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THE FOOD AND FEEDING HABITS OF THE GROUPER, EPINEPHELUS QUERNUS SEALE 1901, IN THE NORTHWESTERN HAWAIIAN ISLANDS

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ABSTRACT

Sixty-seven stomach and spew samples of the grouper, *Epinephelus quernus*, from the Northwestern Hawaiian Islands were examined. The study showed that this grouper forages mainly on bottom-associated crustaceans, fishes, and cephalopods.

Shrimp (predominantly of the family Pandalidae) were the most important food item as determined by an index of relative importance (IRI). The IRI incorporates numbers and volumes of the prey and their frequency of occurrence. Of the 22 families of fishes that were represented in the food samples, members of the families Lutjanidae, Emmelichthyidae, and Congridae were the most important. The results suggest that *E. quernus* is a carnivorous, opportunistic bottom feeder.

Epinephelus quernus
Northwestern Hawaiian Islands
feeding

INTRODUCTION

Some of the Hawaiian fishes of highest commercial value are the bottomfishes which comprise the tropical snapper-grouper complex (Uchida et al., 1979). The lone serranid of commercial value within this group is the grouper, *Epinephelus quernus* Seale. Although the maximum size of this species is not known, specimens >105.9 cm total length and weighing 26.5 kg were caught on the resource survey cruises in the Northwestern Hawaiian Islands (NWHI) conducted by the Honolulu Laboratory, National Marine Fisheries Service (NMFS)(Uchida and Uchiyama, in preparation). This species is only recorded from Hawaii and is the only serranid which "contributes significantly to the commercial landings in Hawaii" (Tinker, 1978; Department of Land and Natural Resources, 1979).

The feeding studies on *Epinephelus* thus far have focused upon such species as *E. striatus*, *E. guttatus*, and *E. morio* in the Atlantic (Longley and Hildebrand, 1941; Bardach and Mowbray, 1955; Randall, 1965, 1967; Moe, 1969; Collette and Talbot, 1972) and *E. fuscoguttatus*, *E. merra*, and *E. hexagonatus* in the Indo-Pacific (Hiatt and Strasburg, 1960; Randall and Brock, 1960; Helfrich et al., 1968; Harmelin-Vivien and Bouchon, 1976; Randall, 1980). In general, these groupers are benthic carnivores and primarily feed on fishes and crustaceans. In addition, Randall (1965, 1967), Moe (1969), and Harmelin-Vivien and Bouchon (1976) found that groupers become more piscivorous as they increase in size.

Feeding periodicity of the groupers vary according to the geographical area and the species. Off Florida, *E. morio* feeds indifferently by day or night and *E. striatus* is primarily a diurnal feeder (Longley and Hildebrand, 1941). Serranids in the Caribbean Sea feed day and night and increase foraging activity during the crepuscular periods (Randall, 1967). Serranids in Madagascar also feed during day and night, but more actively at night (Harmelin-Vivien and Bouchon, 1976). In Tahitian waters, groupers are primarily diurnal; however, they may occasionally feed at night, especially in the presence of a bright moon (Randall and Brock, 1960).

These earlier studies have concentrated on groupers captured in nearshore waters. Although *E. quernus* may be found in the shallow, nearshore waters (Hobson, 1980), the food samples for this study were collected from fish captured on the offshore benthic slopes at depths of 128 to 219 m (70 to 120 fathoms).

Kluegel (1921) published the only report on the feeding habits of *E. quernus*. In her study of the diet of food fishes, she found that this grouper was carnivorous. This was based on the contents of 13 stomachs (10 of which were empty) and the presence of scombroid fish among the food items.

The major objective of this study is to quantitatively determine specific forage items of this deep-dwelling species. This study was part of an overall investigation of the life history of this species and other bottomfishes. Together with feeding studies of other species, such as *Pseudocaranx dentex* (see report in this proceedings by Michael P. Seki), occupying the same or comparable habitat, this diet study of the grouper may provide data on competition among species for prey, and thus may lead to a better understanding of trophic relationships.

METHODS

Field Collection of Food Samples

The 67 stomach and spew samples were collected from groupers captured at deep-sea handlining stations aboard cruises to the NWHI from March 1978 to August 1981. Fifty-nine of the samples were collected on the RV Townsend Cromwell, whereas four spew samples each were collected aboard commercial vessels, the FV Easy Rider, and the FV Libra.

