MARINE SKILL REPORT SUBMITTED TO THE UNIVERSITY OF HAWAII MARINE OPTION PROGRAM

THE INFLUENCE OF GRAZING FISHES ON DISTRIBUTION AND ABUNDANCE OF *DICTYOSPHAERIA CAVERNOSA* IN KANEOHE BAY INCLUDING DIETARY PREFERENCES OF THE FISHES

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INTRODUCTION

Until 1977, the water of Kaneohe Bay, Hawaii received increasing amounts of untreated sewage. In 1977 sewage was diverted to a deep ocean outfall. Prior to the sewage diversion, two studies were prepared concerning the distribution and abundance of *Dictyosphaeria cavernosa* , the first in 1970 (Banner, 1974) and the second in 1977 (Smith, et al., 1981). During the early 1970's, the alga *D. cavernosa* was observed to be outcompeting (cutting out sunlight by overgrowing colonies) *Porites compressa* and other common corals such as *Montipora verrucosa* on the reef slope, the habitat where the two corals and *D. cavernosa* are found in greatest abundance.

After the sewage diversion in 1977-78, the relative abundance of *D. cavernosa* in Kaneohe Bay decreased from its pre-sewage diversion level (Smith, et al., 1981; Hunter and Evans, 1993). At present, the percent cover of this alga is apparently rising once again (Hunter and Evans, 1993), and, in consequence, outcompeting the *P. compressa.*

The abundance of *D. cavernosa* on the reef slope of Kaneohe Bay has been found to vary greatly not only among different patch reefs in the Bay, but also between relatively close sites on each patch reef, rather than being uniformly distributed around the perimeter of the patch reefs (Stimson, Univ. of Hawaii, personal communication).

