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COMPARISON OF FLORIDA REEF FISH ASSEMBLAGES USING A RAPID VISUAL TECHNIQUE

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ABSTRACT

Species composition, species diversity, and relative abundance of four coral reef fish communities in John Pennekamp State Park, Key Largo, Florida, are compared with four communities at Fort Jefferson National Monument in the Dry Tortugas using the species-time, random count technique. The technique is similar to species-area methods but time replaces area.

Fish communities at Pennekamp Park showed the highest overall number of species, scores (reflecting species abundance), and species diversity. Two artificial reefs (shipwrecks) are included in the study and both show closer relationships to adjacent reefs than to wreck-specific species.

Structural complexity and the relatively stable physical environment of tropical coral reefs are generally believed to provide a considerable amount of niche diversification, leading in turn to high species richness and species diversity. The excellent cover tropical reef fishes derive from a complex reef framework is equally effective in rendering most standard fishery sampling methods inadequate (Alevizon and Brooks, 1975). Some workers have had a measure of success in obtaining quantitative data for fish communities around coral reefs by using ichthyocides (Randall, 1963; Wass, 1967; Emery, 1973; Smith, 1973; and others) and a few have even used explosives (Talbot and Goldman, 1973). These methods are undesirable in areas set aside for conservation purposes. Moreover, there are many instances in which biologists are required to make surveys of large sections of reef or large numbers of widely separated reef sites, where such destructive methods would be inconvenient and detrimental to the study and the environment. Ichthyocides and explosives are time-consuming to use and preclude drawing replicate or time-series samples from the same reef or a series of reefs.

There are, therefore, numerous occasions when it is desirable for biologists to use visual methods to evaluate and compare community structure of two or more coral reef fish assemblages. However, upon entry into the water, investigators are frequently overwhelmed by the myriads of tropical reef fishes swarming about reef structures. Visual observations must, therefore, be organized in such a way as to create order out of this apparent chaos.

A number of techniques have evolved whereby one can visually enumerate species and/or individuals over pre-established line transects, quadrats, and other quantifiable sections. Brock (1954) pioneered the first such method in which SCUBA divers estimated fish populations along a series of transects. Several workers have used this technique or variations of it to study Caribbean and Indo-Pacific reef fishes (Risk, 1972; Key, 1973; McCain and Peck, 1973; Smith and Tyler, 1973a; Hobson, 1974; Chave and Eckert, 1974; Itzkowitz, 1974; Jones and Chase, 1975; and others). To these visual observations, Smith and Tyler (1973a), Ebeling et al. (1971) and Alevizon and Brooks (1975) have added underwater television and motion picture (cinetransects) devices. Smith and Tyler (1973b) and Jones and Chase (1975) discuss some of the problems encountered in using visual versus specimen collecting methods.