The fish (34 females, 2 males, and 31 unsexed) were captured at 21 islands or banks stretching from Nihoa to Kure Atoll. They ranged from 38.7 to 109.3 cm total length and weighed from 1.8 to 22.7 kg. The study material included 14 stomachs removed intact from the fish and 53 spew samples.

The handlined fish were caught primarily on hydraulic-powered gurdies, although a few fish from early cruises may have been hauled by hand or on an electric reel. The terminal rig and gurdy specifications are reported by Uchida and Uchiyama (in preparation). Most of the grouper landed were caught on rigs with four hook lines and Tankichi or Izuo ulua hooks Nos. 26 and 28 baited with stripped squid. At handline stations, the vessel was usually allowed to drift over banks 73 to 219 m (40 to 120 fathoms) deep.

Since the fish were taken from great depths, most of the stomachs were everted due to gas bladder expansion when the fish were brought to the surface and much of the contents were regurgitated. Many food items, however, were caught in the throat or gill rakers and were picked out by long forceps and saved. These were classified as spews. All stomachs and spews were preserved immediately in a 10 percent Formalin-seawater mixture. Data on species, station number, date of capture, total and standard lengths, weight, and sex were noted for each sample.

Laboratory Procedure

The laboratory methods for examination of the samples were similar to those reported in Humphreys (1980) and Harrison et al. (1983). For this study, the analyses of stomach and spew samples were treated similarly. The stomach contents were emptied into a fine mesh strainer, rinsed in running water, and sorted into identifiable groups. The volume of the prey items were measured by water displacement and coded for stage of digestion. The codes ranged from 1 through 4 where code 1 represented an item with no perceptible loss in volume and code 4 an item almost completely digested. When more than one item in the same taxon were present and could not be distinguished as whole individual items, the total number and volume of the items were recorded.

Where possible, lengths of the prey items were determined. The measurements, which included standard length (SL) for fish, mantle length (ML) for cephalopods, and carapace length (CL) for crustaceans, were coded as follows: code 1, totally intact specimen which could be measured precisely, and code 2, inexact measurement of a partially digested specimen. No attempt was made to measure the length of any prey item that was well digested.

Food items were identified to the lowest taxon possible, using the methods reported in Harrison et al. (1983). To identify fish, external characteristics and morphometrics were used whenever possible; however, many fish were in an advanced state of digestion and required clearing and staining in Alizarin S so that vertebral counts and morphological characters could be used for identification purposes. Invertebrates were identified by external morphological features. Thus, many of the crustaceans were identified at least to family since the exoskeletons remained intact despite digestion.

Method of Data Analysis

Traditionally, numerical, volumetric, and frequency of occurrence methods have been used in expressing results of food studies. Reintjes and King (1953) stated that, individually, each method has shortcomings, but food items which ranked high in number, volume, and frequency of occurrence were important foods for the predator at the time and area sampled.

Pinkas et al. (1971) attempted to incorporate the three traditional methods of stomach analysis in the development of an index of relative importance (IRI) expressed as:

$$IRI = (N+V)F$$

where

N = percentage of the total number of prey items
V = percentage of the total aggregate volume of the prey items
F = percentage of the occurrence in the stomach samples

For this study, the importance of each of the forage items was determined by the IRI method. The number, volume, and frequency of occurrence percentages were rounded off to the nearest 10th prior to the IRI calculations.

RESULTS

A list of the food items in the 67 stomach and spew samples is presented in Table 1. The numerical, volumetric, and frequency of occurrence analyses, along with the IRI values, are given for the forage items identified to the lowest taxon.