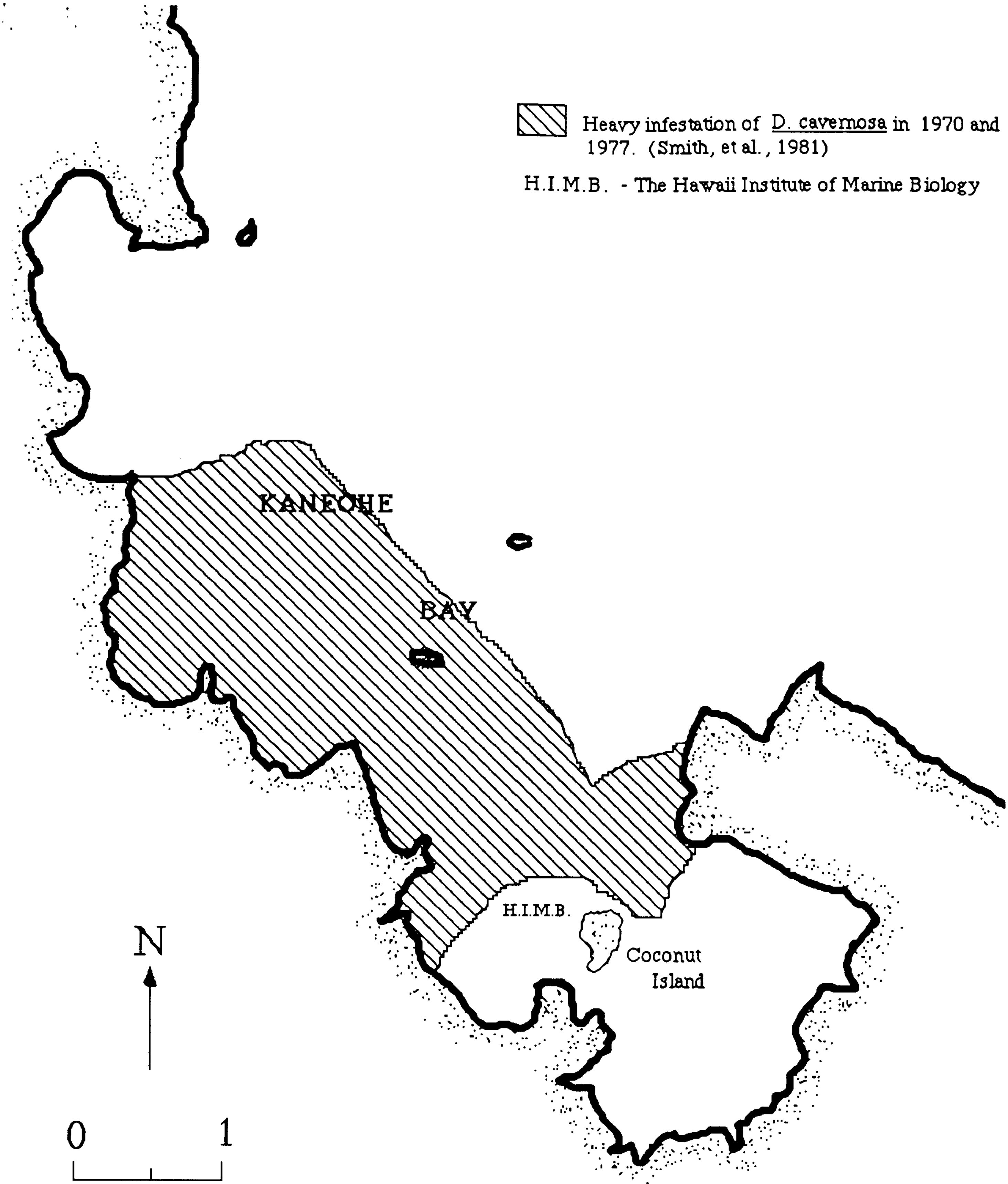


Figure 1. Region of Dictyosphaeria cavernosa abundance in 1970 and 1977.

The reasons for the present patterns of distribution and abundance are not fully understood, but may include in part the input of nutrients from occasional sewage, groundwater, and surface run-off flushing into Kaneohe Bay (Hunter and Evans, 1993). In addition, by reducing the abundance of grazers, recreational, commercial, and subsistence fishing in the Bay may play a part in the development of the high coverage of *D. cavernosa.* In theory, overfishing may reduce the abundance of grazers on the algal community of which *D. cavernosa* is a substantial part. Thus, if the algal community is not held in check by the grazing fishes, the most dominant, most distasteful or fastest growing alga will possibly flourish.

A possible impediment to understanding the reasons for the abundance and wide distribution of *D. cavernosa* is that there has been little to no documentation of its basic characteristics such as morphology, nutrient content, growth rates, etc. Previous studies on *D. cavernosa* have only monitored growth and mortality in terms of comparisons of percent algal coverage.

In order to answer the questions about *D. cavernosa*, its distribution patterns inside the Bay, and the factors which affect those patterns, there is a need for experimentation to provide building blocks which will be important in deciphering this alga's characteristics, such as which factors influence the growth rate.

In this study, I examined the preferences of grazing reef fishes of Kaneohe Bay for different species of algae and the daily quantities of algae consumed by the fishes. Preferences and consumption were monitored during summer 1993. The experiment was performed to determine the degree of preference shown by different species of captive herbivorous fishes for the alga *D. cavernosa* and other reef flat algae, and to determine if preferences could help explain the distribution and rate of growth of *D. cavernosa.* A low preference for *D. cavernosa* is expected and will be tested by the ranking of mean consumption rates (which directly reflect preferences). The four common reef flat species of algae included: *Padina japonica*, *Acanthophora spicifera*, *Kappaphycus alverezii*, and *Gracilaria salicornia*. The four herbivorous reef fishes included: *Acanthurus triostegus*, *Zebrasoma veliferum*, *Zebrasoma flavescens*, and *Scarus* sp.

METHODS AND MATERIALS

Collections and experiments carried out at the Hawaii Institute of Marine Biology (H.I.M.B.), on Coconut Island, in Kaneohe Bay Oahu (Figure 1). The preference studies conducted in this experiment required the trapping of different species of herbivorous reef fishes of two families; *Acanthuridae* and *Scaridae*. The three species of acanthurids consisted of *Acanthurus triostegus*, *Zebrasoma veliferum*, and *Zebrasoma flavescens*. The two young scarid individuals used were not identified to the species level. These species of herbivorous reef fishes were picked for experimentation because they represent some of the more abundant species present on the reef slope and reef flat.

The fishes used in this experiment were either trapped in the wild just prior to the experiment or trapped some days prior to experimentation, and then fed on food pellets daily.

Two traps were used for obtaining grazing reef fishes (Figure 2). The first trap consisted of 2.5-cm mesh chicken wire cut and shaped to form a 90 cm by 90 cm by 30 cm rectangular box fastened at the seams with galvanized wire with a funnel shaped entrance approximately 10 cm by 6 cm. Pieces of white PVC plastic tubing were placed inside and fastened to the bottom of the trap to attract fishes. The second trap consisted of 1.25-cm galvanized wire mesh to form a 90 cm by 75 cm by 30 cm rectangular box fastened at the seams similarly to the first trap with a funnel-shaped entrance

