THE ECOLOGICAL INTERACTION

OF

THE POMACENTRID *DASCYLLUS AQUANUS* (LINNAEUS)

WITH

THE CORAL *ACROPORA ARBUSCULA* (DANA)

A STUDY SUBMITTED TO THE
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By

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ABSTRACT

This study is an autecological survey investigating the relationship of the pomacentrid fish Dascyllus aruanus with the coral Acropora arbuscula Factors considered in the investigation were the behavior and population composition of Dascyllus aruanus in regard to its use of the coral and the life history of the fish. The morphology of the digestive tract and the digestive tract contents were investigated in studying the food habits of D. aruanus. The flora and fauna of Acropora arbuscula were collected and catalogued to locate sources of food items and to determine possible competitors. Repopulation experiments furnished some information concernin movements of the fish population.

Results of the study indicate that Dascyllus aruanus depends on Acropora arbuscula for cover rather than for food. Although the digestive system is adapted primarily for the life of a carnivore, Dascyllus aruanus is omnivorous. The fish is not inclined to migrate to depopulated coralla. Abudefduf leucozona, another pomacentrid, apparently occupies a niche very close to D. aruanus.

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I. INTRODUCTION

The coral reef is one of the most biologically productive areas on earth. One approach to understanding the workings of this complex, crowded environment can be achieved through autecological studies of parts of the whole. The interaction of one species of fish with its environment may be one of these parts.

This work is concerned with such an interaction between the pomacentri Dascyllus aruanus and the coral Acropora arbuscula. Dascyllus aruanus is a small (up to 90 mm.), deep bodied, laterally compressed damselfish (Fig. 1) The most outstanding feature of this common reef fish is the three wide black vertical bars on the body. The alternate vertical bars are white. Like many species in the genus D. aruanus is most often found associated with a specific coral. (Stevenson 1963).

Small schools of these fish can be seen clustered around the branches of Acropora arbuscula. This coral is often found as scattered coralla on the sand bottom of the reef flat. A. arbuscula is a rather fragile coral, growing to about 30 cm. in height (Fig. 2). The living branches of the corallum are brown. Although Dascyllus aruanus is most often seen amon the branches of Acropora arbuscula, the fish has also been observed in A. acuminata. This larger species of coral is found toward the seaward reef margin (Wiens 1962) rather than on the reef flat. All collections for this survey were made from A. arbuscula.

Collecting of fishes and other organisms from Acropora began 1 March 1 and continued at irregular intervals through 20 June 1963. Times of collec all during daylight, varied from 10:00 hrs. to 20:00 hrs. and occurred at a stages of tide.

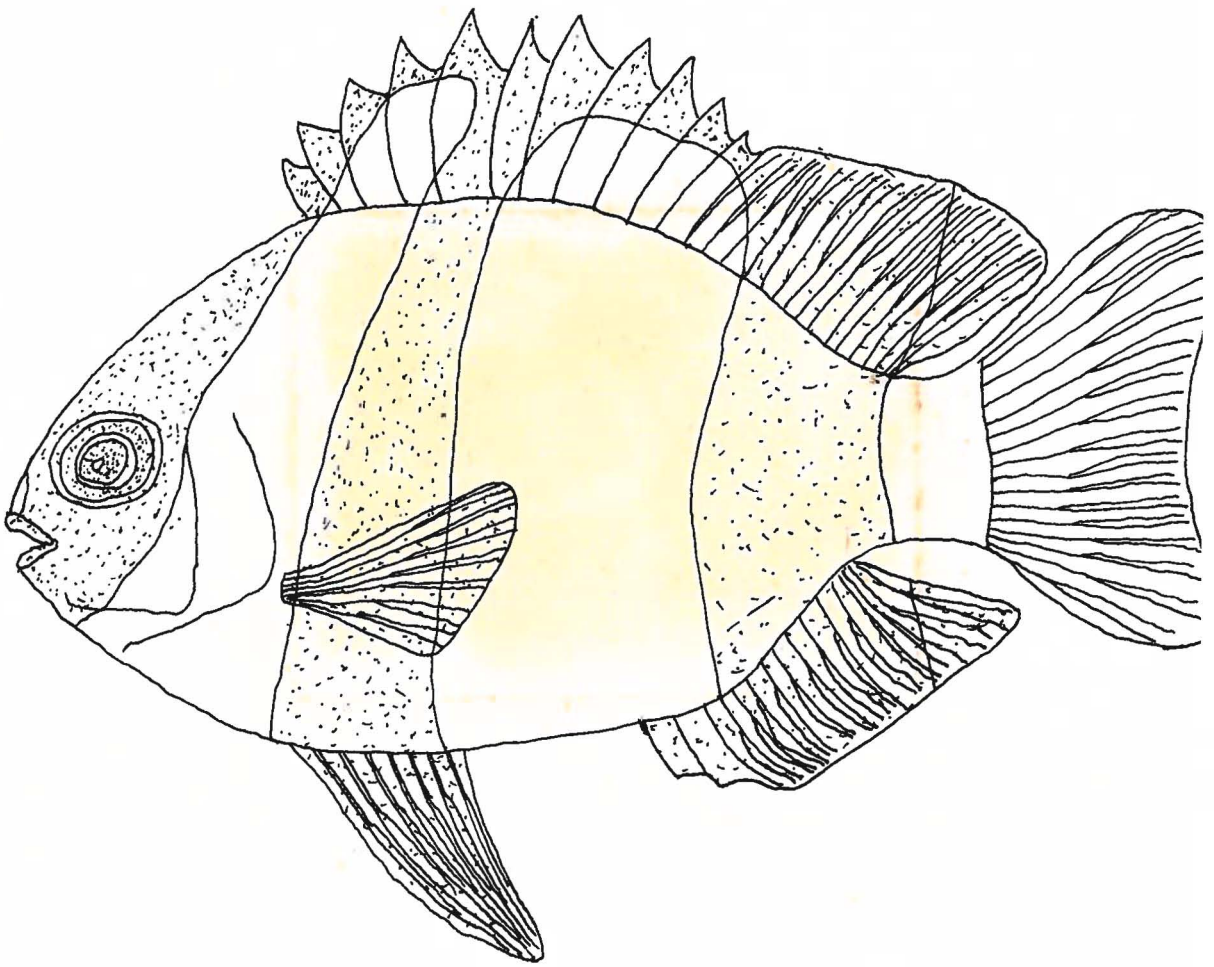

Figure 1 Dascyllus aruanus (Linnaeus)
From Schultz 1960 plate 80

Figure 2 Corallum of *Acropora arbuscula*.

The site of the survey was the reef flat of Tumon Bay off Gognga Beach, Guam, Mariana Islands.

II. METHODS AND MATERIALS

All specimens were taken in water from 0.5 m. to 1.5 m. deep using snorkel equipment, a 5 mm. mesh dipnet, and a plastic bucket in an inner-tube. The method employed was to lift the corallum containing the fish int the bucket while holding the net under the coral to catch anything that mig fall or jump out. A separate bottle was used for the organisms from each corallum. Plastic strings of two colors were tied to depopulated coralla. These coralla were recovered later for repopulation studies. Various combinations of knots distinguished one marker from another. Range marks on the beach provided the necessary aids to navigation in recovery.

A small spring balance was used to weigh each corallum after the specimens were collected from it. The weight of the corallum in sea water subtracted from the weight in air yields the displacement in grams. This figure is divided by the specific gravity of sea water (about 1.03 g/ml.) to give the volume of the corallum in milliliters.

Examination of the gut contents was done in a Petri dish with the bottom marked off in 1 cm. squares. The presence of a piece of alga or an invertebrate in a square was recorded as a count of one for that organism. Each organism was counted only once per square. The number of counts for each, divided by the total counts for all of the organisms found in that fish, gives a percentage for each food plant or animal.

This method of counting gut contents does not give a true measurement of the biomass (Jones thesis). Specifically, the count of one for a single

small copepod in the 1 cm. square carries the same statistical weight as a clump of Enteromorpha that almost fills the square. Another possibility for error is that chitinous shelled, digestion resistant, copepods may remain intact in the digestive system longer than the algae (Gerald 1966). Several species of copepods were grouped together in the counts. Detritus and sand in the gut contents was not measured.

III. RESULTS

A. Behavior

The fact that Dascyllus aruanus is associated with Acropora is an observation of behavior. The analysis of data in the other sections of this paper is an attempt to discover reasons why natural selection would favor this behavior.

