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The Role of Targeted Species in Identification of Technological Interactions in Mid-Atlantic Bight Groundfish Fisheries

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Abstract

Data from commercial sea sampling programs are used to examine the relationship between target species sought and the species composition of resulting catches in the mixed species otter trawl fisheries in the Mid-Atlantic Bight. Correlations between species abundances were higher when data were aggregated over an entire trip rather than when tows were examined singly. Based on discriminant function analysis of a subset of the data, tows from trips targeting cod and summer flounder were relatively easily identified by their characteristic species mix, while tows from trips targeting silver hake and squid were more prone to misclassification. These results indicate that trips target species mixes rather than single species with incidental by-catch; and that the predictability of the species composition of those mixes depends on the target.

Key words: Biological sampling, bycatch, Mid-Atlantic Bight, multispecies fishery

Introduction

Otter trawl fisheries in the Mid-Atlantic Bight link a variety of groundfish species through technological interactions. Regional assemblages consist of over- fully- and under-exploited species, including pleuronectids, gadids, scombrids and cephalopods. Currently, most species in the area are managed individually by two federal fisheries management councils and one interstate fisheries commission. Management measures designed to directly affect the target species under one management plan may consistently indirectly affect co-occurring but separately-managed species through these technological interactions. As direct controls reduce fishing mortality in over-exploited segments of a fishery, fishing effort may shift to other available target species and species mixes. The extent to which effort directed toward one species impacts co-occurring species must thus be quantified, in order to develop management regimes that are consistent with goals of all individual fishery management plans.

Analyses of multispecies fisheries interactions in the Mid-Atlantic Bight have been limited in time or in species considered. Murawski *et al.* (1983) considered observations between 1977 and 1979 in a definition of five major fisheries in the area: a shallow water fishery for cod, yellowtail flounder, winter flounder and haddock; an inshore spring fishery for long-finned squid; a mixed-species small mesh fishery off southern New England, landing red and silver hake; a seasonal fishery for migratory species such as scup, butterfish, and summer and winter flounder; and a deepwater winter fishery for summer flounder. Shepherd and Terceiro (1994) described fishery interactions among summer flounder, scup and black sea bass in the Mid-Atlantic Bight. This paper continues and expands that characterization.

The objective of this paper is to identify the relationship between target species sought in Mid-Atlantic Bight fisheries, and the species composition of resulting catches. Does the designation of target species characterize an associated species composition? What characteristics of the fishery operation can be associated with species sought and species caught?

Methods

Data were obtained from the Northeast Fisheries Science Center (NEFSC) Sea Sampling Program. This program has collected detailed catch data from commercial fishing trips on a tow-by-tow basis since 1989. Species catch data (landings plus discard) from otter trawl tows were summarized for eighteen species of invertebrates and finfish of commercial fisheries importance from 1989–94 (Table 1). Data from Cape Hatteras to the southern edge of Georges Bank (Fig. 1; Northeast region U.S. fisheries statistical areas 525–526, 533–543, 611– 636) were used, based on spatial extent of seasonal distributions from historical survey patterns (Gabriel, 1993). Some corresponding information on spatial and gear characteristics was also included,

TABLE 1. Common and scientific names of species included in analysis of Mid-Atlantic Bight fisheries, species name and the mnemonic identifer.

Common name	Scientific name	Mnemonic
Summer flounder	*Paralichthys dentatus*	SUMM
Scup	*Stenotomus chrysops*	SCUP
Black sea bass	*Centropristis striata*	BSB
Long-finned squid	*Loligo pealeii*	LOLI
Atlantic mackerel	*Scomber scombrus*	MACK
Yellowtail flounder	*Pleuronectes ferrugineus*	YTFL
Winter flounder	*Pleuronectes americanus*	WTFL
Windowpane	*Scopthalmus aquosus*	WIND
Silver hake	*Merluccicus bilinearis*	SHAK
Butterfish	*Peprilus triacanthus*	BUTT
Short-finned squid	*Illex illecebrosus*	ILLE
Goosefish	*Lophius americanus*	GOOS
Atlantic cod	*Gadus morhua*	COD
Red hake	*Urophycis chuss*	RHAK
Atlantic herring	*Clupea harengus*	HERR
Spot	*Leiostomus xanthurus*	SPOT
Atlantic croaker	*Micropogonias undulatus*	CROA
Weakfish	*Cynoscion regalis*	WEAK

