VARIATION IN CATCH RATES AND SPECIES COMPOSITION IN HANDLINE CATCHES OF DEEPWATER SNAPPERS AND GROUPERS IN THE MARIANA ARCHIPELAGO

VARIATIONS DU TAUX DE CAPTURE ET DE LA COMPOSITION SPECIFIQUE DES PRISES PAR LIGNES A MAIN DE VIVANEAUX ET MEROUS DANS L'ARCHIPEL DES MARIANNES

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ABSTRACT

A total of 7621 deepwater snappers and groupers were caught with handline gear in a systematic survey of 22 banks in the Mariana Archipelago with six cruises spanning mid-1982 through mid-1984. Variations in the catch-per-unit effort (CPUE) and catch composition at banks due to geographic and temporal factors is examined.

Both bank type and latitude explain variation in CPUE. Seamounts have higher CPUE values than the high islands at the same latitude while within bank types, CPUE increases with increasing latitude. For both bank CPUE and bank catch composition, variation between banks within a cruise period is substantially greater than variation between banks over the 2-year survey period. A relationship between the index of the diversity of the bank catch composition and an index of the area of bottom fish habitat at the bank is established. Cluster analysis applied to the bank catch composition indicates that all the banks can be grouped into one of three catch profiles which are relatively invariant over the survey period. Bank size appears to explain the catch composition and bank grouping for at least two of the three clusters.

RESUME

Un nombre total de 7621 vivaneaux et mérous des eaux profondes ont été capturés par pêche avec des lignes à main au cours d'une exploration systématique de 22 bancs dans l'archipel des Mariannes (6 croisières de mi-1982 à mi-1984). Les variations du taux de capture par unité d'effort (CPUE) et de la composition spécifique des bancs en fonction des facteurs géographiques et temporels sont examinées.

La variation de CPUE s'explique par le type de banc et aussi par la latitude. Les bancs profonds et isolés, présentent des valeurs de CPUE plus élevées que ceux situés au voisinage des îles émergeantes sous les mêmes latitudes, tandis que, dans un type de banc donné, le CPUE augmente selon la latitude. Pour le CPUE, ainsi que pour la composition spécifique d'un banc, les variations entre bancs pendant la période d'une sortie sont plus importantes que celles observées entre bancs pendant la période de 2 années d'exploration.. Une relation entre l'indice de la diversité de la composition des captures sur un banc et l'indice de l'aire de l'habitat des poissons démersaux est établi. Un groupement hiérachique de la composition des captures sur chaque banc indique que tous les bancs peuvent être groupés dans un des trois profils de capture, qui sont relativement invariables durant la période d'exploration. L'étendue d'un banc semble expliquer la composition des captures et le groupement, au moins pour deux des trois groupes.

INTRODUCTION

Variation in density and community composition of fishes associated with coral reefs has received considerable attention from ecologists (Ehrlich 1975; Goldman and Talbot 1976; Helfman 1978; Sale 1980). Studies have documented a wide variation in density of reef fish populations on nearby patch reefs but little has been learned regarding the factors which are responsible for this variation (Sale 1980). There is some dispute on the subject of stability of coral reef communities. Some researchers find evidence that fish communities associated with coral reef systems are stable over time (Molles 1978; Smith 1978; but others argue that reef fish assemblages are predominantly nonequilibrium and unstable (Talbot et al. 1978; Sale 1980).

While the shallow water reef fishes have been extensively studied, the distribution and stability of species composition due to temporal and geographic factors of deepwater bottom fishes in tropical waters has received little attention. This paper will examine variation in relative abundance and species composition for deepwater bottom fishes found in depths of 125 to 275 m caught with deep-sea handline gear in a fishing survey of 22 islands and banks in the Mariana Archipelago.

Six resource assessment cruises of 40 days each were conducted in the Mariana Archipelago during the period between May 1982 through June 1984. In the subsequent analysis, cruises will be grouped into two cruise periods--one cruise period including the three 1982 cruises, and the other cruise period including the three cruises from the latter part of 1983 and early and mid-1984. During these cruises, the deepwater snapper and grouper community was sampled at the 22 islands and banks shown in Fig. 1. Thirteen of these 22 sites were sampled at least once in each cruise period. Two sites, Pagan Island and Esmeralda Bank, were sampled on each of the six cruises.