Food items are found only on the dead parts of the coral where algae is growing. It is an interesting point that Dascyllus aruanus was rarely collected from a corallum that was less than 70% alive. Over half (27 out of 56) of the coralla collected were estimated to be at least 90% alive. The fish was never collected from the branches of a completely dead corallum.

Many D. aruanus appear to be associated with a single corallum of Acropora. When a swimmer approaches their area the fish swim into the branches of the coral. This habit makes collecting of this species easy, as the fish will not leave the corallum even when the corallum is moved into a net or a plastic bag.

There appears to be less of this behavior as the fish reach a size of about 50 mm. in standard length. These larger fish will often

leave the corallum as the swimmer approaches and then hover over another corallum 2 m. to 3 m. away. If followed to the new position the larger fis will again leave for another corallum. This behavior is most often seen in the area where Acropora almost covers the bottom. The large fish seem less inclined to run where the coralla are spaced farther apart. It is sometimes possible to "shoo" even a large Dascyllus into a corallum.

Reproductive behavior was not observed. However, eighteen of the eighty viscera examined contained eggs. Collected during March and April, the ripe fish ranged from 27 mm. to 47 mm. in standard length.

B. Morphology of the Intestinal Tract, Dentition, and Gill Rakers

Morphology of the digestive tract often gives some indication of a fishes' ability to use various types of foods. Canine or cone-shaped tee and a short intestine are indicative of a carnivorous animal. Cuspid or incisor-like teeth and a long intestine are more suited to herbivores. A pharyngeal mill and/or a gizzard type stomach would be expected in a fish t normally grinds hard material from the substratum (Jones Thesis).

The intestine (Fig. 3) is located almost entirely on the right side of the body cavity against the body wall. The stomach is on the left side and may be partially concealed under the lobes of the liver.

In the following discussions the fish are divided into three groups. The term "juvenile" is used for fish with standard lengths from 8 mm. to 16 mm. "Adult" refers to the group ranging from 17 mm. to 48 mm. and "large adult" is a fish larger than 48 mm.

Measurements of intestines were made on twelve specimens of D. aruanus ranging in size from 9 mm. to 48mm. The intestine measurements ranged from 6 mm. to 90 mm. These intestine measurements were divided by

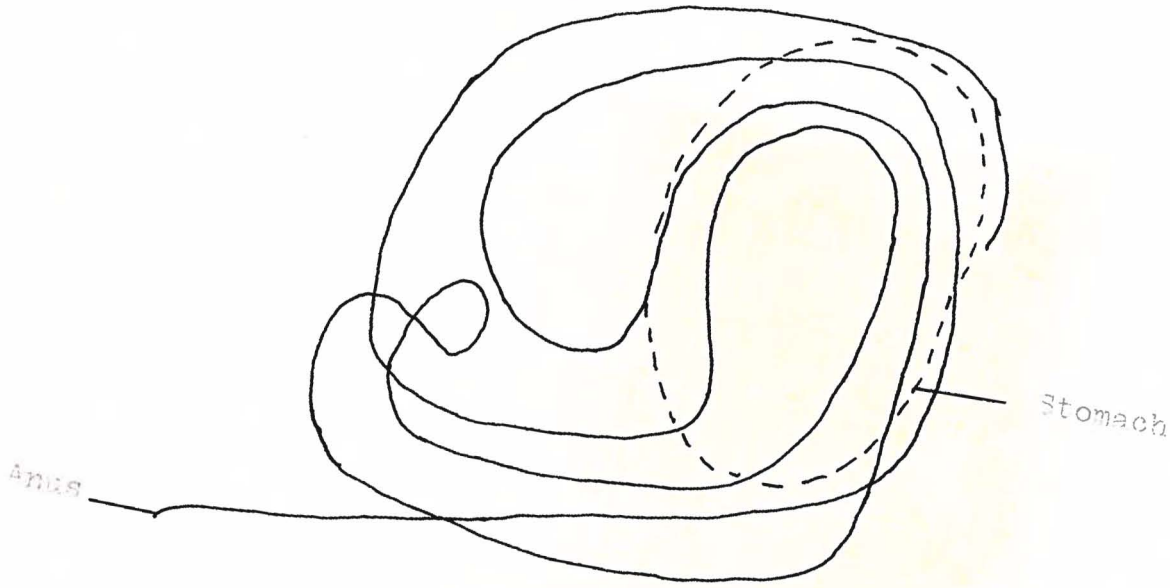

Figure 3 Diagram of the intestine of the adult Dasyllus aruensis.

the standard length of the fish to produce standard length to intestine length ratios ranging from 1:0.6 to 1:2.4. In averaging the ratios and comparing them to the standard lengths of the fish (Fig. 4), the highly carnivorous juvenile group (see Fig. 13) averaged only about half the proportional length of the more herbivorous adult group.

The stomach (Fig. 5) is roughly egg shaped. Both the esophagus and the intestine enter the stomach anteriorly, with the esophagus superior to the intestine. Three pyloric caeca branch near the stomach from the right side of the base of the intestine. Two of these fold around anterior to the left side of the organ.

The teeth of D. aruanus (Figs. 6 and 7) are all cone-shaped and slightly curved posteriorly. There is a single row in both upper and lower jaws. The anterior teeth are larger than those on the sides of the mouth. They appear to be the teeth of a typical carnivore.

Gill rakers (Fig. 8) on the first arch are approximately the same length as the filaments on the arch. There appears to be no pharyngeal grinding mill but there are short, triangular teeth on the gill arches. The formula for the gill rakers is 6 + 1 + 13.

Morphologically D. aruanus seems to show few features of the typical herbivore. The slightly curved, conical teeth are in contrast to the various incisor and brush-like teeth of the herbivorous acanthurids (Jones Thesis).

The greatest intestine length to standard length ratio of 1:2.4 for D. aruanus is far shorter than those reported for members of Acanthuridae (Jones Thesis). Juvenile D. aruanus have a very short intesti compared to the adults of the species. This is indicative of an animal

