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THE FOOD AND FEEDING HABITS OF THE WHITE TREVALLY, *PSEUDOCARANX DENTEX* (BLOCH AND SCHNEIDER 1801), IN THE NORTHWESTERN HAWAIIAN ISLANDS

Michael P. Seki

Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 3830, Honolulu, Hawaii 96812

ABSTRACT

Sixty-four stomach samples of the white trevally, *Psuedocaranx dentex*, caught in the Northwestern Hawaiian Islands were examined to quantitatively determine the items which comprise the diet of this commercially valuable food species.

The results indicated that the white trevally is an opportunistic carnivore. It is primarily piscivorous, although cephalopods and crustaceans are also major contributors to the diet. The findings also strongly indicate that white trevally feeds near the bottom in the deeper waters offshore.

An index of relative importance (IRI) was computed to indicate which forage items were most important to the predators sampled. The IRI incorporates the frequency of occurrence and the percentage in the number and volume of the prey. The IRI showed that members of the families Congridae, Priacanthidae, and Serranidae were the most important fish prey. Cephalopods, crabs, and shrimp had the highest IRI among the invertebrates.

Carangidae — *Pseudocaranx dentex*
feeding — Northwestern Hawaiian Islands

INTRODUCTION

A food study of commercially important bottomfishes was undertaken as part of a survey and assessment of the benthic slope resources in the Northwestern Hawaiian Islands (NWHI). Among the species that comprise these resources is the white trevally, *Pseudocaranx dentex*, also known in Hawaii as the thick-lipped jack, butaguchi, or pig ulua. This species has been known as *Caranx cheilio* Snyder 1904; however, according to Smith-Vaniz and Poss (Department of Ichthyology, The Academy of Natural Sciences of Philadelphia, April, 1982: personal communication), who are working on a revision of the genus *Pseudocaranx*, *C. cheilio* is a synonym of *P. dentex* (Bloch and Schneider 1801). Around Hawaii the species attains a length of 91 cm (3 ft) (Gosline and Brock, 1960).

Outside the NWHI, the Indo-Pacific distribution of *P. dentex* includes South Africa, Australia, Tasmania, Norfolk Island, New Zealand, Japan, Pitcairn, Rapa, Easter, and the Lord Howe Islands (Randall, 1981). In the NWHI, the white trevally is found mainly on the banks and benthic slope at depths between 73 and 183 m (40 and 100 fathoms). The distribution of this species is not, however, limited to the deep slopes. At Kure Atoll, Okamoto and Kawamoto (1980) observed the white trevally in waters 1.5 m (5 ft) deep, occasionally in large schools of 200 to 300 individuals. Hobson (1980) found the species on his transect lines at Midway in depths of 5 m, and traps set as shallow as 18 m (10 fathoms) during our NWHI studies have captured both juveniles and adults.

Although feeding studies of *P. dentex* are nonexistent, a few feeding studies on other species of the family Carangidae have been published. Hobson (1974) and Okamoto and Kawamoto (1980) briefly mentioned the foraging habits of the bluefin trevally, *C. melampygus*, on Hawaiian inshore coral reefs. The same species has been studied on the reefs of the Gilbert Islands (Randall, 1955), the Marshall Islands (Hiatt and Strasburg, 1960; Randall, 1980), and off the east coast of Africa (Williams, 1965). The foraging habits of the giant trevally, *C. ignobilis*, were studied in the Marshall Islands (Randall, 1980), off East Africa (Williams, 1965), and in the NWHI (Okamoto and Kawamoto, 1980; Parrish et al., 1980). Feeding habits of various other common jacks, such as *C. lugubris*, have also been covered by Randall (1955, 1967, 1980). In general, the studies have found jacks to be primarily piscivores; however, the time of feeding appeared to vary among the species. *Caranx melampygus* is a diurnal predator (Williams, 1965; Okamoto and Kawamoto, 1980; Potts, 1980) whereas *C. ignobilis* is a nocturnal feeder (Okamoto and Kawamoto, 1980). In his examination of stomach contents from five species of *Caranx*, Randall (1967) noted that although some species were not ordinarily reef residents, many individuals made foraging trips into reef communities.

At the present time, the knowledge of the feeding habits of jacks has been limited to the species which may be easily captured on the nearshore reefs, although *C. ignobilis* may also be taken in waters as deep as 70 m (40 fathoms). *Pseudocaranx dentex* is known to inhabit coastal waters about 146 m (80 fathoms) deep with other commercially important food species such as the pink snapper or opakapaka, *Pristipomoides filamentosus*, and the hapuupuu, Epinephelus quernus (Hawaii Department of Land and Natural Resources, 1979; Ralston, 1981, 1982). The major objective of this study was to quantitatively determine the items constituting the diet of this deep-dwelling species. Together with food studies of other sympatric predators such as E. quernus (see paper on grouper in this proceedings by Seki), this study may provide a better understanding of the trophic relationships among the species of the demersal community in the NWHI.

