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Factors Influencing Technological Interactions in Mid-Atlantic Bight Groundfish Fisheries

by

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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. Other characteristics of the fishery operation are also examined with respect to their effects on species catch rates in the region. Correlations between species abundances are higher when data are aggregated aver an entire trip rather than when tows are examined singly. Areal and temporal factors are significant influences on individual species catches, which may serve as a basis for reducing by-catches. Based on preliminary discriminant function analysis of a subset of the data, tows from trips targetting cod and summer flounder are most easily idenified by their characteristic species mix rather than tows from trips targetting silver hake and yellowtail flounder. This may in part arise if individual species distributions are more highly variable or if the skipper modifies and expectation of primary species/species mix during the trip.

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 consequently 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, it may be expected that 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 to date 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 1977-1979 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 deepwater winter fishery for summer flounder. Shepherd and Terceiro (in press) described fishery interactions between summer flounder, scup and black sea bass in the Mid-Atlantic Bight. This paper represents work in progress to continue and expand 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 are associated with species sought and species caught?

Gear Selectivity/Technical Interactions Symposium

METHODS

Data were obtained from the Northeast Fisheries Science Center Sea Sampling Program.This program has collected detailed catch data from commercial fishing trips on a tow-by-tow basis, from 1989-1992. Species catch data (landings plus discard) were summarized by otter trawl tow for fifteen species of invertebrates and finfish of commercial fisheries importance (Table 1). Data from Cape Hatteras to the southern edge of Georges Bank (Figure 1)were used, based on spatial extent of seasonal species assemblage distributions of Mid-Atlantic Bight species distributions from historical survey patterns (Gabriel 1993). Some corresponding information on temporal, spatial and gear characteristics was also included, 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 tow.

Descriptive statistics were calculated for each species as catch per tow and catch per trip (not standardized for tow duration). To explore potential relationships of temporal, spatial, gear,and target species effects on catch rates of individual species, a general linear model (GLM) was fitted for each effect-species combination. Preliminary discriminant function and canonical discriminant function analyses were undertaken to examine how well species composition might predict a target species sought. For that analysis, only observations affiliated with 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 undersampled. Statistical analyses were performed using SAS programming packages for UNIX.

RESULTS AND DISCUSSION

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 (5297 tows)(Table 3). Absolute magnitude of coefficients ranged from 0.001 to 0.208, with about 70% of the values with an absolute value of less than 0.05 ($p > 0.001$). The largest negative correlations were for summer flounder with several species including yellowtail, winter and windowpane flounder, Atlantic cod, silver hake, red hake and long-finned squid. Large negative correlations were observed for long-finned squid with yellowtail flounder, winter flounder, windowpane flounder, goosefish and Atlantic cod. Other negative correlations were observed for goosefish with winter flounder, windowpane flounder and Atlantic cod; for windowpane flounder with silver hake and red hake; and for cod with silver hake and red hake. Large positive correlations were observed for summer flounder with black sea bass, butterfish with long-finned squid, herring with mackerel, yellowtail flounder with windowpane flounder, windowpane with winter flounder and cod, silver hake with red hake and short-finned squid, and red hake with butterfish and short-finned squid.

Correlation coefficients of abundance based on 392 trip observations showed fewer significant relationships; over 85% of the relationships would not be significant ($p > 0.001$), compared to about 70% on a tow-by-tow basis. As found by Shepherd and Terceiro (in press), correlations for summer flounder with black sea bass abundance became very strong, as did correlations for scup with black sea bass and short-finned squid. Other large positive correlations listed earlier also persisted at the trip level, e.g., correlations for cod with winter flounder and windowpane flounder emerged more strongly, but correlations for red hake with butterfish and short-finned hake disappeared (at comparable significance levels). Significant negative correlations observed at the disaggregated (tow) level were not observed when aggregated over trip.

As pointed out by Shepherd and Terceiro (in press) for summer flounder, scup and black sea bass, species that appear affiliated on a trip-by-trip basis may not be affiliated as strongly on a tow-by-tow basis. Thus, effects of technological interactions may sometimes be overestimated when based on observations aggregated at the trip level, as fishermen may instead be making changes in areas fished (for example) to catch other species in nearby habitat. Alternatively, species may be co-distributed, but not necessarily in the linear pattern required for identification using linear correlations.

Results of general linear model analysis yielded relatively low R^2 values for most models(Table 4), although F values might indicate statistically significant model effects. (High F values arise in this case due to the large number of observations contributing to a large man square error relative to main effects). In fact, tows in these analyses are not independent observations,as a cluster effect due to trip-related features (skipper, vessel, gear configurations, weather)is also operating. A revised analysis based on data aggregated at the trip level may be more appropriate. Some patterns emerge from GLM results that may warrant additional investigation, as well.