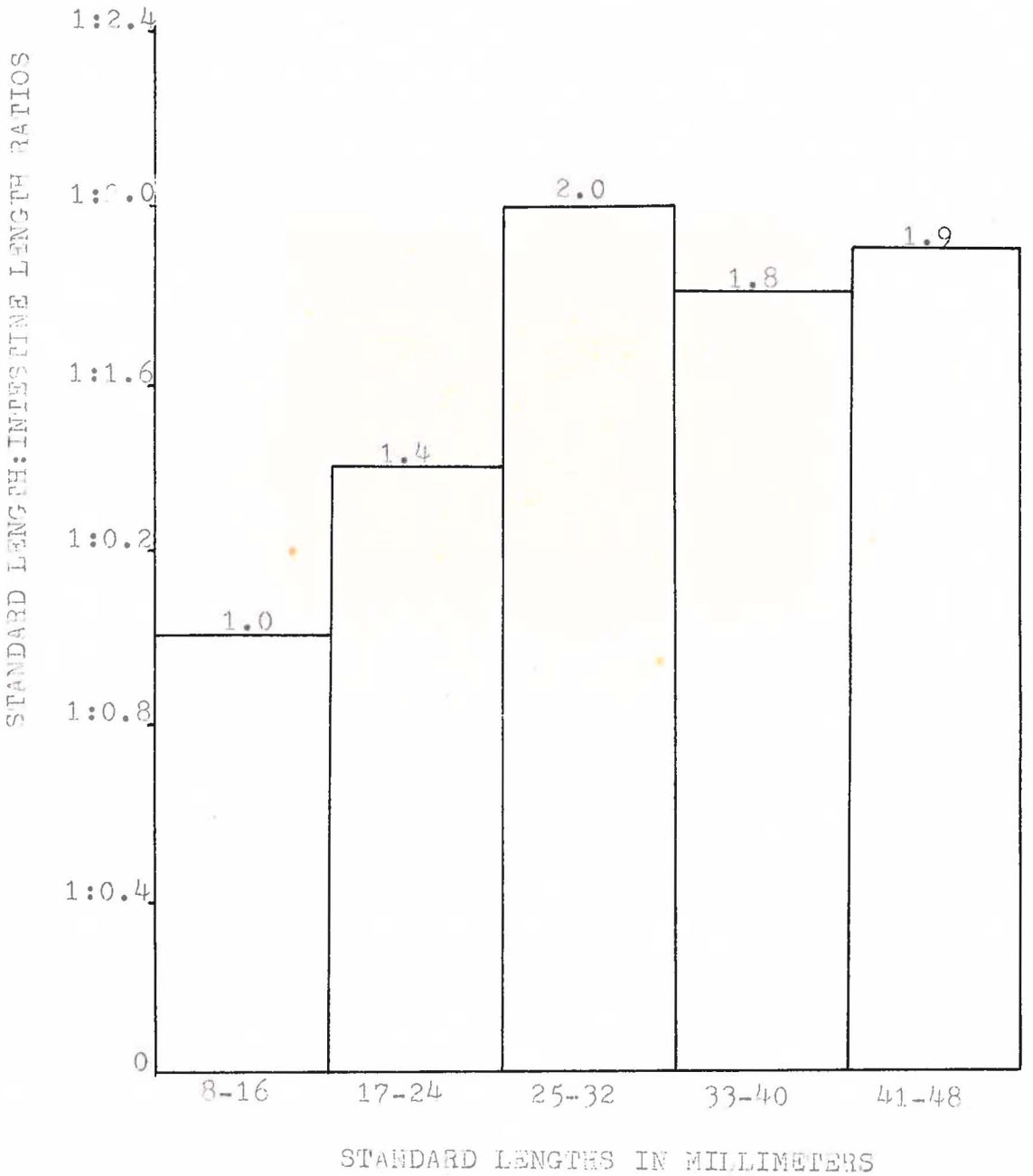

Figure 4 Standard length:intestine length ratios for D. aruanus of various lengths.

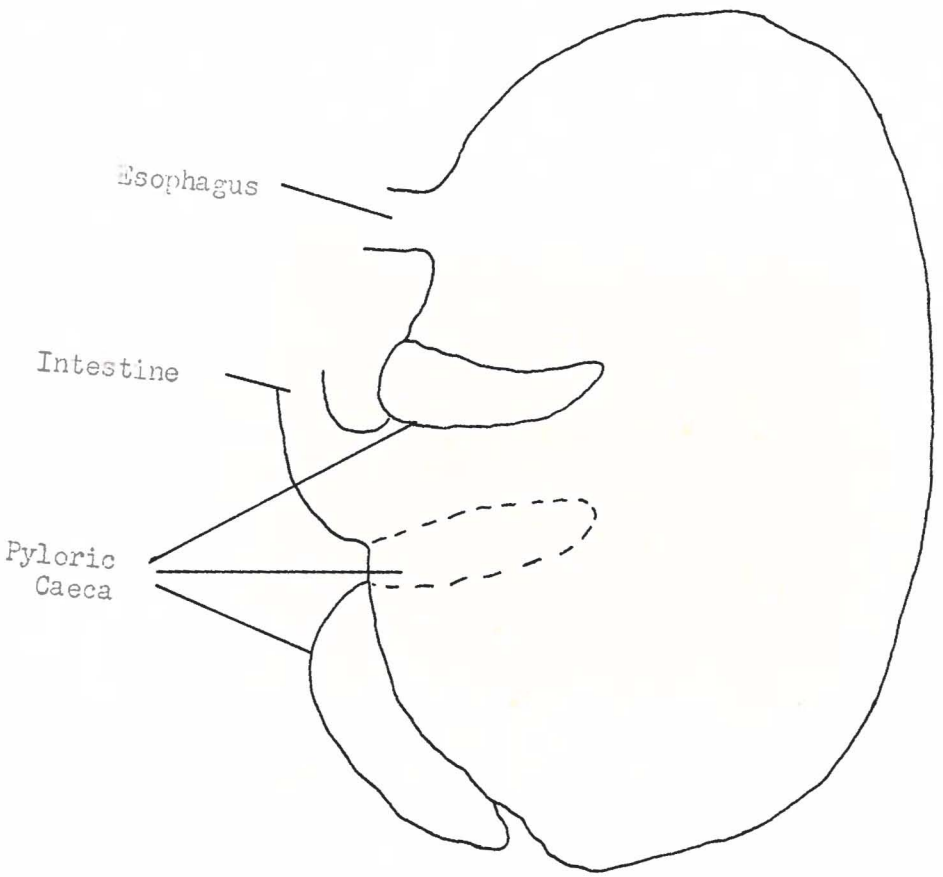

Figure 5 Stomach of Dascyllus aruanus (left side)

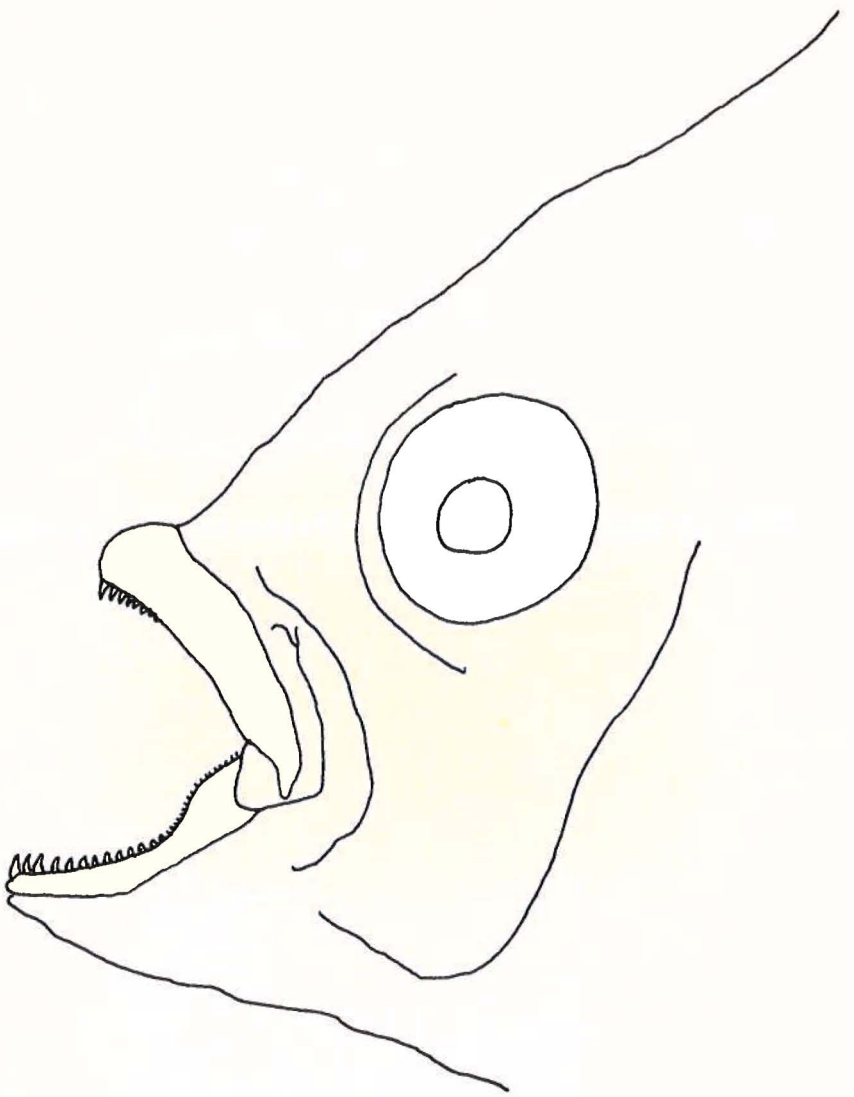

Figure 6 Dentition of *Dascyllus aruanus*.

diet for the juveniles and an omnivorous diet for the adults.

C. Analysis of Digestive Tract Contents

Identification of food items from the gut of D. aruanus helps to determine the relationship between the fish and the coral. If the same specimens are found both in the fish and on the coral it might be assumed that the fish feeds from the coral. The percent of each item in the tract may reflect food preference or availability for the various sizes of the fish.

The gut contents of eighty D. aruanus were examined. The standar lengths of the fish ranged from 8 mm. to 56 mm. The results were expressed for each food item as percent of the total stomach content.

Fourteen food organisms were found in the fish. Table I gives the percent of occurrence for each organism. Table II, based on actual counts, gives the average percentages of each organism in the gut of the fishes sampled. These figures were computed by adding all of the percentag for each food organism and then dividing each by the total number of fish examined (80).