TABLE 1. NUMBER, FREQUENCY OF OCCURRENCE, VOLUME AND INDEX OF RELATIVE IMPORTANCE (IRI) OF THE FORAGE ITEMS IN 67 *EPINEPHELUS QUERNUS* FOOD SAMPLES

Forage Items	No. of Organisms		Occurrence		Aggregate Total Volume		IRI
	Total	Percent	No.	Percent	ml	Percent	
PHYLUM MOLLUSCA							
Class Cephalopoda	1	0.2	11	1.5	23.0	0.7	1.4
Order Octopoda	4	0.8	3	4.5	239.0	7.6	37.8
PHYLUM ARTHROPODA							
Class Crustacea							
Subclass Malacostraca							
Order Isopoda	1	0.2	1	1.5	0.6	<0.1	0.3
Order Amphipoda							
Family Phronimidae							
Phronima sedentaria	1	0.2	1	1.5	1.0	<0.1	0.3
Order Stomatopoda							
Family Squillidae							
Odontodactylus brevirostris	1	0.2	1	1.5	6.5	0.2	0.6
Order Decapoda							
Suborder Natantia (shrimp)	56	11.5	9	13.4	43.6	1.4	172.9
Superfamily Caridea	27	5.6	5	7.5	17.6	0.6	46.5
Family Pandalidae	308	63.4	16	23.9	212.7	6.8	1,677.8
Plesionika longirostris	5	1.0	2	3.0	14.5	0.5	4.5
"Shrimp remains"	—	—	1	1.5	0.3	<0.1	—
Suborder Reptantia	2	0.4	2	3.0	9.8	0.3	2.1
Tribe Anomura							
Family Galatheidae	1	0.2	1	1.5	2.0	0.1	0.4
Munida sp.	2	0.4	2	3.0	3.5	0.1	1.5
Tribe Brachyura	3	0.6	2	3.0	101.0	3.2	11.4
Family Homolidae	1	0.2	1	1.5	20.0	0.6	1.2
Family Raninidae	1	0.2	1	1.5	27.0	0.9	1.6
PHYLUM ECHINODERMATA							
Class Echinoidea	1	0.2	1	1.5	0.3	<0.1	0.3
PHYLUM CHORDATA							
Subphylum Tunicata							
Family Pyrosomatidae	1	0.2	1	1.5	23.0	0.7	1.4
Superclass Pisces							
Class Osteichthyes							
(unidentified fishes)	3	0.6	3	4.5	101.5	3.2	17.1
Order Anguilliformes	2	0.4	1	1.5	13.7	0.4	1.2
Family Congridae	5	1.0	4	6.0	307.0	9.8	64.8
Family Muraenidae	1	0.2	1	1.5	5.0	0.2	0.6
Order Salmoniformes							
Family Argentinidae	1	0.2	1	1.5	3.5	0.1	0.4

Note: Food items were identified to the lowest taxon possible

TABLE 1. NUMBER, FREQUENCY OF OCCURRENCE, VOLUME AND INDEX OF RELATIVE IMPORTANCE (IRI) OF THE FORAGE ITEMS IN 67 *EPINEPHELUS QUERNUS* FOOD SAMPLES (continued)

Forage Items	No. of Organisms		Occurrence		Aggregate Total Volume		IRI
	Total	Percent	No.	Percent	ml	Percent	
Order Gonorhynchiformes							
Family Gonorhynchidae							
Gonorhynchus gonorhynchus	1	0.2	1	1.5	1.9	0.1	0.4
Order Myctophiformes							
Family Myctophidae	3	0.6	2	3.0	76.1	2.4	9.0
Order Polymixiiformes							
Family Polymixiidae	1	0.2	1	1.5	60.0	1.9	3.2
Polymixia berndti	1	0.2	1	1.5	14.0	0.4	0.9
Order Gadiformes							
Family Ophidiidae							
Brotula multibarbata	1	0.2	1	1.5	32.0	1.0	1.8
Order Beryciformes							
Family Trachichthyidae	2	0.4	2	3.0	2.3	0.1	1.5
Paratrachichthys sp.	3	0.6	2	3.0	13.5	0.4	3.0
Family Holocentridae	1	0.2	1	1.5	4.0	0.1	0.4
Order Scorpaeniformes							
Family Scorpaenidae	1	0.2	1	1.5	24.0	0.8	1.5
Order Perciformes							
Family Serranidae	4	0.8	3	4.5	130.5	4.2	22.5
Family Priacanthidae							
Priacanthus sp.	1	0.2	1	1.5	10.0	0.3	0.8
Family Apogonidae	2	0.4	1	1.5	1.5	<0.1	0.6
Family Echeneidae	4	0.8	4	6.0	307.0	9.8	63.6
Family Carangidae							
Decapterus sp.	1	0.2	1	1.5	1.8	0.1	0.4
Seriola sp.	1	0.2	1	1.5	24.0	0.8	1.5
Family Emmelichthyidae	15	3.1	8	11.9	176.4	5.6	103.5
Family Lutjanidae	1	0.2	1	1.5	136.0	4.3	6.8
Etelis carbunculus	1	0.2	1	1.5	780.0	24.8	37.5
Symphysanodon sp.	4	0.8	3	4.5	7.5	0.2	4.5
Family Mullidae							
Parupeneus sp.	1	0.2	1	1.5	43.0	1.4	2.4
Family Pomacentridae	1	0.2	1	1.5	10.0	0.3	0.8
Family Gempylidae	1	0.2	1	1.5	81.0	2.6	4.2
Order Tetraodontiformes							
Family Monacanthidae	1	0.2	1	1.5	5.5	0.2	0.6
Pervagor spilosoma	1	0.2	1	1.5	7.0	0.2	0.6
Family Tetraodontidae	1	0.2	1	1.5	2.5	0.1	0.4
Unidentified fish remains	—	—	2	3.0	13.7	0.4	—
OTHERS							
Unidentified remains	—	—	1	1.5	1.3	0.1	—
"Coral rubble"	—	—	1	1.5	3.5	<0.1	—