The Mariana Archipelago consists of a chain of islands and banks on a north-south axis beginning with Galvez Banks and Santa Rosa Reef at the southernmost end and extending northward to Farallon de Pajaros (30 nmi north of Maug Island), and a chain of seamounts also on a north-south axis about 120 nmi west of the high island chain (Fig. 1). From a geological perspective, there are three distinct types of formations within the Mariana Archipelago. One is the high island chain which is composed of two subgroups. The southern islands in this chain which consist of the formations Santa Rosa Reef, Galvez Banks, Guam, Rota, Aguijan, Tinian, Saipan, and Farallon de Medinilla, are 30 to 40 million years old and represent the oldest formations in the archipelago (Scott et al. 1980). The second is the northern islands in this chain which include Esmeralda Bank and 38-Fathom Bank (lat. 15°18.5'N, long. 145°26'E) and all the islands from Anatahan north to Farallon de Pajaros. They are the youngest in the chain, about 1 million years old, and several are still active volcanoes (Scott et al. 1980). The western seamount chain is the third geological type and is approximately 10 million years old (Scott et al. 1980). The seamounts sampled in the western chain were Bank A (lat. 14°12'N, long. 142°50'E), Arakane Reef, Pathfinder Reef, Bank D (lat. 17°07'N, long. 143°20'E), and Bank C (lat. 18°06'N, long. 143°10'E).

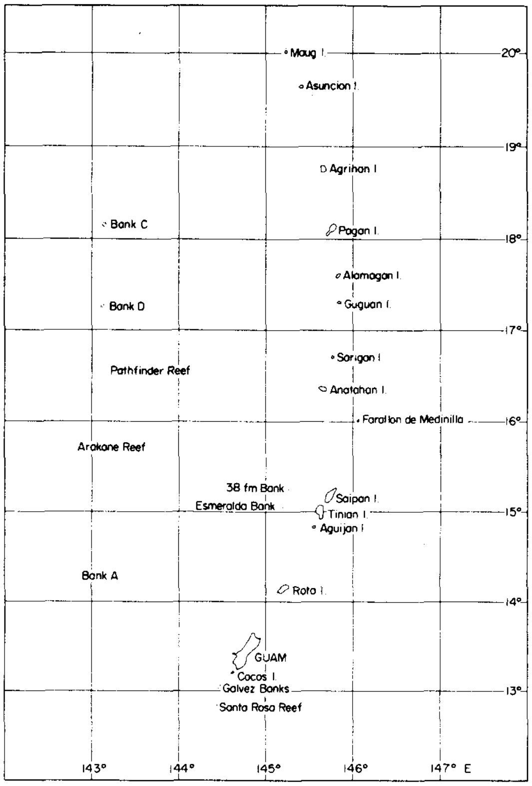

Figure 1. Hawaiian Archipelago showing the 22 islands and banks sampled.

The National Oceanic and Atmospheric Administration (NOAA) ship Townsend Cromwell was used as the fishing vessel for all the cruises. For sampling bottom fish, four hydraulic gurdies were used each with 365 m of braided 90 kg Dacron[1] line. The terminal rig consisted of four hooks spaced approximately 1 m apart and a 2 kg weight. Two of the rigs used No. 20 Tonkichi hooks and two rigs used No. 28 Tonkichi hooks.

At each island and bank, an attempt was made to conduct a systematic fishing survey of the bottom fish community along the 200-m contour. Fishing was conducted while the vessel drifted and targeted the 125 to 275 m depth range. Fishing effort is measured in line-hours and is defined as the product of the number of lines fishing, and the length of time in hours that they are fishing. The basic sampling unit is the fishing drift which is the fishing that occurs during an uninterrupted drift by the vessel while it is fishing in the 125 to 275 m depth range. A fishing station is the sampling unit which corresponds to a specific geographic site around an island or bank. A station may consist of only

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

one drift or may contain multiple drifts which repeatedly fish the specific site. Numerous fishing stations are used in a systematic survey of each island and bank.