The objective of this paper is to compare

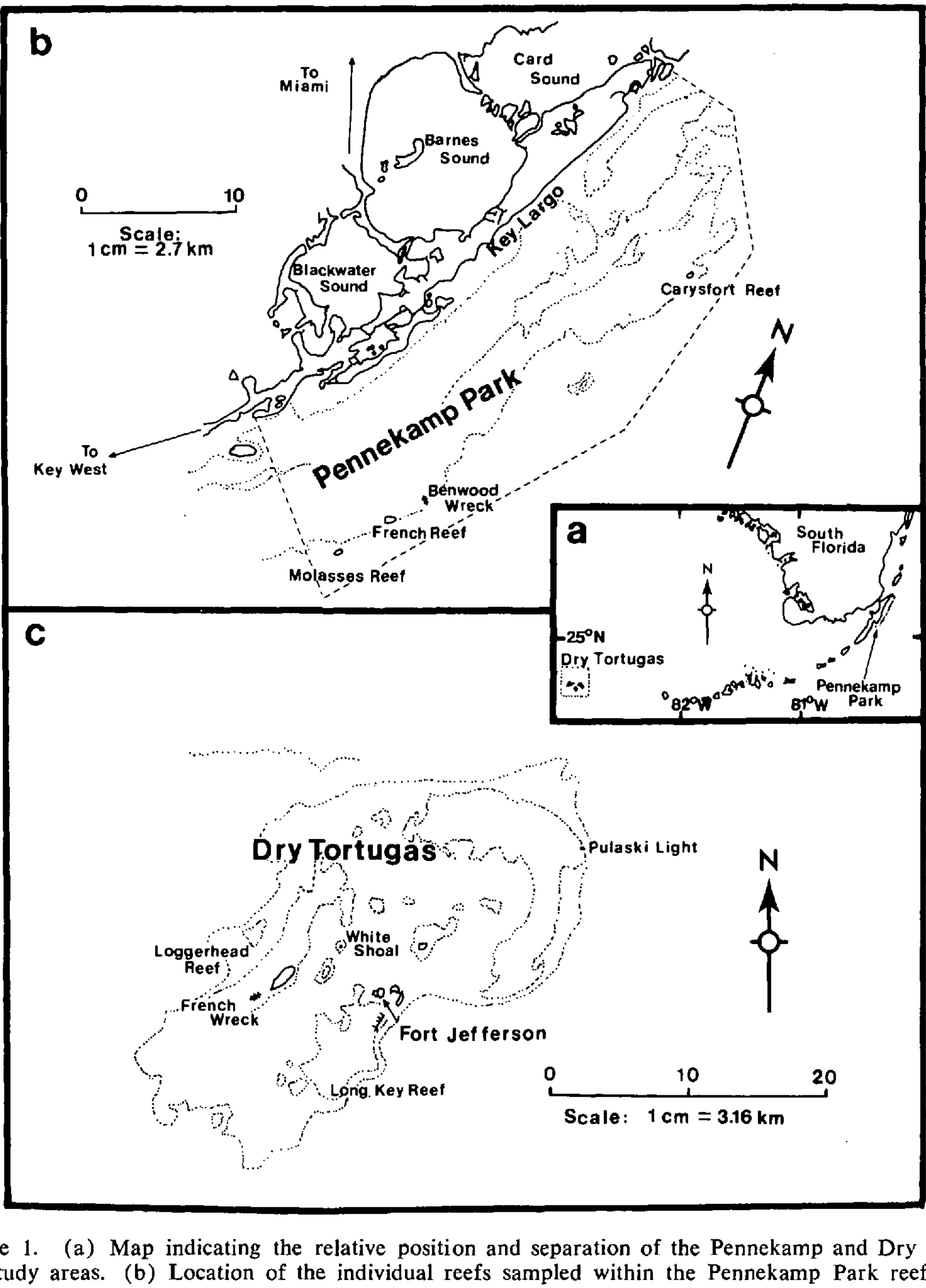

Figure 1. (a) Map indicating the relative position and separation of the Pennekamp and Dry Tortugas study areas. (b) Location of the individual reefs sampled within the Pennekamp Park reef complex. (c) Location of the individual reefs sampled within the Dry Tortugas reef complex.

Florida coral reef fish assemblages using another visual technique which is simple, highly portable, has low equipment requirements and avoids time-consuming transecting methods. This technique, described and tested herein, provides marine biologists with a censusing method for rapid, comparative evaluation between reef communities in basic research as well as in applied situations involving environmental insult, such as oil spills, dredge and fill operations, and so forth.

The reef fish communities compared are in John Pennekamp State Park, Florida Keys, and in Fort Jefferson National Monument, Dry Tortugas (Fig. 1). Both are marine preserve areas within the West Indian faunal province and were expected to show considerable similarity. The study was conducted in July and August, 1975.

The Study Areas

The Florida coral reef tract (Fig. 1a) extends from St. Lucie Inlet southward to the island group collectively known as the Dry Tortugas (Milliman, 1973). Most species of hermatypic corals occur along this entire tract but the northernmost active coral reef development is believed to end at Fowey Rocks near Miami (Smith, 1971). The fishes of the Florida reef tract are well-known systematically (Longley and Hildebrand, 1941; and Starck, 1969) but few efforts have been made to quantify the fish communities.

John Pennekamp Coral Reef State Park lies seaward (east) of Key Largo, Florida, and contains some of the best developed reefs in the Florida reef tract. Pennekamp can be considered the northernmost major reef complex in the system.

The Dry Tortugas reef complex is isolated by 104.6 km of open water from the main body of the Florida reef tract, but is considered the southern terminus of the tract. Dry Tortugas is currently under the jurisdiction of the National Park Service and its surrounding marine areas are part of Fort Jefferson National Monument. The existence of two marine preserves, at opposite ends of the Florida reef tract, provided an ideal situation for comparative ecological studies and for testing the proposed fish censusing method.

This study compares the fish community structure of three reefs in the Pennekamp Park reef complex with three reefs in the Dry Tortugas complex. Study sites at Pennekamp were Molasses Reef, French Reef, and Carysfort Reef (Fig. 1b). Long Key Reef, White Shoal, and Loggerhead Reef were studied in the Dry Tortugas (Fig. 1c). In addition to these natural habitats, one shipwreck, considered an artificial "reef" structure, was compared in each park.

Pennekamp Park (Fig. 1b)

Molasses Reef is located on the seaward boundary of Pennekamp Park. It is one of the most complex and productive reefs within the Park and a favorite spot for sport divers. Molasses is a barrier reef with a lagoon community on its shoreward side (Glynn, 1973). It differs from southern Caribbean reefs in having the extensive back reef rubble zone separated from a poorly defined *Acropora palmata* reef crest by a slightly deeper barren zone. A well-defined spur and groove system occurs on the outer face of the reef. The forereef slope levels off at approximately 14 m.

French Reef is located 3.7 km to the north and is topographically similar to Molasses. In this case, however, the spur and groove system is not as well defined and the zone of active coral growth extends farther seaward. Spur and groove formation at French Reef is composed more of *Montastrea annularis* than of *A. palmata* (Shinn, 1963). Extensive overgrowth of *M. annularis* produces networks of cavernous passages beneath the reef. French Reef is also a favorite sport diving site.

Carysfort Reef, unlike other reefs in the Pennekamp reef complex, shows a zonation and structure typically described for southern Caribbean reefs (Goreau, 1959). There is a well-developed backreef zone and *A. palmata* reef crest, which may be exposed at low tide; a forereef slope and terrace; a barren zone; and a deep reef slope ending in a sand terrace at approximately 21 m. Because of its location at the northern end of Pennekamp Park, Carysfort is somewhat less frequented by sport divers than the other park reefs.

Benwood Wreck is the remains of a freighter, torpedoed and grounded during World War II. The wreck lies between 7.6 and 14 m in depth and the hull is relatively intact. Its location is 2.4 km north of French Reef.

Dry Tortugas (Fig. 1c)

Long Key Reef is a combination of the reef structures seen in Pennekamp Park. Its deeper portions, 9 to 20 m, are similar to those at Carysfort. There is a well-defined barren zone between the deep reef slope and the poorly defined forereef terrace. No *A. palmata* reef crest exists at this site although skeletal and rubble fragments indicate there has been such a structure in the past (P. Dustin, pers. comm.). An extensive, shallow rubble zone separates the reef proper from a lagoon community on the inner side. This rubble zone is much broader and shallower than similar features at reefs in Pennekamp Park.

White Shoal is the second major reef type surveyed in Fort Jefferson National Monument. It consists of a shallow plateau, dominated on its upper portions by rubble and thickets of *Acropora cervicornis*. *Montastrea annularis* and *Diploria* sp. characterize coral growth along the steep sides of the plateau from 9 to 15 m, where coral growth terminates.

Loggerhead Reef is constructed entirely of extensive *A. cervicornis* thickets. The reef lies at a uniform depth ranging from 9 to 12 m. The low profile *A. cervicornis* thickets, sometimes 2 to 2.5 m in height, form long, gently rounded spurs.