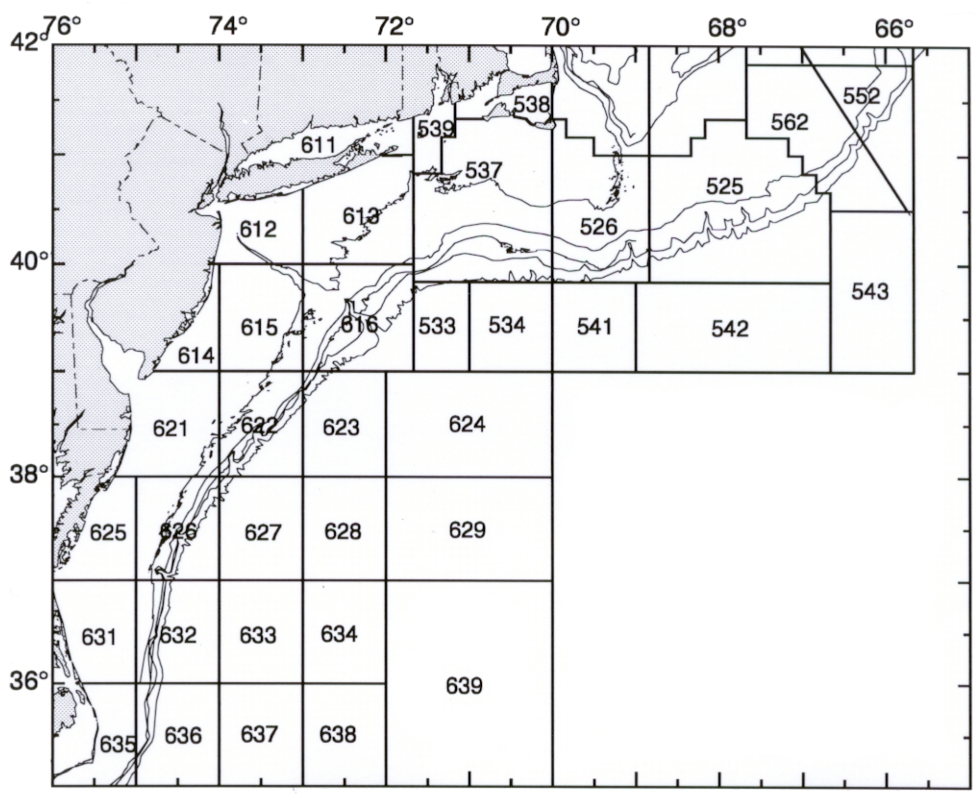

Fig. 1. Northeastern region of the USA fisheries statistical areas. Depth contours correspond to 55, 110, 165, 183 and 914 m.

as well as data on primary species sought, as identified by the vessel captain at the outset of the trip (Table 2). This resulted in a vector of observations of fishery variables and species composition for each sampled tow.

Pearson's coefficient of correlation was calculated for each species pair, based on observations as catch per tow and aggregated as catch per trip (not standardized for tow duration). General linear models (GLM) were used to evaluate the importance of primary species sought (as a categorical variable) on catch per trip of individual species:

$$\ln(\text{catch} + 1) = \alpha + \beta(\text{primspp}) + \varepsilon$$

where catch = catch of species in trip (kg) and primspp = primary species sought on trip. For each species, mean catch rates by primary species sought were compared using Tukey-Kramer tests. When less than four trips targeted a particular primary species, those trips and the primary species were not included in any GLM.

Discriminant function and canonical discriminant function analyses were undertaken to examine how well species composition might correspond predictively to a target species sought, and to determine the relative importance of each species in distinguishing among primary species sought. For that analysis, only observations affiliated with Atlantic cod, silver hake, yellowtail flounder, summer flounder and squid as primary species sought were included, as other categories were non-specific (e.g. finfish) or were undersampled. Discriminant functions were estimated using a random subsample of 75% of the observations, and classification success was evaluated using the remaining observations.

Tows included in the discriminant function analysis were grouped by primary species sought; and median location of tow (degree latitude) and median mesh size of gear used during tow (cm) were calculated. Mesh size was based on the minimum of the size of cod-end mesh or the cod-end liner mesh, if a liner was used.

Results

Correlation coefficients of abundance of species on a tow-by-tow basis were low, but often significant, due to the relatively large number of observations (6 050 tows) (Table 3, lower half of matrix). Absolute magnitude of coefficients ranged from <0.001 to 0.61, with about 80% of the values falling between 0.05 and -0.05. Large positive correlations were observed for weakfish with spot, silver hake with red hake, Atlantic herring with Atlantic mackerel, and windowpane with yellowtail flounder and winter flounder. Positive correlations were also observed between long-finned squid, butterfish and short-finned squid. Smaller positive

TABLE 2. Fishery characteristics included as variables in analysis of Mid-Atlantic Bight fisheries. NS = Non-specific.

Spatial Characteristics	Gear Characteristics	Primary Species Sought
Area	Codend mesh size	Atlantic cod
Latitude	Net liner mesh size	Silver hake
		Witch flounder
		Yellowtail flounder
		Winter flounder
		Haddock
		White hake
		Summer flounder
		Flatfish (NS)
		Groundfish (NS)
		Atlantic herring
		Atlantic mackerel
		Butterfish
		Tuna
		Pelagic (NS)
		Skate
		Dogfish
		Finfish (NS)
		Lobster
		Crab
		Squid
		Unknown

TABLE 3. Correlation coefficients for selected species based on sea sampling of otter trawl trips in the Mid-Atlantic Bight. The upper right half of the matrix includes coefficients based on tows summed over trips (N = 483); the lower left half of the matrix includes coefficients based on individual tows (N = 6 050). Significant correlations (p >0.05) are in bold type. (See Table 1 for species mnemonics.)

