Structure and dynamics of the fishery harvest in Broward County, Florida, during 1989

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Abstract.—Florida's rich fisheries are among the state's most valuable resources, attracting the interest of fishermen, divers, and others. Commercial and recreational exploitation of these resources has altered the abundances of some valuable species; consequently fishery regulations and a system to monitor landings have evolved in response.

Until now, the biological structure of the multispecies harvest has not been examined. Landings from commercial trips in Broward County during 1989 were used to describe the structure and seasonal dynamics of that harvest. Cluster analysis classified fishing trips into distinct groups associated with different habitats and gear. Swordfish landings dominated this low-diversity harvest. There were significant seasonal changes in the species assemblages landed. However, most species associations were weak and negative.

The observed structure of the Broward County harvest reflects the selectivity inherent in commercial fishing. It is a balance between the differential availability of various species to the gear used and the market values driving the fishermen to select some species and discard others. Seasonal changes in the harvest structure reflect changes in the availability of various species and in the fishermen's ability to adapt to these changes by switching to alternate target species. The strong biases introduced by the selectivity of this system can obscure events in the natural system and provide little insight into the changes in the natural fish community.

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Florida waters are rich in fish and shellfish. Although the greatest diversity is found in coral reef habitats (Starck, 1968), hundreds of species are found throughout Florida's marine waters (Anderson and Gehringer, 1965; Herrema, 1974; Gilmore, 1977). Statewide, commercial landings are reported to the Department of Environmental Protection by using 531 different species codes, some of which represent groups of species. This assemblage is two to three times larger than any other state's marine fishery resource.

Historically, fish communities containing commercially valuable species have been strongly influenced by human activities, especially fishing (e.g. Cushing, 1961; Idyll, 1973; Beddington and May, 1982; Gulland, 1983; Beddington, 1986; Sissenwine, 1986; Laevastu and Favorite[1]). Florida's fishery resource has been intensely exploited both commercially and recreationally for many years (e.g. Nakamura and Bullis, 1979; Newlin, 1991). Bohnsack et al. (1994) have provided a good description of the complexity of Florida fisheries, explored the effects of exploitation, and discussed the difficulties in interpreting available landings data. The effects of exploiting this multispecies resource have been demonstrated for a few valuable species (Spanish mackerel: Williams et al.[2]; king mackerel: Fable, 1990; spiny lobster: Moe, 1991; red drum: Goodyear[3]; billfishes: Anonymous[4]; swordfish: Anonymous[5]; red grouper: Goodyear and Schirripa[6]). However,

[1] Laevastu, T., and F. Favorite. 1978. The control of pelagic fishery resources in the eastern Bering Sea. Northwest and Alaska Fisheries Science Center, National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle, WA 98115. Proceedings report. (Manuscript.)

[2] Williams, R. O., M. D. Murphy, and R. G. Muller. 1985. A stock assessment of the Spanish mackerel, *Scomberomorus maculatus*, in Florida. Unpublished, third draft. Prepared for the Florida Marine Fisheries Commission, 2540 Executive Center, Circle West, Tallahassee, FL 32301, 65 p.

[3] Goodyear, C. P. 1987. Status of red drum stocks in the Gulf of Mexico. Contribution report CRD 86/87-34, Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Dr., Miami, FL 33149, 49 p.

[4] Anonymous. 1982. Draft fishery management plan, draft environmental impact statement, and regulatory impact review for the Atlantic billfishes: white marlin, blue marlin, sailfish and spearfish. South Atlantic Fishery Management Council, 1 South Park Circle, Suite 306, Charleston, SC, report G#27 BF Fmwk 8/82, 64 p.

[5] Anonymous. 1991. Reference paper on 1991 swordfish stock assessments by SCRS swordfish assessment group. Miami Laboratory, Southeast Fisheries Science Center, NMFS, NOAA, Miami, FL, rep. SCRS/91/16, 193 p.

[6] Goodyear, C. P., and M. J. Schirripa. 1991. The red grouper fishery of the Gulf of Mexico. Miami Laboratory, Southeast Fisheries Science Center, NMFS, NOAA, 75 Virginia Beach Dr., Miami, FL 33149. Contribution rep. MIA-90/91-86, 79 p.

only anecdotal reports of associations among harvested species exist.

Concern about the effects of harvesting this resource has stimulated research on the structure and dynamics of Florida's marine fish community. Structure of the harvest is related to the structure of the natural community and to the economics influencing fishermen's behavior. It integrates the differential fishing mortality affecting the natural community. In 1984, the Florida Department of Environmental Protection (FDEP) established a trip-ticket reporting system (Marine Fisheries Information System) to monitor the fishery harvest and provide a database of basic information on commercial landings from this resource. All dealers buying fish from fishermen or fishing for themselves must report the amounts of all species landed on each fishing trip. These records normally represent those species brought to shore on a single fishing trip and sold (landed). They do not include species or individuals caught and subsequently discarded, those used as bait, or those brought to shore but not sold. Harvesting occurs in many different ways (e.g. traps, nets, hook-and-line) and can have a variety of effects on the fishery resource and the natural community as a whole. A better understanding of the multispecies resource and the potential effects of the harvest can be gained by relating the structure and its variability to what is known about the natural fish assemblage and the harvesting behavior of fishermen. This study uses commercial landings data collected by the Marine Fisheries Information System (MFIS) to examine the structure and temporal dynamics of the harvest in Broward County, Florida (Fig. 1), during 1989.