French Wreck lies 1 km southwest of Loggerhead Key (Fig. 1c). This old steamer ran aground in the 1920's. Wreckage may have been blasted because it is spread over a larger area than Benwood Wreck. The depth of French Wreck is a uniform 6.7 m around the site.

Geologically, the Pennekamp Reefs are built upon hard, pre-existing, pleistocene reef platforms (Hoffmeister, 1974), while those of Dry Tortugas are built upon a mud bank type formation (L. Land, pers. comm.). Pennekamp's reefs are structurally more similar to each other than are the reefs surveyed in Dry Tortugas. The Dry Tortugas reef complex lies farther from the Gulf Stream than the Pennekamp complex. Thus, there is a somewhat reduced potential for larval dispersal and recruitment and turbidity levels are frequently higher. Extensive mangrove communities dominate the shoreward boundaries of Pennekamp Park and may provide an additional nursery ground for juvenile development of certain fishes not available to the Dry Tortugas fish populations.

Methods

The technique employed is taken from the basic concept of species-area used by plant ecologists (Oosting, 1956). Time is substituted for area and, therefore, an observation based on species-time is obtained. Beals (1960) used a similar technique to study bird communities. In our study, an observer is equipped with SCUBA, a watch, and underwater writing slate and is allowed a total of 50 min of free swimming to locate and record as many fish species as possible. All habitats within the reef are available to the observer and there is no requirement to remain on a transect line or within a quadrat. It is only necessary to stay within the physical confines of the specific reef being studied. Species are recorded only once and credited to the specific 10-min time interval in which they are first encountered. A total of five 10-min intervals are used.

Division of search time into 10-min intervals allowed us to obtain estimates of the relative abundance of each species observed in addition to the presence or absence data derived from the species lists themselves. The assumption is that those species occurring in the earliest time intervals are likely to be the most abundant in the community under investigation. Fishes occurring in the

Table 1. P_k and cumulative P_k values for 11 counts at Molasses Reef. (Examples: 28 spp. were observed in only one count, 37 were observed in all 11 counts)

No. of Counts	No. of Species	P_k	Cum P_k
1	28	.571	.571
2	15	.111	.682
3	9	.067	.749
4	5	.051	.800
5	5	.042	.842
6	5	.035	.877
7	1	.031	.908
8	4	.027	.935
9	7	.024	.959
10	16	.021	.980
11	37	.019	.999
Total	132		

first 10-min interval were credited with a score of five, those in the second interval with four, and so on until the fifth interval wherein species were given scores of one. A single such count would be of little significance, due to the unevenness of fish distribution across a coral reef. Hence, replicate counts were made for each community studied and the assigned interval scores for each species in each replicate were summed. In this way, variation resulting from the species aggregation and the chance occurrence of a rare species in the first interval of any count is evened out within the replicates. The scores are similar to the "prominence values" of Beals (1960) which are presumed to be related to the density of each species. Initially, following Beals' example, we multiplied frequency of occurrence by species score totals to generate an "index of abundance." Statistical analysis indicated, however, that the frequency factor did not enhance the reliability of the data, therefore this step was eliminated and community comparisons were based upon species score sums alone.

The P_k statistic of Gaufin et al. (1956) was used to determine the number of replicate 50-min counts considered necessary to account for 90% or more of the expected number of ubiquitous species in a community.[1] P_k is the average probability that a given species will be present in the k-th of a set of $k \leqslant n$ samples but in no previous sample. It is assumed that the species has occurred in at least one of the set of n samples. The investigator must choose *a priori* the number of samples considered more than adequate to account for the desired number of species. We chose 11 replicate counts. Table 1 shows that in a set of test data seven of the 11 counts were needed to account for the desired percentage of species. Eight were actually used in each community as an additional margin for error.

Length of each count was determined by bottom time and diver fatigue. Diver fatigue adversely influenced counts exceeding 60 min even when working in depths of 9 m or less. Some reefs we knew would be deeper than 9 m so we limited bottom time to avoid decompression dives. We elected to use a 50-min count as a realistic operational unit. This allowed us to work in depths up to 20 m without decompression.

A total of 64 units (50-min counts) comprised our test study (eight replicates/community × four communities/study area × two study areas). This amounted to more than a total of 50 man-hours of bottom time. Between-community comparisons were made using the Shannon-Weaver diversity function and evenness values of Pielou (1966), the ANOVA (one-way) and Duncan's Multiple Range Test (Steel and Torrie, 1960), and the Bray and Curtis Index (1957). The total combined species list, including scores, for the Pennekamp communities was also compared with that for the Dry Tortugas, using the above methods as well as the Wilcoxen matched-pairs, signed ranks test (Siegal, 1956).

Our use of the Shannon-Weaver diversity function to compare scores derived from the species-time method may be considered questionable because it does not use actual counts of individuals. However, other work-

[1] Such visual censusing techniques overlook most cryptic species and therefore our community analyses are relative rather than absolute.

ers have substituted weight for numbers in computation of this index (Bechtel and Copeland, 1970) and we feel that the species-time substitution is an equally valid inference of species abundance.

Results and Discussion

Table 2 is a checklist of the fishes observed by using the species-time, random count technique. The total score for each species is provided to indicate relative abundance of the species in each study area and in both areas combined. The maximum score possible for a species in either study area is 160 and that for both communities combined is 320. No species achieved a perfect score in the combined areas but several did reach 160 in the individual study areas.

The data in Table 2 show a total of 165 species observed in the combined study areas. One hundred and fifteen of the observed species were shared in common between Pennekamp and the Dry Tortugas, while 31 were seen only in the Pennekamp study area and 19 were observed only in the Tortugas study area. This is not meant to imply that species not shared in common would not eventually appear in counts for both study areas if enough additional counts were made.

The Bray and Curtis Index (C) showed an overlap of only 71% based on species and scores between the two areas. In the Wilcoxen test the null hypothesis (that there is no difference in species and their scores between the Pennekamp and Tortugas communities) is rejected at $P \leqslant .0001$ ($T = 4{,}366, Z = 3.94$).