	SUMM	SCUP	BSB	LOLI	MACK	YTFL	WTFL	SPOT	CROA	WIND	SHAK	BUTT	ILLE	GOOS	COD	RHAK	HERR	WEAK
SUMM	*	-.01	**.21**	-.00	-.02	-.06	**-.09**	-.02	-.01	-.06	-.05	-.01	-.02	-.03	-.06	-.02	0.04	-.03
SCUP	**-.03**	*	**.23**	**.12**	-.01	-.06	-.04	-.02	-.03	-.05	.03	.05	-.02	-.02	-.05	.04	-.02	-.02
BSB	**.04**	**.06**	*	**.11**	-.01	-.03	-.06	-.02	-.02	-.04	-.01	-.00	-.01	-.02	-.04	-.02	.01	-.02
LOLI	**-.08**	.02	**.03**	*	-.02	-.06	-.07	-.03	-.03	-.07	.05	**.34**	**.59**	-.03	-.06	**.14**	-.03	-.03
MACK	-.02	-.01	-.00	-.02	*	-.02	-.03	-.01	-.01	-.02	-.02	-.02	-.01	-.02	-.02	-.01	**.81**	-.01
YTFL	**-.09**	**-.03**	-.02	**-.06**	-.01	*	.03	-.02	-.02	**.36**	-.01	-.04	-.01	-.00	.06	-.01	-.02	-.03
WTFL	**-.14**	**-.03**	**-.03**	**-.08**	-.02	.02	*	-.03	-.03	**.19**	-.01	-.02	-.02	-.04	**.15**	-.02	-.03	-.05
SPOT	-.02	-.01	-.00	-.02	-.00	-.01	-.02	*	.07	-.02	-.03	-.01	-.01	-.02	-.02	-.03	-.01	**.80**
CROA	-.01	-.01	-.01	-.02	-.00	-.01	-.02	**.04**	*	-.02	-.04	-.02	-.01	-.02	-.02	-.04	-.02	.02
WIND	**-.10**	**-.03**	-.02	**-.08**	-.01	**.21**	**.11**	-.01	-.01	*	-.06	-.04	-.01	-.03	**.18**	-.07	.00	-.02
SHAK	**-.07**	.01	-.00	-.01	-.01	**-.03**	-.01	-.01	-.02	**-.05**	*	.08	.02	.02	-.06	**.56**	.01	-.04
BUTT	**-.04**	.01	-.00	**.11**	-.01	**-.03**	-.02	.00	-.01	**-.04**	.02	*	**.30**	-.01	-.04	**.18**	-.03	-.02
ILLE	**-.04**	-.01	-.01	**.18**	-.00	-.02	-.02	-.00	-.01	-.02	-.00	**.06**	*	.01	-.01	**.15**	-.01	-.01
GOOS	**-.04**	-.02	-.02	**-.06**	-.01	-.02	**-.06**	-.01	-.02	**-.05**	-.02	-.02	-.01	*	-.03	.01	-.03	-.03
COD	**-.10**	**-.03**	-.02	**-.07**	-.01	.01	**.04**	-.01	-.01	**.08**	**-.05**	**-.03**	-.02	**-.05**	*	-.06	.02	-.03
RHAK	**-.05**	.01	.01	**.03**	-.01	-.02	-.02	-.01	-.02	**-.05**	**.40**	**.06**	-.01	-.01	**-.05**	*	-.03	-.05
HERR	-.02	-.00	.02	-.02	**.31**	-.01	-.01	-.00	-.01	.01	.01	-.01	-.01	-.02	-.01	.01	*	-.02
WEAK	-.02	-.00	-.01	-.02	-.00	-.01	-.02	**.61**	.02	-.01	-.02	-.01	-.01	-.02	-.00	-.02	-.01	*

correlations were observed for scup with black sea bass, Atlantic cod with windowpane and red hake with butterfish. The largest negative correlations were observed for summer flounder with winter flounder, windowpane, Atlantic cod, and yellowtail flounder. Other negative correlations were observed for long-finned squid with yellowtail flounder, winter flounder, windowpane flounder, goosefish and Atlantic cod.

When component tows were aggregated over trip (N = 483) and analyzed, correlations became more positive (Table 3, upper half of matrix). Absolute magnitude of coefficients ranged from <0.001 to 0.80. Although the number of significant positive correlations increased only marginally (from 14 to 16, p >0.05), the number of significant negative correlations dropped from 29 to 1. The total number of positive correlations increased from 29 to 36, and positive correlations had higher values at the trip level than at the tow level. In some cases, the significance level of the correlation could be observed to increase, e.g. correlations between black sea bass and summer flounder and between short-finned squid and scup were stronger at the trip level than at the tow level. In other cases, correlations at tow and trip levels were already highly significant (p >0.0001); thus the interpretation of the increase in those correlations at the trip level can only be qualitative. Species associations at the trip level can thus arise from the aggregation of tows over the course of the trip, rather than from continuous simultaneous co-occurrence of those species over the range of the trip.

Primary species sought had a significant effect on single species catch per trip for each species analyzed (p >0.05, Table 4). The strongest effects of primary species sought on individual species catch rates were observed for Atlantic cod, yellowtail flounder, and summer flounder, followed by long-finned squid, silver hake, butterfish, window-pane, weakfish, winter flounder, and red hake. Although winter flounder and silver hake could be designated as a potential primary species sought, the relationships between catch rate and target species designation were not as strong for these species. The effect of primary species sought appeared smallest for short-finned squid and croaker, followed by goosefish and black sea bass.

