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Title: Diet and Assimilation Efficiency of the Surgeonfish *Acanthurus lineatus* (Pisces, Acanthuridae) on Guam

Approved: ______________________________
Dr. Stephen G. Nelson, Chairman, Thesis Committee

Diets and assimilation efficiencies of 3 size classes of *Acanthurus lineatus* from Agat Bay, Guam, were investigated. Analysis of stomach contents revealed that these fish ingested a wide variety of algae. Species of Rhodophyta formed the bulk of the diet. *Hypnea* sp. had the highest relative abundance in the stomachs of all size classes. Among the algal types, filamentous algae were the most preferred, while calcified were the least preferred.

Organic assimilation efficiencies ranged from 29 to 35% and were similar between size classes. Likewise, ash contents of algae and fecal materials were similar between size classes.

DIET AND ASSIMILATION EFFICIENCY OF THE SURGEONFISH *ACANTHURUS LINEATUS* (PISCES, ACANTHURIDAE) ON GUAM

BY

AHSER E. EDWARD

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The members of the Committee approve the thesis of Ahser E. Edward presented December 12, 1986.

Dr. Stephen G. Nelson, Chairman

Dr. Steven Amesbury, Member

Dr. Dirk Ballendorf, Member

ACCEPTED:

Dr. James A. Marsh
Dean, Graduate School and Research

Date

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

The patterns of resource use by fish are known to change with age or size (Grossman and Moyle, 1980; Tallman and Gee, 1982; Holbrook _et al_., 1985), and several investigators have suggested that such changes may act to decrease intraspecific competition (Grossman, 1980; Polis, 1984; Vollestad and Andersen, 1985). As a result of morphological changes, fishes tend to change diets as they grow (Jones, 1968a; Belk, 1975; Lassuy, 1980). Also, adult aggressive behavior may limit the food items that are available to juveniles (Werner and Hall, 1975). In some cases, the change in resource use with size is such that juveniles function essentially as different species within the ecosystem (Vondracek and Moyle, 1985).

Herbivorous reef fishes are thought to be generalists in regard to food habits (Roughgarden, 1974) since many fish species feed on the same kinds of algae (Randall, 1967; Jones, 1968a; Robertson and Gaines, 1986). If diets overlap broadly between species it would seem less likely that size classes within a species would differ much in diet. However, as fish grow they may be able to consume larger, tougher or more highly calcified algae. Also, larger fishes may, through the exclusion of competitors, be better able to obtain algae which are of greater nutritional value or assimilability. Either of these processes could result in partitioning of dietary resources by size classes within the population. Detailed comparisons of the diets of different size classes of these fish should reveal such partitioning if it exists.

In addition, determination of the food resources of different size classes of reef fishes will allow the determination of their functional roles within the coral reef ecosystem. Thus, the purpose of this work was to compare diets and assimilation efficiencies of three size classes of <u>Acanthurus</u> <u>lineatus</u>, a surgeonfish (Acanthuridae) common on Pacific coastal reefs.

METHODS AND MATERIALS

COLLECTION

Fish were collected from the reef margin of Agat Bay, Guam, during the morning hours when the fish were actively feeding. Two collections were made, approximately two months apart. Fish were speared and immediately placed in iced water to reduce the digestive activities of the intestinal enzymes. They were returned to the lab, where they were immediately weighed, measured and frozen for later stomach content analysis.

Three size classes of fish were established based on the standard lengths (s.l.) of the fish. For the stomach analysis, there were eight fish in the smallest size class (7.7 cm to 10.8 cm s.l.), 19 in the middle size class (10.9 cm to 14.0 cm s.l.), and 13 in the largest size class

(>14.1 cm. s.l.). An additional 30 fish were used to estimate assimilation efficiencies.

STOMACH CONTENT ANALYSIS

To examine the stomach contents, the fish were thawed. Their stomachs were removed and preserved in 70% alcohol. Each stomach was ruptured, and its contents placed in a petri dish. A small portion was then evenly distributed over an area in the middle of a microscope slide and covered by a cover slip.