Table 3 is a summary of the census data obtained and shows that the total number of Pennekamp species was 146 (community $\bar{x} = 75.3$) and that for the Dry Tortugas was 134 ($\bar{x} = 62.9$). Total scores are also higher in the former study area (community $\bar{x} = 315.1$) than in the latter ($\bar{x} = 262.3$). Equitability of score distribution (J'_s) among the species was slightly higher in the combined Pennekamp communities than in the

Table 2. Checklist of fishes and species-time scores

Species	Pennekamp Park	Dry Tortugas	Total
Dasyatidae			
Dasyatis americana	0	8	8
Urolophus jamaicensis	2	0	2
Myliobatidae			
Aetobatus narinari	6	1	7
Muraenidae			
Gymnothorax funebris	22	0	22
G. moringa	13	0	13
Clupeidae			
Harengula sp.	9	0	9
Jenkinsia sp.	57	0	57
Sardinella sp.	0	4	4
Synodontidae			
Synodus intermedius	29	24	53
Belonidae			
Tylosaurus crocodilus	4	0	4
Holocentridae			
Adioryx coruscus	3	5	8
A. vexillarius	61	41	102
Holocentrus ascensionis	22	34	56
H. rufus	57	20	77
Myripristis jacobus	50	4	54
Aulostomidae			
Aulostomus maculatus	147	0	147
Centropomidae			
Centropomus undecimalis	64	4	68
Serranidae			
Alphestes afer	4	0	4
Cephalopholis fulva	20	0	20
Epinephelus adscensionis	14	0	14
E. cruentatum	128	47	175
E. itajara	0	10	10
E. morio	0	74	74
E. striatus	39	9	48
Hypoplectrus aberrans	25	72	97
H. gemma	123	150	273
H. guttavarius	12	0	12
H. gummigutta	9	0	9
H. nigricans	63	81	144
H. puella	23	142	165
H. unicolor	144	149	293
Liopropoma rubre	30	0	30
Mycteroperca bonaci	89	85	174
M. interstitialis	36	76	112
M. phenax	0	49	49
M. tigris	26	4	30
M. venenosa	0	35	35
Serranus baldwini	0	4	4
S. tabacarius	5	6	11
S. tigrinus	113	66	179
Grammistidae			
Rypticus saponaceus	19	5	24
Priacanthidae			
Priacanthus arenatus	7	2	9

Table 2. (Continued)

Species	Pennekamp Park	Dry Tortugas	Total
P. cruentatus	139	10	149
Emmelichthyidae			
Inermia vittata	25	27	52
Apogonidae			
Apogon binotatus	22	14	36
A. maculatus	23	25	48
A. pseudomaculatus	0	7	7
A. townsendi	17	0	17
Branchiostegidae			
Malacanthus plumieri	3	0	3
Echeneidae			
Echeneis naucrates	22	10	32
Carangidae			
Caranx bartholomaei	29	20	49
C. fusus	0	3	3
C. latus	5	0	5
C. ruber	146	128	274
Decapterus sp.	3	2	5
Trachinotus falcatus	14	3	17
Lutjanidae			
Lutjanus analis	33	65	98
L. apodus	137	114	251
L. buccanella	36	0	36
L. griseus	102	140	242
L. jocu	70	23	93
L. mahogoni	108	56	164
L. synagris	67	40	107
Ocyurus chrysurus	138	145	283
Lobotidae			
Lobotes surinamensis	20	0	20
Pomadasyidae			
Anisotremus surinamensis	105	5	110
A. virginicus	155	98	253
Haemulon album	7	36	43
H. aurolineatum	86	143	229
H. carbonarium	110	82	192
H. chrysargyreum	118	29	147
H. flavolineatum	159	143	302
H. macrostomum	137	105	242
H. melanurum	74	0	74
H. parrai	48	37	85
H. plumieri	158	159	317
H. sciurus	159	128	287
Sparidae			
Calamus bajonado	13	0	13
C. calamus	15	124	139
Sciaenidae			
Equetus acuminatus	42	39	81
E. punctatus	69	0	69
Odontoscion dentex	105	28	133
Mullidae			
Mulloidichthys martinicus	144	96	240
Pseudupeneus maculatus	129	66	195
Pempheridae			
Pempheris schomburgki	121	20	141

Table 2. (Continued)

Species	Pennekamp Park	Dry Tortugas	Total
Kyphosidae			
Kyphosus sp.	70	45	115
Ephippidae			
Chaetodipterus faber	30	0	30
Chaetodontidae			
Chaetodon capistratus	121	121	242
C. ocellatus	107	126	233
C. sedentarius	28	60	88
C. striatus	75	28	103
Holocanthus bermudensis	15	155	170
H. ciliaris	101	119	220
H. tricolor	131	5	136
Pomacanthus arcuatus	101	149	250
P. paru	102	26	128
Pomacentridae			
Abudefduf saxatilis	133	113	246
Chromis cyanea	159	60	219
C. multilineata	112	9	121
C. scotti	18	103	121
Microspathodon chrysurus	150	98	248
Pomacentrus fuscus	74	60	134
P. leucostictus	8	125	133
P. mellis	7	80	87
P. partitus	159	152	311
P. planifrons	149	160	309
P. variabilis	73	158	231
Cirrhitidae			
Amblycirrhitus pinos	20	4	24
Labridae			
Bodianus rufus	136	88	224
Clepticus parrai	135	42	177
Halichoeres bivittatus	78	144	222
H. garnoti	153	79	232
H. maculipinna	130	103	233
H. poeyi	3	0	3
H. radiatus	66	64	130
Hemipteronotus splendens	1	2	3
Lachnolaimus maximus	90	106	196
Thalassoma bifasciatum	159	153	312
Scaridae			
Cryptotomus roseus	6	0	6
Scarus coelestinus	114	115	229
S. coeruleus	128	122	250
S. croicensis	154	158	312
S. quacamaia	34	6	40
S. taeniopterus	80	1	81
S. vetula	148	97	245
Sparisoma aurofrenatum	160	152	312
S. chrysopterum	35	8	43
S. radians	33	42	75
S. rubripinne	126	76	202
S. viride	160	154	314
Sphyraenidae			
Sphyraena barracuda	54	103	157