Relative Abundance

A total of 7,621 bottom fishes of over 30 species were caught with handline gear during the six cruises. Pristipomoides zonatus accounted for 51.2% of the catch and three species, P. zonatus, P. auricilla, and Etelis carbunculus accounted for 79.1% of the total catch.

Catch per unit effort (CPUE) is measured in number of fish per line-hour. For each bank, bank CPUE is computed as the mean of all the drift CPUE values where a drift CPUE is the number of fish caught during an uninterrupted drift divided by the drift line-hours. Mean drift CPUE is used as a measure of bank CPUE because to a large extent the drifts within a bank appear to represent replicates from the total bank population and as such allow for the estimation of within bank variation in CPUE. The mean drift CPUE is presented for all 22 banks and islands in Table 1.

There was considerable variation in mean drift CPUE between banks. A nested analysis of variance shows that when the variation in drift CPUE within banks is taken into account, the differences in mean drift CPUE between the two cruise periods is not significant ($P>0.10$), whereas the differences in mean drift CPUE among banks and bank types both pooled over cruise period are significant ($P<0.025$). Taken by bank type, the seamounts (Table 1) have the greatest mean drift CPUE (4.68 fish per line-hour) followed by the northern islands (3.19 fish per line-hour) and then the southern islands (2.46 fish per line-hour). The inhabited islands of the Marianas are Guam, Saipan, Rota, and Tinian--all in the southern group. Fishermen at these islands exploit the local stocks of bottom fishes which most likely accounts for the relatively low CPUE values for the populated islands. The mean of the bank CPUE for the uninhabited islands and banks in the southern group is 3.36 fish per line-hour which suggests that when islands with heavy fishing mortality are excluded, there is no difference in bottom fish standing stock between the northern and unfished southern islands. The seamounts, however, appear to support a higher standing stock than the unfished (northern and southern) islands and banks. There also appears to be a trend of increasing drift CPUE with latitude within the northern and seamount groups (Table 1). An analysis of covariance using just the drift CPUE from the seamounts and northern islands, where fishing mortality is not a factor, shows that latitude and bank type explain a statistically significant portion of variation in drift CPUE ($P = 0.0001$ for both variables). Thus, at the same latitude, the seamounts have a higher relative abundance than the high northern islands and for both types of formations, the relative abundance increases with increasing latitude.

Table 1. Bank, mean drift, catch per unit effort (CPUE), standard error (SE), and latitude over the survey period.

Bank	No. of drifts	Mean drift CPUE (numbers)	SE	Latitude N
Northern Islands				
Maug	7	5.03	1.02	20°02'
Asuncion	17	2.16	0.49	19°40'
Agrihan	45	4.20	0.31	18°46'
Pagan	100	4.57	0.40	18°06'
Alamagan	118	2.37	0.19	17°36'
Guguan	32	3.01	0.30	17°19'
Sarigan	28	2.82	0.37	16°43'
Anatahan	38	2.31	0.23	16°21'
38-Fathom	61	3.12	0.26	16°20'
Esmeralda	114	2.29	0.15	14°58'
Average drift CPUE		3.19		
Southern Islands				
Farallon de Medinilla	32	3.29	0.65	16°01'
Saipan	17	1.72	0.34	15°10'
Tinian	20	1.96	0.29	15°00'
Aguijan	13	3.84	0.98	14°52'
Rota	19	1.91	0.40	14°10'
Guam	20	1.53	0.35	13°25'
Galvez and Santa Rosa	41	2.95	0.31	13°00'
Average drift CPUE		2.46		
Seamounts				
Bank C	8	5.91	1.57	18°08'
Bank D	20	5.85	0.51	17°09'
Pathfinder	136	4.58	0.23	16°30'
Arakane	84	3.36	0.24	15°38'
Bank A	24	3.71	0.57	14°12'
Average drift CPUE		4.68		

CATCH COMPOSITION

To facilitate analysis of the catch composition among banks and cruise sets, the catch is partitioned into seven species categories. Due to their large contribution to the overall catches, P. zonatus, P. aurcilla, and P. flavipinnis each represent single species categories. Other species categories are the groupers which consist of all the Serranidae, and the jacks which are composed of all the Carangidae. Etelis carbunculus and E. coruscans are combined into an Etelis group, and all the other snappers, Aprion virescens, P. sieboldii, P. amoenus, P. filamentosus, are combined to form the other snapper group.