The method used to determine the relative abundances of algae in the stomach samples was essentially the same as that developed by Jones (1968b) except that a grid with 81 intersect points was used instead of 17. A similar method was also used by Hynes (1950) for describing the food habits of fresh-water sticklebacks.

A microscope equipped with a 1-mm ocular grid was used to estimate the relative abundance of each algal species found in the stomachs. The grid contained 100 points, and the 81 internal points were used in determining the relative abundances of algae. Five equidistant points were marked on the slide to locate areas of focus. An algal species was counted only if it touched one of the points on the grid. All the stomach contents were examined under low power (10x) magnification, but higher magnifications were used for identification of the algae if necessary.

To determine the relative abundances of the algae, each thallus touching a point of the grid was identified and counted, and then the total number of points with a particular algal species was divided by the number of points for all algae tallied for the entire field. This ratio was multiplied by 100 to express the relative abundances as percentages. The mean relative abundances at each of the 5 marks were determined and used to represent the relative abundances of dietary algae for each slide. A mean of the results for three replicate slides was used to represent the mean relative abundance of the dietary algae in each individual. The mean relative abundance of each algal species in each size class was determined by dividing the mean relative abundance of each alga by the total number of stomachs analyzed within that size class. The algae in the stomachs were identified to the the lowest possible taxonomic level. The algae were also classified as either calcified, thalloid, or filamentous.

ASSIMILATION EFFICIENCY

For the analysis of assimilation efficiencies, the contents of the posteriormost 1/4 of the digestive tract and of the stomach were removed and dried overnight at 50° C. The dried samples were finely ground with mortar and pestle, redried overnight in a drying oven, then stored at room temperature in a desiccator for later analysis.

To determine the organic content of the stomach and rectal samples from each size class, three 0.05-g subsamples were placed in preweighed crucibles and heated to 500° C for 4 hours. The crucibles, with the resultant ash, were cooled to room temperature over desiccant and then weighed. The ash weight was subtracted from the sample weight to determine the ash-free portion of the samples.

Organic assimilation efficiency was calculated by the ash-ratio method described by Montgomery and Gerking (1980), Edwards and Horn (1982), and Horn and Neighbors (1984). Before calculation of assimilation efficiencies, a correction for ash absorption was established: corrected fecal material (%) =[(% ash in algae)(% ash in feces)$^{-1}$] X % organic matter in feces. Organic assimilation efficiency was then calculated based on the following formula: Organic assimilation efficiency (%) = 1 - [(corrected fecal organic matter %)(% organic matter in algae)$^{-1}$] X 100%.

STATISTICAL ANALYSIS

All statistical analyses were carried out with the BMDP statistical programs (available from the Health Sciences computing facility of the University of California at Los Angeles, Los Angeles, California 90025 USA) on an IBM PC-XT. Percentage values for relative abundances of algae and algal types (calcified, thalloid, and filamentous) were square-root transformed to obtain a normal distribution, and analysis of variance was used to compare algal divisions and algal types in the stomach contents of the three size classes of fish.

RESULTS

DIET

Analysis of the stomach contents of _A. lineatus_ revealed that these fish ingest a wide variety of algae (Tables 1 and 2). The number of algal species found in the stomachs ranged from 21 for the small size class to 27 in the middle and the largest size classes. The filamentous algae, primarily Rhodophyta, form the bulk of the diet of _A. lineatus_. The red alga, _Hypnea_ sp., has the highest relative abundance in the stomachs of each size class. The three other most common red algae in the stomachs were _Gelidiopsis intricata_, _Polysiphonia_ sp. and _Champia compressa_. Among the green algae (Chlorophyta), _Boodlea composita_ had both the highest percent occurrence and the highest relative abundance. Blue-green algae (Cyanophyta) in the stomach samples consisted primarily of _Microcoleus lyngbyaceus_ with _Schyzothrix mexicana_ as an occasional contributor. Although _Microcoleus lyngbyaceus_ was found in most of the stomachs, its relative abundance was low. Among the brown algae (Phaeophyta), the prevalent genera included _Ectocarpus_ and _Sphacelaria_.