Year effects were relatively larger for summer flounder and yellowtail flounder, two overexploited flatfish species with truncated age structure: year effects likely reflect most recent recruitment patterns, e.g., failure of the 1988 year class of summer flounder, followed by two years of fair recruitment, for example. Especially stronger seasonal components were observed for summer flounder, reflecting higher catch rates in winter seasons of a directed fishery, and a more diffused distribution of the species in summer months. Seasonal patterns of availability may also operate for winter and windowpane flounder, both estuarine spawners. Effect of area on catch rates were implied for many species, reflecting spatial distribution patterns of fish and effort, e.g., concentration of summer flounder trips and landings from southern areas, vs. northern-most areas for Atlantic cod, offshore areas for goosefish and central statistical areas (statistical areas 612-623) for long-finned squid. Preferred depth zones for either fish and/or the fishery are reflected for shallow water species (winter flounder, windowpane flounder, depth zone 1, 0-30 fm), inner shelf species (long-finned squid, butterfish, depth zone 3, 45-60 fm), mid-to outer shelf species (silver hake,red hake, depth zone 4, 60-100 fm), and species caught along the shelf break (short-finned squid, goosefish, depth zones 5-6, > 100 fm). Extreme southern and northern distributions of summer and winter flounder and Atlantic cod are reflected by latitude effects, as are more northern distributions of yellowtail and windowpane flounder. While longitude effects for long-finned squid may reflect concentrations of sampling and distribution off Long Island, effects for silver hake appear to arise from a few large values in one relatively poorly-sampled cell. Port effects likewise reflect areal distribution patterns in the case of summer and windowpane flounder; however, strong port effects for Atlantic mackerel and herring may arise as a few very large trips were landed in only a few ports. Cluster sampling effects also arise in evaluation of effects of gear characteristics: effects of gross registered tonnage of vessel appears a trip/vessel effect in many cases, as the number of observations (tows) in many tonnage class cells are low (1-20). Tonnage class levels should be pooled in future analyses to avoid this problem. This condition also applies to analyses of liner and footrope length effects: further inspection of gear-catch rate relationships and alternative levels of aggregation should be considered in future analysis.

The effect of primary species sought appeared smallest for black sea bass and short-finned squid, followed by scup and butterfish. The apparently large effect of species sought on goosefish catch rates is likely an artifact: 37 tows were associated with tuna as primary species sought, which included one very large reported catch of goosefish, making the mean catch rate within that cell very large. Otherwise, the strongest relationships between primary species sought and individual species catch rates were observed for summer flounder, long-finned squid, Atlantic mackerel, Atlantic cod and Atlantic herring. Although yellowtail flounder, winter flounder and silver hake could be designated as a potential primary species sought, the relationships between catch rate and target species designation are not as strong for these species.

A preliminary discriminant function analysis, used to describe the relationship between species composition and designated primary species sought, showed patterns similar to those obtained from univariate GLMs. The results are considered preliminary and descriptive, because covariance matrixes were not homogeneous and because all observations were used to generate the classification functions (biasing misclassification rates downwards). Out of five potential target species (cod, sliver hake, yellowtail flounder, squid), the highest percentage correct classification rates were obtained for tows where cod or summer flounder were designated as primary species sought (90% or more tows correctly classified)(Figure 2). Criteria for identifying squid as primary species sought was third most accurate, with up to 58% of tows correctly classified, and about 24% of tows misclassified as targeting summer flounder and 10% misclassified as targeting cod. A similar accuracy rate was obtained for functions to identify twos targeting yellowtail flounder: while 56% of those were correctly identified to target, 36% were misidentified as targeting cod. Identification of silver hake tows was most problematic, with only 45% of tows correctly identified, 22% misidentified as targeting yellowtail founder and 20% misidentified as targeting summer flounder. Indications of these results are displayed graphically in Figures 3-5, as summarized from canonical discriminant analysis.

The sometimes poor relationship between species composition of catch and primary species sought may arise if co-occurring species have highly variable or patchy distribution patterns, or if a relatively rarer species is sought but more common species are caught in the process, or if the skipper modifies an expectataion of primary species sought as the trip progresses. The latter possibility may be very likely but not reflected in data available.