The percentage of the catch in the seven species groups at each bank pooled over all cruises is given in Table 2. While most of the seven species groups are represented at all of the islands and banks there do appear to be differences in the diversity of the catch compositions between islands and banks. For example, at the seamounts three species accounted for about 90% of the catch while at many other islands and banks at least five species must be combined to account for 90% of the catch composition (Table 2).

Table 2. Bank catch composition pooled over all cruises.

Bank	*Etelis*	*Pristipomoides zonatus*	Groupers	Jacks	*P. auricilla*	Other snappers	*P. flavipinnis*
Maug	10.6	43.9	4.1	3.3	35.8	0.8	1.6
Asuncion	5.4	58.9	17.9	3.6	8.9	5.4	0
Agrihan	12.6	60.2	3.9	2.1	10.3	4.6	6.4
Pagan	14.8	70.0	2.6	1.1	8.9	1.3	1.3
Alamagan	20.2	49.6	2.9	1.4	23.3	1.4	1.1
Guguan	13.1	61.5	3.6	2.8	18.3	0.4	0.4
Sarigan	9.9	64.6	7.3	2.1	14.1	1.0	1.0
Anatahan	8.4	54.0	2.5	2.0	11.9	6.4	14.9
Farallon de Medinilla	11.5	47.9	3.7	6.3	9.4	4.7	16.7
Saipan	7.6	22.8	1.3	1.3	8.9	24.1	34.2
38-Fathom	6.4	43.4	4.5	6.6	22.8	11.7	4.7
Tinian	19.4	0	0	0	8.3	2.8	69.4
Aguijan	0	27.1	0	2.1	6.3	22.9	41.7
Esmeralda	5.4	39.7	3.0	2.0	4.0	9.3	36.6
Rota	9.5	36.2	1.9	2.9	16.2	21.9	11.4
Guam	12.9	16.1	0	6.5	25.8	25.8	12.9
Galvez and Santa Rosa	6.8	32.2	1.7	9.3	36.4	8.5	5.1
Bank C	22.9	35.6	0.9	0	39.0	1.7	0
Bank D	39.4	48.0	0	1.5	9.1	1.5	0.5
Pathfinder	21.5	50.6	0.4	8.2	17.3	1.6	0.4
Arakane	16.9	41.2	0.7	12.8	18.8	9.3	0.3
Bank A	15.9	60.7	0.4	2.5	18.4	1.3	0.8
Total	15.2	51.4	2.3	4.5	15.4	4.7	6.6

A measure of the species diversity of the catch at a bank can be computed from the Shannon-Weaver measure of the diversity (H) of the catch composition given by the equation:

$$H = -\sum_{i=1}^{7} p(i)\ln(p(i))$$

where p(i) is the proportion of the catch at a bank which belongs to the ith species category (i = 1, ..., 7 in our application) (Shannon and Weaver 1963).

A regression of H against the natural log of the length of the 200-m isobath, which is an index of the area of bottom fish habitat, indicates that there is a positive linear relationship between H and ln (length of 200-m isobath) (Table 3). The regression has a slope of 0.19 and an R^2 of 0.28 ($P = 0.013$). Thus the larger the bank the greater the diversity of the catch.

To assemble banks into groups of similar catch composition and to determine if these groups are invariant over time, a multivariate procedure known as cluster analysis was applied to form clusters of banks with similar catch composition within each of the two cruise periods. The catch composition for each bank is simply the number of fish caught in the seven species groups described earlier. The cluster analysis groups banks together based on the chi-squared distance between their catch composition.

Table 3. The Shannon-Weaver measure of diversity (H) and length of the 200-m contour for each bank.