Table 1. Mean percentage of fish in each of 3 size classes found with specified algal taxa in their stomachs.

Algae	Class I	Class II	Class III
Chlorophyta			
Boodlea composita	87.5	73.7	61.5
Bryopsis sp.	----	10.5	----
Caulerpa serrulata	----	5.3	----
Chaetomorpha sp.	----	----	15.4
Cladophoropsis sp.	12.5	15.8	11.3
Enteromorpha clathrata	62.5	47.4	53.9
Cyanophyta			
Calothrix sp.	----	5.2	----
Hormothamnion sp.	12.5	----	8.0
Microcoleus lyngbyaceus	100.0	84.2	76.9
Oscillatoria sp.	----	----	7.7
Schyzothrix mexicana	50.0	52.6	61.5
Phaeophyta			
Dictyota sp.	50.0	63.1	69.2
Ectocarpus sp.	100.0	84.2	84.6
Lobophora variegata	----	21.1	15.4
Sargassum cristaefolium	----	10.5	15.4
Sphacelaria sp.	100.0	100.0	84.6
Turbinaria ornata	----	5.3	15.4
Rhodophyta			
Amphiroa fragilissima	62.5	73.3	77.0
Acanthophora spicifera	----	----	7.7
Centroceros sp.	50.0	52.6	69.2
Ceramium sp.	87.5	73.7	100.0
Champia compressa	62.5	68.4	69.2
Gelidiella acerosa	12.5	21.1	23.1
Gelidiopsis intricata	100.0	100.0	92.3
Gelidium pusillum	12.5	57.9	53.9
Herposiphonia sp.	12.5	5.3	----
Hypnea sp.	87.5	89.5	100.0
Jania capillacea	75.0	84.2	84.6
Laurencia sp.	25.0	31.6	23.1
Leveiilea jungermannioides	----	15.8	46.2
Polysiphonia sp.	100.0	89.5	92.3

Table 2. Mean relative abundances of algal taxa in the stomach contents of 3 size classes of *Acanthurus lineatus*. Means are for all fish sampled from each size class.

Algae	Class I	Class II	Class III
Chlorophyta			
Boodlea composita	10.9	10.8	6.6
Bryopsis sp.	----	.1	----
Caulerpa serrulata	----	.3	----
Chaetomorpha sp.	----	----	.2
Cladophoropsis sp.	1.0	.4	.9
Enteromorpha sp.	3.0	.6	.5
Cyanophyta			
Calothrix sp.	----	.1	----
Hormothamnion sp.	.1	----	.1
Microcoleus lyngbyaceus	4.3	3.1	1.6
Oscillatoria sp.	----	----	.1
Schyzothrix mexicana	.9	1.0	.9
Phaeophyta			
Dictyota sp.	3.9	5.9	6.7
Ectocarpus sp.	5.8	3.9	4.3
Lobophora variegata	----	.4	.2
Sargassum cristaefolium	----	.1	.4
Sphacelaria sp.	15.1	14.5	8.4
Turbinaria ornata	----	.1	.7
Rhodophyta			
Amphiroa fragilissima	2.4	8.6	5.0
Acanthophora spicifera	----	----	.1
Centroceros sp.	2.3	2.5	2.5
Ceramium sp.	3.6	2.2	3.3
Champia compressa	6.1	7.2	4.7
Gelidiella acerosa	.1	.9	.7
Gelidiopsis intricata	15.0	8.7	11.8
Gelidium pusillum	.1	2.2	4.1
Herposiphonia sp.	.1	.1	----
Hypnea sp.	18.3	12.1	22.6
Jania capillacea	4.8	4.5	2.7
Laurencia sp.	.8	.8	.6
Leveiilea jungermannioides	----	.9	3.1
Polysiphonia sp.	5.3	6.2	3.9

Some non-algal materials were found in the stomach samples, but their relative abundance values were small (<0.1%) and so were not included in the tables. These materials included crustaceans, sand, foraminiferans and diatoms.

