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RESULTS OF BOTTOM FISH RESEARCH IN THE NORTHWESTERN HAWAIIAN ISLANDS

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INTRODUCTION

From October 1976 to September 1981, the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service (NMFS), under a Tripartite Cooperative Agreement with the U.S. Fish and Wildlife Service and the State of Hawaii's Division of Aquatic Resources, Department of Land and Natural Resources (DLNR), conducted surveys of the demersal and coastal pelagic fishes and macroinvertebrates of the island shelves, banks, reefs, seamounts, and overlying waters within the U.S. Fishery Conservation Zone around the Northwestern Hawaiian Islands (NWHI). The University of Hawaii Sea Grant Program also became a partner to this investigation about a year later. The resource assessment surveys were conducted in response to recommendations by the Governor's Task Force on Oceanography (State of Hawaii 1969) and on Hawaii and the Sea (State of Hawaii 1974) to investigate the magnitude of the marine resources in waters of the NWHI as well as to learn about the interaction of these marine resources with terrestrial animals such as the endangered Hawaiian monk seal, *Monachus schauinslandi*, green turtle, *Chelonia mydas*, and sea and land birds that reside on the islands.

Results of the first phase of the bottom fish survey, conducted in October 1976-June 1979, were summarized by Uchida et al. (1979) and by Moffitt.[1] These papers describe the sampling procedure, the gears used, and present results of studies on bottom fish distribution and relative abundance, spawning and fecundity, food and feeding behavior, ciguatera, and age and growth.

This paper summarizes the results of all NMFS bottom fish studies conducted to date in the NWHI. It includes brief reviews of studies completed or ongoing on distribution, relative abundance, and cluster analysis; age and growth; food and feeding habits; ciguatera; fecundity and spawning; and length-weight relationships.

THE BOTTOM FISH RESOURCE

The volcanic processes by which the Hawaiian Islands were built up from the ocean floor produced relatively steep-sided bases for all the islands. Newman (1976) pointed out that these island bases are less than 250 km in width at the bottom and that the slope averages about 400 m/km. It is this steep underwater gradient that limits the shelf zone to a narrow band that surrounds each island, a factor which is vitally important to fishing in Hawaiian waters. Unlike the continental shelf that characterizes most of the world's great fishing areas, the island shelf is narrow, poorly developed, and does not offer the marine environmental conditions that are so vital to high fishery yields.

The Hawaiian commercial fishery exploits about 60-70 species of the 680+ species of fish reported to occur in Hawaiian waters. The bulk of the landings is from within 20 nmi of the main islands; however, in recent years long-ranging vessels of the Hawaiian fleet have begun to make larger contributions to the State landings with fish and shellfish harvested from waters of the NWHI.

The demersal fish resource of the NWHI can be conveniently divided into three groups or species complex, depending on their vertical distribution over the island shelf and slope or over the summit of seamounts. The first is the reef fish complex occupying the subsurge zone over the inner and outer shelves, the second is the snapper-grouper complex inhabiting the shelf edge down to the bottom of the upper slope zone, and the third is the armorhead-alfonsin complex associated with the summits of some of the seamounts in the northern edge of the Hawaiian Archipelago. This report will be concerned only with the snapper-grouper complex; the reef fish complex was essentially researched by the DLNR and the results of their study are not included here. The seamount-groundfish resource, which includes the pelagic armorhead, *Pentaceros richardsoni*, and alfonsin, *Beryx splendens*, has been reported on by Uchida and Tagami.[2]

FISHES OF THE SNAPPER-GROUPER COMPLEX

The species included in this category are opakapaka, *Pristipomoides filamentosus*, kalekale, *P. sieboldii*, gindai, *P. zonatus*. onaga, *Etelis coruscans*, ehu, *E. carbunculus*, hapuupuu, *Epinephelus quernus*, butaguchi, *Pseudocaranx dentex*, kahala, *Seriola dumerili*, and nohu, *Pontinus macrocephalus*.