Table 2. (Continued)

Species	Pennekamp Park	Dry Tortugas	Total
Opistognathidae			
Opistognathus aurifrons	27	75	102
Clinidae			
Acanthemblemaria sp.	0	4	4
Malacoctenus aurolineatus	0	11	11
M. triangulatus	0	106	106
Starksia sp.	0	1	1
Blenniidae			
Blennius marmoreus	0	40	40
Ophioblennius atlanticus	0	20	20
Callionymidae			
Callionymus bairdi	8	0	8
Gobiidae			
Coryphopterus glaucofraenum	126	143	269
C. personatus	124	110	234
Gnatholepis thompsoni	82	2	84
Gobiosoma oceanops	66	145	211
Ioglossus calliurus	54	15	69
I. helanae	0	2	2
Acanthuridae			
Acanthurus bahianus	154	87	241
A. chirurgus	130	121	251
A. coeruleus	153	155	308
Scombridae			
Scomberomorus regalis	31	14	45
Scorpaenidae			
Scorpaena plumieri	3	0	3
Bothidae			
Bothus lunatus	3	0	3
Balistidae			
Alutera scripta	10	4	14
Balistes vetula	0	9	9
Cantherhines pullus	59	23	82
C. macroceros	1	0	1
Canthidermis sufflamen	64	17	81
Monacanthus ciliatus	16	0	16
M. tuckeri	2	3	5
Ostraciidae			
Lactophrys bicaudalis	20	0	20
L. quadricornis	0	1	1
L. triqueter	77	62	139
Tetraodontidae			
Canthigaster rostrata	149	79	228
Sphoeroides spengleri	0	9	9
Diodontidae			
Diodon holocanthus	3	0	3
D. hystrix	5	12	17

Species found: Pennekamp only—31, Tortugas only—19, Both areas—115, Total spp.—165.

combined Tortugas communities. As would be expected from these data, the Shannon-Weaver diversity index (H'_s) of Pennekamp is also greater than that for Dry Tortugas. It is apparent then, from the results of this study, that the relative species richness and abundance of fishes in the Pennekamp communities are generally higher than those for the Tortugas communities.

Results of a one-way ANOVA show a significant difference ($P < .001$) for mean number of species and mean scores between the eight communities studied (Table 4). A Duncan's Multiple Range Test (DMRT) grouped the French Reef, Molasses Reef, and Benwood Wreck communities together on the basis of mean species observed and mean scores assigned. The Carysfort community was grouped, in both number of species and scores, with Long Key Reef and French Wreck of the Tortugas communities. As noted above, the structural similarities of Carysfort and deeper portions of Long Key reefs are considerable in terms of reef framework and vertical profile. It is obvious from Table 4, that the lowest ranking communities for scores and observable species are White Shoal and Loggerhead. Both are dominated by *Acropora cervicornis* thickets. The steep dropoff, with large *Montastrea* and *Diploria* colonies along its sides, provides the White Shoal reef fish community a somewhat more complex physical habitat than that available to the Loggerhead fish community.

The Bray and Curtis Index (C) was also computed for each pair of communities and placed in a matrix of similarity coefficients (Table 5). Dissimilarity coefficients were then computed as the difference between the calculated coefficients of similarity and the maximum possible value. These values are calculated because the community ordination (below) depends on differences between communities rather than similarities. The maximum value would theoretically be 1.00, however, as Beals (1960) points out, a maximum value of less than 1.00 may more readily approximate the true com-

Table 3. Data summary for areas studied (H'_s = species diversity by scores, J'_s = equitability by scores)

Area	Total Species	Total Scores	H'_s	J'_s
Molasses	120	2,627	4.510	.942
French Reef	118	2,640	4.507	.945
Benwood Wreck	117	2,616	4.529	.951
Carysfort	104	2,200	4.412	.950
Long Key	101	2,221	4.398	.953
White Shoal	88	2,033	4.257	.951
Loggerhead	90	1,915	4.279	.951
French Wreck	86	2,253	4.290	.963
Totals				
Pennekamp	146	10,083	4.6355	.9301
Tortugas	134	8,419	4.4919	.9171
Combined	165	18,502		

munity upon which replicate samples have been drawn. We found that 0.90 was more suitable to our data. The dissimilarity coefficients (0.90-C) were placed in the mirror image of the similarity matrix (Table 5) and used in a simple community ordination procedure such as that adapted from Bray and Curtis (1957) by Beals (1960). The result is a two dimensional ordination of the communities studied, on the basis of X and Y coordinates (Fig. 2). The degree to which the spacing of the communities on the ordination accounts for variations in community composition is estimated by correlation of ordination interval with observed dissimilarity between community pairs (Beals, 1960). The correlation coefficient was $r = 0.92$ for the data in Figure 2.

The separation of the grouping of the Pennekamp communities from the similarly grouped Dry Tortugas communities is obvious (Fig. 2). This is in basic agreement with the results of the one-way ANOVA and DMRT of Table 4. In terms of overall ecological relationships, it is important to note

Table 4. Results of ANOVA (one-way) and Duncan's Multiple Range Test for mean species and mean scores (stations grouped by bars show no significant differences among means; all others show significant difference at $P < .05$)

	ANOVA				
	Source of Variation	df	SS	MS	F
Species	Among stations	7	3,793.1	541.9	24.921***
	Within stations (error)	56	1,217.6	21.7	
	Total	63	5,010.7		
	+ correction factor	64			
Scores	Among stations	7	70,703.2	10,100.5	19.057***
	Within stations (error)	56	29,680.8	530.0	
	Total	63	++++		
	+ correction factor	64			
	(***$P < .001$)				

DMRT			
Mean Species		Mean Scores	
French Reef	78.4	French Reef	329.9
Molasses	78.1	Molasses	328.4
Benwood	77.2	Benwood	327.0
Carysfort	69.4	French Wreck	279.8
Long Key	68.5	Long Key	276.6
French Wreck	66.0	Carysfort	275.0
White Shoal	61.0	White Shoal	253.6
Loggerhead	56.2	Loggerhead	239.1