Table 2 presents the analysis of the food items by major classes and groups. The classes are listed in descending order of IRI values for fishes and invertebrates. Primarily, the prey fishes are presented by the families and the invertebrates by class or order. The IRI values and the percentages used in the IRI calculations are given in the table.

Overall, fishes (IRI = 5,384.9) and crustaceans (IRI = 5,009.2) made up the bulk of the forage items. Molluscs (IRI = 54.9), other miscellaneous invertebrates (IRI = 3.3), and unidentifiable remains made up the rest of the food items.

Fishes, representing 22 families, occurred in 59.7 percent of the food samples, comprised 76.2 percent of the total aggregate volume, and represented 14.0 percent of the total number of food items. Lutjanidae (229.5), Emmelichthyidae (103.5), and Congridae (64.8) had the highest IRI. Although unidentified fishes (IRI = 17.1) are significantly represented, the individuals represented various species.

Crustaceans, which made up the majority of the invertebrate forage, appeared in 50.7 percent of the samples and comprised 84.2 percent of the organisms and 14.6 percent of the total aggregate volume. Shrimp (Natantia) represented 96.8 percent of all the crustaceans, and the family Pandalidae represented 79.0 percent of all the shrimp. the lone species of shrimp identifiable beyond the family level was Plesionika longirostris. crabs (Reptantia), stomatopods, amphipods, and isopods made up the rest of the crustaceans in the forage.

Molluscs were present in 5.9 percent of the samples; all but one were octopuses. They comprised 8.3 percent of the total aggregate volume and 1.0 percent of the total number of forage items.

Other invertebrates were not significant contributors to the forage. One tunicate, family Pyrosomatidae, and an echinoid comprised 3.0 percent of the forage and made up 0.7 percent of the total aggregate volume and 0.4 percent of the organism total.

Unidentified remains and coral rubble comprised the remaining items in the samples. The IRI for these classifications and "fish remains" was not computed because it was not possible to determine the number of these items in the samples.

Individual lengths, length ranges, and mean lengths of the prey items are presented in Table 3. The lengths of prey fish ranged from 35 mm (a trachichthyid) to 516 mm (a congrid eel). Among the invertebrates, lengths ranged from 7-mm CL (a pandalid shrimp) to 85 mm ML (an octopod).