Catch rates of individual species usually were significantly different (higher) in trips targeting the individual species as the primary species sought, based on results of Tukey HSD tests (ln-transformed catch rates) and inspection of tables of arithmetic means of catch per trip by individual species caught and primary species sought (Table 5). For example, directed Atlantic mackerel catch per trip was significantly different from Atlantic mackerel catch

TABLE 4. Results of general linear models of ln (catch per trip +1) as a function of primary species sought, for eighteen finfish and invertebrate species, Mid-Atlantic Bight. Primary species targets for which less than four trips were observed were excluded (haddock, witch flounder, white hake, Atlantic herring, pelagic (NS), and lobster) together with associated trips, for a total of sixteen levels of target species/species groups effects and 474 observations (see Table 1.)

Catch species	R^2	F	Significance
Atlantic cod	.518	32.77	p >0.0001
Yellowtail flounder	.505	31.21	p >0.0001
Winter flounder	.269	11.20	p >0.0001
Windowpane	.282	11.99	p >0.0001
Silver hake	.295	12.76	p >0.0001
Red hake	.262	10.85	p >0.0001
Summer flounder	.461	26.10	p >0.0001
Scup	.207	7.97	p >0.0001
Black sea bass	.136	4.79	p >0.0001
Short-finned squid	.333	15.24	p >0.0001
Long-finned squid	.055	1.78	p >0.0344
Butterfish	.286	12.23	p >0.0001
Atlantic mackerel	.215	8.38	p >0.0001
Atlantic herring	.190	7.15	p >0.0001
Goosefish	.116	3.99	p >0.0001
Spot	.233	9.26	p >0.0001
Atlantic croaker	.078	2.58	p >0.0010
Weakfish	.281	11.95	p >0.0001