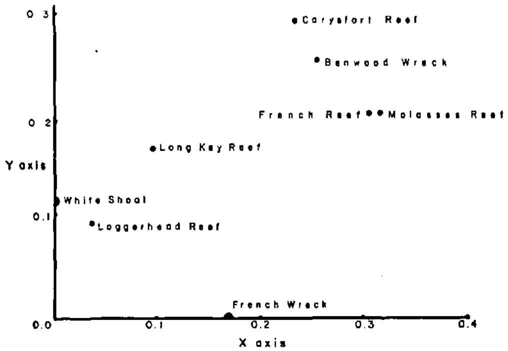

Figure 2. Two-dimensional ordination of communities based on species-time scores (units of the X and Y axes are essentially dimensionless, being defined mathematically by Beals, 1960).

that the data in Table 4 involve mean number of species and scores while those in Table 5, used for construction of the ordination, rely on the community comparison index (C). The latter takes into account the relationship of each species in a community to its counterpart in another community. Therefore, although the mean number of species in two communities may be nearly equal, they are not necessarily the same species. The same pitfall is evident for the Shannon-Weaver function (H'_s). There, the number of species and evenness values (J'_s) could be the same but the communities might have no actual species in common. Such lumping of data with the subsequent loss of the species as a basic ecological unit is unfortunate. We consider the species by species evaluation of (C) to be a better approach.

The similarity values in Table 5 are useful in examining each community pair. It is clear from the data that Molasses and French Reefs have the greatest degree of similarity (0.87). This is not surprising since both reefs are located along the same isobath, both are seaward reefs of very similar construction and they are only 3.7 km apart. The two artificial structures, French Wreck and Benwood Wreck, are located in different study areas but might be expected *a priori* to show considerable similarity in their fish community composition. This is not the case as the two communities show one of the lowest similarity indices (0.60) of all the possible pairs. The primary reason for these differences is most likely in the position of grounding of the two wrecks. For example, French Wreck is grounded on a relatively barren reef flat with very little well-developed reef structure nearby. Moreover, the wreck is in relatively shallow water and is scattered over the bottom. Benwood Wreck, on the other hand, is grounded on the same isobath that both French and Molasses reefs have developed on, is a more intact shelter and is only 2.4 km north of French Reef. As a result, the Benwood community receives its potential recruitment from the same environment that produced the rich and diverse fish communities at French and Molasses reefs. The similarity

Table 5. Similarity and dissimilarity (.90—similarity) values based on the Bray and Curtis Index

		DISSIMILARITY							
		ML	FR	BW	CF	LK	WS	LH	FW
SIMILARITY	ML	×	.03	.17	.15	.23	.32	.30	.23
	FR	.87	×	.14	.16	.23	.31	.29	.23
	BW	.73	.76	×	.19	.25	.30	.32	.30
	CF	.75	.74	.71	×	.15	.27	.25	.28
	LK	.67	.67	.65	.75	×	.13	.15	.19
	WS	.58	.59	.60	.63	.77	×	.12	.24
	LH	.60	.61	.58	.65	.75	.78	×	.19
	FW	.67	.67	.60	.62	.71	.66	.71	×

Table 6. Rank order of dominant species by species-time score for the two study areas, separated and combined

Combined Ranks		Pennekamp Ranks		Tortugas Ranks	
317	*H. plumieri*	160	*S. aurofrenatum*	160	*P. planifrons*
314	*S. viride*	160	*S. viride*	159	*H. plumieri*
312	*T. bifasciatum*	159	*H. flavolineatum*	158	*P. variabilis*
312	*S. croicensis*	159	*H. sciurus*	158	*S. croicensis*
312	*S. aurofrenatum*	159	*C. cyanea*	155	*H. bermudensis*
311	*P. partitus*	159	*P. partitus*	155	*A. coeruleus*
309	*P. planifrons*	159	*T. bifasciatum*	154	*S. viride*
308	*A. coeruleus*	158	*H. plumieri*	153	*T. bifasciatum*
302	*H. flavolineatum*	155	*A. virginicus*	152	*P. partitus*
293	*H. unicolor*	154	*S. croicensis*	152	*S. aurofrenatum*
287	*H. sciurus*	154	*A. bahianus*	150	*H. gemma*
283	*O. chrysurus*	153	*H. garnoti*	149	*H. unicolor*
274	*C. ruber*	153	*A. coeruleus*	149	*P. arcuatus*
273	*H. gemma*	150	*M. chrysurus*	145	*O. chrysurus*
269	*C. glaucofraenum*	149	*P. planifrons*	145	*G. oceanops*
253	*A. virginicus*	149	*C. rostrata*	144	*H. bivittata*
251	*L. apodus*	148	*S. vetula*	143	*H. aurolineatum*
251	*A. chirurgus*	147	*A. maculatus*	143	*H. flavolineatum*
250	*P. arcuatus*	146	*C. ruber*	143	*C. glaucofraenum*
250	*S. coeruleus*	144	*H. unicolor*	142	*H. puella*
248	*M. chrysurus*	144	*M. martinicus*	140	*L. griseus*
246	*A. saxatilis*	139	*P. cruentatus*	128	*C. ruber*
245	*S. vetula*	138	*O. chryurus*	128	*H. sciurus*
242	*L. griseus*	137	*L. apodus*	126	*C. ocellatus*
242	*H. macrostomum*	137	*H. macrostomum*	125	*P. leucostictus*
242	*C. capistratus*	136	*B. rufus*	124	*C. calamus*
241	*A. bahianus*	135	*C. parrai*	122	*S. coeruleus*
240	*M. martinicus*	133	*A. saxatilis*	121	*C. capistratus*
234	*C. personatus*	131	*H. tricolor*	121	*A. chirurgus*
233	*C. ocellatus*	130	*H. maculatus*	119	*H. ciliaris*
233	*H. maculipinna*	130	*A. chirurgus*	115	*S. coelistinus*
232	*H. garnoti*	130	*H. maculipinna*	114	*L. apodus*

index between Benwood Wreck and nearby French Reef is 0.76.