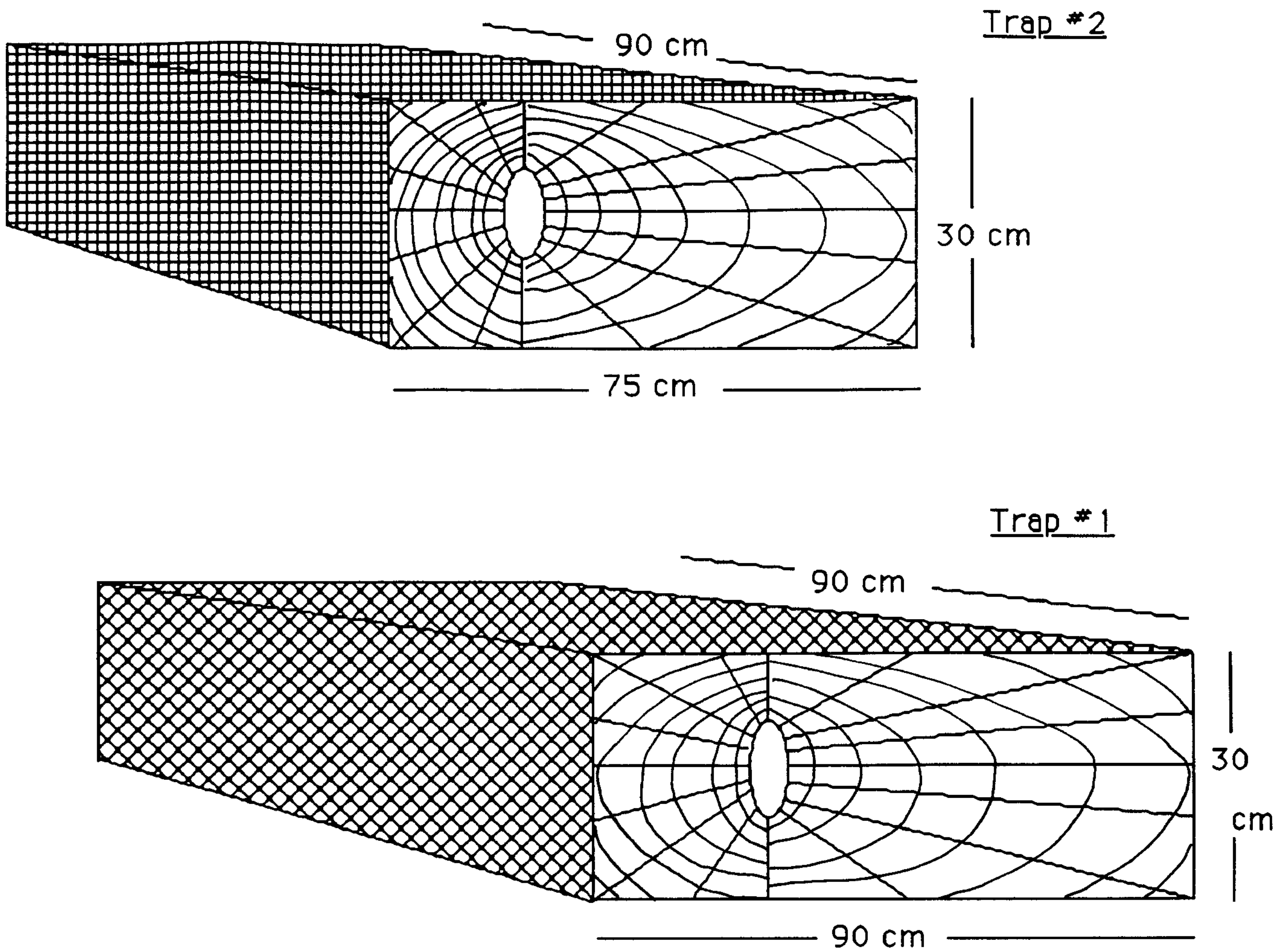


Figure 2. Trap #1 and trap #2 are models of traps used in the capture of herbivorous reef fishes for experimentation. (figure not drawn to scale).

approximately 7 cm by 3.5 cm. Again, pieces of white PVC plastic tubing were fastened to the inside of the second trap. Traps were kept continuously in the water to develop a coating of algae.

These two traps were both placed on the reef slope (at a depth of one to three meters) and at sites on the fringing reef flat on Coconut Island (Figure 3).