The results to date indicate the need to be concerned for the need for multispecies management across at least three regional fishery management plans, to address technological interactions among yellowtail flounder, winter flounder, and windowpane flounder associated with the Atlantic cod fishery; among silver hake, red hake, butterfish, and long-finned squid in the silver hake and squid fisheries, and interactions between the silver hake and yellowtail flounder fisheries, to maximize positive impacts of potential direct controls in those fisheries. The addition of additional temporal and spatial features in further defining these fisheries appears promising.

References

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Murawski, S., A. Lange, M. Sissenwine, and R. Mayo. 1983. Definition and analysis of multispecies otter trawl fisheries off the Northeast Coast of the United States. J. Cons. Int. Explor. Mer. 41: 13-27.

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Table 1. Common and scientific names of species included in analysis of Mid-Atlantic Bight fisheries. Mnemonics used in some subsequent tables are also given.

Common name	Scientific name	Mnemonic
Summer flounder	*Paralichthys dentatus*	SUMM
Scup	*Stenotomus chrysops*	SCUP
Black sea bass	*Centropristis striata*	BSB
Long-finned squid	*Loligo pealei*	LOLI
Atlantic mackerel	*Scomber scombrus*	MACK
Yellowtail flounder	*Pleuronectes ferrugineus*	YTFL
Winter flounder	*Pleuronectes americanus*	WTFL
Windowpane flounder	*Scopthalmus aquosus*	WIND
Silver hake	*Merluccius bilinearis*	SHAK
Butterfish	*Peprilus triacanthus*	BUTT
Short-finned squid	*Illex illebrosus*	ILLE
Goosefish	*Lophius americanus*	GOOS
Atlantic cod	*Gadus morhua*	COD
Red hake	*Urophycis chuss*	RHAK
Atlantic herring	*Clupea harengus*	HERR

Table 2. Fishery characteristics included as variables in analysis of Mid-Atlantic Bight fisheries.

Time/Space Characteristics	Vessel\Gear Characteristics	Potential Target Species
Year	Gross registered tonnage	Atlantic cod
Month	Codend mesh size	Silver hake
Area	Net liner mesh size	Witch flounder
Depth	Footrope length	Yellowtail flounder
Latitude	Sweep type	Winter flounder
Longitude		Summer flounder
Port		Flatfish (NS)
		Groundfish (NS)
		Atlantic herring
		Atlantic mackerel
		Butterfish
		Tuna
		Pelagic (NS)
		Skate
		Finfish (NS)
		Lobster
		Crab
		Shrimp
		Squid

Table 3. Pearson correlation coefficients for species abundance based on tow-by-tow data (N= 5297). (Mnemonics for species names in Table 1).

	SCUP	BSB	LOLI	MACK	YTFL	WTFL	WIND	SHAK	BUTT	ILLE	GOOS	COD	RHAK	HERR
SUMM	-.024	0.053	-0.066	-0.256	-0.091	-0.136	-0.103	-0.064	-0.032	-0.031	-0.043	-0.106	-0.068	-0.03
SCUP		0.056	0.031	-0.005	-0.031	-0.037	-0.031	-0.004	0.025	-0.010	-0.028	-0.035	-0.018	-0.01
BSB			0.038	-0.005	-0.019	-0.028	-0.034	0.001	-0.002	0.000	-0.017	-0.023	-0.013	-0.00
LOLI				-0.020	-0.063	-0.083	-0.091	-0.006	0.151	-0.024	-0.064	-0.084	-0.008	-0.02
MAKC					-0.012	-0.018	-0.015	-0.012	-0.009	-0.004	-0.014	-0.013	-0.011	0.314
YTFL						0.016	0.208	-0.027	-0.030	-0.017	-0.022	-0.005	-0.017	-0.01
WTFL							0.114	-0.035	-0.031	-0.021	-0.067	0.040	-0.040	-0.01
WIND								-0.049	-0.045	-0.025	-0.055	0.078	-0.052	0.007
SHAK									0.007	0.182	-0.011	-0.049	0.362	0.008
BUTT										0.009	-0.031	-0.042	0.053	-0.01
ILLE											0.097	-0.022	0.134	-0.00
GOOS												-0.052	-0.012	-0.02
COD													-0.053	-0.01
RHAK														0.006

Table 4 . Results of general linear models relating fishery variables to species abundance (by tow): R2 values. DEP = Depth zone, LAT = latitude (degree), LON = longitude (degree), GRT = gross registered tonnage, COD = cod-end mesh size, LIN = cod-end liner size, FOOT = footrope length, SWEEP = sweep type. No entry is included for models with R2 less than 0.3.