As illustrated in Fig. 9, copepods were the predominant food item in juvenile D. aruanus. The lowest copepod consumption was found in the adult range. This consumption of copepods by the juveniles, almost to the exclusion of other foods, is again reflected in Fig. 10.

Enteromorpha was the dominant algal genus found in Dascyllus aruanus (Tables I, II and Fig. 11). The juveniles again reflect their dependence on copepods by the almost complete absence of Enteromorpha in their digestive tracts. Adult fish show a rather high proportion. The drop in percentage in the large adult group reflects a diversification

Copepods	96%	Foraminifera	33%	
Enteromorpha	79%	Schacelaria	24%	
Boodlea	70%	Bryopsis	13%	
Hyperiid amphipods	62%	Cladophora	13%	
Hypnea	53%	Calothrix	10%	
Spyridea	44%	Schizothrix	4%	
Annelid	35%	Lyngbya	1%	(less than)

Table I List of food organisms and their frequency of occurrence in the 80 D. aruanus sampled.

Copepods	36%	Annelid	2%	
Enteromorpha	30%	Foraminifera	1%	
Boodlea	11%	Bryopsis	1%	
Hyperiid amphipods	7%	Sphacelaria	1%	
Hypnea	4%	Schizothrix	1%	(less than)
Calothrix	3%	Lyngbya	1%	(less than)
Spyridea	3%			

Table II Average percentages of various organisms found in the gut of the D. aruanus specimens sampled.

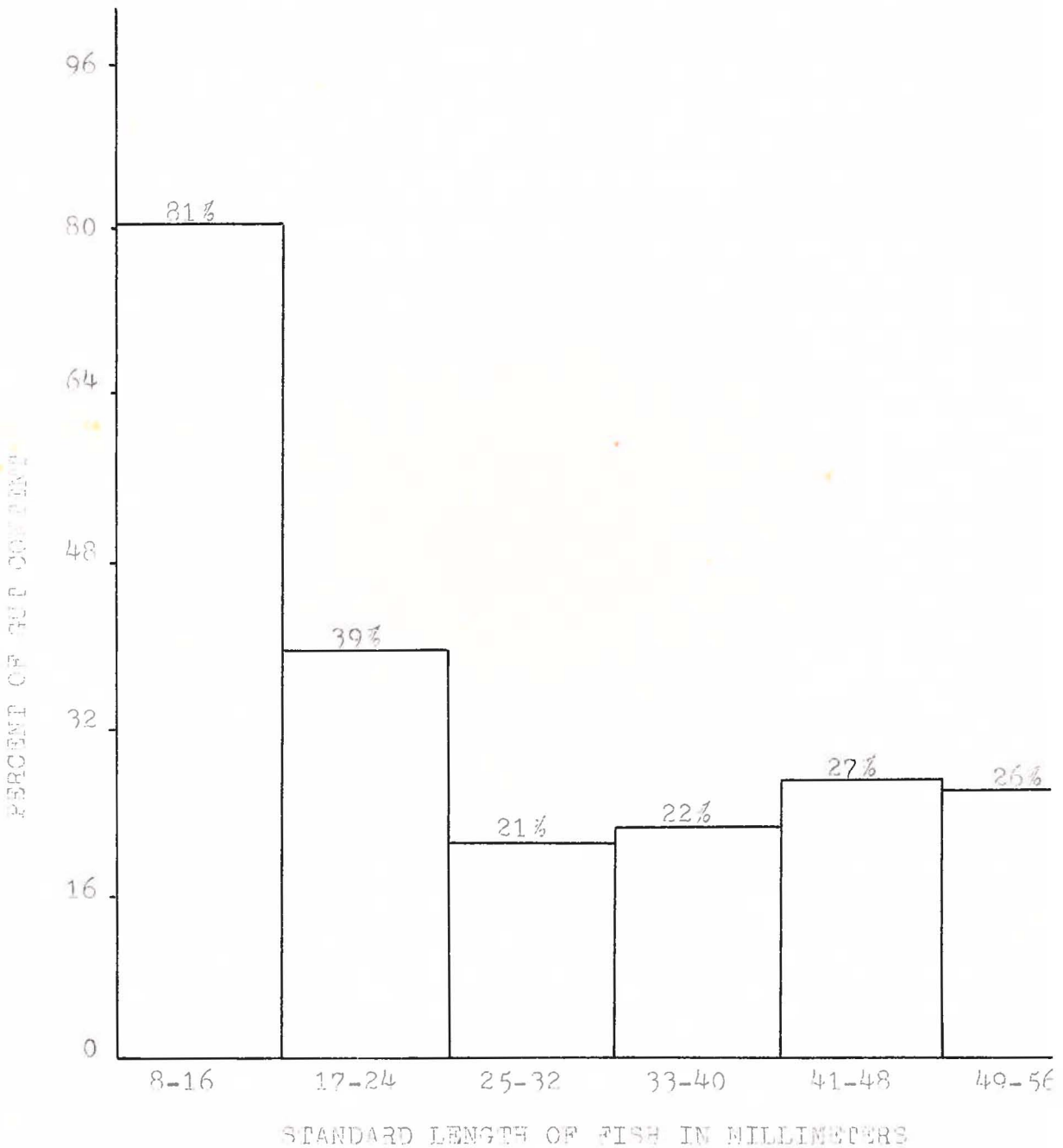

Figure 9 Average percent of copepods in the gut of D. arcuatus of various sizes.

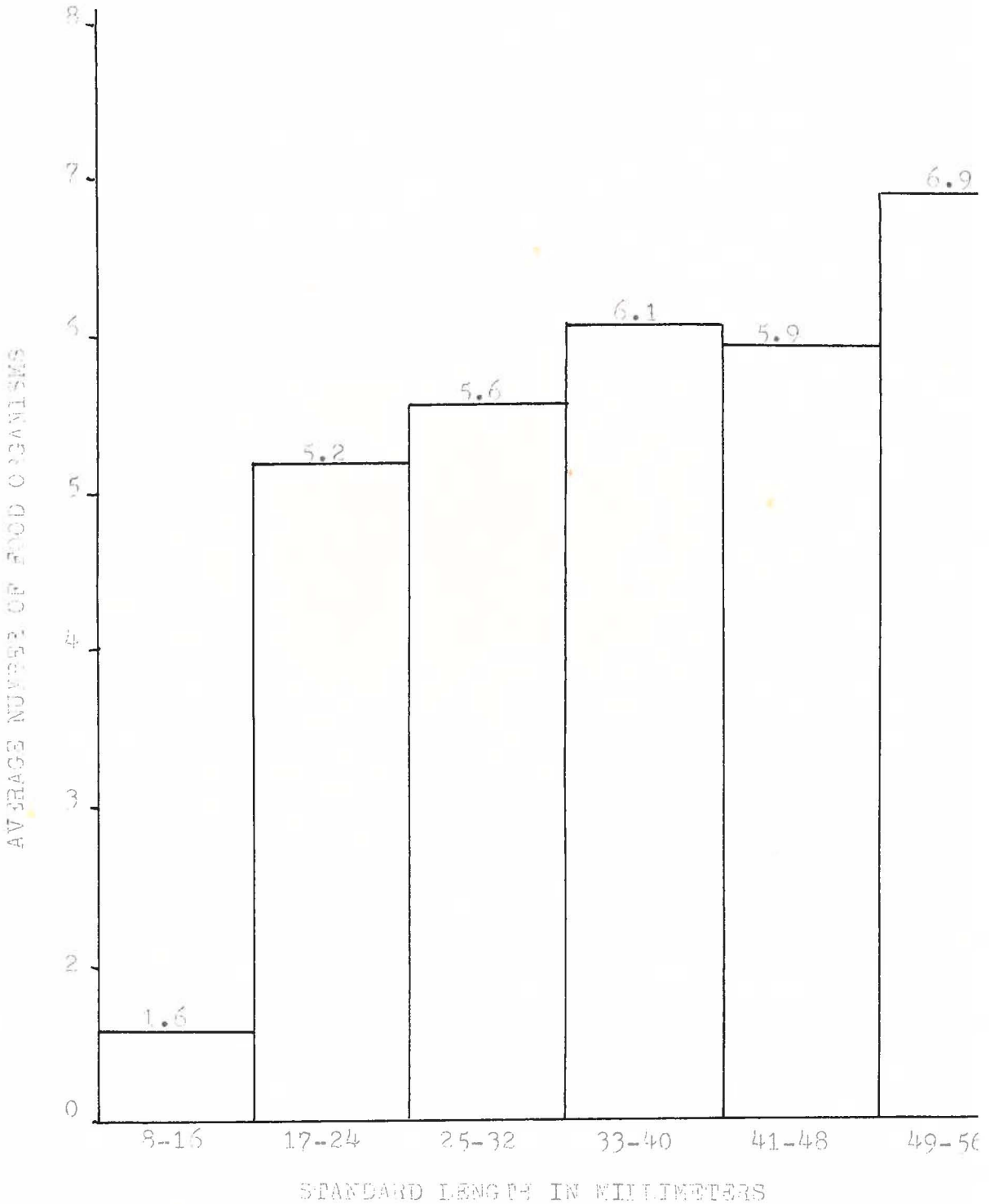

Figure 10 Average number of different organisms used as food by *D. aruanus* of various lengths.