Experiments on food preferences of the herbivorous fishes were carried out in 40- to 80-liter tanks made of glass and covered with a rectangular sheet of 0.5-cm square black plastic mesh used to reduce irradiance levels and prevent fish and algae fragments from escaping. Each tank was aerated with its own air line and air stone. Each tank was also continuously supplied with new sea water pumped in from the reef slope. Fish were kept in the glass aquaria during the feeding trials. Five different species of algae (all of approximately equal weights) were presented to each fish. The five species of algae offered consisted of: *Dictyosphaeria cavernosa (D.c.)*, *Padina japonica (P.j.)*, *Acanthophora spicifera (A.s.)*, *Kappaphycus alverezii (K.a.)*, and *Gracilaria salicornia (G.s.)*. All algae were collected from the fringing reef flat on the windward side of Coconut Island (Figure 3). *D. cavernosa* was also collected from reef slopes of various patch reefs in the general proximity of the Bay. These pieces of algae (thalli) were all pre-weighed (wet) prior to being attached to a 9 cm by 9 cm by 2 cm square cement block by a single rubber band. The method of weighing consisted of patting each piece of algae with a terry-cloth towel until excess water was removed after which the algae were weighed and recorded to the nearest hundredth of a gram. One set of algae was placed in a tank designated as a control, a tank like the experimental tanks, but without a fish. Each run consisted of three to five tanks, one of which was used as a control tank. Each run lasted from 36 hours to 71 hours before the algae were removed from the tanks and re-weighed (wet) using the Sartorius top loading digital balance to determine the amount consumed by grazing fish in each tank.

The grams of algae consumed by each fish were computed as the final weight - initial weight - the amount of growth shown by control algae over the test period. The grams of algae consumed by each fish per day (G) is defined by Equation 1.

$$(Fe\text{-}Ie\text{-}Ee) = G \qquad \text{Equation (1)}$$

where Fe is the final weight in grams for the experimental thallus, Ie is the initial weight in grams for the experimental thallus, and Ee is defined by equation 2:

$$[(Fe + Ie)/2] \times [(Fc - Ic)/Ic] = Ee \qquad \text{Equation (2)}$$

where Fc is the final weight in grams of the control thallus, and Ic is the initial weight in grams of the control thallus. All values are in grams/day.

Fragments of algae loosened by grazing of fishes either sank to the bottom of the tank and collected or were collected at the surface and were not washed out of the tank. These fragments were then separated by species and weighed, the weight was then added to the final weight of that species thallus.