			TIME/SPACE						VESSEL/GEAR				TARGET
Species	YR	MO	AREA	DEP	LAT	LON	PORT	GRT	COD	LIN	FOOT	SWEEP	SPECIES
Summer flounder	.04	.10	.18	.05	.13	.11	.29	.31		.05	.07	.03	.38
Scup			.05					.07			.08		.05
Black sea bass			.03										
Long-finned squid		.05	.15	.08	.04	.13	.06	.25		.14	.12		.26
Atlantic mackerel							.69	.07			.08		.42
Yellowtail flounder	.05		.06		.05	.05	.04	.20		.05	.04		.20
Winter flounder		.06	.08	.07	.14	.06	.07	.27		.03	.12		.15
Windowpane flounder		.04	.06	.04	.04	.08	.10	.16		.04	.09		.17
Silver hake		.03	.04	.03	.03	.12	.04	.11		.05	.27		.15
Butterfish				.05				.07		.09	.05		.05
Short-finned squid		.05		.10				.06			.12		.02
Goosefish	.03	.05	.11	.35	.04	.03	.18	.33		.04	.24		.43
Atlantic cod		.04	.12		.05	.18	.13	.49		.05	.04		.30
Red hake			.03	.09	.03	.04	.07	.08		.05	.12		.16
Atlantic herring			.04				.24	.23			.03		.25

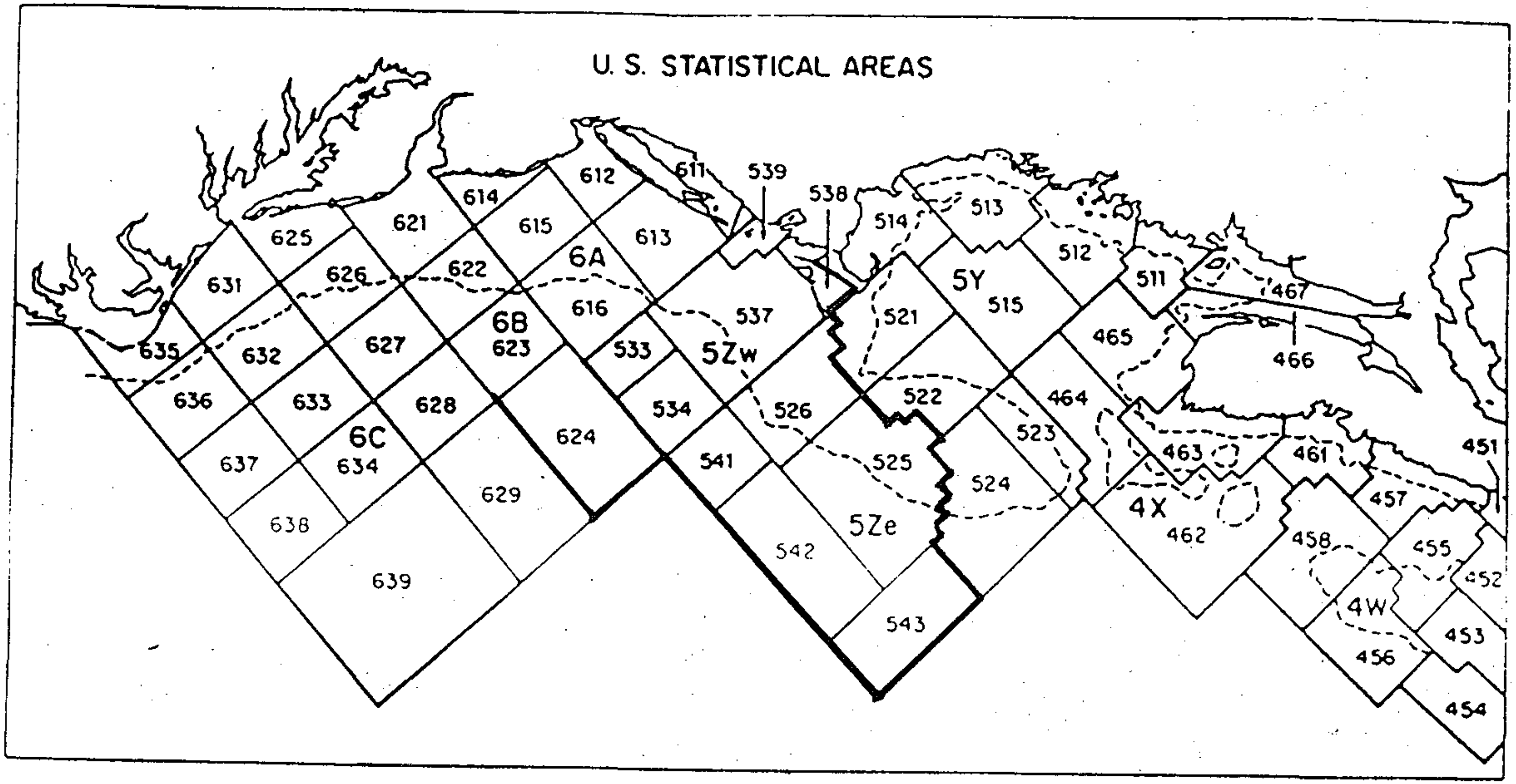

Fig. 1. Statistical reporting areas, including northern boundary to Mid-Atlantic Bight region used in analysis (Statistical Areas 538, 526, 542 and south).