Methods

The MFIS database includes, but is not limited to, information on the weight of each species landed from each commercial fishing trip, the date on which those landings occurred, and the time spent fishing. Information on depth and fishing area were provided on a voluntary basis in 1989 but the spaces for reporting such information were often left blank by reporting dealers. Information on gear used was not provided.

All commercial landings reported from Broward County during 1989 were used in this analysis. This subset of the MFIS database was chosen for this study because Broward County fisheries landings are some of the most valuable in the state. Furthermore, because 3,246 landings records (out of more than 2.5 million) exist, it is computationally one of the most manageable data sets available. Each month of data was analyzed separately in an attempt to detect seasonal trends in species assemblage structure. Monthly assemblages were constructed on the basis of total monthly landings of each species.

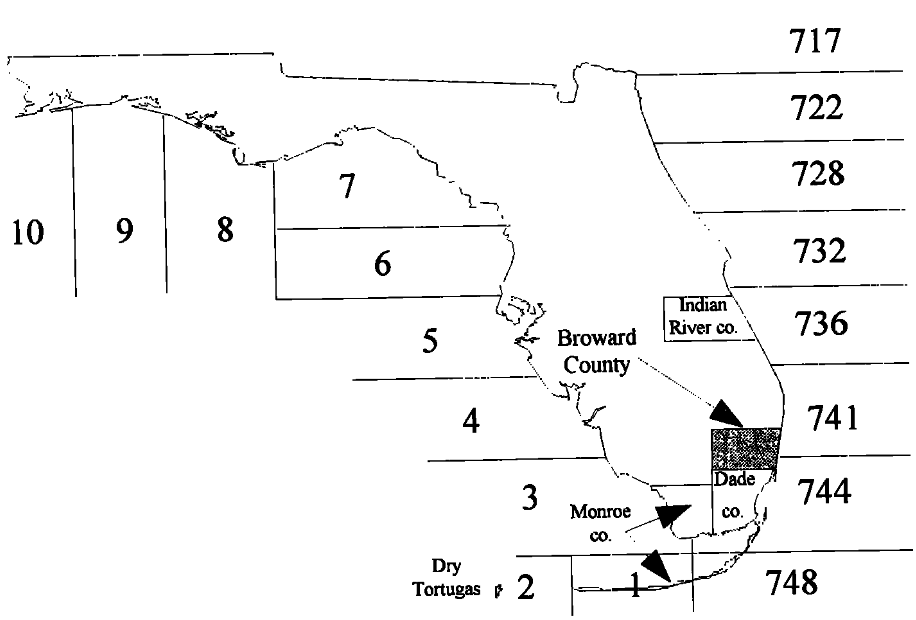

Figure 1

Designations of fishing areas used by the Florida Marine Information System. Broward County's location on the southeast coast is indicated by the shaded area.

Diversity was described by using the Shannon-Wiener Information Index (H') (Shannon and Weaver, 1949) and its component parts, richness (number of species) and evenness (V') (Pielou, 1977).

$$H' = -\sum p_i \log_e p_i$$
$$V' = H'/\log_e s^*,$$

where p_i is the proportion of species i and s^* is the number of species in the entire community (Pielou, 1977). In this study, the value of s^* was set to the total number of species landed in a given month when calculating evenness per ticket, and to the total number of species (76) landed over the entire year when calculating evenness per month.

Heterogeneity ratios (HR) (HR actually measures beta diversity, which is an index of dissimilarity, Kobayashi, 1987) were calculated to measure the similarity between all pair-wise comparisons of monthly assemblages. All pair-wise combinations of assemblages were tested for significant differences (α=0.05) by using a Monte Carlo simulation technique that compares the observed number of species common to the two assemblages of interest with that expected from randomly extracting two assemblages (each having the same number of species as one of the observed assemblages) from the community as a whole (FAUNSIM) (Raup and Crick, 1979; McKenna and Saila, 1991).

A nonhierarchical cluster analysis (SAS FASTCLUS, SAS, 1985) was applied to classify the trips according to the species assemblage landed each month. A maximum of 3 iterations and 20 clusters were specified. No minimum radius was specified. The REPLACE = option was set to RANDOM so that a simple pseudorandom sample of observations was chosen as initial cluster seeds. The DRIFT option was specified to adjust cluster seeds to their cluster mean each time an observation was added.

Spearman's rank correlation analysis was performed on every pair-wise combination of monthly species landings, on a trip-by-trip basis, to test for significant associations. A Z-test was applied to determine the significance of each correlation at the 0.01 level (Freund, 1970, p. 311–313).

Results

A total of 1,355,421 kg (2,981,926 pounds) of finfish and shellfish were landed in Broward County during 1989 according to the 3,246 commercial fishing trips reported (Table 1). The monthly average was 112,840 kg (248,247 pounds) ranging from 41,889 kg (92,156 pounds) to 178,489 kg (392,675 pounds) (Fig. 2).

Geography of the harvest

Florida's commercial fishing fleet is, in general, artisanal (small boats operating near shore). In 1989, 907 saltwater products licenses, 61 wholesale dealer licenses, and 408 retail dealer licenses were issued to residents of Broward County. Most fishermen worked in the waters immediately adjacent to the Broward County coast. The fishing area (Fig. 1) was reported for 76% of the trips landing fish in Broward County. According to those trip-tickets that included fishing area, fishermen harvested from areas 741 (45%) or 744 (37%) on 82% of fishing trips. The number of trips diminished as one moved away from the Broward County coast. Fish were caught from areas as far north as the waters off Indian River County (area 736), as far south and west as the Tortugas (area 2). Rarely, landings were reported from waters of Florida Bay off mainland Monroe County (area 3).