Relative Abundance

During the course of the NWHI investigation, we fished 25 banks with handline gear to determine the distribution and relative abundance of bottom fish species. Among the more productive banks were Nero Seamount where 18.8 line-h of fishing produced 5.319 fish/line-h with ehu predominating in the catch. Other banks with excellent fishing were Bank No. 9, a submerged pinnacle located at lat. 27°00'N, long. 175°35'W, where the catch rate reached 3.608 fish/line-h and ehu, hapuupuu, and kahala dominated the catch, and at Pearl and Hermes Reef where the catch rate was

3.252 fish/line-h in 234.93 line-h of fishing. The catch at Pearl and Hermes was composed predominantly of ehu, hapuupuu, butaguchi, kahala, kalekale, onaga, and nohu. We also experienced relatively good fishing for bottom fish at Midway, Maro Reef, French Frigate Shoals, and Bank No. 8, located at lat. 26°17'N, long. 174°34'W. Analysis of the bottom fish data is continuing.

Age Determinations

Age determinations of bottom fish were made on the assumption that rings in otoliths indicated daily marks and in some species, annual marks. Previous studies have supported the hypothesis that the smallest discernible growth increments in the sagittae of fish are deposited daily (Pannella 1971, 1974). Recent studies have provided direct evidence that these growth increments are daily phenomena in sagittae of both temperate (Brothers et al. 1976; Taubert and Coble 1977; Barkman 1978) and tropical species (Ralston 1976; Struhsaker and Uchiyama 1976; Wild and Foreman 1980). We have completed a number of studies on age and growth for such species as opakapaka, gindai, ehu, and kahala. Studies on kalekale and hapuupuu are currently in progress and should be completed shortly.

Figure 1 shows the growth curves for opakapaka, ehu, and kahala for which studies have been completed. Based on 93 fish, the von Bertalanffy growth parameters for opakapaka were as follows: L_∞ = 97.1 cm; K = 0.31; and t_0 = 0.02 yr. Growth parameters of the kahala, based on 14 fish including juveniles less than 4 cm in fork length (FL) as well as adults, were L_∞ = 149.4 cm; K = 0.31; and t_0 = 0.04 yr. The growth parameters of ehu, based on 14 fish from 23 to 49 cm FL were L_∞ = 63.9 cm; K = 0.36; and

t_0 = -0.60 yr. It should be noted that the L_∞ calculated for ehu was almost identical to the size of the largest ehu taken, which measured 63.0 cm FL.

Cluster Analysis

We have also used multivariate techniques to document biological variation in waters of the NWHI. A statistical technique called cluster analysis used on a sample of 4,319 bottom fish caught in the NWHI over the past 5 yr suggests that the banks can be aggregated.[3] Grouping the data into six clusters gave the greatest reduction in variance among the species composition vectors. Nihoa, Lisianski, and Pearl and Hermes formed one cluster with catches consisting primarily of ehu and hapuupuu. Northampton Seamount, by itself, formed a second cluster with catches predominated by ehu and gindai. A third cluster was formed by Gardner Pinnacles, Laysan, and Raita Bank where the catch was predominately composed of ehu, opakapaka, butaguchi, hapuupuu, and kahala. Midway and Kure formed a fourth cluster with catches predominantly composed of ehu, hapuupuu, and butaguchi. The fifth cluster included Necker, French Frigate Shoals, and Brooks Banks where the catches primarily included opakapaka and hapuupuu. The final cluster detected was Maro Reef which had predominantly opakapaka, hapuupuu, and butaguchi.

Food and Feeding Habits

Determination of the food and feeding habits of several members of the snapper-grouper complex is extremely difficult because when the fish are hooked at depths of about 130-240 m and brought to the surface, expansion of the gas bladder invariably causes the stomach to evert, leaving only traces of food items either caught in the throat or gill rakers. For some species such as the carangids, however, entire stomachs can be collected for study.

Among fishes of the snapper-grouper complex, we have completed diet studies on kahala, butaguchi, and hapuupuu. Brief summaries of the results are given below.

Butaguchi: The butaguchi, like many other members of the Family Carangidae, is an opportunistic bottom feeder (Seki [4]). In 64 stomachs examined, fishes of the Families Congridae, Priacanthidae, and Serranidae were the most important and cephalopods, crabs, and shrimps were the most important invertebrates. Fish occurred in 69% of the stomachs and represented 20 families. The invertebrates included four phyla with the majority beonging to Arthropoda, Class Crustacea. Crustaceans were found in 53% of the samples with crabs of the Suborder Reptantia, the most frequently encountered. Caridean shrimps, stomatopods, and amphipods were also important constituents of the diet.