Analysis of variance of the square-root transformed data showed that there were significant differences between size classes in the relative abundances of algal divisions of Phaeophyta ($F=5.141$, $p<0.05$), and Rhodophyta ($F=55.753$, $p<0.005$), but there were no significant differences between size classes in the relative abundances of algal divisions of Chlorophyta ($F=0.722$, $p>0.05$) and Cyanophyta ($F=1.823$, $p>0.05$). The Phaeophyta were less prevalent in the diets of the smallest fish than the other size classes. As fish size increased, the consumption of rhodophytes increased (Table 3). Tests also showed significant differences between size classes in the relative abundances of thalloid ($F=3.667$, $p<0.05$) and filamentous algae ($F=3.742$, $p<0.05$) with no significant difference between size classes in the amount of calcified algae in the diets ($F=2.115$, $p>0.05$). Filamentous algae were most abundant in all size classes as indicated in Table 4. The largest size class of fish ingested higher amounts of thalloid algae, and lower amounts of filamentous algae than did the smaller size groups. Calcified algae were the least favored.

ASSIMILATION EFFICIENCY

The percentage ash contents in the stomach and rectal samples were similar between size classes (Table 5). Likewise, assimilation efficiencies were similar between size classes. These were 31% for the smaller size class, 35% for the middle size class, and 29% for the larger size class.

Table 3. Mean relative abundances of algal divisions found in the stomach contents of 3 size classes of *Acanthurus lineatus*.

	Class I	Class II	Class III
Chlorophyta			
Back-Transformed Means	9.55	8.18	5.20
95% Confidence Limit L1	1.51	3.13	0.62
L2	24.60	15.60	14.21
Cyanophyta			
Back-Transformed Means	4.41	3.69	2.60
95% Confidence Limit L1	3.10	3.42	1.46
L2	5.95	3.96	4.04
Phaeophyta			
Back-Transformed Means	20.40	49.00	46.50
95% Confidence Limit L1	9.86	36.84	33.52
L2	34.81	62.88	61.62
Rhodophyta			
Back-Transformed Means	20.40	116.88	145.20
95% Confidence Limit L1	9.86	85.01	100.40
L2	34.81	120.78	198.25

Table 4. Mean relative abundances of 3 algal types for 3 size classes of <u>Acanthurus</u> <u>lineatus</u>.

		Class I	Class II	Class III
Calcified				
Back-Transformed Means		6.92	12.82	9.61
95% Confidence Limit	L1	3.92	8.12	5.52
	L2	10.78	18.58	14.90
Thalloid				
Back-Transformed Means		17.64	20.25	34.57
95% Confidence Limit	L1	4.88	14.36	26.01
	L2	38.32	27.14	44.49
Filamentous				
Back-Transformed Means		73.27	60.53	51.55
95% Confidence Limit	L1	61.94	51.98	44.22
	L2	85.56	69.72	59.44

Table 5. Mean ash contents of stomach and rectal samples of <u>Acanthurus lineatus</u> (n=3 in each case).

	Class I	Class II	Class III
Mean % Ash in Stomach Sample	21.0±1.41	28.3±2.52	31.0±2.24
Mean % Ash in Rectal Sample	36.5±4.95	38.0±0.00	39.5±0.71

DISCUSSION

The food habits of *Acanthurus lineatus* at Guam were found to be similar to those reported by Jones (1968a) for several species of acanthurids and by Robertson *et al.* (1979) and Robertson and Gaines (1986) for *A. lineatus* at Aldabra atoll. Studies conducted concerning the diets of herbivorous reef fishes, particularly of acanthurids, siganids, and pomacentrids, have all reported the high incidence of filamentous algae in the diets (Jones, 1968a; Tsuda and Bryan, 1973; Belk, 1975; Robertson *et al.* 1979; Lassuy, 1980, 1984; Robertson and Gaines; 1986).