Bank	H	Length of 200-m contour (nmi)	$\log_e$ (length of 200-m contour (nmi))
Northern Islands			
Maug	1.31	10	2.30
Asuncion	1.27	11	2.40
Agrihan	1.32	18	2.89
Pagan[1]	1.29	30	3.40
Alamagan	1.29	11	2.40
Guguan	1.14	9	2.20
Sarigan	1.15	9	2.20
Anatahan	1.42	17	2.83
Southern Islands			
Farallon de Medinilla	1.56	77	4.34
Saipan	1.57	53	3.97
38-Fathom	1.59	3	1.10
Tinian	0.89	29	3.37
Aguijan	1.31	16	2.77
Esmeralda[1]	1.42	12	2.48
Rota	1.64	32	3.47
Guam	1.70	79	4.37
Galvez and Santa Rosa	1.57	53	3.97
Western Seamounts			
Bank C	1.18	3	1.10
Bank D	1.09	3	1.10
Pathfinder	1.16	3	1.10
Arakane	1.20	3	1.10
Bank A	1.11	4	1.39

[1]For Pagan and Esmeralda most of the fishing was restricted to a 10 nmi length of 200-m contour for purpose of replicated sampling, thus H may not reflect species diversity of the entire bank.

Although selecting the number of clusters which is appropriate for a data set can be subjective, the decision rule used here is to determine the number of clusters as the minimum number of clusters which achieve the greatest relative decrease in the maximum within cluster distance. In both the 1982 and the 1983-84 cruise periods, three clusters provide the greatest relative reduction in intracluster distance. The three clusters are similar for both cruise periods in their bank composition and catch composition (Tables 4, 5, and 6). Although the clusters do not entirely segregate along the three geological bank types, there is considerable similarity. As a naming convention, it is descriptive to refer to the three clusters as northern, seamount, and southern clusters for both cruise periods, but it should be kept in mind that the clusters and the island types of the same name do not contain exactly the same set of banks. In both cruises, the southern cluster was characterized by its high proportion of *P. flavipinnis* 30% in one period and 16% in the other period,

Table 4. Banks in the three clusters from the 1982 cruise period.

Northern cluster	Seamount cluster	Southern cluster
Galvez and Santa Rosa	Pagan[1]	Esmeralda[1]
38-Fathom	Bank A[1]	Anatahan[1]
Agrihan[1]	Pathfinder[1]	Farallon de Medinilla[1]
Guguan[1]	Arakane[1]	Tinian
Maug		Aguijan
Alamagan[1]		Saipan
Asuncion		Rota[1]
Sarigan[1]		Guam[1]

[1]Banks sampled in both cruise periods.

Table 5. Banks in the three clusters from the 1983-84 cruise period.

Northern cluster	Seamount cluster	Southern cluster
Guguan[1]	Pathfinder[1]	Guam[1]
Pagan[1]	Bank D	Rota[1]
Sarigan[1]	Bank C	Arakane[1]
	Bank A[1]	Agrihan[1]
	Alamagan[1]	Anatahan[1]
		Farallon de Medinilla[1]
		Esmeralda[1]

[1]Banks sampled in both cruise periods.

Table 6. Cluster catch composition by cruise periods.

Cluster	Number of fish	Species catch composition in percent						
		Etelis	Pristipomoides zonatus	Groupers	Jacks	P. auricilla	Other snappers	P. flavipinnis
1982 Cruise Period								
Northern	1,328	6.5	48.6	5.7	4.2	24.6	6.8	3.5
Seamount	936	18.4	56.2	2.0	7.8	9.8	4.4	1.4
Southern	812	8.3	37.1	3.2	3.8	7.5	9.7	30.4
1983-84 Cruise Period								
Northern	977	13.1	71.6	2.9	1.4	9.6	0.7	0.7
Seamount	2,455	23.1	50.1	0.8	5.3	18.9	1.3	0.5
Southern	1,108	12.1	45.0	1.8	3.3	11.9	10.1	15.8

while the other clusters contained less than 4%. The seamount cluster was characterized in both cruise periods by its higher proportion of Etelis species, just about twice the amount in the other clusters within each cruise period. For banks in the seamount cluster essentially three species accounted for the entire catch.

Of the 13 banks sampled on both cruise periods, 9 were in the same cluster in both periods and 4 changed clusters. Under the hypothesis that banks are randomly assigned to clusters, the probability that nine or more do not change clusters between the two periods is less than 0.01.