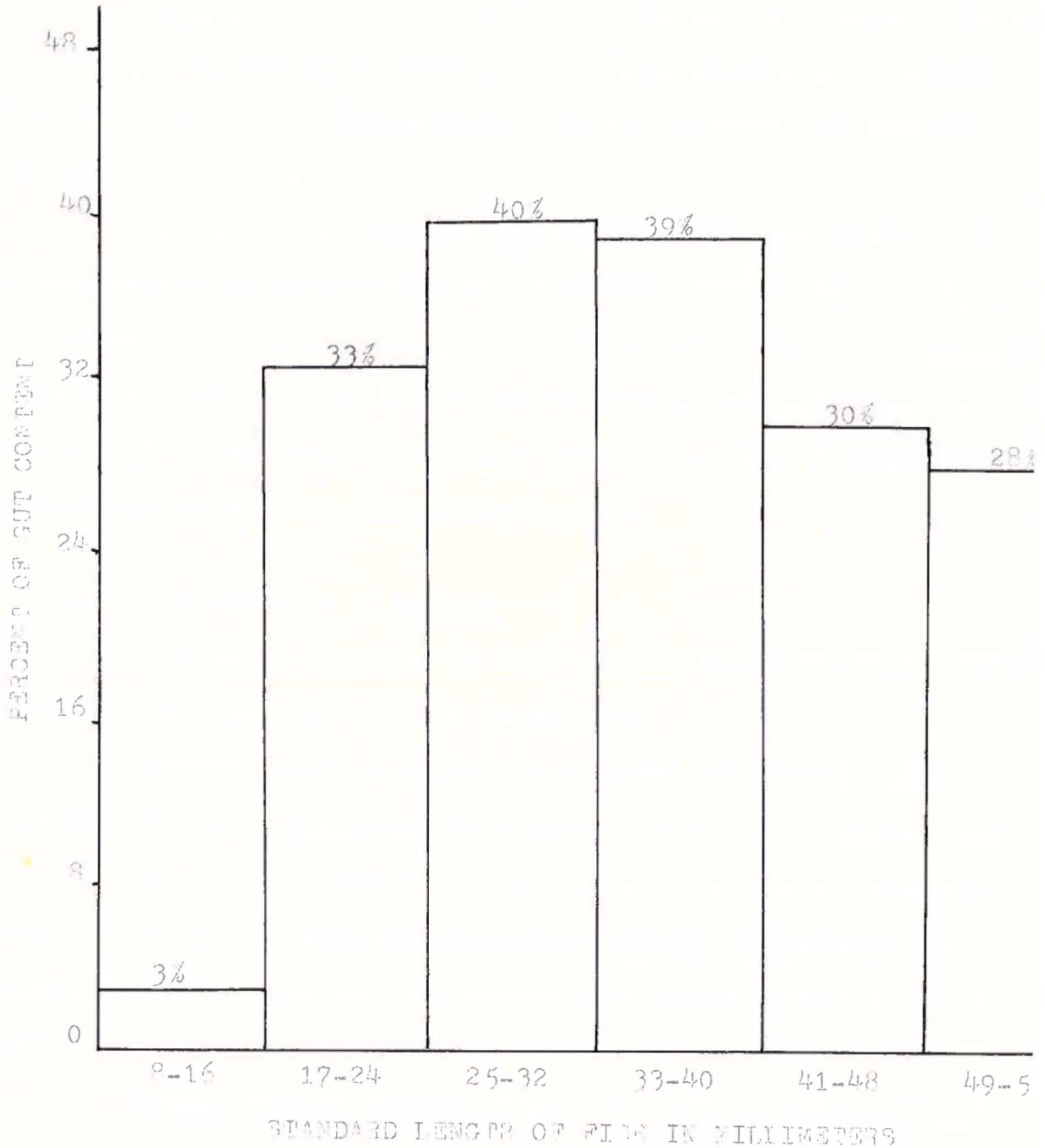

Figure 11 Percent of Enteromorpha in the gut of D. aruanus.

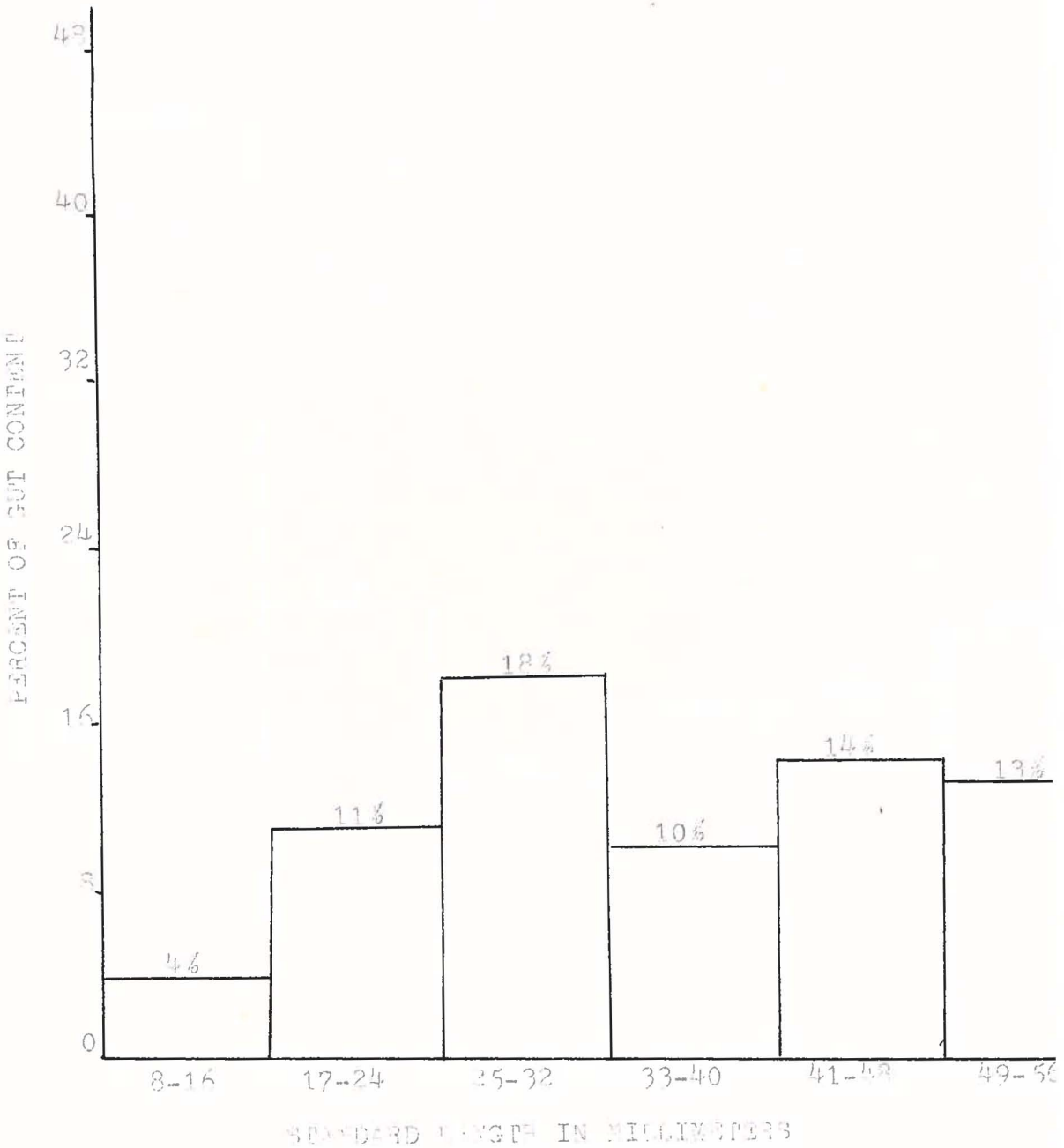

Figure 12. Average percent of Beetles in gut of D. erueri of various sizes.