METHODS

Field Collection of Food Samples

Sixty-four stomach samples of adult white trevally were collected at deep-sea handline stations aboard the RV Townsend Cromwell on resource survey cruises to the NWHI from September 1978 to August 1981. The samples were collected at 11 banks from Nihoa to Kure Atoll (Figure 1).

Fish sampled ranged from 42.7 to 82.2-cm fork length and weighed from 1.35 to 10.73 kg. Thirty-three of the specimens were females, 29 were males, and 2 were unsexed. Sixty of the samples were whole stomachs removed intact from the fish. The remaining four consisted of regurgitated food items removed from the gill rakers. Empty stomachs were not collected.

The fish were caught with hook and line on hydraulic-powered gurdies. The terminal rig and gurdy specifications have been described in a forthcoming publication edited by R.N. Uchida and J.H. Uchiyama. Briefly, the gurdies had a terminal rig with four hooks (Tankichi or Izuo No. 26 and/or No. 28). Each hook was usually baited with stripped squid. Handline stations were conducted with the vessel adrift in depths of 73 to 220 m (40 to 120 fathoms).

When fish were landed, stomachs were removed, examined, and unless empty, preserved in a 10 percent Formalin-seawater solution for later analysis. Regurgitated food items (spew) caught in the gill rakers when the stomachs everted due to gas bladder expansion were also preserved.

Laboratory Procedure

The laboratory methods for examination of the samples were similar to those reported by Humphreys (1980) and Harrison et al. (1983). The stomach contents were emptied into a fine mesh strainer, rinsed in running water, and sorted into identifiable groups. The volume of prey items were measured by water displacement. Where more than one item in the same taxon was present and could not be distinguished as a whole individual, the total volume and number of individuals comprising the volume were recorded. When possible, lengths of the prey were taken, including standard length for fish, mantle length for cephalopods, carapace length for shrimp, carapace width for crabs, and total