TABLE 2. NUMBER, FREQUENCY OF OCCURRENCE, VOLUME, AND INDEX OF RELATIVE IMPORTANCE (IRI) FOR MAJOR CLASSES OF FORAGE ITEMS IN 67 EPINEPHELUS QUERNUS FOOD SAMPLES

Forage Classes	No. of Organisms		Occurrence		Aggregate Total Volume		IRI
	Total	Percent	No.	Percent	ml	Percent	
INVERTEBRATES							
Natantia (shrimp)	396	81.5	24	35.8	288.9	9.2	3,247.1
Reptantia	10	2.1	8	11.9	163.3	5.2	86.9
Cephalopoda	5	1.0	4	6.0	262.0	8.3	55.8
Tunicata	1	0.2	1	1.5	23.0	0.7	1.4
Stomatopoda	1	0.2	1	1.5	6.5	0.2	0.6
Amphipoda	1	0.2	1	1.5	1.0	<0.1	0.3
Isopoda	1	0.2	1	1.5	0.6	<0.1	0.3
Echinoidea	1	0.2	1	1.5	0.3	<0.1	0.3
FISHES							
Lutjanidae	6	1.2	5	7.5	923.5	29.4	229.5
Emmelichthyidae	15	3.1	8	11.9	176.4	5.6	103.5
Congridae	5	1.0	4	6.0	307.0	9.8	64.8
Echeneidae	4	0.8	4	6.0	307.0	9.8	63.6
Serranidae	4	0.8	3	4.5	130.5	4.2	22.5
Trachichthyidae	5	1.0	4	6.0	15.8	0.5	9.0
Myctophidae	3	0.6	2	3.0	76.1	2.4	9.0
Polymixiidae	2	0.4	2	3.0	74.0	2.4	8.4
Gempylidae	1	0.2	1	1.5	81.0	2.6	4.2
Carangidae	2	0.4	2	3.0	25.8	0.8	3.6
Monacanthidae	2	0.4	2	3.0	12.5	0.4	2.4
Mullidae	1	0.2	1	1.5	43.0	1.4	2.4
Ophidiidae	1	0.2	1	1.5	32.0	1.0	1.8
Scorpaenidae	1	0.2	1	1.5	24.0	0.8	1.5
Anguilliformes (unidentified eels)	2	0.4	1	1.5	13.7	0.4	1.2
Priacanthidae	1	0.2	1	1.5	10.0	0.3	0.8
Pomacentridae	1	0.2	1	1.5	10.0	0.3	0.8
Apogonidae	2	0.4	1	1.5	1.5	<0.1	0.6
Muraenidae	1	0.2	1	1.5	5.0	0.2	0.6
Holocentridae	1	0.2	1	1.5	4.0	0.1	0.4
Argentinidae	1	0.2	1	1.5	3.5	0.1	0.4
Tetraodontidae	1	0.2	1	1.5	2.5	0.1	0.4
Gonorhynchidae	1	0.2	1	1.5	1.9	0.1	0.4
Unidentified fishes	3	0.6	3	4.5	101.5	3.2	17.1
Fish remains	—	—	2	3.0	13.7	0.4	—
OTHERS							
Unidentified remains	—	—	1	1.5	1.3	0.1	—
"Coral rubble"	—	—	1	1.5	3.5	0.1	—

TABLE 3. LENGTHS AND LENGTH RANGES OF ITEMS FOUND IN 67 *EPINEPHELUS QUERNUS* FOOD SAMPLES

Forage Items	No. of Organisms	Lengths or Range of Length and Mean Length (mm)
INVERTEBRATES		
Cephalopoda		
Octopoda	2	47-85 ($\bar{x}$ = 66.0)
Crustaceans		
Isopoda	1	27
Stomatopoda		
Odontodactylus brevirostris	1	75
Decapoda		
Natantia (shrimp)	2	10-13 ($\bar{x}$ = 11.5)
Caridea	1	12
Pandalidae	98	7-20 ($\bar{x}$ = 11.35)
Plesionika longirostris	5	13-22 ($\bar{x}$ = 16.8)
Reptantia		
Galatheidae	1	45
Munida sp.	2	24-38 ($\bar{x}$ = 36.0)
Brachyura	3	38-39 ($\bar{x}$ = 38.33)
Homolidae	1	43
Raninidae	1	66
FISHES		
Anguilliformes		
(unidentified eels)	1	174
Congridae	4	116-516 ($\bar{x}$ = 297.75)
Argentinidae	1	79
Gonorhynchidae		
Gonorhynchus gonorhynchus	1	78
Myctophidae	2	146-156 ($\bar{x}$ = 151.0)
Polymixiidae	1	161
Polymixia berndti	1	87
Ophidiidae		
Brotula multibarbata	1	158
Trachichtyidae	2	35-37 ($\bar{x}$ = 36.0)
Paratrachichthys sp.	3	50-67 ($\bar{x}$ = 57.33)
Holocentridae	1	63
Serranidae	3	93-197 ($\bar{x}$ = 143.33)
Priacanthidae		
Priacanthus sp.	1	71
Echeneidae	4	179-197 ($\bar{x}$ = 237.5)
Carangidae		
Seriola sp.	1	125
Emmelichthyidae	9	45-126 ($\bar{x}$ = 96.89)