Species Caught	Species Sought															
	Atlantic Cod	Yellowtail flounder	Winter flounder	Summer flounder	Silver hake	Squid	Butter-fish	Atlantic Mackerel	Skate	Dogfish	Tuna	Crabs	Flatfish	Groundfish	Finfish	Unknown
Atlantic cod	**2 861.1**	**267.3**	**517.3**	**0.6**	**4.6**	**4.0**	**35.7**	**1.6**	**6.6**	**0**	**1.3**	**0**	**12.0**	**128.9**	**5.6**	**22.0**
	3 996.0	556.9	1 167.7	5.1	12.4	28.3	107.2	3.6	9.6	0	2.5	0	21.3	428.8	16.3	95.7
Yellowtail flounder	**200.8**	**4 266.6**	**112.4**	**11.3**	**94.3**	**45.9**	**10.8**	**0.4**	**8.2**	**0**	**18.8**	**0**	**41.4**	**154.8**	**19.1**	**97.3**
	435.7	6 639.9	290.3	49.6	368.7	201.2	23.0	0.4	16.3	0	37.9	0	100.6	544.7	89.6	346.1
Winter flounder	**442.9**	**329.7**	**259.2**	**24.8**	**119.3**	**108.0**	**169.0**	**0**	**46.0**	**0**	**233.1**	**0.3**	**1 037.4**	**102.6**	**30.7**	**26.1**
	855.6	499.3	232.7	120.7	213.0	377.7	435.4	0	54.7	0	577.9	0.7	1 811.2	212.9	100.4	63.1
Window-pane	**322.2**	**863.6**	**561.7**	**38.3**	**9.8**	**53.1**	**33.9**	**0.1**	**49.0**	**17.6**	**26.8**	**39.5**	**63.8**	**112.9**	**22.6**	**26.7**
	523.9	1 707.7	1 346.3	110.6	21.3	301.3	100.9	0.2	54.0	26.4	79.6	76.2	80.1	494.7	67.7	70.0
Silver hake	**108.7**	**1 135.8**	**99.1**	**928.3**	**8 103.0**	**1 428.7**	**1 060.6**	**8.4**	**565.3**	**58.7**	**4 265.4**	**8.1**	**157.3**	**1 761.9**	**695.6**	**2 165.9**
	346.3	3 375.3	233.6	4 210.2	12 617.0	3 659.0	974.7	12.4	1 085.7	127.9	9 072.0	15.2	274.0	3 926.7	1 520.2	3 379.1
Red hake	**23.9**	**371.2**	**2.5**	**299.8**	**2 077.1**	**485.5**	**1 026.6**	**0**	**14.5**	**4.8**	**356.6**	**2.7**	**83.7**	**688.2**	**92.0**	**334.8**
	80.2	1 094.0	7.2	1 260.0	2 849.6	1 200.2	1 359.7	0	29.0	11.1	766.4	5.7	215.7	1 623.9	302.2	847.5
Summer flounder	**11.8**	**18.3**	**42.1**	**1 588.2**	**37.8**	**122.5**	**211.5**	**0**	**5.7**	**42.0**	**20.9**	**105.4**	**206.7**	**229.9**	**106.6**	**459.4**
	50.2	37.4	119.8	1 950.4	148.6	302.2	413.9	0	10.2	72.1	57.7	65.1	488.1	1 181.9	345.0	958.8
Scup	**54.5**	**20.3**	**111.2**	**171.4**	**192.8**	**1 303.6**	**243.9**	**0**	**1.8**	**5.0**	**495.3**	**0.4**	**122.0**	**994.3**	**993.9**	**1 631.9**
	222.7	125.9	188.9	387.9	670.7	2 890.1	636.5	0	3.6	7.9	1 485.8	0.7	309.8	2 523.4	2 862.7	2 504.1
Black sea bass	**4.7**	**0.5**	**1.6**	**81.9**	**24.6**	**59.2**	**4.7**	**0**	**0**	**2.0**	**0.6**	**0.6**	**16.0**	**28.4**	**65.8**	**70.6**
	23.5	2.0	3.2	310.7	151.6	204.7	8.7	0	0	2.2	1.8	1.0	44.9	89.1	180.6	207.3
Short-fin. squid	**93.9**	**98.8**	**70.7**	**275.9**	**498.0**	**6 647.9**	**3 529.8**	**12.9**	**632.3**	**38.8**	**603.0**	**11.1**	**200.8**	**794.7**	**450.9**	**4 290.6**
	455.6	462.6	160.5	581.4	1 284.4	10 071.0	5 326.9	12.3	1 261.6	62.7	1 627.4	22.7	582.5	1 723.9	919.4	5 780.9
Long-fin. squid	**0.9**	**25.0**	**0**	**5.6**	**165.9**	**3 667.4**	**53.7**	**2.5**	**0**	**2.0**	**103.7**	**36.7**	**0.2**	**141.6**	**6.6**	**24.1**
	2.7	98.7	0	21.6	679.0	24 880.0	105.2	5.7	0	5.6	146.8	97.2	0.8	900.2	20.7	56.5
Butterfish	**12.0**	**115.6**	**41.1**	**118.5**	**435.5**	**1 325.5**	**10 952.0**	**5.7**	**70.9**	**4.2**	**1 003.1**	**32.6**	**21.5**	**897.9**	**407.7**	**1 018.2**
	38.6	429.2	134.4	318.0	1 031.7	3 289.8	19 055.0	12.5	108.5	8.5	2 009.5	55.8	63.7	2 700.2	950.9	1 632.0
Atlantic mackerel	**48.9**	**31.7**	**37.9**	**513.7**	**100.3**	**298.3**	**481.4**	**123 759.0**	**0.3**	**1 551.7**	**9.9**	**0**	**0.2**	**275.4**	**173.4**	**89.3**
	118.0	141.4	122.5	2 437.5	310.7	1 497.6	1 139.1	138 506.0	0.7	3 628.7	29.6	0	0.8	1 074.3	809.9	331.6
Atlantic herring	**225.9**	**57.6**	**51.3**	**62.8**	**311.8**	**63.1**	**133.7**	**8 224.4**	**4.9**	**0**	**0.1**	**3.1**	**42.8**	**59.5**	**7.1**	**17.5**
	1 024.3	158.3	130.1	250.5	793.4	289.8	228.4	7 711.7	9.7	0	0.2	5.5	124.3	201.8	19.5	41.0
Goosefish	**79.4**	**218.9**	**51.7**	**348.0**	**114.8**	**212.1**	**181.3**	**0.6**	**13.1**	**17.1**	**6 682.1**	**1.9**	**21.5**	**1 576.1**	**57.7**	**277.0**
	167.1	441.3	106.4	701.2	166.1	1 008.9	240.3	1.4	10.2	32.7	12 372.0	3.6	28.6	4 531.0	152.4	471.4
Spot	**0**	**0**	**0**	**13.9**	**0**	**0.1**	**0**	**0**	**0**	**0**	**0**	**5.1**	**3.3**	**2.3**	**310.6**	**47.0**
	0	0	0	43.7	0	0.7	0	0	0	0	0	13.5	9.0	17.8	981.5	215.4
Atlantic croaker	**0**	**0**	**0**	**15.1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**19.2**	**10.3**	**0**	**1.4**	**8.0**
	0	0	0	75.1	0	0	0	0	0	0	0	50.9	30.8	0	3.9	36.6
Weakfish	**1.4**	**0**	**0**	**21.0**	**<0.1**	**11.4**	**10.9**	**0**	**0**	**0.3**	**0**	**6.0**	**2.4**	**2.1**	**449.4**	**11.7**
	5.9	0	0	111.2	0.2	33.7	22.9	0	0	1.0	0	10.6	6.9	8.9	741.7	35.4
No. of trips	25	50	11	85	49	77	9	5	4	8	9	7	9	83	22	21
No. of tows	439	785	80	1 364	366	1 018	138	35	16	67	102	55	119	933	161	933

per trip when other species were targeted, e.g. Atlantic cod, silver hake, etc. This pattern was also observed for Atlantic cod, yellowtail flounder, winter flounder, silver hake, summer flounder, long-finned squid, and butterfish. Not every pairwise comparison of directed to non-directed catch rates (Tukey HSD, $\alpha = 0.05$) was significant, however, particularly where sample size was relatively small. Nine trips targeting butterfish yielded catch rates of butterfish statistically similar to those targeting squid and "unknown" species. Four trips targeting skate yielded catch rates of silver hake, squid and winter flounder statistically similar to levels observed in trips targeting those species. Non-significant differences were observed between winter flounder catch rates for trips targeting cod, yellowtail flounder, tuna (pair-trawling), and butterfish *vs* eleven trips targeting winter flounder. Seven trips targeting crabs yielded catch rates of summer flounder statistically similar to trips targeting summer flounder under the Tukey HSD test on log transformed data (although this difference was not observed in untransformed data.)

