistidae	Sufflamen bursa	Lei Triggerfish	humuhumulei
Balistidae	Sufflamen fraenatus	Bridled Triggerfish	humuhumumimi
Ostraciidae	Ostracion meleagris	Spotted Boxfish	moa
Tetraodontidae	Arothron meleagris	Spotted Puffer	'o'opuhue
Tetraodontidae	Canthigaster amboinensis	Ambon Toby	

Appendix I continued.

Family	TaxonName	Common Name	Hawaiian Name
Tetraodontidae	Canthigaster coronata	Crown Toby	
Tetraodontidae	Canthigaster jactator	HI Whitespotted	