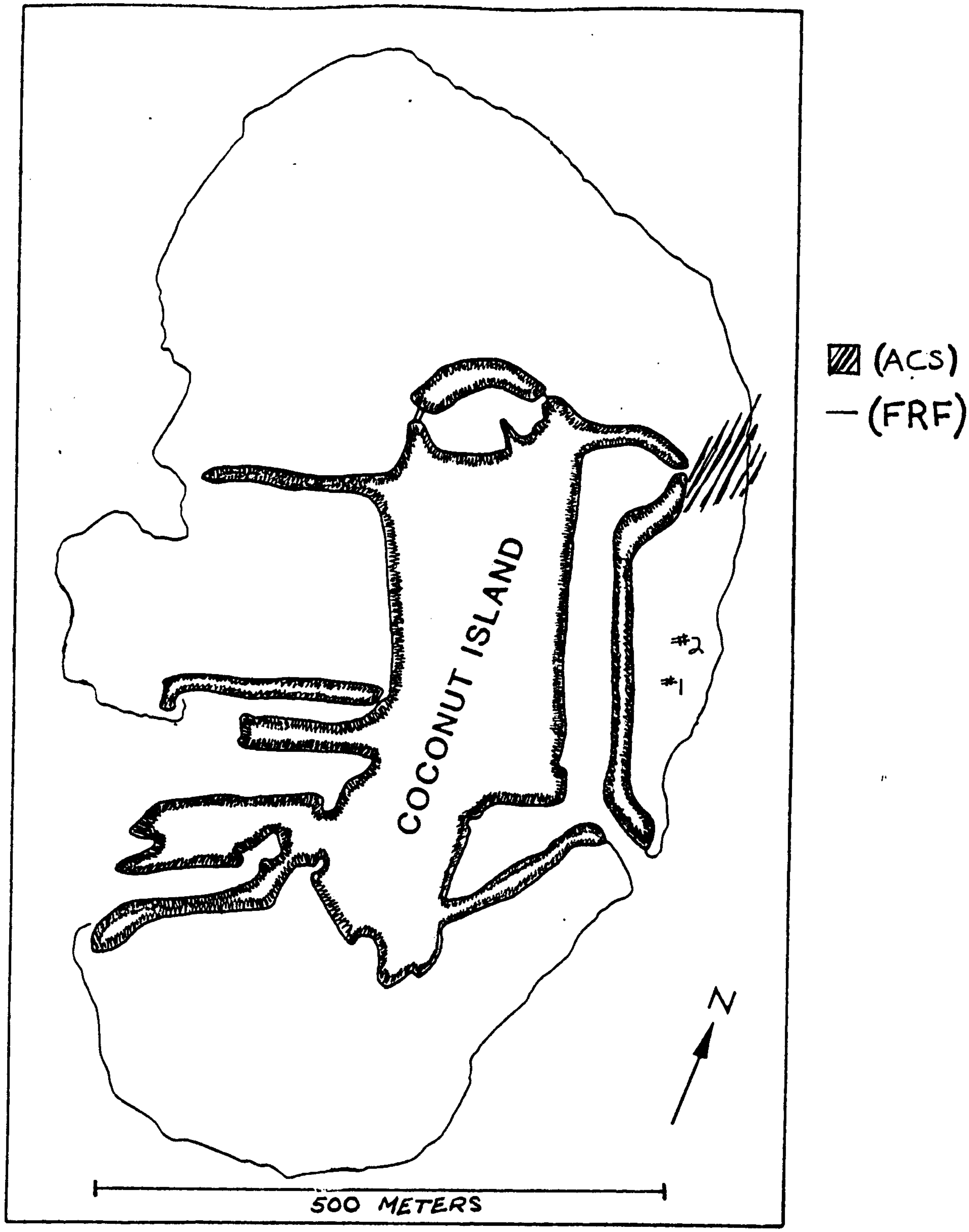


Figure 3. Algae collection site (ACS), two trapping sites (#1 and #2), and fringing reef flat (FRF) along Coconut Island, Kaneohe Bay, Hawaii.

RESULTS

Mean consumption rates (g/day) for fishes of the family *Acanthuridae* were similar to those recorded for *Scaridae*, but no attempt has been made to correct consumption rates for the weights of fishes used. In both families of fishes, consumption rates were greater for *A. spicifera* than any other species of algae; *A. spicifera* represented approximately 65 percent of total algal tissue consumed (6.39 g/day of 9.97 g/day). The calcareous alga *P. japonica* was the second most heavily consumed alga by scarids while very little of this alga was consumed by acanthurids, being the least favored by *A. triostegus* (Table 1). Consumption rates of individual fishes are given in Appendix 1. Statistical analysis was not used in this experiment because of small sample sizes.

The relationship between total algal consumption per day by a fish and the weight of the fish is not clear (Figure 4). Consumption rate did appear to increase with weight of fish, but above 200 grams the relationship is uncertain. For this reason consumption was not standardized on the basis of fish weight (Table 2).

Preference rankings were assigned to each alga based on the degree of consumption for that alga, with a ranking of one being highest. Overall, the preference of *D. cavernosa* was the second lowest or lowest in these two families, being slightly preferred over *K. alverezii* by the scarids and slightly preferred over *P. japonica* by the acanthurids (Table 2). *D. cavernosa* was shown to have the lowest consumption rate and preference value if computed by pooling results from both families of fish. The consumption rate of *G. salicornia* by the scarids was slightly higher than its consumption rate by acanthurids although it was the median preference of both families (Table 1). Standing out as the most preferred was *A. spicifera*, which was observed to have the highest growth rate by control thalli (Table 3).