The similarity in the catch composition and bank composition of corresponding clusters between cruise periods suggests that variation in the species composition of the archipelago over the 2-year period between cruises was less than the variation in species composition within the archipelago. When the catch composition for each cruise period was combined and cluster analysis performed on the combined data again, three clusters were selected based on their relative reduction in the maximum intracluster distance. Again, these three clusters will also be called northern, seamount, and southern (Tables 7 and 8).

Table 7. Banks grouped by three clusters when both cruise periods are combined.

Northern cluster	Seamount cluster	Southern cluster
Asuncion	Maug	Esmeralda
Agrihan	Alamagan	Tinian
Anatahan	Pagan	Saipan
Farallon de Medinilla	Guguan	Aguijan
38-Fathom	Sarigan	Rota
Galvez and Santa Rosa	Bank C	Guam
Arakane	Bank D	
	Pathfinder	
	Bank A	

The species composition of the three clusters is very similar to the composition of the clusters from each cruise period. The southern cluster is characterized by a high proportion of P. flavipinnis, and the seamount cluster differs from the others in its higher proportion of Etelis species and lower diversity. In general there is an increase in diversity measured by the Shannon-Weaver Index (H) and a corresponding increase in the index of habitat area going from the seamount to northern to southern clusters (Table 8). The fishing mortality for P. zonatus based on pooled length-frequency data is estimated for each cluster and used as an index of fishing pressure (Wetherall et. al. 1985). The islands and banks of the northern and seamount clusters are unfished while those of the southern cluster are fished (Table 8). The most noticeable feature of the catch composition of the southern cluster is the high proportion of P. flavipinnis relative to the other clusters and it is hypothesized that this is due to fishing pressure present at the southern cluster and absent from the other two clusters. Even within the southern cluster the three islands and banks, which after Tinian where no P. zonatus was caught, have the highest proportion of P. flavipinnis also have an estimate of fishing mortality for P. zonatus of 0.26/year which is slightly more than twice the value of

Table 8. Cluster catch compositions based on three clusters and data pooled over both cruise periods together with the Shannon-Weaver index of diversity for the cluster catch composition (H), the mean of the $\log_e$ (length of 200-m contour) (L), and the fishing mortality (F) on *Pristipomoides zonatus*.

Cluster	Percentage of catch									
	Etelis	Pristipomoides zonatus	Groupers	Jacks	P. auricilla	Other snappers	P. flavipinnis	H	L	F
Southern	9	24	1	3	11	18	34	1.62	3.32	[1]0.12
Northern	10	48	5	7	16	7	7	1.57	2.58	0.0
Seamount	19	53	3	3	20	1	1	1.25	1.16	0.0

[1]Three banks, Saipan, Esmeralda, and Aguijan, each of which have over 34% of the catch composed of *P. flavipinnus*, have a combined estimate of F of 0.26.

fishing mortality based on length-frequency data from all the islands and banks of the southern cluster pooled, further supporting the hypothesis of a relationship between fishing pressure and relative abundance of *P. flavipinnis*.

DISCUSSION

For CPUE and catch composition there was substantial variation among banks within the archipelago, and this pattern of variation was relatively invariant over the 2-year survey period.

The higher bank CPUE at the western seamounts relative to the unfished northern and southern islands and banks is intriguing. Unfortunately we can only speculate at the factors which might be responsible for the difference. One hypothesis is that the difference is due to the Taylor column effect. A model of a small pinnacle exposed to current flow indicates that a deep eddy can form above and around the pinnacle (Uda and Ishino 1958). It has been speculated that this eddy, termed a Taylor column, can entrain larvae, create an upwelling and serve to increase primary and secondary production (Shomura and Barkley 1979; Owens and Hogg 1980).

The results of cluster analysis indicate that banks can be grouped into one of three catch profiles which are relatively invariant over time. It appears that both bank size which determines the bottom fish habitat, and fishing pressure explain variation in the diversity of the catch composition. The *Etelis* group, *P. zonatus*, and *P. auricilla* are the dominant species when habitat is relatively small. As the amount of habitat increases other species increase their relative abundance. In the absence of fishing mortality, it is hypothesized, *P. flavipinnis* is not able to establish a significant population, and it is only in the presence of fishing pressure, perhaps because stocks of competing species are reduced, that *P. flavipinnis* can become established.

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