Alga	No. of Coralla with Alga Present	Relative Abundance Dominant*	Common**	Present***
Cladophora	9	1	4	4
Dictyota	5	2		3
Spyridea	4		2	2
Enteromorpha	4			4
Padina	3	2		1
Calothrix	3		1	2
Acanthophoa	3			3
Neomeris	3			3
Polysiphona	3			3
Gracilaria	2	1		1
Halimeda	2	1		1
Boodlea	2		1	1
Pocockiella	2		1	1
Hypnea	2			2
Sphacelaria	2			2
Bryopsis	1			1
Laurencia	1			1
Sargassum	1			1

Table III Survey of algae growing on ten coralla of Acropora

NOTE: (*) Approximately 50% of dead parts of corallum covered by the alga
(**) Approximately 20% of dead parts of corallum covered by the alga
(***) Alga identified on the corallum

Organism	No. of Coralla with Organism Present	Total No. Counted or Relative Abundance where not Counted
Portunidae	9	46
Xanthidae	9	13
Copepods	7	present
Foraminifera	7	present
Hermit crabs	5	24
Holothuria	5	11
Caridean shrimp	4	20
Sponge	2	common
Strombus	2	4
Mollusk egg cases	2	common
Cypraea moneta	2	5
Majidae	1	4
Alpheidae	1	3
Hyperid amphipods	1	present
Bullidae	1	2
Annelid	1	1 (different from anneli in Dascyllus foods)

Table IV List of invertebrates collected from ten coralla of Acropora

aruanus was never seen in the area near the beach where these algae grow in abundance.

Enteromorpha and Boodlea often float out over the reef flat where the coral and fish are found. Exceptionally heavy concentrations of floati Enteromorpha were observed 5 and 12 March and 2, 17, and 20 June. Only fish collected on 5 March were examined for gut content. These seven individuals, ranging in standard length from 22 mm. to 45 mm., contained an average of 69% Enteromorpha.

All Enteromorpha was swept from the intertidal area by an unusually heavy surf on 16 April. By 21 April Enteromorpha had again grown to a height of 0.25 m.

In the survey of the invertebrates inhabiting Acropora arbuscula (Table IV), the crabs of the families Portunidae and Xanthidae were found in nine of the ten collections. Foraminifera and copepods were present in seven while hermit crabs and Holothuria were present in five. In all, sixteen different invertebrate organisms were taken from the coral. Foraminifera and copepods were most often found in the Cladophora mats on the dead parts of the coral. Hyperiid amphipods were found only in one corallum. The annelid that comprises 2% of the stomach contents of Dascyllus aruanus (Table II) was not found on the coral. As the worm has no appendages for swimming, it is probably from the sand bottom.

Samples of bottom sand were collected in bottles near Acropora. Copepods were observed, under a dissecting microscope, swimming in the water poured off the top of the sand. Their manner of swimming in irregular hops indicates that they live on top of the sand. Several hyperiid amphipods were observed dead on the surface of the sand after the addition of

formaldehyde. Foraminifera were also present in the sand.

E. Other Fish

A catalogue of other fish collected (Tables V and VI) from Acropora arbuscula provides a sampling of possible competitors in the community.

Abudefduf leucozona, another pomacentrid, is the fish most often found with Dascyllus aruanus in these collections. The food organisms found in four Abudefduf leucozona examined (Table VII) were similar to those found in Dascyllus.

Morphologically, the gill rakers of both species were of about the same size. The teeth (Fig. 14) of Abudefduf, however, were more like those of a herbivore (Jones Thesis) than the teeth of Dascyllus aruanus. The difference may be ecologically significant.

The percentage of other fish (Table VI) found in Acropora with Dascyllus aruanus is small. Of the eleven remaining families only the Apogonidae makes up as much as 8% of the population.

F. Population Composition of Dascyllus aruanus

Size comparison of the D. aruanus population serves to bring out several characteristics of their life history.

A total of 128 D. aruanus were collected from 56 corallia between 1 March and 20 June. The juvenile group (Fig. 15) has more than three times as many members as similar adult size ranges. The drop in number of fish in the large adult range may be somewhat effected by the "running" behavior described in part A. However, if fish were seen to leave a corallum it was usually not depopulated.

The absence of any Dascyllus smaller than 8 mm. around the

Name of Fish	Percent of Population 1st Depopulation	2nd Depopulation
Dascyllus aruanus	60%	36%
Abudefduf leucozona	14%	14%
Apogonidae	5%	14%
Scaridae	5%	7%
Eleotridae	2%	14%
Phrynelox melas	4%	
Scorpaenoides kelloggi	2%	
Lutjanidae		7%
Gobiidae		2%
Rhinecanthus aculeatus		2%
Chaetodontidae		2%

Table V Changes in fish population repopulating 2 Acropora corallia.

Name of Fish	Number Collected	% of Population
Dascyllus aruanus	188	57%
Abudefduf leucozona	44	15%
Apogonidae	24	8%
Eleotridae	8	3%
Scaridae	6	2%
Gobiidae	4	1%
Phrynelox melas	3	1%
Labridae	2	1%
Acanthuridae	1	
Chaetodontidae	1	
Muraenidae	1	
Scorpaenoides kelloggi	1	
Sebastinistes bynoensis	1	
Syngnathidae	1	

Table VI Fishes found with D. aruanus in Acropora corall during the course of the research.

Standard Length of Fish	Food Organisms
67mm	Bryopsis Foraminifera Hyperiid amphipods
37mm	Enteromorpha
31mm	Calothrix Spyridea Enteromorpha Copepods
25mm	Hyronea

Table VII Organisms present in the digestive tracts of four Abudefduf leucozona.

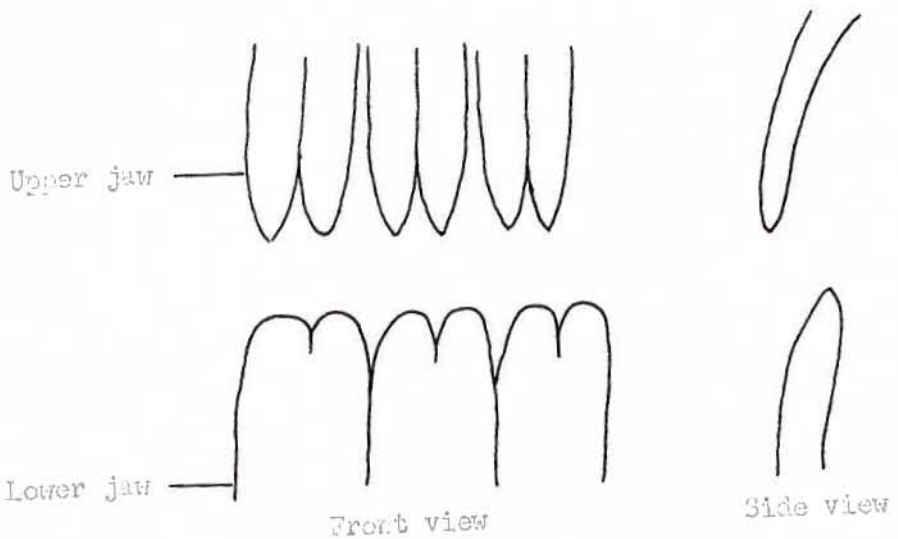

Figure 14 Teeth of *Abudefduf leucozona*.