The effects of primary species sought extended to catch rates of non-target species as well. Catch rates of herring in trips targeting Atlantic mackerel were significantly different from rates in trips targeting all other species/species groups, as were catch rates of red hake in trips targeting silver hake. Catch rates of windowpane in trips targeting cod or yellowtail flounder were significantly different from rates in trips targeting silver hake, summer flounder, mackerel, butterfish, tuna, squid, groundfish (NS), finfish (NS) and "unknown" groups. Catch rates of scup in trips targeting summer flounder, squid and groundfish (NS) differed from trips targeting cod, silver hake and yellowtail flounder. These examples indicate that identification of target species has implications for catch rates of non-target species as well as target species.

A discriminant function analysis, used to describe the relationship between species composition and designated primary species sought, showed patterns similar to those obtained from univariate single species GLMs. The results should be considered descriptive, because covariance matrixes were not homogeneous. Functions based on observations at the trip level were not evaluated because the number of observations (N = 211, a 75% subset of trips targeting Atlantic cod, silver hake, yellowtail flounder, summer flounder or squid) used to develop the functions was too small. In the case of functions based on observations at the tow level (N= 3,013), the test subset of 959 observations had an overall misclassification rate of 32.4% (Table 6). The highest percentage correct classification rate for the five potential target species examined was obtained for trips where Atlantic cod were designated as primary species sought (92% of trips correctly classified). Criteria for identifying summer flounder as primary species sought was second most accurate, with up to 87% of trips correctly classified, and about 7% of trips misclassified as targeting Atlantic cod, 3% misclassified as targeting silver hake, 2% targeting squid and 1% targeting yellowtail flounder. Lower accuracy rates were obtained for functions to identify trips targeting yellowtail flounder: while 66% of those were correctly identified to target yellowtail flounder, 28% were misidentified as targeting Atlantic cod. Only 50% of the trips targeting squid were correctly classified, with misclassification primarily to summer flounder (21%) and silver hake (13%) targets. Identification of tows targeting silver hake was most problematic, with only 43% of tows correctly identified, about 24% each misidentified as targeting summer flounder and yellowtail flounder, and 5% each among squid and Atlantic cod targets.

TABLE 6. Summary of classification results for reserved subset of data, based on discriminant function analysis to separate trips by primary species sought, including Atlantic cod, silver hake, yellowtail flounder, summer flounder and squid.

	Classified into					
Classified from	Atlantic cod	Silver hake	Yellowtail flounder	Summer flounder	Squid	Total (N)
Atlantic cod	91.67	2.78	3.70	0.93	0.93	103
Silver hake	4.65	43.02	24.42	23.26	4.65	86
Yellowtail flounder	27.71	2.14	66.31	2.14	1.60	187
Summer flounder	7.44	2.68	0.60	86.90	2.38	336
Squid	8.68	12.81	7.02	21.49	50.00	242
Error count by primary species	8.33	56.98	33.69	13.10	50.00	32.42

The first two canonical variables from canonical discriminant analysis accounted for 67% of the variance in the variance-covariance matrix of species catch (by tow) and in the five primary species sought (Table 7). All canonical correlations were significant (p >0.0001). The first canonical variable separated Atlantic cod, winter, yellowtail and windowpane flounder (large positive coefficients) from summer flounder (large negative) (Fig. 2) and contrasted Atlantic cod and yellowtail flounder *vs* summer flounder as primary species sought. The second canonical variable contrasted long-finned squid, co-occurring scup and to a lesser extent, silver hake, with Atlantic cod and flounder species, including summer flounder. The third canonical variable separated yellowtail flounder (as primary species sought) and co-occurring windowpane from Atlantic cod and co-occurring winter flounder. The fourth canonical variable separated silver hake as primary species sought, with co-occurring red hake, from other species.

The first canonical variable appears to represent a difference between eastern and western large mesh fisheries. Because the continental shelf extends southwestward in this region (Fig. 1), those westward distributions would also reflect large southward components. The second variable may reflect a gradient from small-mesh fisheries to large-mesh fisheries associated with primary species sought. These interpretations are suggested by a plot of median latitude *vs* median mesh size of tows by primary species sought (Fig. 3), which shows a pattern of separation similar to that generated by the scores for canonical variables plotted in Fig. 2.