Diversity

Diversity of landed species was low in comparison with the natural diversity of this subtropical community. A total of 76 species (or groups of species) were landed in Broward County in 1989. Diversity (H') of the total harvest was 1.86; evenness (V') was 0.43. Mean monthly diversity (1.88) was almost identical to that for the total harvest (Table 2). Monthly evenness values varied between 0.31 and 0.62, a mean of 0.43. Diversity and evenness followed roughly sinusoidal patterns throughout the year, with peaks in September (H'=2.69, V'=0.62) approximately double the minimum value in May (H'=1.36, V'=0.31). Monthly richness approached 50 species most of the year; June (36) and July (44) had the lowest values, April (54) and November (55) had the highest values. Despite the fact that the waters off Broward County contained a relatively rich (at least 76 species commercially harvested) multispecies fish community, as many as half of all trips in any given month landed only a single species. Mean alpha diversity (defined here as diversity based on landings from a single fishing trip) was low (0.44) and showed little variability (Fig. 3). It was greatest in January and February and dropped to about 60% of those values for the rest of the year. Richness displayed a very small range (2.5–3.5 species per trip).

Similarity

Beta diversity (HR) among pair-wise comparisons of monthly assemblages ranged from 1.05 to 1.26 (Table 3). The species assemblages landed in March and September were most similar and those landed in

Table 1

Fish and shellfish landed in Broward County, Florida, during 1989. Species groups are identified by the following: BC = blue crab, BF = bait fishes, GS = grouper-snappers, ID = inshore demersals, IP = inshore pelagics, LB = lobsters, OD = offshore demersals, OP = offshore pelagics, SC = stone crab, SH = shrimps, and UM = unidentified miscellaneous fishes. Golden crab landings are included in the category "misc. invertebrates."

Species or complex	Weight (lb)	Group	Species or complex	Weight (lb)	Group
Amberjack	4,315	OP	Sea bass, mixed	327	ID
Bait Fish	246	BF	Shark	59,352	OP
Ballyhoo	23,204	BF	Shark fins	35	OP
Bluefish	38	IP	Sheepshead	120	ID
Bluerunner	813	BF	Hogfish	6,895	ID
Bonito (little tunny)	161	OP	Snapper, lane	833	GS
Bumper, Atlantic	94	BF	Snapper, mangrove	3,335	GS
Cobia	1,350	OP	Snapper, mutton	29,555	GS
Croaker	434	ID	Snapper, red	337	GS
Dolphin	32,704	OP	Snapper, silk	68	GS
Eels	20	ID	Snapper, vermilion	3,358	GS
Goggle eye or scad	1,510	BF	Snapper, yellowtail	23,443	GS
Grouper, black	33,255	GS	Snapper, mixed	11,438	GS
Grouper, gag	6,155	GS	Snapper, other	1,102	GS
Grouper, Nassau	40	GS	Spot	40	ID
Grouper, red	10,612	GS	Swordfish	811,896	OP
Grouper, scamp	194	GS	Tilefish, golden	320	OD
Grouper, snowy	939	GS	Tilefish, gray	800	OD
Grouper, Warsaw	764	GS	Triggerfish	2,289	ID
Grouper, yellowedge	74	GS	Tuna, bigeye	66,437	OP
Grouper, yellowfin	8	GS	Tuna, blackfin	457	OP
Jewfish	232	GS	Tuna, bluefin	2,530	OP
Grouper, mixed	527	GS	Tuna, skipjack	15	OP
Grouper, other	1,496	GS	Tuna, yellowfin	58,626	OP
Grunts	2,700	ID	Tuna, mixed	499	OP
Jack, crevalle	2,304	IP	Wahoo	759	OP
Jack, mixed	1,075	IP	Whiting	37	ID
Jack, other	392	IP	Misc. food fish	57,240	UM
Mackerel, king	25,848	OP	Misc. industrial fish	730	UM
Mackerel, Spanish	723	IP	**Total finfish**	**1,299,945**	
Menhaden (pogies)	218	IP	Crabs, blue (hard)	7,564	BC
Mojarra	697	ID	Crabs, stone, large	265	SD
Mullet, black	9	IP	Lobster, Spanish	225	LB
Mullet, silver	1,451	IP	Lobster, spiny	37,068	LB
Permit	1	IP	Octopus	163	ID
Pinfish	2	BF	Shrimp, pink	5,280	SH
Pompano	378	IP	Shrimp, bait	453	SH
Porgies	2,092	ID	Misc. invertebrates	4,458	OD
			Total invertebrates	**55,475**	
			Grand total	**1,355,421**	

February and June were least similar. About half (28 out of 66) of all possible unique pair-wise comparisons revealed significantly different assemblages (Table 3). These differences were usually due to changes in the proportion of landings contributed by swordfish and to the prevalence of lobster and baitfish.

The composition of the assemblage landed in a particular month varied considerably. The assemblage landed during any given month was significantly different from those of as few as two to as many as nine of the other eleven months. Assemblages of adjacent months were not significantly different, with the exception of July–August (owing to a sharp drop in swordfish landings and to a large increase in lobster landings at the beginning of the season) and September–October (owing to a sharp increase in swordfish landings and a general reordering of the dominance of other species) (Table 3). October was different from all months, except November and December, and July was different from all months, except June and September. January was different only from July and October, whereas December was different only from February and July. Generally, there were significant differences between winter (large proportion of swordfish and other offshore pelagics) and late summer–fall (relatively small proportions of offshore pelagics with a mix of species from other groups) assemblages.