Hapuupuu: Because of the difficulty in collecting intact stomachs from this species, sampling concentrated also on spew samples, that is, food items that were caught in the throat or gill rakers of the fish (Seki[5]). Fish representing 22 families occurred in 60% of the samples; members of the Families Lutjanidae, Emmelichthyidae, and Congridae were the most important. Crustaceans were the most important among the invertebrates and were present in 51% of the samples. The crustaceans included shrimps of which members of the Family Pandalidae were the most frequently encountered. Crabs, stomatopods, amphipods, and isopods made up the bulk of the remaining invertebrates. Molluscs represented only a small part of the diet, being present in only 6% of the samples.

Kahala: Our study on kahala had two objectives: One was to learn about the feeding habits of the species and the second was to compare feeding habits of ciguatoxic and nonciguatoxic fishes. The results showed that among large kahala, that is, those larger than 9 kg, mackerel scad, Decapterus sp., were the most important food item irrespective of the area of capture or ciguatoxicity (Humphreys and Kramer6). For kahala smaller than 9 kg, mackerel scad were again the predominant food item but with two exceptions: those taken in the NWHI and those ciguatoxic fish taken in the lower main Hawaiian Islands had fed relatively more on bottom-associated fauna including shrimps, other crustaceans, lizardfish, and scorpaenids. From these results, the investigators hypothesized that small kahala in the lower main Hawaiian Islands are more susceptible to ciguatoxin contamination and that the occurrence of large, ciguatoxic kahala was primarily the result of the toxin's long retention time. They also suggested that conditions for ciguatoxin production are less optimal in the NWHI than in the lower main Hawaiian Islands and that a more readily available bottom-associated prey fauna exists for small kahala in the NWHI.

Length-Weight and Standard Length-Fork Length Relationships

Uchiyama et al.[7] determined the length-weight and standard length-fork length relationships for the kahala, butaguchi, opakapaka, kalekale, gindai, ehu, onaga, and hapuupuu from the NWHI. The results of this study showed that except for hapuupuu, there was no significant difference between mean weight for males and females. The highly significant difference between the sexes observed for hapuupuu was attributed to the very small sample size for the males. Comparison of group means also showed significant differences among cruises for kahala, butaguchi, opakapaka, ehu, and hapuupuu and among banks for all the species studied except butaguchi. The investigators explained these differences as a result of uneven distribution of commercial fishing pressure on the banks, that is, those banks closer to the inhabited main islands were fished down first whereas the more distant banks were pristine with large fish predominating in the catch.

The regression equations describing the length-weight and standard length-fork length relationships of the eight species are given in Tables 1 and 2.

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TEXT FOOTNOTES

[1] R. B. Moffitt. 1980. Groundfish resources of the central and western Pacific. Unpubl. manuscr. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812, 17 p.

[2] R. N. Uchida and D. T. Tagami. Manuscr. in prep. Fishery for groundfish over seamounts in the North Pacific Ocean. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

[3] J. J. Polovina, Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812, pers. commun., April 13, 1982.

[4] M. P. Seki. Manuscr. in prep. The food and feeding habits of the thick-lipped trevally, Pseudocaranx dentex (Bloch and Schneider) in the Northwestern Hawaiian Islands. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

[5] M. P. Seki. Manuscr. in prep. The food and feeding habits of the sea bass, Epinephelus quernus Seale in the Northwestern Hawaiian Islands. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

[6] R. L. Humphreys, Jr. and S. H. Kramer. Manuscr. in prep. Ciguatera and the feeding habits of the greater amberjack, Seriola dumerili, in the Hawaiian Archipelago. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

[7] J. H. Uchiyama, S. H. Kuba, and D. T. Tagami. Manuscr. in prep. Length-weight and standard length-fork length relationships of deep-sea handline-caught fishes of the Northwestern Hawaiian Islands. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

Table 1.--Length-weight relationships of fishes commonly caught in the deep-sea handline fishery in the Northwestern Hawaiian Islands (see text footnote 7).