In the Dry Tortugas communities, the White Shoal and Loggerhead reefs show lowest overall diversity (H'_s) but the greatest similarity (C) with one another (0.78). Both reefs are dominated by similar *Acropora cervicornis* thickets. These two fish communities also show surprising similarity with Long Key Reef which is an entirely different structure both in terms of vertical profile, coral species composition, and physiography. This would seem to imply that the natural reef communities of the Dry Tortugas are conservative with regard to their fish communities.

Table 6 gives an indication of the dominant fish species for the Florida Reef Tract, based on combined data and on the two study areas considered separately. There is some variation between the rank order of the dominant fishes in each study area. Moreover, some of the species are clearly more apparent in one area than the other. The latter species were either not observed at all in one of the study areas or had significantly higher scores in one versus the other. Table 7 was constructed to identify some of these species. The table shows that 21 such species occurred in the Pennekamp Park study area and 13 in the Dry Tortugas study area.

Pennekamp species, *Aulostomus maculatus*, *Haemulon melanurum*, *Jenkinsia* sp.,

Table 7. Percent overlap of scores for selected species between Pennekamp and Dry Tortugas communities (species were selected where overlap of scores was <50% and where at least one of the scores was ⩾30)

	Scores		
Pennekamp Species	Pennekamp	Tortugas	% overlap
C. cyanea	158	60	38
A. maculatus	147	0	0
P. cruentatus	139	10	7
C. parrai	135	42	31
H. tricolor	131	5	4
E. cruentatum	128	47	37
P. schomburgki	121	20	17
H. chrysargyreum	118	29	25
C. multilineatus	112	9	8
A. surinamensis	105	5	5
O. dentex	105	28	27
P. paru	102	26	25
G. thompsoni	82	2	2
S. taeniopterus	80	1	1
H. melanurum	74	0	0
E. punctatus	69	0	0
C. undecimalis	64	4	6
Jenkinsia sp.	57	0	0
M. jacobus	50	4	8
L. rubre	30	0	0
C. faber	30	0	0

	Scores		
Tortugas Species	Tortugas	Pennekamp	% overlap
P. variabilis	158	73	46
H. bermudensis	155	15	10
G. oceanops	145	66	46
H. puella	142	23	16
P. leucostictus	125	8	6
C. calamus	124	15	12
M. triangulatus	106	0	0
C. scotti	103	18	17
P. mellis	80	7	9
E. morio	74	0	0
C. sedentarius	60	28	47
M. venenosa	35	0	0
B. marmoreus	30	0	0

Chaetodipterus faber, *Equetus punctatus*, and *Liopropoma rubre*, were not observed in any of the 32 counts from the Dry Tortugas. This is particularly surprising for the ubiquitous trumpetfish which would seem to be a common inhabitant of all West Indian reefs. The observers searched well beyond the regular Dry Tortugas counts without success in locating this species. *Liopropoma rubre* and *Equetus punctatus* are cryptic species but usually the animals are found in predictable under-ledge habitats in Pennekamp Park. Diligent search of similar ledges in the Dry Tortugas failed to turn up these species. Four species, *Blennius marmoreus*, *Malacoctenus triangulatus*, *Mycterperca venenosa*, and *Epinephelus morio*, were observed in the Tortugas counts but not in the Pennekamp counts. Unlike the preceding species, these four were observed in the Pennekamp communities at times other than during the formal counts, but none are common on the Pennekamp reefs.

Myripristis jacobus, *Pempheris schomburgki*, and *Odontoscion dentex* occur commonly in Pennekamp Park habitats similar to those of *Liopropoma rubre* and *Equetus punctatus*. Although present in the Dry Tortugas, these species were less abundant there (Table 7).

The important tropical reef fish families Chaetodontidae, Labridae and Scaridae shared most of their species equally in common between the two study areas. Exceptions were the chaetodonts, *Pomacanthus paru* and *Holocanthus tricolor*; the labrid, *Clepticus parrai*; and the scarid, *Scarus taeniopterus*, which were all common in the Pennekamp study area but less so in the Dry Tortugas. On the other hand, the chaetodonts, *Chaetodon sedentarius* and *Holocanthus bermudensis* scored higher in the Dry Tortugas study area.

In another common reef fish family, the Pomacentridae, there was more divergence than expected. The normally very common mid-water dwelling *Chromis cyanea* and *C. multilineata* scored high in Pennekamp but low in the Dry Tortugas. The reverse was true for *Chromis scotti*, *Pomacentrus variabilis*, *P. leucostictus*, and *P. mellis*. *Chromis scotti*, extremely common at Long Key Reef, is very rarely seen in Pennekamp shallower than 38 m.

Longley and Hildebrand (1941) recorded some 440 fish species from the Tortugas area. Their list, however, includes many species not directly associated with coral reefs. Starck (1969) listed a total of 517 species, of which 389 were coral reef types from his 9-year research at Alligator Reef in the Florida Keys. Starck divides his coral reef species into "Primary" and "Secondary" reef fishes. Primary reef species are those species characteristically associated with the reef itself. Secondary reef species are forms which, although occurring on reefs, are also equally characteristic of areas without coral growth. Our study was restricted only to areas of active coral growth, and detected 125 (49%) of Starck's 253 primary reef fishes within the two week sampling period in Pennekamp Park. These figures are slightly misleading, however, because of the extensive use of ichthyocides by Starck at Alligator Reef. Of Starck's 128 primary reef fish species not detected in this study, 86 (67%) are either cryptic, nocturnal, or rare, and it is unlikely that visual techniques would ever record such species.

Comparing species estimated as common by Starck with those recorded visually in Pennekamp Park showed a 6% variation. This not only helps to confirm the stated philosophy of visual species detection techniques, but also validates the P_k statistical estimation that eight replicates per station would account for 93.5% of the commonly visible fish species on Florida's reefs.