Table 2

Monthly diversity of commercial fisheries landings in Broward County, Florida, during 1989. H′ = Shannon-Wiener diversity; V′ = evenness; R = species richness.

Month	H′	V′	R
Jan	1.73	0.40	48
Feb	2.04	0.47	50
Mar	1.49	0.34	52
Apr	1.49	0.34	54
May	1.36	0.31	51
Jun	1.41	0.32	36
Jul	1.90	0.44	44
Aug	2.66	0.62	48
Sep	2.69	0.62	52
Oct	2.35	0.54	54
Nov	1.90	0.44	55
Dec	1.56	0.36	53
Mean	1.88	0.43	50

Classification

Cluster analysis classified trips on the basis of the similarity of the species assemblages landed. I used an artificial, but operational, system of general habitat associations and species complexes to classify species into eleven groups (Table 1). Groupers and snappers inhabit a wide variety of habitats (Smith, 1976; Robins et al., 1986) and were frequently landed together. They were assigned to their own group rather than limited to a single habitat. Similarly, bait fish often formed a unique cluster and thus a "bait fish" group was used. "Miscellaneous food/industrial fish (UM)" was a "catch all" group used by fishermen to report species that were not explicitly given an identification code by the MFIS. It usually included such species as angelfishes (Pomacanthidae), parrotfishes (Scaridae), butterfish (*Peprilus* spp.),

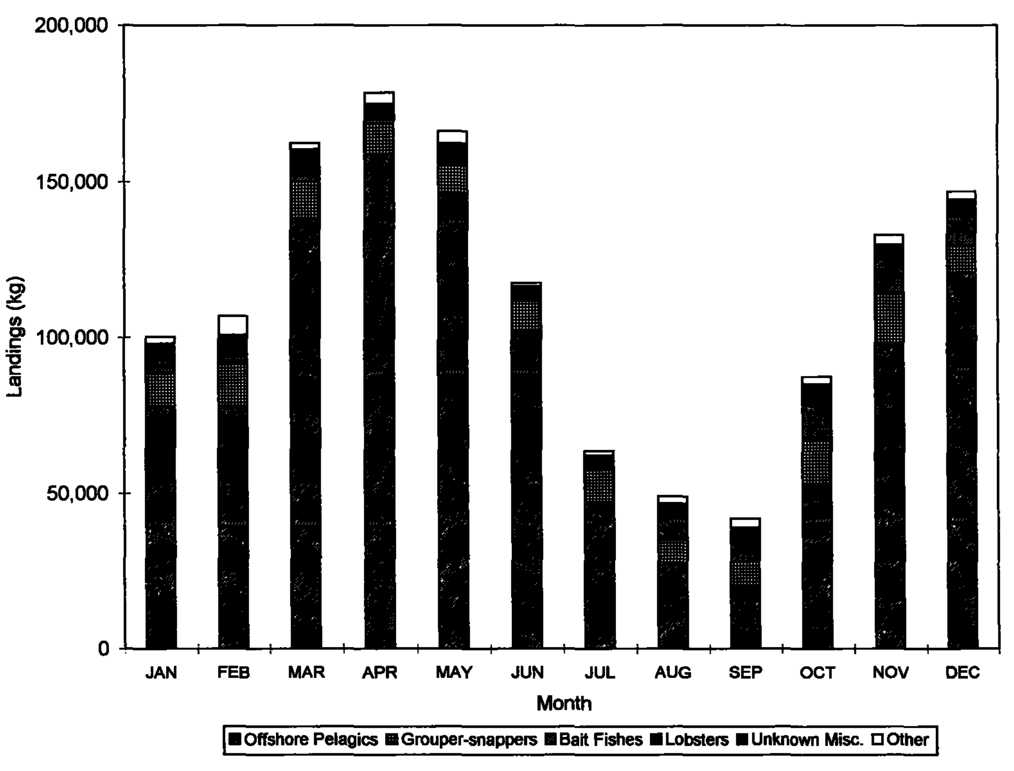

Figure 2

Total monthly landings in Broward County, Florida, during 1989 and the contribution of each species group. See Table 1 for species within each group. Each segment of each vertical bar represents the portion of total landings attributable to one of the five major groups (offshore pelagics, grouper-snappers, lobsters, bait fishes, and unknown miscellaneous fishes) or other species.

spadefish (*Chaetodipterus faber*), and tripletail (*Lobotes surinamensis*).

The persistence of each group in the harvest varied throughout the year. Offshore pelagics (OP, e.g. swordfish, *Xiphias gladius*) and tuna (*Thunnus* spp.), grouper-snapper (GS), bait fish (BF, e.g. ballyhoo, *Hemiramphus brasiliensis*), and unknown miscellaneous (UM) fishes occurred in each month. Lobsters (LB) occurred during each month of the open season (August–March) but declined steadily from the opening of the season. Blue crabs (BC, *Callinectes sapidus*) occurred in summer and fall (May–September and December). Inshore pelagics (IP, e.g. mullet, *Mugil* spp.) occurred in January, March, April, and August. Stone crabs (SC, *Menippe mercenaria*) and inshore demersals (ID, e.g. sheepshead, *Archosargus probatocephalus*) were landed in November and December. Shrimps (*Penaeus* spp.) occurred in February and April. Offshore demersals (OD, e.g. tilefish [Malacanthidae]) occurred only in July.