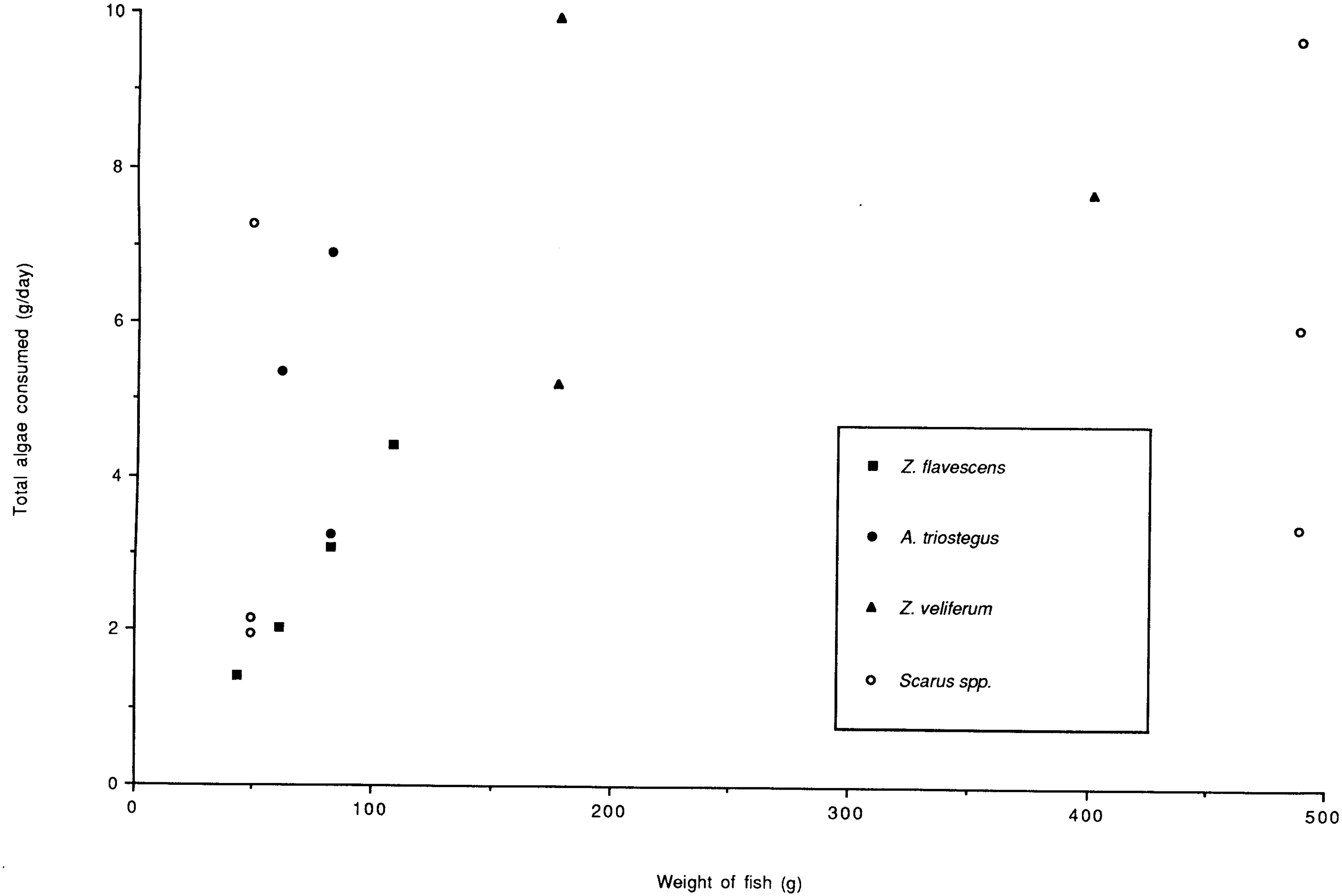
Table 1. Mean rates of consumption and rankings for the families *Acanthuridae* and *Scaridae* for the five types of algae experimented with, expressed in grams per day (g/day) per fish. Algal species names abbreviated. (Negative values indicate alga has been grazed). Sample size for *Scaridae* n=2 and *Acanthuridae* n=10.

Alga Spp. / Fish Spp.	*P.j.*	*A.s.*	*D.c.*	*K.a.*	*G.s.*	Total (g/day)
Avg. *Acanthuridae*	-0.18	-3.43	-0.34	-0.59	-0.38	-4.92
rank	*5	*1	*4	*2	*3	
Avg. *Scaridae*	-1.09	-2.96	-0.25	-0.07	-0.68	-5.05
rank	*2	*1	*4	*5	*3	
Avg. both families	-0.52	-3.26	-0.31	-0.40	-0.50	-4.99
rank	*2	*1	*5	*4	*3	

Table 2. Total algae consumed (g/day) per fish, approximate weights (w) in grams (g) and total lengths (L) in millimeters (mm) of all herbivorous reef grazing fishes experimented with, using the equations: $w = .000008625 \times L \text{ (in mm)}^{3.31}$ for *Scaridae* and $w = .00000552 \times L \text{ (in mm)}^{3.45}$. (R. Brock, Univ. of Hawaii, personal communication). *Scaridae* consumption averaged for three runs.

Spp. / fish #	Weight (g)	Length (mm)	Total algae consumed (g/day)
Z. flavescens / 1	43.85	100	1.42
Z. flavescens / 2	60.92	110	2.03
Z. flavescens / 3	82.24	120	3.07
Z. flavescens / 4	108.40	130	4.42
A. triostegus / 1	82.24	120	6.91
A. triostegus / 2	82.24	120	3.25
A. triostegus / 3	60.92	110	5.35
Z. veliferum / 1	177.60	150	5.22
Z. veliferum / 2	177.60	150	9.93
Z. veliferum / 3	401.46	190	7.68
Scarus spp. / 1	49.29	110	3.80
Scarus spp. / 2	488.85	220	6.33

Figure 4. Total weight of algae consumed (g/day) vs' weight of fish (g) for all species.



DISCUSSION

The results of this study indicate that within the two families of herbivorous reef grazing fishes, *Acanthuridae* and *Scaridae*, there are strong feeding preferences. The factors responsible for these preferences were not examined in this study, but may include chemical defenses of algae (Hay, 1991; Paul and Hay, 1986), which may be present in the cell walls of the alga. Another type of defense an alga has towards its predators is its morphology (Hay, 1981), a particular morphology can be disadvantagous to some grazers while at the same time being advantageous to others. One example would be a leafy alga that grows from the base of a colony of coral polyps which puts the alga in a position to be grazed by fishes only down to a level just below the surface of the coral head. The content of nutrients within the alga also attracts or deters organisms from preying on them (Lubchenco and Gaines, 1981). These are factors to take into consideration when interpreting the results of this experiment.