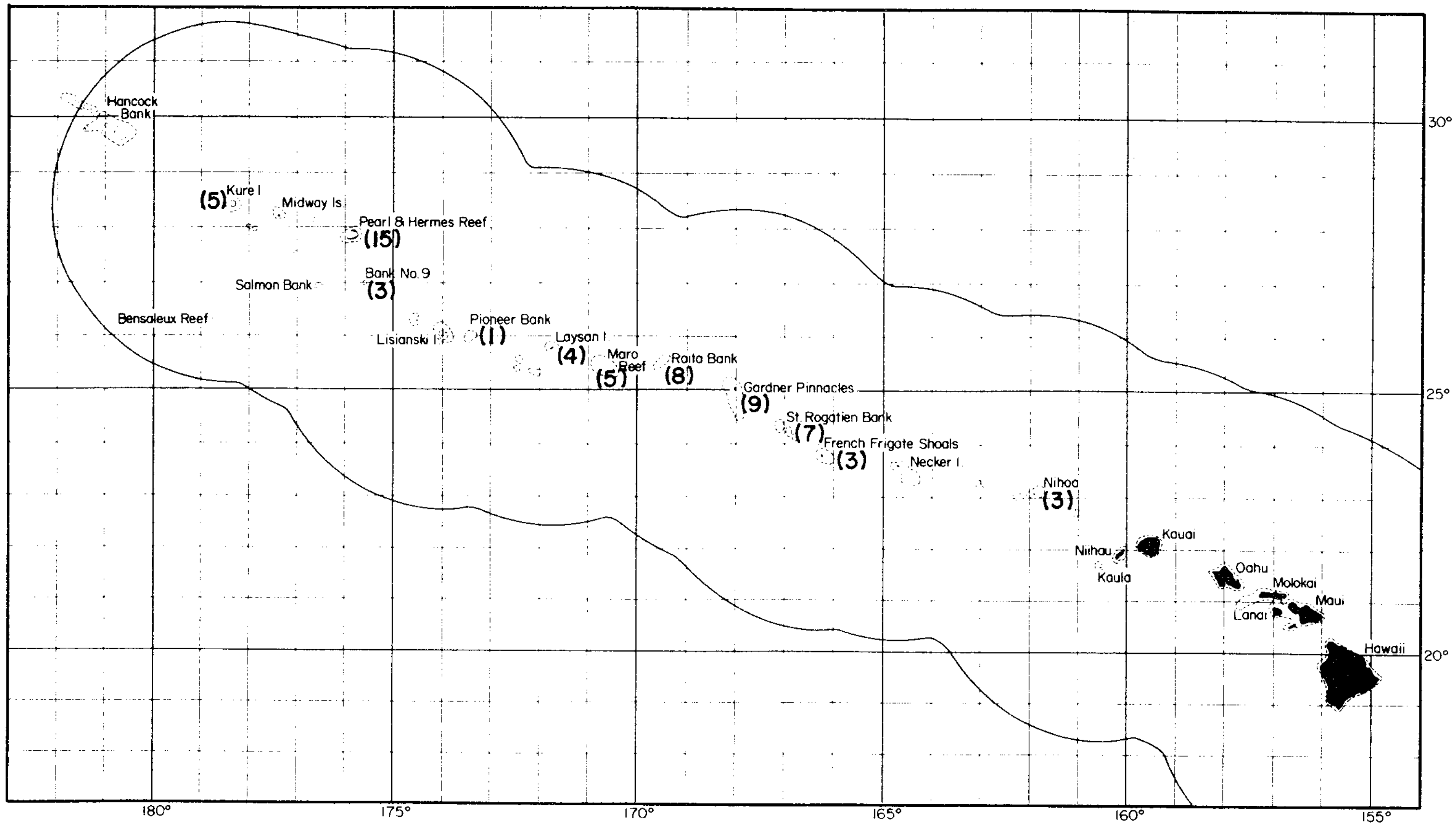

Figure 1. The Northwestern Hawaiian Islands. The number of stomach samples collected at each bank is shown in parentheses.

length for all others. No attempt was made to measure the lengths of any prey items that were well digested.

Food items were identified to the lowest possible taxon using the methods of Harrison et al. (1983). When possible, fish were identified by external characteristics and morphometrics. In most cases, however, the fish were in an advanced stage of digestion and required clearing of the flesh and staining of the vertebrae with Alizarin S. A combination of vertebral counts and morphological characters was then used for identification. Invertebrates were identified by external morphological features; thus many of the crustaceans were identified at least to family since the exoskeletons remained intact or nearly intact despite digestion.

Many samples included bottom sediment and debris (classified as "rubble") which were saved for further identification of small infaunal invertebrates that may be of nutritional value to the predator. The volume of the rubble was determined by water displacement. The volume was also determined for unidentifiable digested remains.

DATA ANALYSIS

The importance of each of the forage items was determined by the method described by Pinkas et al. (1971), who developed the index of relative importance defined as

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

where

N = Percentage of total aggregate number of a prey item

V = Percentage of total aggregate volume of a prey item

F = Percentage of occurrence of a prey item in the stomach samples

The IRI value provides a basis for ranking the prey items by incorporating the three measures traditionally used in stomach content analysis. Rubble and unidentified remains were not used in determining IRI.

RESULTS

The forage items found in the 64 stomach samples are listed in Table 1. The classification or taxonomic rank, the percent numerical, volumetric and frequency of occurrence, and the IRI values are given for each forage item.

TABLE 1. NUMBER, FREQUENCY OF OCCURRENCE, VOLUME, AND INDEX OF RELATIVE IMPORTANCE VALUES OF THE FORAGE ITEMS IN 64 *PSEUDOCARANX DENTEX* FOOD SAMPLES

Forage Items	No. of Organisms		Occurrence		Aggregate Total Volume		IRI
	Total	Percent	No.	Percent	ml	Percent	
PHYLUM ANNELIDA							
Class Polychaeta	8	1.9	3	4.7	2.3	0.2	9.9
PHYLUM MOLLUSCA							
Class Gastropoda	18	4.3	10	15.6	1.2	0.1	68.6
Class Bivalvia							
Order Mytiloida							
Family Pinnidae							
Pinna muricata	2	0.5	2	3.1	14.0	1.4	5.9
Order Veneroida							
Family Cardiidae							
Nemocardium thaanumi	1	0.2	1	1.6	8.0	0.8	1.6
Class Cephalopoda	12	2.9	10	15.6	8.1	0.8	57.7
Order Octopoda	7	1.7	6	9.4	64.5	6.3	75.2
PHYLUM ARTHROPODA							
Class Crustacea	14	3.4	7	10.9	4.4	0.4	41.4
Subclass Malacostraca							
Order Amphipoda	1	0.2	1	1.6	0.1	<0.1	0.3
Order Stomatopoda	1	0.2	1	1.6	0.1	<0.1	0.3
Family Squillidae							
Lysiosquilla sp.	1	0.2	1	1.6	0.1	<0.1	0.3
Odontodactylus sp.	15	3.6	6	9.4	5.9	0.6	39.5
Pseudosquilla sp.	1	0.2	1	1.6	0.3	<0.1	0.3
Order Decapoda							
Suborder Natantia (shrimp)	14	3.4	5	7.8	3.5	0.3	28.9
Superfamily Caridea	15	3.6	3	4.7	6.0	0.6	19.7
Family Pandalidae	2	0.5	1	1.6	1.0	0.1	1.0
Family Crangonidae	2	0.5	1	1.6	0.4	<0.1	0.8
"Shrimp remains"	1	0.2	1	1.6	0.6	0.1	0.5
Suborder Reptantia							
Tribe Palinura							
Family Palinuridae							
Panulirus sp.	1	0.2	1	1.6	0.1	<0.1	0.3
Tribe Anomura							
Family Paguridae	2	0.5	2	3.1	1.6	0.2	2.2
Family Galatheidae							
Munida sp.	1	0.2	1	1.6	1.0	0.1	0.5
Tribe Brachyura	2	0.5	2	3.1	0.7	0.1	1.9
"Crab"	23	5.5	16	25.0	18.2	1.8	182.5
PHYLUM ECHINODERMATA							
Class Ophiuroidea	2	0.5	2	3.1	0.6	0.1	1.9
Class Echinoidea							
Order Cidaroida							
Family Cidaridae							
Prionocidaris hawaiiensis	1	0.2	1	1.6	5.5	0.5	1.1