Offshore pelagics (OP) accounted for the largest proportion of landings in all months (Fig. 2). They also accounted for the majority of landings on most of the fishing trips from May through July, again in October and November. Groupers and snappers accounted for much of the remaining landings and dominated trips in January and December. Together the offshore pelagics (OP) and the grouper-snappers (GS) accounted for over 80% of landings in all months, except August, September, and October. The addition of lobster (LB) landings raises the totals for August and October to more than 80%. Inclusion of bait fish landings helps to account for more than 80% of September landings. Unknown miscellaneous (UM) fishes account for most of the remaining landings in each month.

Species associations

Despite the classification of landings (trip assemblages) into distinct groups of species assemblages, associations between individual species were weak. Less than 4% of the unique pair-wise comparisons of species occurrence in any given month were significant. One fourth to half of these accounted for more than 50% of the variation in their ranked abundances. Four associations accounted for more than 70% and only one association accounted for more than 80% of the variation in correlated species abundances. Roughly half of the significant associations were positive. However, most of these were between two uncommon (landed on less than ten trips per month) species. Only the swordfish-tuna association was consistently strong (r'>50%) and positive. Mutton snapper (*Lutjanus analis*) was positively associated with black grouper (*Mycteroperca bonaci*), mojarras (Gerreidae), and a number of other species, but these associations were not evident in every month and were usually weak (r'<50%). Only significant associations are considered in the following discussion.

Table 3

Dissimilarity and probabilities in comparing all pair-wise combinations of species assemblages landed in Broward County, Florida, during each month of 1989. The upper half matrix contains the dissimilarity values based on the Heterogeneity Ratio (HR), which is a measure of beta diversity. The lower half matrix contains the associated probabilities, generated by faunal similarity analysis (FAUNSIM), that the number of species observed to be common to each pair was less than that expected. Values in boldface are significant at the 0.05 level or greater.

	HR											
Month	1	2	3	4	5	6	7	8	9	10	11	12
1	—	1.057	1.073	1.107	1.084	1.179	**1.186**	1.143	1.104	**1.181**	1.112	1.112
2	0.07	—	1.071	**1.141**	**1.157**	**1.262**	**1.201**	1.118	**1.137**	**1.176**	1.109	**1.128**
3	0.53	0.40	—	1.069	1.101	**1.233**	**1.149**	1.087	1.050	**1.150**	1.089	1.089
4	0.80	**0.99**	0.43	—	1.098	**1.205**	**1.182**	1.101	1.064	**1.163**	**1.158**	1.105
5	0.38	**0.99**	0.67	0.75	—	1.160	**1.161**	**1.137**	1.098	**1.124**	1.081	1.082
6	0.71	**1.00**	**0.98**	0.87	0.47	—	1.161	1.159	**1.201**	**1.245**	**1.234**	1.212
7	**1.00**	**0.99**	**0.95**	**1.00**	**0.99**	0.62	—	1.157	1.137	**1.229**	**1.212**	**1.151**
8	0.93	0.80	0.66	0.73	**0.99**	0.66	1.00	—	1.063	**1.187**	1.130	1.089
9	0.80	0.97	0.33	0.51	0.86	**0.96**	0.83	0.10	—	**1.148**	**1.110**	1.090
10	**1.00**	**1.00**	**1.00**	**0.99**	**0.95**	**0.99**	**1.00**	**1.00**	**0.99**	—	1.115	1.095
11	0.76	0.88	0.75	**1.00**	0.58	**0.97**	**1.00**	**0.94**	**0.96**	0.86	—	1.070
12	0.77	**0.96**	0.75	0.84	0.50	0.90	**0.95**	0.66	0.88	0.67	0.44	—