The results from the partially calcified alga *P. japonica* indicate that it was preferred by the scarids but not the acanthurids. One reason for this preference might be the morphology of the fishes' mouth. Scarids have a jaw which is actively used to rasp the substratum (Brock, 1979), while in comparison, acanthurids have a smaller protruding mouth. This may account for the higher grazing intensity on this calcified alga by scarids. A low nutritional, protein, and lipid content could also play a role in why energy is not expended by the acanthurids in order to include *P. japonica* in their diet (Montgomery and Gerking 1980; Steinberg and Paul 1990).

Both families of fishes studied show the highest preference for *A. spicifera*. This could indicate that this fleshy alga has the highest nutritional value of the five species in this study (Montgomery and Gerking, 1980). The persistence of this alga on the reef flat may be due to its high growth rate as observed in control thalli (Table 3).

The results of the alga *D. cavernosa* showed a very low preference by each family in this study. As discussed above, this might be because of this particular alga's morphology, low nutrient content, or possible chemical defenses. The morphology of this alga is leafy on the top surface where its lobes are loosely layered. As it is grazed, this alga becomes increasingly compact and may be more difficult to bite which may account for reduced preferences. In this study, the *D. cavernosa* thalli used resembled the compact morphology which is discussed above.

The results for *K. alverezii* have indicated that this alga is preferred by the acanthurids but not by the scarids. One reason might be that this alga possesses a chemical defense that is more potent to scarids or a nutrient deficiency to the scarid diet.

These results for the red alga *G. salicornia* indicate that this alga is preferred by both families studied but not as highly as *A. spicifera*. This could mean that *G. salicornia* has a morphology that is susceptible to being grazed by scarids and acanthurids, and no harmful chemical defense which inhibits herbivory. Furthermore, *G. salicornia* may not be as heavily grazed as *A. spicifera* (Table 1)

Table 3. Growth of algae controls in grams per day (g/day), using the equation: Fc - Ic.

Species/ Fish #/rep.	*P.j.*	*A.s.*	*D.c.*	*K.a.*	*G.s.*
Z. flavescens/ 1	0.60	0.73	0.05	0.15	-0.07
Z. flavescens/ 2	0.60	0.73	0.05	0.15	-0.07
Z. flavescens/ 3	0.50	0.77	0.07	0.15	-0.02
Z. flavescens/ 4	0.50	0.77	0.07	0.15	-0.02
A. triostegus/ 1	0.60	0.73	0.05	0.15	-0.07
A. triostegus/ 2	0.60	0.73	0.05	0.15	-0.07
A. triostegus/ 3	0.50	0.77	0.07	0.15	-0.02
Z. veliferum/ 1	0.50	0.77	0.07	0.15	-0.02
Z. veliferum/ 2	0.50	0.77	0.07	0.15	-0.02
Z. veliferum/ 3	0.00	0.47	-0.06	0.14	-0.20
Avg. Acanthuridae	0.36	0.66	0.02	0.15	-0.10
Sample Size	3	3	3	3	3
Scarus spp./ 1/a	0.79	0.68	0.10	0.30	0.23
Scarus spp./ 1/b	0.15	1.34	0.07	0.06	0.20
Scarus spp./ 1/c	0.78	2.25	0.26	0.25	0.03
Scarus spp./ 2/a	0.30	0.41	0.10	0.15	0.10
Scarus spp./ 2/b	0.78	2.25	0.26	0.25	0.03
Scarus spp./ 2/c	0.00	0.47	-0.06	0.14	-0.20
Avg. Scarus spp.	0.47	1.07	0.12	0.19	0.06
Sample Size	6	6	6	6	6

because it is lower in nutrients. The relatively low preferences displayed for *G. salicornia* corresponds with its invasion of reef slope along with *D. cavernosa.*

Overall, preferences by scarids and acanthurids differ to some degree but seem to indicate a general theme with the five algal species studied. *D. cavernosa* was indicated to be the least preferred algae looked at, which is consistent with its high abundance and broad distribution within Kaneohe Bay. This phenomenon could be affected by the location of *D. cavernosa* on the reef slope as it has been shown in terrestrial plants that any particular defense is likely to become less effective as a plant is subjected to attack by different types of herbivores. Since its morphology is so different from that of other algal species on the reef slope it could be possible that *D. cavernosa* receives "specialized" grazing from a low number of herbivores meaning that its defenses haven't had to adapt to multiple styles of grazing. It could be that this feature alone is the key to its success in Kaneohe Bay (Lubchenco and Gaines 1981).