TABLE 1. NUMBER, FREQUENCY OF OCCURRENCE, VOLUME, AND INDEX OF RELATIVE IMPORTANCE VALUES OF THE FORAGE ITEMS IN 64 *PSEUDOCARANX DENTEX* FOOD SAMPLES (continued)

Forage Items	No. of Organisms		Occurrence		Aggregate Total Volume		IRI
	Total	Percent	No.	Percent	ml	Percent	
PHYLUM CHORDATA							
Superclass Pisces							
Class Osteichthyes							
(Unidentified fishes)	19	4.6	6	9.4	10.3	1.0	52.6
Order Anguilliformes	5	1.2	4	6.2	61.8	6.1	45.3
Family Congridae	30	7.2	5	7.8	55.7	5.5	99.1
Congrina aequoria	2	0.5	1	1.6	10.0	1.0	2.4
Family Ophichthidae	3	0.7	2	3.1	9.5	0.9	5.0
Muraenichthys cookei	2	0.5	1	1.6	7.0	0.7	1.9
"Leptocephalus larvae"	1	0.2	1	1.6	0.8	0.1	0.5
Order Myctophiformes							
Family Synodontidae	5	1.2	2	3.1	60.1	5.9	21.3
Family Chlorophthalmidae	1	0.2	1	1.6	2.5	0.2	0.6
Family Myctophidae	1	0.2	1	1.6	0.5	<0.1	0.3
Order Gadiformes							
Family Moridae	1	0.2	1	1.6	37.0	3.6	6.1
Family Ophidiidae	27	6.5	3	4.7	7.9	0.8	34.3
Order Lophiiformes							
Family Ogcocephalidae	2	0.5	1	1.6	1.6	0.2	1.1
Halieutaea retifera	1	0.2	1	1.6	3.5	0.3	0.8
Malthopsis sp.	1	0.2	1	1.6	0.3	<0.1	0.3
Order Scorpaeniformes							
Family Scorpaenidae	7	1.7	2	3.1	26.6	2.6	13.3
Order Dactylopteriformes							
Family Dactylopteridae							
Dactyloptena orientalis	1	0.2	1	1.6	1.3	0.1	0.5
Order Pegasiformes							
Family Pegasidae							
Pegasus papilio	2	0.5	2	3.1	0.8	0.1	1.9
Order Perciformes							
Family Serranidae	13	3.1	4	6.2	8.6	0.8	24.2
Anthias sp.	3	0.7	3	4.7	6.4	0.6	6.1
Family Priacanthidae							
Priacanthus sp.	12	2.9	1	1.6	207.0	20.4	37.3
Family Lutjanidae	16	3.9	3	4.7	9.1	0.9	22.6
Symphysanodon sp.	5	1.2	1	1.6	7.7	0.8	3.2
Family Percophididae							
(= Bembropsidae)	1	0.2	1	1.6	2.3	0.2	0.6
Family Ammodytidae							
Embolichthys sp.	12	2.9	3	4.7	53.9	5.3	38.5
Order Gobiesociformes							
Family Callionymidae	1	0.2	1	1.6	0.8	0.1	0.5
Order Pleuronectiformes							
Family Bothidae	7	1.7	6	9.4	20.8	2.0	34.8
Bothus thompsoni	1	0.2	1	1.6	1.0	0.1	0.5
Order Tetraodontiformes							
Family Monacanthidae	2	0.5	1	1.6	8.0	0.8	2.1
Family Tetraodontidae	18	4.4	5	7.8	18.1	1.8	48.4
Fish remains	—	—	6	9.4	5.3	0.5	—
"Rubble"	—	—	20	31.2	21.9	2.2	—
Unidentified remains	—	—	43	67.2	194.1	19.1	—

Table 2 presents the analysis of food items by major classes and the ranks of the forage items in descending order of IRI values for the invertebrates and fishes. Fish prey were primarily grouped at the family level and the invertebrates primarily at the class or order level.