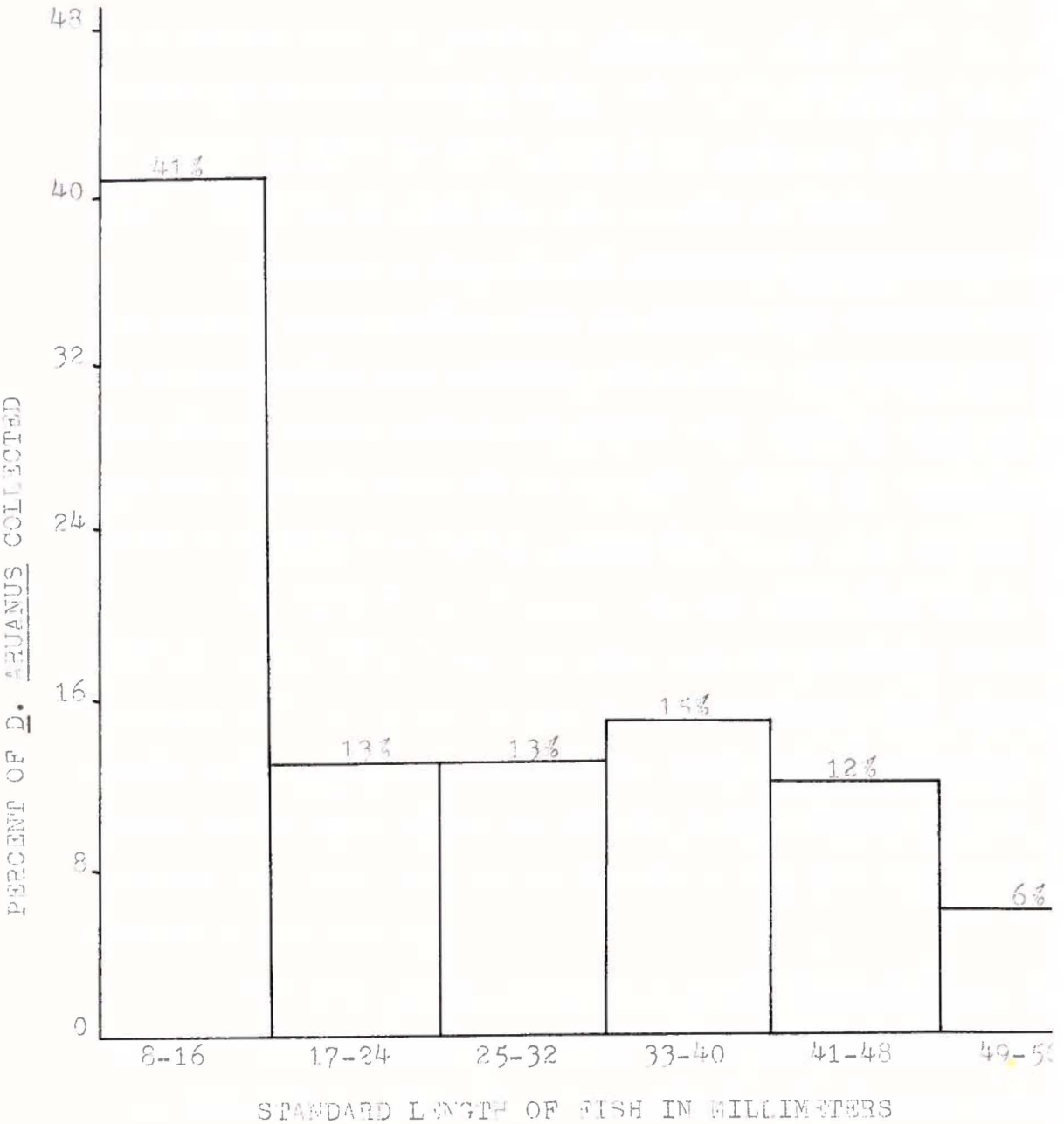

Figure 15 Distribution of various lengths of Dascyllus aruanus collected.

Volume of Corallum	No. of Fish	Size	Adults Present	Other Species Present
3550ml	1 2	12mm 9	yes	yes
1900ml	3 5	9mm 8	yes	yes
1000ml	1 1 2	10mm 9 8	yes	yes
1000ml	1 4	9mm 8	no	no
900ml	1 3 2	10mm 9 8	yes	no
700ml	4	9mm	no	yes
650ml	4	9mm	yes	yes
600ml	1 2	10mm 9	yes	yes
600ml	1 2 2	10mm 9 8	no	yes
550ml	5 2 1	11mm 9 8	no	yes

Table VIII Data pertaining to "juvenile schools"

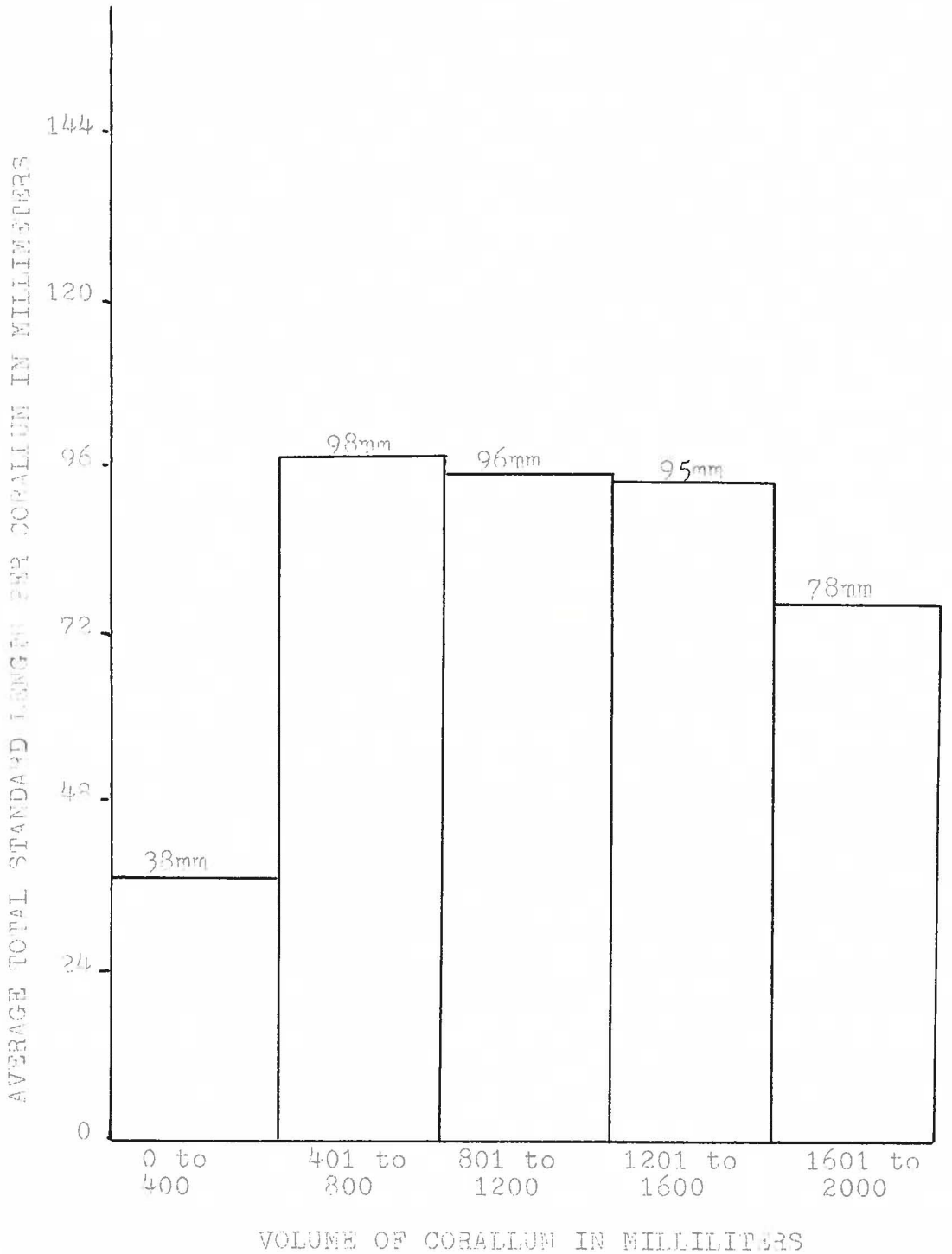

Figure 16 Average total standard lengths of Descyllus cruanus collected from various size coralla.