Conclusions

Pennekamp communities and those in Dry Tortugas were not expected to differ greatly in species composition since they are separated by less than one half degree of latitude and are part of the same West Indian faunal regime (Fig. 1a). In spite of these similarities, the species-time technique did draw some fairly clear distinctions between the two study areas in general and between the study communities in particular.

The species-time, random count method appears to yield relatively accurate quantification of the fish community under study within the limits of its design. It should again be made clear that visual methods can only account for the more ubiquitous fishes of the suprabenthic reef community and do not account for the majority of the cryptic or secretive species. Therefore, the "state-of-the-community" as measured by this method is relative only. It is our contention, however, that the ratio of relative abundance among the more commonly occurring (visible) suprabenthic species is representative of a given reef fish community.

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Literature Cited

Alevizon, W. S., and M. G. Brooks. 1975. The comparative structure of two western Atlantic reef-fish assemblages. Bull. Mar. Sci. 25: 482–490.

Beals, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bull. 72: 156–181.

Bechtel, T. J., and B. J. Copeland. 1970. Fish species diversity indices as indicators of pol-

lution in Galveston Bay, Texas. Control in Mar. Sci. 15: 101–132.
Bray, J. R., and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monog. 27: 325–349.
Brock, V. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildl. Mgmt. 18: 297–308.
Chave, E. H., and D. B. Eckert. 1974. Ecological aspects of the distributions of fishes at Fanning Island. Pacif. Sci. 28: 297–317.
Ebeling, A. W., Jr., R. Larson, W. S. Alevizon, and F. DeWitt, Jr. 1971. Fishes of the Santa Barbara kelp forest. Abstr. Coastal Shallow Water Res. Conf. No. 3: 61.
Emery, A. R. 1973. Comparative ecology and functional osteology of 14 species of damselfish at Alligator Reef, Florida Keys. Bull. Mar. Sci. 23: 649–770.
Gaufin, A. R., E. K. Harris, and H. J. Walter. 1956. A statistical evaluation of stream bottom sampling data obtained from three standard samplers. Ecology 37: 643–648.
Glynn, P. W. 1973. Aspects of the ecology of coral reefs in the western Atlantic region. Pages 271–324 *in* P. A. Jones and K. Endean, eds., Biology and geology of coral reefs. Academic Press, New York and London. Vol. 2 (Biology 1), 480 pp.
Goreau, T. F. 1959. The ecology of Jamaican coral reefs 1. Species composition and zonation. Ecology 40: 67–90.
Hobson, E. S. 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull. 72: 915–1031.
Hoffmeister, J. E. 1974. Land from the sea: The geologic story of South Florida. Univ. of Miami Press, Coral Gables, Fla. 143 pp.
Itzkowitz, M. 1974. A behavioural reconnaissance of some Jamaican reef fishes. Zool. J. Linn. Soc. 55: 87–118.
Jones, R. S., and J. A. Chase. 1975. Community structure and distribution of fishes in an enclosed high island lagoon in Guam. Micronesica 11: 127–148.
Key, G. S. 1973. Reef fishes in Kaneohe Bay, Hawaii. Pages 51–66 *in* S. V. Smith, K. E. Chave, and D. T. O. Kam, eds. Atlas of Kaneohe Bay: A reef ecosystem under stress. Univ. of Hawaii Sea Grant Tech. Rept. 128 pp.
Longley, W. H., and S. F. Hildebrand. 1941. Systematic catalogue of the fishes of Tortugas, Florida with observations on color, habits and local distributions. Pap. Tortugas Lab. 34: 331 pp.
McCain, J. C., and J. M. Peck, Jr. 1973. The effects of a Hawaiian power plant on the distribution and abundance of reef fishes. Sea Grant Advisory Report UNIHI-SEAGRANT-AR-73-03: 11 pp.
Milliman, J. D. 1973. Caribbean coral reefs. Pages 1–44 *in* O. A. Jones and R. Endean, eds., Biology and Geology of Coral Reefs: Geology 1. Academic Press, New York.
Oosting, H. J. 1956. Plant communities. W. H. Freeman and Co., San Francisco. 440 pp.
Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13: 131–144.
Randall, J. E. 1963. An analysis of the fish populations of artifical and natural reefs in the Virgin Islands. Carib. J. Sci. 3: 1–16.
Risk, M. J. 1972. Fish diversity on a coral reef in the Virgin Islands. Atoll Res. Bull. 193: 1–6.
Shinn, E. A. 1963. Spur and groove formation on the Florida reef tract. J. Sed. Pet. 33: 291–303.
Siegal, S. 1956. Non-parametric statistics for the behavioral sciences. McGraw-Hill, New York. 312 pp.
Smith, C. L. 1973. Small rotenone stations: a tool for studying coral reef fish communities. Am. Mus. Novit. 2412: 1–21.
———, and J. C. Tyler. 1973a. Direct observations of resource sharing in coral reef fish. Helgalender wiss. Meersunters. 24: 264–275.
———, and ———. 1973b. Population ecology of a Bahamian suprabenthic shore fish assemblage. Am. Mus. Novit. 2528: 1–38.
Smith, F. G. W. 1971. Atlantic reef corals. Univ. of Miami Press, Coral Gables, Fla. 112 pp.
Starck, W. A. 1969. A list of fishes of Alligator Reef, Florida with comments on the nature of the Florida reef fish fauna. Undersea Biol. 1: 4–40.
Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures in statistics. McGraw-Hill, New York. 281 pp.
Talbot, F. H., and B. Goldman. 1973. A preliminary report on the diversity and feeding relationships of reef fishes of One Tree Island, Great Barrier Reef System. Pages 425–442 *in* Symposium on corals and coral reefs. Mandoporan Camp. India. Mar. Biol. Assoc. India. 591 pp.
Wass, R. C. 1967. Removal and repopulation of fishes on an isolated patch coral reef in Kaneohe Bay, Oahu, Hawaii. M.S. Thesis, Univ. of Hawaii.

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