Fishes, molluscs, and crustaceans formed the bulk of the forage items in the samples. Fish prey yielded a total IRI value of 7,884.5 compared with 1,454.9 for crustaceans and 653.6 for molluscs.

Fishes as a whole occurred in 68.8 percent of the stomach samples and represented 64.2 percent of the total aggregate volume, and 50.4 percent of the total number of forage items. Twenty families of fishes were represented, and families that had high IRI values were Congridae (IRI = 133.5), Priacanthidae (IRI = 74.7), and Serranidae (IRI = 58.9). Unidentified fish (IRI = 52.6) which were also included in the analysis deserve mention only to the extent that individuals which comprised this group were not of the same species, but of various species.

The invertebrate forage included four phyla, with the majority belonging to Arthropoda, class Crustacea. Crustaceans appeared in 53.1 percent of the samples and represented 4.3 percent of the total aggregate volume and 23.1 percent of the total forage items. Among the crustaceans, crabs (suborder Reptantia) ranked the highest (IRI = 277.7), followed by shrimp (suborder Natantia) (IRI = 131.1), of which most were carideans. Stomatopods (primarily *Odontodactylus* sp.) and an amphipod were also found.

Molluscs were present in 34.4 percent of the samples and comprised 9.4 percent of the total volume and 9.6 percent of the total number of forage organisms. Cephalopods (IRI = 256.2), mainly octopods (IRI = 75.2), were the primary contributor from this phylum appearing in 21.9 percent of the samples and representing 7.1 percent of the total aggregate volume. Gastropods and bivalves were also present.

Other invertebrates were minor contributors to the diet of the white trevally sampled. These included eight polychaetes (IRI = 9.9) and three echinoderms (IRI = 6.1); together they comprised 2.6 percent of the forage items, 0.8 percent of the total aggregate volume, and appeared in 9.4 percent of the samples. Many small invertebrates and limestone fragments were found in the rubble. A list of these organisms (identified through the courtesy of B. Burch, Bishop Museum, Honolulu, Hawaii) and their taxonomic rank are presented in Appendix 1.

To examine differences in diet with respect to location of capture, the islands and banks were divided into three geographical regions as described by Moffitt (1980) (Table 3). Region 1 ranges from Nihoa to Gardner Pinnacles and represents the area in the NWHI fished most by commercial vessels in recent years,

TABLE 2. NUMBER, FREQUENCY OF OCCURRENCE, VOLUME, AND INDEX OF RELATIVE IMPORTANCE VALUES OF MAJOR CLASSES OF FORAGE ITEMS IN 64 *PSEUDOCARANX DENTEX* FOOD SAMPLES