FAUNSIM probability

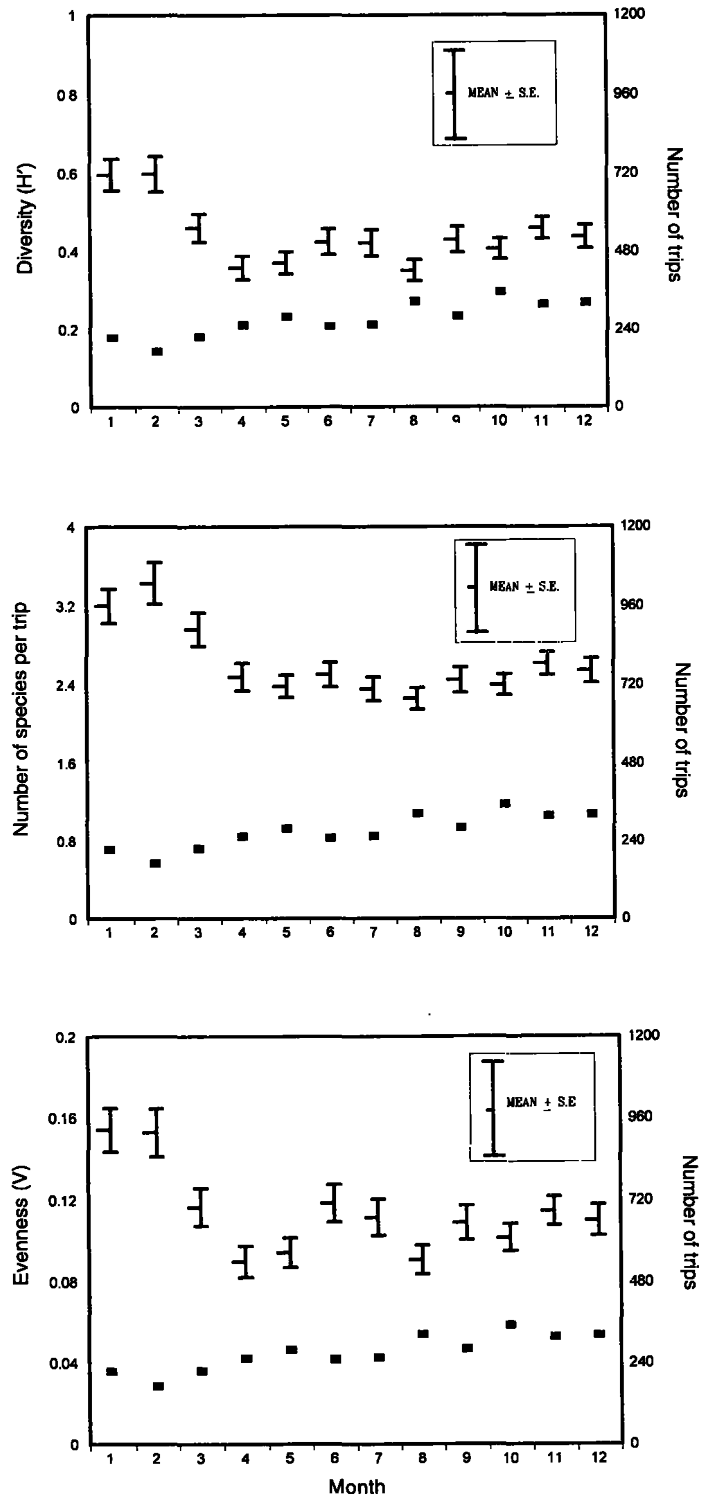

Figure 3

Monthly values of alpha diversity for trips landing fish in Broward County during 1989. Species richness, evenness, and the Shannon-Wiener information index are represented by these high-low graphs. Each horizontal tick mark indicates the mean value. Each vertical bar indicates one standard error. Solid rectangles represent the number of fishing trips associated with each high-low bar.

A strong, positive association between swordfish and both bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) existed in spring and fall. In December, the association between each of these tunas and swordfish accounted for over 70% of the variations in their landings. Swordfish showed significant negative associations with shark in the early part of the year and with dolphin (*Coryphaena hippurus*) throughout the year.

In 1989, all species of shark landed were reported under the unspecific "mixed shark" code. At least eleven species of shark are landed throughout the state, but blacktip shark (*Carcharhinus limbatus*), sandbar shark (*Carcharhinus plumbeus*), and shortfin mako (*Isurus oxyrinchus*) are most common in the landings from southeast Florida (Brown[7]). Shark landings were negatively correlated with all significant associates in Broward County. There were strong negative associations between sharks and both groupers and snappers throughout most of the year and between sharks and dolphins in spring and fall.

Dolphin landings were negatively correlated with all significant associates except for a few rare positive associations with tunas in mid-summer. They showed strong negative associations with groupers in the early part of the year and with snappers throughout most of the year.

King mackerel (*Scomberomorus cavalla*) is a migratory species and a seasonal member of the offshore pelagics (OP) group (Manooch, 1979; Collette and Russo, 1984). Those caught in the waters off Broward County are considered part of the Atlantic stock from 1 April until 1 November, when they become part of the Gulf–Atlantic stock. The fishery on the Gulf–Atlantic stock is quota-regulated in Florida and usually closes in late December or early January. In 1989, king mackerel landed in Broward County displayed strong, negative associations with dolphin, groupers, and snappers. It also was rarely associated with baitfishes, lobsters, and other offshore pelagics.

Spiny lobster (*Panulirus argus*) landings in Florida occur only during the open sea-

[7] Brown, S. T. 1994. Florida Marine Research Inst., Florida Dep. Environmental Protection, 100 8th Ave SE, St. Petersburg, FL 33701. Personal commun.

son (6 August through 31 March). Broward County lobster landings were consistently negatively associated with yellowtail snapper (*Ocyurus chrysurus*) and "mixed snapper." They were positively associated with grunts (Haemulidae) and "other groupers" in December. A strong positive association with Spanish lobster (*Scyllarides aequinoctialis*) occurred in October.

Black grouper occurred with nine other species and UM. It was negatively associated with lobsters and members of the offshore pelagics group, especially dolphin, king mackerel, and shark. There was a consistent positive association only with mutton snapper.

Hogfish (*Lachnolaimus maximus*) occurred with a dozen other species and UM. This species showed a strong and consistent negative association with sharks and sporadic positive associations with mutton snapper in summer and fall.

Mutton snapper was significantly associated with the largest number of other species (25) but showed consistent associations with only a few. There was a consistent negative association with sharks and dolphin throughout most of the year. Landings of mutton snapper were positively related to those of groupers and mojarra (Gerreidae) in the latter half of the year. This species was frequently associated with hogfish in summer and fall.

Yellowtail snapper was also significantly associated with a large number of other species (18), but showed few consistent associations. Positive associations were rare but negative associations with dolphin, shark, and spiny lobster were common.