Discussion

While species associations at the tow level are likely to reflect smaller scale ecologically-based patterns of co-occurrence, species associations defined at the trip level may additionally reflect fleet behavior patterns. The degree of overlap in distributions of summer flounder, scup, and black sea bass varies seasonally, depending on individual species migration patterns (Shepherd and Terceiro, 1994). Shepherd and Terceiro (1994) also noted that even within a particular season and area, small scale differences in habitat usage would separate species, e.g. although summer flounder, scup and black sea bass would occur in inshore shallow waters, summer flounder would occupy sand bottom habitats while scup and black sea bass would be found in hard bottom, structured habitats. In this study, stronger affiliations were observed on a trip-by-trip basis than on a tow-by-tow basis for nearly all species. Fishermen thus may be changing areas fished to catch a mixture of species in nearby habitats, rather than (or in addition to) simply accumulating a mixture of species over a wide

TABLE 7. Pooled within-class standardized canonical coefficients, descriptive statistics: canonical discriminant analysis of species composition of tows and associated primary species sought.

	Canonical Coefficients			
Species	Variate 1	Variate 2	Variate 3	Variate 4
Summer flounder	-0.820	-0.220	-0.020	0.011
Scup	0.074	0.341	-0.138	-0.116
Black sea bass	-0.057	0.010	-0.000	0.012
Long-finned squid	0.138	0.631	-0.260	-0.287
Atlantic mackerel	-0.071	0.020	-0.050	-0.087
Yellowtail flounder	0.235	-0.225	0.453	-0.268
Winter flounder	0.269	-0.126	-0.392	0.117
Windowpane	0.210	-0.206	0.368	-0.304
Silver hake	0.062	0.136	0.207	0.491
Butterfish	-0.000	0.096	-0.030	-0.056
Short-finned squid	0.016	0.086	-0.030	-0.030
Goosefish	-0.004	0.070	0.010	-0.090
Atlantic cod	0.325	-0.484	-0.680	0.193
Red hake	0.107	0.015	0.237	0.525
Atlantic herring	0.040	0.014	0.008	0.181
Adjusted canonical correlation	0.695	0.603	0.527	0.506
Eigenvalue	0.946	0.580	0.395	0.344
Proportion of variance	0.418	0.256	0.174	0.152
Cumulative proportion of variance	0.418	0.674	0.848	1.000