Forage Classes	No. of Organisms		Occurrence		Aggregate Total Volume		IRI
	Total	Percent	No.	Percent	ml	Percent	
INVERTEBRATES							
Reptantia "crabs"	28	6.8	20	31.2	21.5	2.1	277.7
Cephalopoda	19	4.6	14	21.9	72.6	7.1	256.2
Natantia (shrimp)	34	8.2	9	14.1	11.5	1.1	131.1
Stomatopoda	18	4.3	9	14.1	6.4	0.6	69.1
Gastropoda	18	4.3	10	15.6	1.2	0.1	68.6
Crustacea (unidentified)	14	3.4	7	10.9	4.4	0.4	41.4
Bivalvia	3	0.7	3	4.8	22.0	2.2	13.9
Annelida (Polychaeta)	8	1.9	3	4.7	2.3	0.2	9.9
Echinodermata	3	0.7	3	4.7	6.1	0.6	6.1
Amphipoda	1	0.2	1	1.6	0.1	<0.1	0.3
Reptantia "lobsters"	1	0.2	1	1.6	0.1	<0.1	0.3
FISHES							
Congridae	32	7.7	6	9.4	65.7	6.5	133.5
Priacanthidae	13	3.1	2	3.1	213.6	21.0	74.7
Serranidae	16	3.9	7	10.9	15.0	1.5	58.9
Osteichthyes (Unidentified fishes)	19	4.6	6	9.4	10.3	1.0	52.6
Tetraodontidae	18	4.3	5	7.8	18.1	1.8	47.6
Anguilliformes (Unidentified eels)	5	1.2	4	6.2	61.8	6.1	45.3
Bothidae	8	1.9	7	10.9	21.8	2.1	43.6
Lutjanidae	21	5.1	4	6.2	16.8	1.6	41.5
Ammodytidae	12	2.9	3	4.7	53.9	5.3	38.5
Ophidiidae	27	6.5	3	4.7	7.9	0.8	34.3
Synodontidae	5	1.2	2	3.1	60.1	5.9	22.0
Scorpaenidae	7	1.7	2	3.1	26.6	2.6	13.3
Ophichthidae	5	1.2	2	3.1	16.5	1.6	8.7
Moridae	1	0.2	1	1.6	37.0	3.6	6.1
Ogcocephalidae	4	1.0	2	3.1	5.4	0.5	4.6
Monacanthidae	2	0.5	1	1.6	8.0	0.8	2.1
Pegasidae	2	0.5	2	3.1	0.8	0.1	1.9
Chlorophthalmidae	1	0.2	1	1.6	2.5	0.2	0.6
Percophididae (= Bembropsidae)	1	0.2	1	1.6	2.3	0.2	0.6
Dactylopteridae	1	0.2	1	1.6	1.3	0.1	0.5
Leptocephalus larvae	1	0.2	1	1.6	0.8	0.1	0.5
Callionymidae	1	0.2	1	1.6	0.8	0.1	0.5
Myctophidae	1	0.2	1	1.6	0.5	<0.1	0.3
Fish remains	—	—	6	9.4	5.3	0.5	—
OTHERS							
"Rubble"	—	—	20	31.2	21.9	2.2	—
Unidentified remains	—	—	43	67.2	194.1	19.1	—

TABLE 3. RANKS AND INDEX OF RELATIVE IMPORTANCE VALUES OF THE MAJOR FORAGE CLASSES OF PREY ITEMS BY REGION

Forage Classes	Region 1 (n = 22)		Region 2 (n = 18)		Region 3 (n = 23)	
	Rank	IRI	Rank	IRI	Rank	IRI
INVERTEBRATES						
Annelida (Polychaeta)	12	1.6	11	2.6	—	—
Gastropoda	9	4.6	9	4.7	5*	15.5
Bivalvia	7	5.8	—	—	15	1.6
Cephalopoda	—	—	5*	14.4	6	15.0
Octopoda	2*	58.6	—	—	—	—
Crustacea (unidentified)	17	0.4	12	2.4	4*	17.2
Amphipoda	—	—	21	0.4	—	—
Stomatopoda	17	0.4	20	0.4	2*	48.5
Natantia (shrimp)	1*	77.7	—	—	11	4.9
Reptantia "lobsters"	—	—	—	—	22	0.4
Reptantia "crabs"	3*	37.6	7	7.4	1*	59.3
Echinodermata	11	3.2	—	—	21	0.4
FISHES						
Osteichthyes (Unidentified fishes)	6	6.2	13	1.9	9	9.5
Anguilliformes (Unidentified eels)	—	—	21	0.4	12	2.9
Congridae	—	—	1*	132.9	—	—
Ophichthidae	10	3.4	18	1.0	—	—
"Leptocephalus larvae"	—	—	—	—	20	0.5
Synodontidae	—	—	19	0.9	8	10.2
Chlorophthalmidae	—	—	—	—	17	0.8
Myctophidae	16	0.4	—	—	—	—
Moridae	—	—	8	6.0	—	—
Ophidiidae	—	—	10	4.3	7	14.2
Ogcocephalidae	—	—	17	1.0	16	1.3
Scorpaenidae	5*	13.5	—	—	—	—
Dactylopteridae	—	—	—	—	19	0.6
Pegasidae	—	—	15	1.8	—	—
Serranidae	8	5.7	16	1.1	3*	17.5
Priacanthidae	13	1.4	2*	36.2	—	—
Lutjanidae	4*	25.9	14	1.9	—	—
Percophididae	15	0.7	—	—	—	—
Ammodytidae	—	—	3*	24.4	18	0.6
Callionymidae	—	—	—	—	20	0.5
Bothidae	—	—	6	13.3	10	9.0
Monacanthidae	—	—	—	—	13	2.0
Tetraodontidae	14	1.1	4*	15.1	14	1.8

*Highest ranked classes for each region

Region 2 is from Raita Bank to Lisianski Island, and Region 3 is from Pearl and Hermes Reef to Kure Atoll. The latter two regions are separated by a natural break in the chain. The IRI values of the prey classes for each region were used to rank the importance of the classes in the three regions. The highest value was given the rank of 1. The top ranked classes in Regions 1 and 3 were invertebrates, primarily crustaceans. The top classes in Region 2 were fishes (Congridae, Priacanthidae, Ammodytidae, and Tetraodontidae).