TABLE 3. LENGTHS AND LENGTH RANGES OF ITEMS FOUND IN 67 *EPINEPHELUS QUERNUS* FOOD SAMPLES (continued)

Forage Items	No. of Organisms	Lengths or Range of Length and Mean Length (mm)
Lutjanidae	1	202
Etelis carbunculus	1	377
Symphysanodon sp.	4	53-56 ($\bar{x}$ = 54.25)
Mullidae		
Parupeneus sp.	1	128
Pomacentridae	1	68
Gempylidae	1	267
Monacanthidae	1	67
Pervagor spilosoma	1	66

Note: Means are given in parentheses

DISCUSSION AND CONCLUSION

As mentioned earlier, most of the food samples were spews which were caught in the throat or gill rakers of the groupers when the stomachs everted due to gas bladder expansion. It is possible that the spewed organisms are more likely to be retained due to some morphological structure (such as the antennules and antennae of pandalid shrimps) or perhaps size, and therefore a biased interpretation of the actual feeding habits and diet may result. Thus, it is possible that the results obtained may not completely represent the diet of this species. This problem was also encountered by Kluegel (1921) in the deeper-dwelling food fishes (including *E. quernus*), by Forster et al. (1970) in *Etelis marshi* (= *E. carbunculus*, Anderson (1981)), and by Moe (1969) in the red grouper in the Gulf of Mexico.

The results of this study support the conclusions of other studies on *Epinephelus*, i.e., *E. quernus* is a benthic carnivore. This grouper appears to be primarily piscivorous, although crustaceans and cephalopods also contribute to the forage. As concluded with other species of *Epinephelus* (Bardach and Mowbray, 1955; Hiatt and Strasburg, 1960; Moe, 1969), *E. quernus* appears to be an unspecialized feeder.

The items found in the food samples reflect the bottom-feeding behavior of this grouper. All 22 of the identified fish families contributing to the diet are usually found near the bottom, most being bottom inhabitants. Of particular interest was the occurrence of a red snapper, *E. carbunculus* (377 mm for length), in the stomach of a large (1,059 mm total length) grouper. This snapper is also a bottomfish which belongs to the tropical snapper-grouper complex mentioned earlier.

The invertebrates in the diet were generally small; shrimp were numerous. Shrimp (primarily Pandalidae) appear to be a very important food item for this grouper in the NWHI. Again, it is possible that the abundance of shrimp in the forage may be attributed to the sampling problem and that the long appendages characteristic of the shrimp are responsible for their high representation in the diet. However, 120 shrimp were found in one intact stomach. The lone pandalid shrimp that was identifiable to species was P. longirostris. King (1981) showed that this species was distributed along the benthic slopes in tropical Pacific islands, and our trapping results show this to hold true in the NWHI. This would indicate that the shrimp occupy a similar habitat as E. quernus, and thus their presence in the diet is not surprising. The presence of other invertebrates such as octopuses and galatheid crabs among the forage items further show the opportunistic benthic foraging behavior of E. quernus as well as a potential nocturnal or crepuscular behavior. Time of feeding, however, could not be determined due to lack of sufficient data. This species will take a baited hook both night and day (Moffitt, 1980), so it seems that E. quernus, like its congeners (Longley and Holdebrand, 1941; Randall and Brock, 1960; Randall, 1967; Harmelin-Vivien and Bouchon, 1976), feeds indifferently by day or night but may increase its foraging activities during certain periods of the day.

Trapping data collected on research cruises to the NWHI indicated possible depths of foraging by the grouper (Uchida and Uchiyama, in preparation). Adult E. quernus were caught in depths ranging from 18 to 230 m (10 to 126 fathoms) which includes the depths over which bottom handlining stations were conducted. This suggests that the grouper may forage over a wide range of depths very close to the bottom.

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