Species	Equation[1]	Y-axis intercept	Regression coefficient	N	Correlation coefficient	Fork length	
						max. (mm)	min. (mm)
Seriola dumerili	1	2.6066	0.3348	74	0.982	1,115	524
	2	-7.4727	2.8791				
	3	2.2601	0.3410				
	4	-7.6275	2.9327				
Pseudocaranx dentex	1	2.5879	0.3229	123	0.979	830	464
	2	-7.6509	2.9676				
	3	2.5831	0.3299				
	4	-7.8310	3.0316				
Pristipomoides filamentosus	1	2.5857	0.3427	211	0.992	779	268
	2	-7.4102	2.8691				
	3	2.5816	0.3506				
	4	-7.4772	2.8934				
Pristipomoides sieboldii	1	2.5760	0.2806	71	0.922	435	245
	2	-7.8283	3.0306				
	3	2.5794	0.3043				
	4	-8.4769	3.2864				
Pristipomoides zonatus	1	2.5571	0.2998	57	0.977	469	282
	2	-8.1330	3.1833				
	3	2.5560	0.3069				
	4	-8.3288	3.2585				
Etelis carbunculus	1	2.5856	0.3240	474	0.987	629	269
	2	-7.7587	3.0036				
	3	2.5843	0.3284				
	4	-7.8682	3.0447				
Etelis coruscans	1	2.5993	0.3376	44	0.979	880	480
	2	-7.3542	2.8399				
	3	2.5945	0.3448				
	4	-7.5248	2.9003				
Epinephelus quernus	1	2.5971	0.3105	284	0.989	[2]1,100	235
	2	-8.1604	3.1486				
	3	2.5945	0.3140				
	4	-8.2618	3.1844				

[1] Predictive equation 1: $\log_{10}X = \log_{10}a + b \log_{10}Y$
Predictive equation 2: $\log_{10}Y = \log_{10}c + d \log_{10}X$
Functional equation 3: $\log_{10}X = \log_{10}u + v \log_{10}Y$
Functional equation 4: $\log_{10}Y = \log_{10}w + x \log_{10}X$

where X = fork length (mm)
Y = weight (kg)
Y-intercept: a, c, u, w
regression coefficient: b, d, v, x

[2] Total length.

Table 2.--Standard length-fork length relationships of fishes commonly caught in the deep-sea handline fishery in the Northwestern Hawaiian Islands (see text footnote 7).

Species	Equation[1]	Y-axis intercept	Regression coefficient	n	Correlation	Range of fork length		Range of standard length	
						maximum (mm)	minimum (mm)	maximum (mm)	minimum (mm)
Seriola	1	3.5344	0.9391	74	0.996	1,494	524	1,367	504
dumerili	2	2.1377	1.0572						
	3	0.7493	0.9425						
	4	-0.7889	1.0610						
Pseudocaranx	1	-0.1106	0.9448	129	0.997	830	464	772	431
dentex	2	4.6975	1.0510						
	3	-2.2639	0.9481						
	4	2.4134	1.0547						
Pristipomoides	1	2.5515	0.9012	203	0.997	779	268	723	242
filamentosus	2	0.5081	1.1034						
	3	1.0884	0.9037						
	4	-1.1713	1.1065						
Pristipomoides	1	4.2166	0.8983	70	0.987	435	245	403	225
sieboldii	2	4.0474	1.0853						
	3	0.0356	0.9098						
	4	-0.0218	1.0992						
Pristipomoides	1	-13.889	0.9506	42	0.985	489	282	452	256
zonatus	2	26.828	1.0207						
	3	-20.0176	0.9650						
	4	20.7707	1.0362						
Etelis	1	-2.8201	0.9185	434	0.993	629	269	581	241
carbunculus	2	9.8694	1.0728						
	3	-6.0045	0.9253						
	4	6.5023	1.0807						
Etelis	1	-0.5400	0.9169	40	0.998	480	876	440	810
coruscans	2	3.4976	1.0859						
	3	-1.8766	0.9189						
	4	2.0160	1.0883						
Epinephelus	1	-13.152	0.8630	289	0.997	[2]1,100	235	956	181
quernus	2	18.896	1.1525						
	3	-14.758	0.8653						
	4	17.096	1.1556						

[1] Prediction equation 1: $X = a + b\,Y$ where X = standard length
Prediction equation 2: $Y = c + d\,X$ — Y = fork length
Functional equation 3: $X = u + v\,Y$ — Y intercept: a, c, u, w
Functional equation 4: $Y = w + y\,X$ — regression coefficient: b, d, v, y