Species assemblages

Seasonal differences suggested by changes in diversity and similarity were evident in the species assemblages landed each month (Table 4). Offshore pelagic species dominated Broward County landings in 1989 (Fig. 2). Swordfish, shark, and dolphin were listed on at least ten trip tickets every month. Swordfish dominated annual landings as well as those for each month; it accounted for 60% of annual landings (Fig. 4) and more than 50% of landings in all months except August, September, and October. Other offshore pelagics accounted for 18% of annual landings (Fig. 4). Bigeye and yellowfin tunas occurred commonly in nine or more months but were uncommon in the summer. King mackerel occurred commonly in all months except January through March, when the fishing season was closed. Spiny lobster accounted for less than 3% of the annual landings (Fig. 4) but made a large contribution to the landings in the first part of the open season (August: 15% of the landings) and tapered off throughout the fall. Groupers and snappers accounted for more than 6% of the annual landings, but only black grouper, mutton snapper, and yellowtail snapper accounted for more than 1% of annual landings each (Fig. 4). Black grouper, hogfish, mutton snapper, yellowtail snapper, and mixed snappers occurred commonly in every month. Red grouper (*Epinephalus morio*) was common every month, except January. Gag (*Mycteroperca microlepis*) was common only in April, and "other grouper" in winter and September. Unknown mis-

Table 4

Species contributions (as a percentage) to monthly landings in Broward County, Florida, during 1989. (See Table 1 for group definitions.)

Group	Species or complex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GS	Black grouper	3.0	4.3	2.0	1.8	1.7	2.0	3.7	3.8	4.6	3.4	1.6	1.7
	Mutton snapper	1.4	2.3	0.7	0.6	0.9	2.2	3.3	2.5	5.1	5.9	5.1	1.3
	Yellowtail snapper	3.2	2.0	1.0	0.7	0.9	2.2	2.9	4.8	5.2	2.3	1.6	0.4
	Mixed snapper	0.7	0.5	0.3	0.4	0.4	0.6	2.0	1.5	2.1	2.4	1.3	0.7
LB	Lobster	2.0	1.4	1.9	0.0	0.0	0.0	0.0	16.5	9.0	7.8	4.5	4.0
OP	Bigeye tuna	5.0	8.3	5.4	1.9	3.2	2.7	1.8	5.8	1.1	6.8	7.6	7.7
	Dolphinfish	1.8	1.7	1.6	1.0	1.4	5.4	9.7	8.8	4.7	2.0	0.5	0.7
	King mackerel	0.0	0.0	0.0	9.0	1.7	0.4	0.7	2.3	0.7	1.8	0.6	1.0
	Shark	4.3	3.4	5.8	5.7	6.6	4.7	2.3	4.1	5.2	4.0	1.9	2.4
	Swordfish	62.8	53.5	68.2	67.2	71.4	68.2	54.5	25.4	29.5	38.6	55.2	65.2
	Yellowfin tuna	2.3	3.3	1.8	3.6	3.3	5.2	4.4	8.0	5.7	6.8	7.3	4.8
UM	Misc. food fish	5.0	5.0	3.1	2.7	3.3	3.7	6.6	5.7	10.6	7.7	3.4	3.0
	Other species	12.3	13.1	13.2	11.1	10.4	5.8	8.7	14.0	13.6	8.3	12.0	8.3

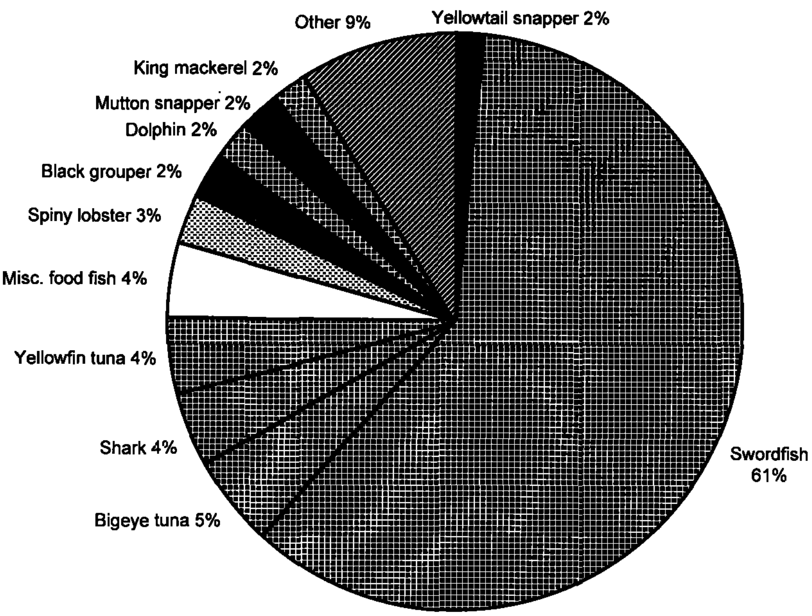

Figure 4

Fish species assemblage, based on the total weight of commercial landings in Broward County during 1989. Pie slices shaded with a crosshatch pattern identify species classified as offshore pelagics (OP), those shown as black identify species classified as members of the grouper-snapper (GS) complex, those shown as white identify unknown miscellaneous fishes (UM), those with a dot pattern identify lobsters (LB) landings, and those with a diagonal line pattern identify other species.

cellaneous food fish accounted for 4.2% of Broward County landings in 1989.

Discussion

The diversity of the Broward County harvest in 1989 was relatively low compared with that of a natural marine fish community in Florida. The tropical reef communities of the Florida Keys are some of the richest in the world; more than 500 fish species have been reported on Alligator Reef alone (Starck, 1968). Species-rich fish communities, however, are not restricted to coral reef habitats. Gilmore (1977) and Gilmore and Hastings (1983) reviewed fish collections associated with the Indian River system. They were able to compile a list of 685 species and projected that more than 700 species should be found in that region. The species richness in those studies varied considerably (26–275 species) from habitat to habitat. Grass flats, inlets, and offshore reefs had the richest fish faunas (>200 species). From offshore continental-shelf habitats alone, more than 170 species were found. Anderson and Gehringer (1965) collected 64 species of fish in 94 hours of trawling over the continental shelf of the Indian River region. Herrema's (1974) marine fish collections from off parts of Broward and Palm Beach counties included 583 species, although many of these are not commercially harvested or are taken in limited number for aquarium collectors. Nevertheless, 76 species of fish and shellfish commercially landed from more than 3,000 fishing trips is a poor representation of the fauna known to be present.