It was interesting to note that, in this study, blue-green algae were found in most of the stomach samples of *A. lineatus*, and that the blue-green alga *M. lyngbyaceus* had a higher relative abundance in juveniles than in the larger size classes. This species was not eaten by *Siganus argenteus* (Tsuda and Bryan, 1973) when it was offered in preference trials. However, *M. lyngbyaceus* was the primary blue-green alga consumed by juveniles of the pomacentrid *Stegastes lividus* (Lassuy, 1984). Lassuy (1984) suggested that because *S. lividus* juveniles are only effective in repelling fairly small fishes, such as juvenile scarids and acanthurids, their territories are regularly browsed by many reef herbivores and therefore they have to feed on what is rejected by the larger herbivorous fishes. *Microcoleus lyngbyaceus* has been proven to be an unfavorable, chemically defended alga in bioassays with *Siganus spinus* (Paul *et al*., in preparation) and has been shown to be toxic (Moore, 1970). Tsuda and Kami (1973) suggested that the prevalence of blue-greens in reef environments is favored by browsing herbivorous fishes because blue-greens are less heavily grazed than are more palatable species.

The red algae were found to be prevalent in the stomachs of all size classes of *A. lineatus*. This may be a reflection of the abundance and the availability of this group within the habitat. Thalloid algae were not consumed to the extent of the filamentous algae, although their relative abundances increased with fish size. Montgomery and Gerking (1980) reported that the filamentous and thalloid rhodophyta are frequently preferred by herbivorous fishes over other groups. They found that non-calcified red algae generally contain higher levels of proteins and carbohydrates than either brown, green or calcareous algae.

I found that there was considerable overlap in diets of size classes of *A. lineatus*, although there were significant dietary differences at even the higher taxonomic levels. Robertson et al. (1979) showed that *A. lineatus* of both sexes and of all sizes hold territories. He described the territories of *A. lineatus* as being closely packed, with each territory normally sharing most of its border with that of a neighboring conspecific. These groups of territories are composed of the territories of a few adults with several juveniles. This overlap in microhabitat may contribute to the degree of dietary overlap between size classes. Differences in the diets may have resulted from either morphological changes or the increased effectiveness of aggression of the larger fish.

Although the diets differed between the size classes, the changes in the diet with size seem to have little impact on the nutritional quality of the diet. Organic assimilation efficiencies were found to be similar among size classes (Table 5). The values I found for A. lineatus, 29 to 35%, are similar to those reported for other herbivorous marine fishes. For example, Bryan (1975), using the C-14 method, estimated assimilation efficiencies of rabbitfish Siganus spinus to range from 6 to 39% in adults and from 9 to 60% in juveniles. Horn et al. (1985) using similar methods reported up to 68% assimilation efficiency for Cebidichthys violaceus fed on macroalgae. More directly comparable are those studies which have used the ash-ratio method to estimate assimilation efficiency. For example, Lassuy (1984) found total organic assimilation efficiency of juvenile Stegastes lividus (30 to 40%) to be lower than that of adults (70 to 80%). Also, estimates of assimilation efficiencies for Cebidichthys violaceus, which feed on macroalgae, ranged from 31 to 52% (Edwards and Horn, 1982). Organic assimilation efficiency of an aquatic macrophyte by Tilapia zillii was estimated as 29% by Buddington (1979).

From the present study, the larger size class of A. lineatus does not seem to have any particular nutritional advantage over the smaller size classes. Though, the ash content of the diet of the larger fish is slightly higher than for the smaller size classes; the assimilation efficiencies are similar between size groups.

Although there is overlap among the diets of the three size classes of A. lineatus, there are significant differences in the contributions of algal taxa and algal growth forms to the diets of the three size classes. Since the nutritional quality of the diet varies little with size, it is likely that these differences are simply the result of morphological changes associated with size rather than intraspecific competition. As a general rule, size classes of fish probably differ in diets. There is no need to evoke an adaptationist theory to explain such changes.

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