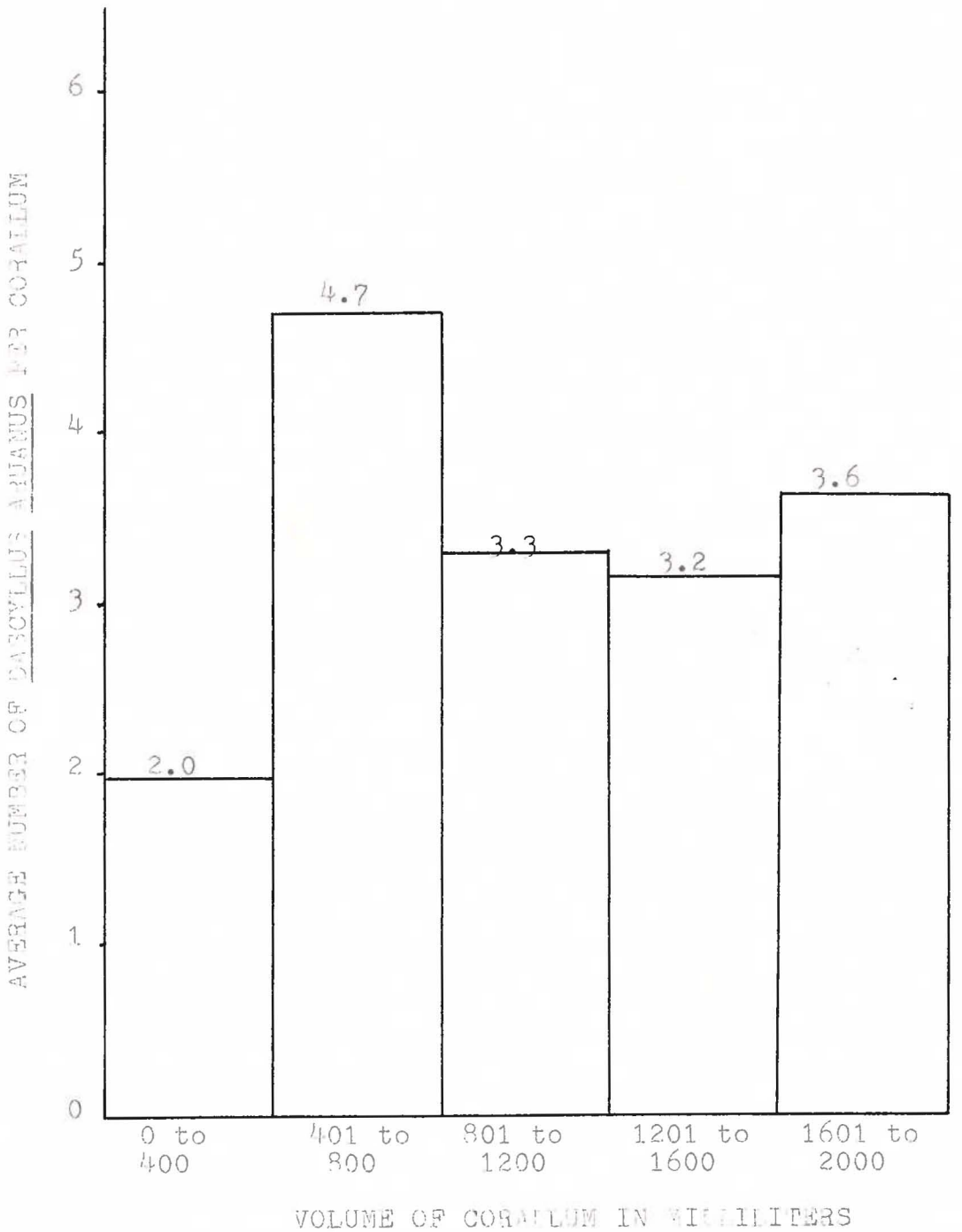

Figure 17 Average number of Bascyllus aruanus collected from various sizes of corallia.

"juvenile schools" were collected from this group.

G. Repopulation Experiments

Many of the coralla from which the fish were removed were marked for later recovery. This was done in order to obtain data on the rate and composition of repopulation. Nine coralla were recovered and several of these retaken a second and third time. They are labeled A through I in Table IX and are listed by order of the dates of their last recovery.

In the first depopulation a total of 56 fishes were collected. D. aruanus comprised 68% of the total (Table V). The proportions of the various types of fishes from the nine coralla (Table V) is similar to those of the entire collection (Table VI). The recovery of these coralla (Table yielded a total of 42 fish. Recovery dates varied from 2 to 74 days after the first depopulation with an average of 36 days (Table IX). In the first recovery collections D. aruanus averaged only 36% of the population. Members of the families Apogonidae and Eleotridae (Table V) were found to make up a larger part (14%) of the population than they did in the original collections. Only five of the ten families collected were present in both collections.

The average standard length of D. aruanus in the first depopulati was 26 mm. The average length of the same species in the recovery group wa 9 mm. This average included three coralla that contained no Dascyllus when they were recovered.

Three coralla, (C, E, and F) were recovered a second time and two of these (E and F) were located a third time (Table IX). The irregular timing of these depopulations makes it difficult to draw parallels in their repopulations.

NOTE: (*) represents number of days between collections

Volume of Corallum	1st Collection		*	2nd Collection		*	3rd Collection	*	4th Collection
Cor. A 1650ml	Dascyllus aruanus	37mm 28 21 19 10 10	33	D. aruanus	10mm				
	Abudefduf leucozona	11mm 10		A. leucozona	11mm				
				Apogonidae	29mm 19 19 11				
				Eleotridae	18mm				
				Gobiidae	27mm				
Cor. B 1000ml	Dascyllus aruanus	36mm 27 25 18 16	49						
	Abudefduf leucozona	25mm 18							
	Ehrynelox melas	32mm 22							
				Apogonidae	23mm				
				Eleotridae	27mm				

Volume of Corallum	1st Collection		*	2nd Collection		*	3rd Collection	*	4th Collection
Cor. G 1100ml	Dascyllus aruanus	47mm 37 25	59	D. aruanus A. leucozona Acoronidae	10mm 26mm 13 23mm				
Cor. H 950ml	Dascyllus aruanus	40mm 36 26 20 19 12	2						
	Abudefduf leucozona	18mm 11							
	Scaridae	40mm 37 36		Scaridae	28mm 27				
Cor. I 2000ml	Dascyllus aruanus	37mm	74	D. aruanus	26mm 22				
	Scorpaenoides kelloggi	51mm		R. aculeatus Eleotridae	25mm 34mm 16 15 12				
				Chaetodontidae	23mm				

Table IX Repopulations of nine corella of Acropora
NOTE: (*) represents number of days between collections

Several observations may be pertinent for some of the collections Corallum A grew a flora of Padina, Boodlea, Gracilaria, Spyridea and Acanthophora in the 33 days between collections. A large variety of hermit crabs, crabs, and shrimp moved into corallum B. Padina, Sphacelaria and a mat of Cladophora also appeared. Corallum B was 50% dead and bare at the time of the first collection 49 days previously.

Between collections on D a large (1.5 m.) Sargassum grew about 0.25 m. from the coral. The alga hung over and shaded the site that had be in the sun at the time of the first depopulation. No fish were collected during the second visit.

IV. DISCUSSION

The following are comments on the possible meaning of some of the result reported in section III. The limited scope of the project makes it difficu to do more than suggest likely explanations.

It appears that Dascyllus aruanus is not necessarily dependent on Acropora arbuscula for its food. The chief algal foods do not grow on the corallum. The important invertebrate food items appear to be present in th sand surrounding the coral as well as in the algal mat covering the dead parts of the corallum. The strong preference of D. aruanus for live corall indicates the algal mat on the dead coral is not particularly attractive to the fish.

That the coral serves as a refuge from danger is evident in the usual movement of the fish into the corallum at the approach of a swimmer.

From the stomach analysis and morphological observations, it might be hypothesized that Dascyllus aruanus has a carnivorous evolutionary

heritage but has changed now to an omnivorous diet during its adult life.

The life history probably begins with the emersal eggs of Dascyllus aruanus hatching into planktonic larva. The fish feed on the plentiful zooplankton of the open sea during their larvalexistance. The metamorphosi into reef dwelling fish finds the juveniles with a diminished supply of animal foods in their new habitat. A large supply of filamentous algae is available on the reef. As the fish grows, the intestine gradually becomes longer enabling the fish to use the algae. The ability of D. aruan to become omnivorous as an adult is probably a large contributing factor in the success of the species.

The smaller average standard length of D. aruanus in the repopulating group of depopulated coralla seems to indicate that the adults of the species are not inclined to migrate to unoccupied coralla.

Gause's Principle that "no two species can exist in the same ecological niche" must have some bearing on the relationship between Dascyllus aruanus and Abudefduf leucozona. The study of the ecological factors separating the two species would be a logical further step in this study.

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