The lengths of fish prey ranged from 14 mm (*Pegasus papilio*) to 306 mm (an ophichthid eel). Lengths of invertebrate forage items ranged from 5 mm (a crangon shrimp) to 42 mm (a stomatopod, *Odontodactylus* sp.). Measurements, ranges, and mean lengths of prey items are presented in Table 4.

DISCUSSION

The results of this diet study indicate that as in other carangids previously studied, the white trevally is a high-level opportunistic carnivore. The species is primarily piscivorous, although cephalopods and crustaceans are also major contributors to their diet. The results also strongly indicate that this species is a bottom feeder. By comparison, Randall (1967) noted small amounts of sand in a few stomachs of *Caranx ruber*, indicating that at times they were feeding on prey directly off the bottom. The presence of some coral tissue and algae provided evidence that *C. ignobilis* also forage occasionally on the bottom (Williams, 1965). In this study, the presence of rubble in about 31 percent of the samples shows that the white trevally feeds on the bottom to an even greater degree.

Nineteen of the 20 fish families found in the forage can be classified as benthic, the exception being myctophids, which although inhabiting the water column, may approach the bank slopes during their vertical migrations. Nearly half of the fish families represented in the diet of white trevally were also represented in the food of another bottom feeder, *E. quernus* (see paper on grouper in this proceedings by Seki). Fishes of the Congridae and Serranidae families, which were two of the most important groups in the diet of the white trevally, were also among the most important fishes in the *E. quernus* stomach samples.

The bottom feeding behavior of white trevally is also reflected in the invertebrate forage. The invertebrates with the highest IRI ranking were crabs, octopi, and gastropods, all bottom dwellers. The occurrence of other invertebrates such as echinoderms, bivalves, and shrimp (even if taken infrequently) in the forage composition reflects the probable browsing behavior of the species. It is noteworthy that among the outstanding morphological features of white trevally are the thick, fleshy lips on a mouth that features an inferior jaw, uncharacteristic of most other carangids. This morphology would appear to facilitate bottom browsing.

TABLE 4. LENGTHS OR RANGE OF LENGTHS OF THE ITEMS FOUND IN 64 *PSEUDOCARANX DENTEX* FOOD SAMPLES

Forage Items	No. of Organisms	Lengths or Range of Lengths and Means (mm)	
INVERTEBRATES			
Polychaeta	6	10-29	($\bar{x}$ = 15.0)
Gastropoda	8	5-8	($\bar{x}$ = 6.5)
Crustacea			
Amphipoda	1	7	
Stomatopoda			
Odontodactylus sp.	7	30-42	($\bar{x}$ = 33.9)
Pseudosquilla sp.	1	33	
Lysiosquilla sp.	1	13	
Decapoda			
Natantia (shrimp)	7	6-16	($\bar{x}$ = 10.3)
Caridea	14	11-12	($\bar{x}$ = 8.4)
Pandalidae	2	11-11	($\bar{x}$ = 11.0)
Crangonidae	2	5-6	($\bar{x}$ = 5.5)
Reptantia - "crab"	4	6-11	($\bar{x}$ = 9.2)
Anomura			
Paguridea	1	14	
Galatheidae			
Munida sp.	1	14	
Brachyura	1	9	
Ophiuroidea	1	6	
FISHES			
Anguilliformes			
(unidentified eels)	3	73-162	($\bar{x}$ = 108.0)
Congridae	11	80-135	($\bar{x}$ = 114.0)
Congrina aequoria	2	120-148	($\bar{x}$ = 134.0)
Ophichthidae	1	306	
Muraenichthys cookei	2	167-196	($\bar{x}$ = 181.5)
Synodontidae	2	40-75	($\bar{x}$ = 57.5)
Chlorophthalmidae	1	62	
Moridae	1	152	
Ophidiidae	14	45-54	($\bar{x}$ = 49.7)
Ogcocephalidae	2	38-38	($\bar{x}$ = 38.0)
Halieutaea retifera	1	52	
Malthopsis sp.	1	22	
Scorpaenidae	5	27-69	($\bar{x}$ = 52.6)
Dactylopteridae			
Dactyloptena orientalis	1	30	

Note: Means are given in parentheses

TABLE 4. LENGTHS OR RANGE OF LENGTHS OF THE ITEMS FOUND IN 64 *PSEUDOCARANX DENTEX* FOOD SAMPLES (continued)