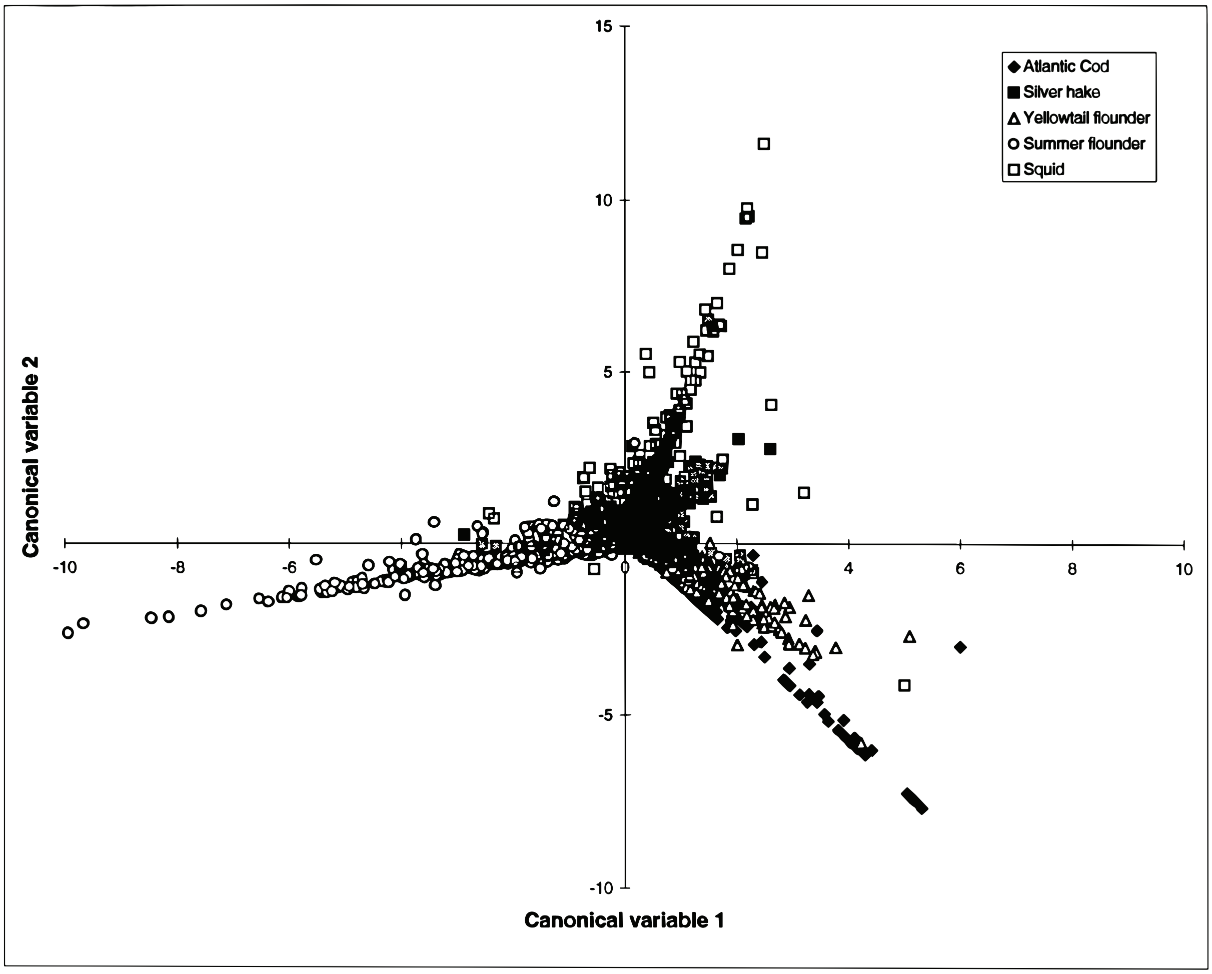

Fig. 2. Separation of tows based on scores for first and second canonical variables from canonical discriminant analysis, which summarizes variation in species composition between classes of primary species sought. Symbols are for classes of primary species sought.

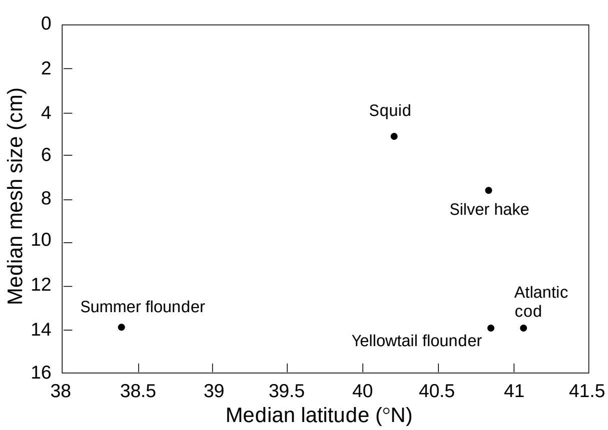

Fig. 3. Median latitude and median mesh size (including cod-end liners) of tows summarized by primary species sought.

range of bottom types in the course of a single tow. Effects of technological interactions may potentially be overestimated when based on observations aggregated at the trip level. The development of a commercial fishery catch assemblage from subsets of the ecological assemblage is consistent with theoretical models of fleet behavior which indicate the benefits of spreading effort over a variety of different fishing "zones" (Allen and McGlade, 1986).

For this gear and region, the primary species sought characterizes the catch rates of both target and non-target species. This is consistent with empirical observations that these fishers view areas in terms of species mixes obtainable there (Clay, MS 1993). The predictability of species composition given primary species sought is higher for species targeted by large-mesh fisheries: Atlantic cod, yellowtail flounder, and summer flounder. From an ecological perspective, the distributions of most species caught in small-mesh fisheries are influenced by temperature, and seasonal migration patterns (Murawski, 1993). Distributions of those species are likely to be more dynamic and less predictable than distributions of more sedentary Atlantic cod and northern flounder species. Consequently, small mesh fisheries may be much more opportunistic and reflective of species availability in the time and area of the trip.

The use of captains' designations of primary species sought has generally not been extensively evaluated as a basis for defining fishing practices as metiérs or strategies (gear/target species/areal combinations: e.g. Laurec *et al.*, 1991; Rogers and Pikitch, 1992). Rogers and Pikitch (1992) found that for trawl fisheries off the coasts of Washington and Oregon, fish assemblages defined from catches corresponded to identified strategies for 48–99% of the associated tows, depending on analytic technique and strategy. They attributed misclassification errors to misidentification of strategy in the field, in which the strategy was identified by an observer only in terms of gear type and water depth, omitting the target species component; or to ineffective targeting. Similar to this study, they found that the correspondence between target and species catch composition varied as a function of target. For the Mid-Atlantic region, however, there are preliminary indications (Fig. 2 and 3) that mesh size and area might perform as well as primary species sought in explaining variation in species composition, a topic which could be further evaluated.

Potential inconsistencies in definition of primary species sought require cautious interpretation of these results. While primary species sought was intended to have been defined by the captain at the outset of the trip under this data collection system, target species and species groups may have shifted in the course of the trip, e.g. apparently from pair trawling for tuna to trawling for groundfish in several cases. In other cases, the target may have been identified after the trip, reflecting realized species composition. This would either lead to artificially poorer or better predictability of species compositions from primary species sought, depending on which scenario was applicable. (Under a revised protocol, the target species is now identified at the outset of each tow.)

Based on current results, significant technological interactions occur among species managed under at least three regional fishery management plans. Species that co-occur on a trip basis may be managed under different management plans, with potentially conflicting objectives and regulations. While a multispecies approach identifies likely conflicts between management plans, it may also enable the evaluation of the effect of management measures on different fishery sectors (e.g. in terms of species targets/metiérs and the relative impacts on different fleet components which exploit them) (Brugge and Holden, 1991).

Changes in technological interactions may be expected to arise in response to regulatory effects. Various forms of direct controls have been implemented, to date primarily for the management of summer flounder and New England groundfish. If effort is simply redirected toward alternative target species following recent patterns, the impact of that effort on co-occurring species could be evaluated. These analyses indicate some potential to map fishing mortality on the target species into fishing mortality on co-occurring species. As noted by Gulland (1991), however, the future usefulness of models of technological interaction as forecasting tools for management will depend on accurate predictions of fishermen's responses to regulation.

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