[2] Total length

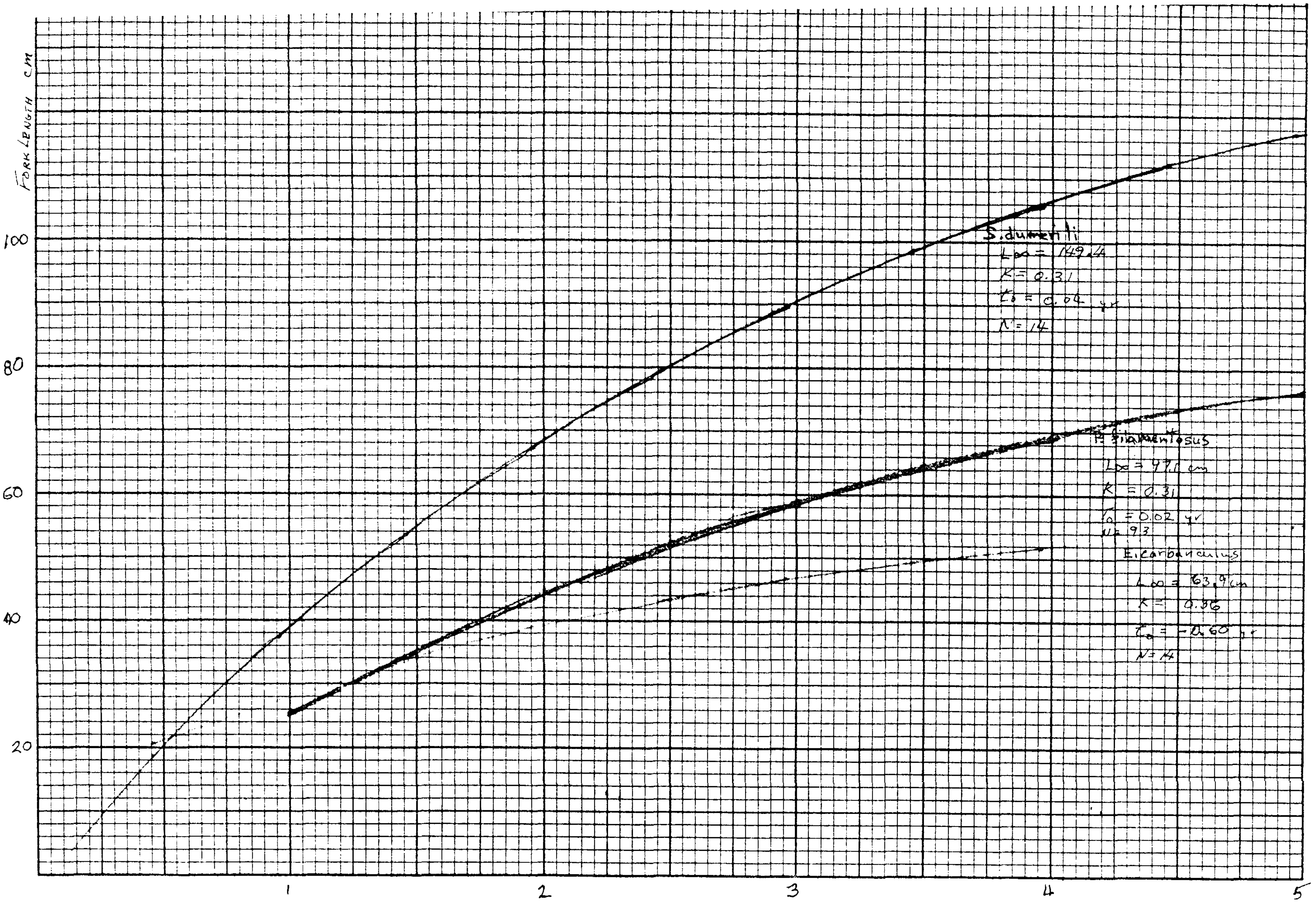

Figure 1.--Estimated growth curves of *Seriola dumerili*, *Pristipomoides filamentosus*, and *Etelis carbunculus* from the Northwestern Hawaiian Islands as determined from otolith examinations.