REFERENCES

Banner, A.H. 1974. Kaneohe Bay, Hawaii: Urban pollution and a coral reef ecosystem. Proc. 2d Internat. Symp. Coral Reefs. 2:685-702. Great Barrier Reef Commitee, Brisbane.

Brock, R.E. 1979. An experimental study on the effects of grazing by parrotfishes and the role of refuges in benthic community structure. Marine Biology 51:381-388.

Hay, M.E. 1981. The functional morphology of turf-forming seaweeds: persistence in stressful marine habitats. Ecology 62(3):739-750.

Hay, M.E. 1991. Marine-terrestrial contrasts in the ecology of plant chemical defenses against herbivores. Tree 6:362-365.

Hunter, C.L. and C.W. Evans. 1993. Reefs in Kaneohe Bay, Hawaii: two centuries of western influence and two decades of data. Proceedings of: Global Aspects of Coral Reefs: Health, Hazards, and History Miami, Florida (In Press).

Lubchenco, J. and S.D. Gaines. 1981. A unified approach to marine plant-herbivore interactions. 1. populations and communities. Ann. Rev. Ecol. Syst. 12:405-437.

Montgomerey, W.L. and S.D. Gerking. 1980. Marine macroalgae as foods for fishes: an evaluation of potential food quality. Env. Biol. Fish. 5(2):143-153.

Paul, V.J. and M.E. Hay. 1986. Seaweed susceptibility to herbivory: chemical and morphological correlates. Marine Ecology 33:255-264.

Smith, S.V., W.J. Kimmerer, E.A. Laws, R.E. Brock, and T.W. Walsh. 1981. Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbation. Pacific Science 35(4):279-397.

Steinberg, P.D. and V.J. Paul. 1990. Fish feeding and chemical defenses of tropical brown algae in Western Austrailia. Marine Ecology Progress Series 58:253-259.

Appendix 1. Comparison of consumption rates from two families of herbivorous fishes feeding on five species of reef flat algae.

	Algae- Spp./fish#/rep.#	(g)consumed/day P.j.	(g)consumed/day A.s.	(g)consumed/day D.c.	(g)consumed/day K.a.	(g)consumed/day G.s.
Acanthurids	Z.f. /1/-	0.09	-1.31	0.04	-0.06	-0.18
	Z.f. /2/-	0.08	-1.89	-0.10	-0.12	0.00
	Z.f. /3/-	-0.49	-1.98	-0.30	-0.20	-0.10
	Z.f. /4/-	-0.52	-2.69	-0.69	-0.26	-0.26
	Avg. Z.f.	-0.21	-1.97	-0.26	-0.16	-0.13
	A.t. /1/-	-0.45	-5.32	-0.02	-0.65	-0.47
	A.t. /2/-	0.24	-2.74	-0.06	-0.43	-0.26
	A.t. /3/-	-0.03	-3.97	-0.07	-0.81	-0.47
	Avg. A.t.	-0.08	-4.01	-0.05	-0.63	-0.40
	Z.v. /1/-	-0.36	-3.20	-0.17	-1.32	-0.17
	Z.v. /2/-	-0.10	-5.71	-1.77	-1.20	-1.15
	Z.v. /3/-	-0.24	-5.49	-0.25	-0.90	-0.80
	Avg. Z.v.	-0.23	-4.80	-0.73	-1.14	-0.71
	Avg. Acanth.	-0.18	-3.43	-0.34	-0.59	-0.38
	Std.Dev.	0.27	1.61	0.54	0.45	0.35
	rank	*5	*1	*4	*2	*3
Scarids	S.d. /1/a	0.16	-1.82	-0.28	-0.15	0.14
	S.d. /1/b	-0.15	-1.95	-0.18	0.05	0.06
	S.d. /1/c	-0.94	-5.85	-0.28	-0.08	-0.13
	S.d. /2/a	-0.96	-1.27	-0.16	0.03	-1.01
	S.d. /2/b	-2.31	-5.00	-0.25	-0.10	-2.01
	S.d. /2/c	-2.37	-1.90	-0.37	-0.18	-1.14
	Avg. S.d.	-1.09	-2.96	-0.25	-0.07	-0.68
	Std.Dev.	1.06	1.94	0.08	0.09	0.85
	rank	*2	*1	*4	*5	*3
	Avg. of all values	-0.52	-3.26	-0.31	-0.40	-0.50
	rank	*2	*1	*5	*4	*3

*values refer to rankings of avg. consumption rate values. (all fish species abbreviated).