Forage Items	No. of Organisms	Lengths or Range of Lengths and Means (mm)	
Pegasidae			
Pegasus papilio	2	14-24	($\bar{x}$ = 19.0)
Serranidae	7	21-43	($\bar{x}$ = 32.0)
Anthias sp.	2	32-39	($\bar{x}$ = 35.5)
Priacanthidae			
Priacanthus sp.	10	82-94	($\bar{x}$ = 89.1)
Lutjanidae	6	28-61	($\bar{x}$ = 39.2)
Symphysanodon sp.	3	50-57	($\bar{x}$ = 53.7)
Ammodytidae			
Embolichthys sp.	6	93-100	($\bar{x}$ = 96.5)
Callionymidae	1	52	
Bothidae	2	70-70	($\bar{x}$ = 70.0)
Bothus thompsoni	1	37	
Monacanthidae	2	60-71	($\bar{x}$ = 65.5)
Tetraodontidae	15	22-45	($\bar{x}$ = 37.7)
Unidentified fishes	3	24-87	($\bar{x}$ = 45.7)

Unlike the other species of jacks which feed on reef fishes (Randall, 1955, 1980; Williams, 1965; Hobson, 1974; Okamoto and Kawamoto, 1980; Parrish et al., 1980), the white trevally feeds on fishes found in the deeper waters offshore. Most of the species such as *Halieutaea retifera* and *Bothus thompsoni* in the diet of white trevally have been captured in bottom trawls between 55 and 92 cm (30 and 50 fathoms) (Uchida and Uchiyama, in preparation). The trap catch data collected during the NWHI resource survey also provide a relative indication to the feeding grounds of this species. Although food samples were not collected from trap-caught fish, the data provided depths of capture and thus information on foraging depths. Adult white trevally were captured in traps set in waters 18 to 124 m (10 to 68 fathoms) deep, suggesting a fairly wide range of foraging depths. This diet study concentrated on adults; however, it is worth noting that large numbers of juveniles (100 to 252 individuals per trap) were caught in traps set in water 60 to 64 m (33 to 35 fathoms) deep.

The wide variety of forage organisms and the absence of any dominant prey in the gut contents suggests opportunistic feeding. This is consistent with the results of the studies by Major (1978) and Potts (1980), where *C. ignobilis* and *C. melampygus* exhibited opportunistic feeding habits; however, it may be that the number of stomach samples was inadequate to demonstrate possible selective feeding or other trends.

A small sample size also prohibited an investigation of the extent stomach contents are influenced by seasonal effects. Although sampling was conducted throughout the year, 37 (58 percent) of the stomachs were collected in the summer. For the other seasons, 15 (23 percent) were collected in the spring, 9 (14 percent) in the fall, and 3 (5 percent) in the winter.

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APPENDIX A.

Components of rubble found in *Pseudocaranx dentex* stomachs. (Identified through the courtesy of B. Burch, Bishop Museum, Honolulu, Hawaii)

Limestone "rubble"
Phylum Protozoa
  Order Foraminifera
    Family Nummulitidae
      Heterostegina depressa
    Family Homotrematidae
      Miniacina miniacea
    Family Amphisteginidae
      Amphistigina cf. *bicirculata*
    Family Soritidae
      Marginopora vertebralis

Phylum Coelenterata
  Order Scleractinia
    Family Fungiidae (coral)
      Cycloseris fragilis

Phylum Echinodermata
  Class Echinoidea
    Family Cidaroidae
    Family Fibulariidae
      Echinocyamus elongatus
  Class Ophiuroidea

Phylum Mollusca
  Class Gastropoda
    Family Strombidae
      Strombus helli
    Family Eulimidae
    Family Atyidae
    Family Naticidae (Natica)
    Family Cerithiidae
    Family Littorinidae
      ?*Peasiella tantilla*
    Family Epitoniidae
    Family Hipponicidae
      Sabia conica
    Family Xenophoridae
      Xenophora peroniana
    Family Triphoridae
      Tripbora cf. *tubularis*
    Family Columbellidae
    Family Pteropoda
    Family Bursidae
      Gyrineum pusillum
    Family Turbinidae
      Gibbula marmorea
    Family Rissoidae
      Zebina tridentata
    Family Turridae
  Class Bivalvia
    Family Ostreidacea
    Family Cardiidae
      Nematocardium thaanumi
    Family Spondylidae
      Spondylus linguafelis
    Family Carditidae
      Carditella sp.
    Family Mytilidae
      Brachidontes crebrestriatus
    Family Arcidae
    Family Pectinidae
    Family Pinnidae
  Class Scaphopoda
    Family Dentalidae

Phylum Arthropoda
  Class Crustacea
  Order Amphipoda
    Family Gammaridae
  Tribe Brachyura
    Family Xanthidae
    Family Portunidae
    Family Leucosiidae
  Tribe Anomura
    Family Paguridea