This low species richness is, of course, a reflection of the selectivity of commercial fishing efforts. Only certain sizes of the vulnerable species are available to the gear and only a fraction of these are captured. However, it is unlikely that a catch will be restricted to the two or three species that were landed per trip, on average (Fig. 3) (Fisher et al., 1943). Fishermen keep only the species and sizes that have a market value, discarding all others. The clear seasonal changes in the assemblages landed reflects a balance between changing availability of different fish species to the gear and market values of the various species. Presumably, the commonly landed species were the most valuable. Offshore pelagic species, especially swordfish, were clearly targeted in 1989, as were groupers and snappers. The low summer landings of offshore pelagics may reflect a decrease in availability as swordfish moved out of the fishing area (Hoey[8]) or a decline in market value, or both. An examination of catch records showed no evidence that fishermen who harvest offshore pelagics had switched to another fishery. However, the increase in landings of lobsters by some fishermen who target grouper-snappers and inshore demersals is indicative of a shift to the more valuable lobster fishery when the season opens.

The grouping of trips into distinct clusters that roughly correspond to different habitats indicates a structure among the fishermen, based on what they target. The use of specific gear and fishing sites restricts the diversity of the catch. The fisherman's ability to use different gear (sometimes on the same trip) and visit different sites is a key characteristic of Florida's fisheries. Twenty-five types of gear were registered by Broward County fishermen in 1989. Such unusual combinations as longlining for swordfish and pulling traps for lobster commonly occur on the same trip. Six hundred and ninety-eight of the 907 fishermen registered rod-and-reel as one of the gear types they possessed (not necessarily used). Each fisherman may register more than one type of gear. The fishing potential of each gear is also different. Only 72 fishermen registered surface long lines, but those 72 lines had a total of 29,445 hooks.

Florida also requires special licenses for use of certain gear and for landing some species. Two hundred and eighty-two lobster (crawfish) licenses were issued to Broward County fishermen in 1989 (207 fishermen registered a total of 32,433 traps). Other special licenses included: blue crab (76), stone crab (123), shrimp (2), and purse seine (1).

Species groups identified by the cluster analysis (Table 1) correspond to those that are vulnerable to different gear types. Species in the offshore pelagic group are caught in offshore surface waters with hook-and-line and surface long lines (Berkely et al., 1981). Most of the common groupers and snappers are caught in shallow, nearshore or shelf waters with hook-and-line. Bait fish are found in all surface waters and are caught with small purse seines and lampara nets. Lobsters and stone crabs are found offshore, whereas blue crabs are harvested from inshore and estuarine waters. All three are caught in traps, but lobster are also landed with shrimp in trawls. By having more than one gear type, a fisherman can simply rerig his vessel (and possibly work a different site) and partake of a completely different component of the fishery.

The general negative associations among species is another indication of the selective behavior of commercial fishermen. Since the ideal catch for a fisherman is a monocrop of the most valuable targeted species available, landed assemblages are likely to be as close to that ideal as possible. The catch is sorted and filtered such that the vessel's hold capacity is filled with the greatest amount of the most valuable species caught by the gear (Gulland, 1983). Thus, one would expect some trips to be monospecific, others to include a minimum number of other species. Without detailed information on discards and fisherman behavior, it is difficult to determine if negative associations represent an ecological condition whereby the two species avoid each other (or have different, but overlapping habitat requirements) or if they are an artifact of gear selection and fisherman behavior. Most likely they are the result of a combination of these factors.

The selectivity of the commercial fishing process and the nonrandom sampling of the natural environment makes it extremely difficult to use commercial landings data to gain insight into the natural fish community of a region. The commercial data provide only one component of the mortality affecting a fish community. Landings by recreational fishermen can be substantial (Essig et al., 1991) but are often unavailable. Moreover, fish discarded at sea often represent the largest component of fishing mortality in a region (FAO, 1973); the market values that drive the selection process are often not available with the landings data. Nonrandom spatial and temporal distribution of harvest can yield only biased estimates of fish population sizes, and the extent of that bias cannot be determined.

Conclusions

There was clear structure to the commercial fishery harvest in Broward County during 1989. The low diversity, classification of trips into habitats fished, and negative species associations were clear indications of the selectivity in the system. A rich variety of species were landed by the fishery as a whole, but fishermen focused individual trips on a restricted subset of these species. The multispecies nature of the fishery and the potential for fishermen to exploit different components of the fishery are important features and should be carefully considered when forming management strategies.

These commercial data tell us little about the natural fish community from which the harvest was

[8] Hoey, J. J. 1985. Addendum to the source document for the swordfish fishery management plan, Part I. Prepared by and available from: South Atlantic Fishery Management Council, 1 South Park Circle, Suite 306, Charleston, SC, 132 p.

drawn. All that can be stated with certainty about the biological community is the tautology: the fish that were landed were present at the site where the gear was deployed and were available to the gear used at the time. The biases introduced by the selectivity of this system obscure events in the natural system and provide little insight into the changes in the fish community. However, these data do show a clear structure of the harvest due to fishing behavior and how that structure changes seasonally. The causes of those changes remain unclear. To address this problem, more effort in quantifying discards, recreational fishing mortality, and natural variability is needed, as well as a better understanding of the accessibility and economics driving the social system.

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