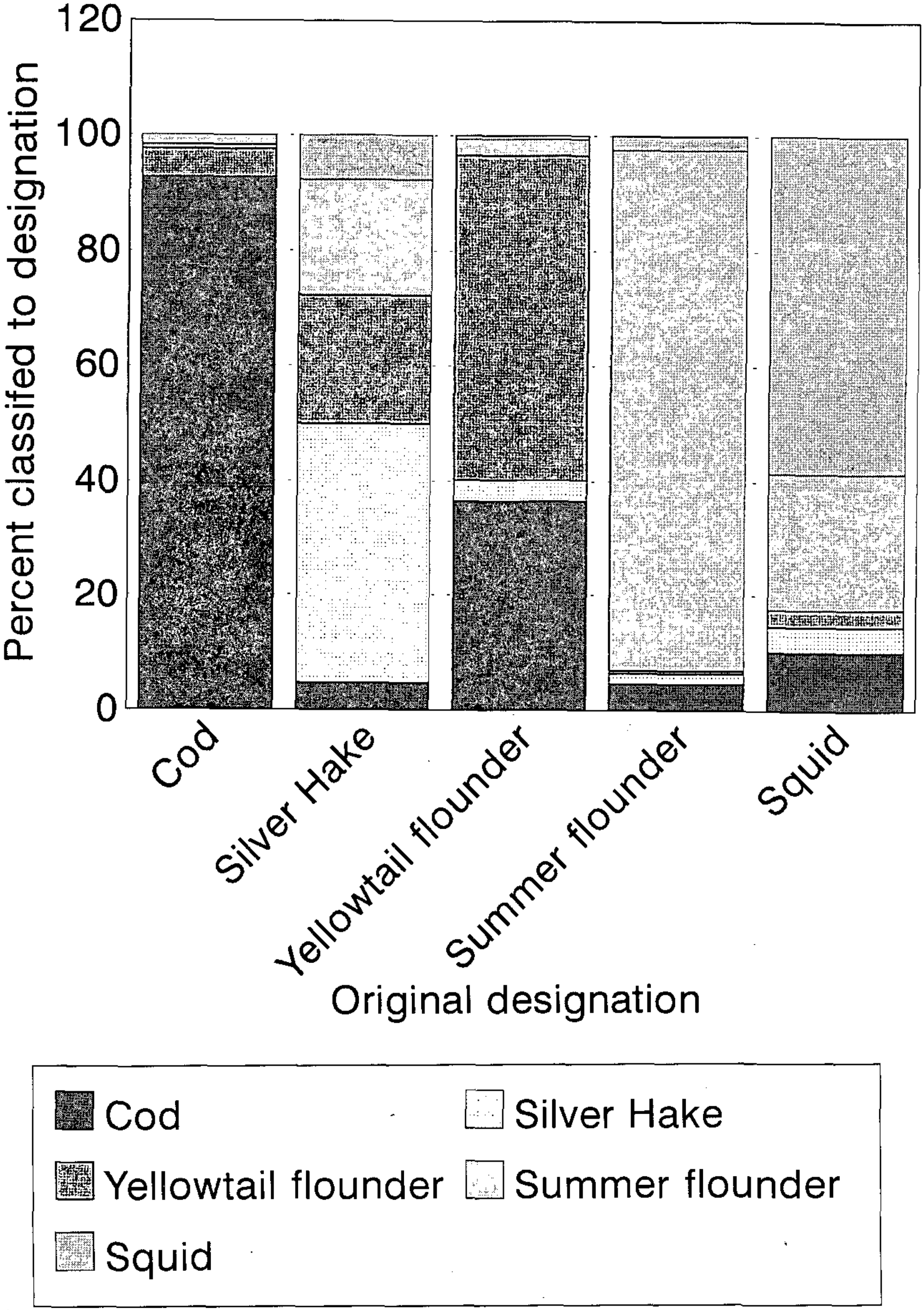

Fig. 2. Percentage of tows that were classified to original and alternative target species designations by discriminant function analysis.

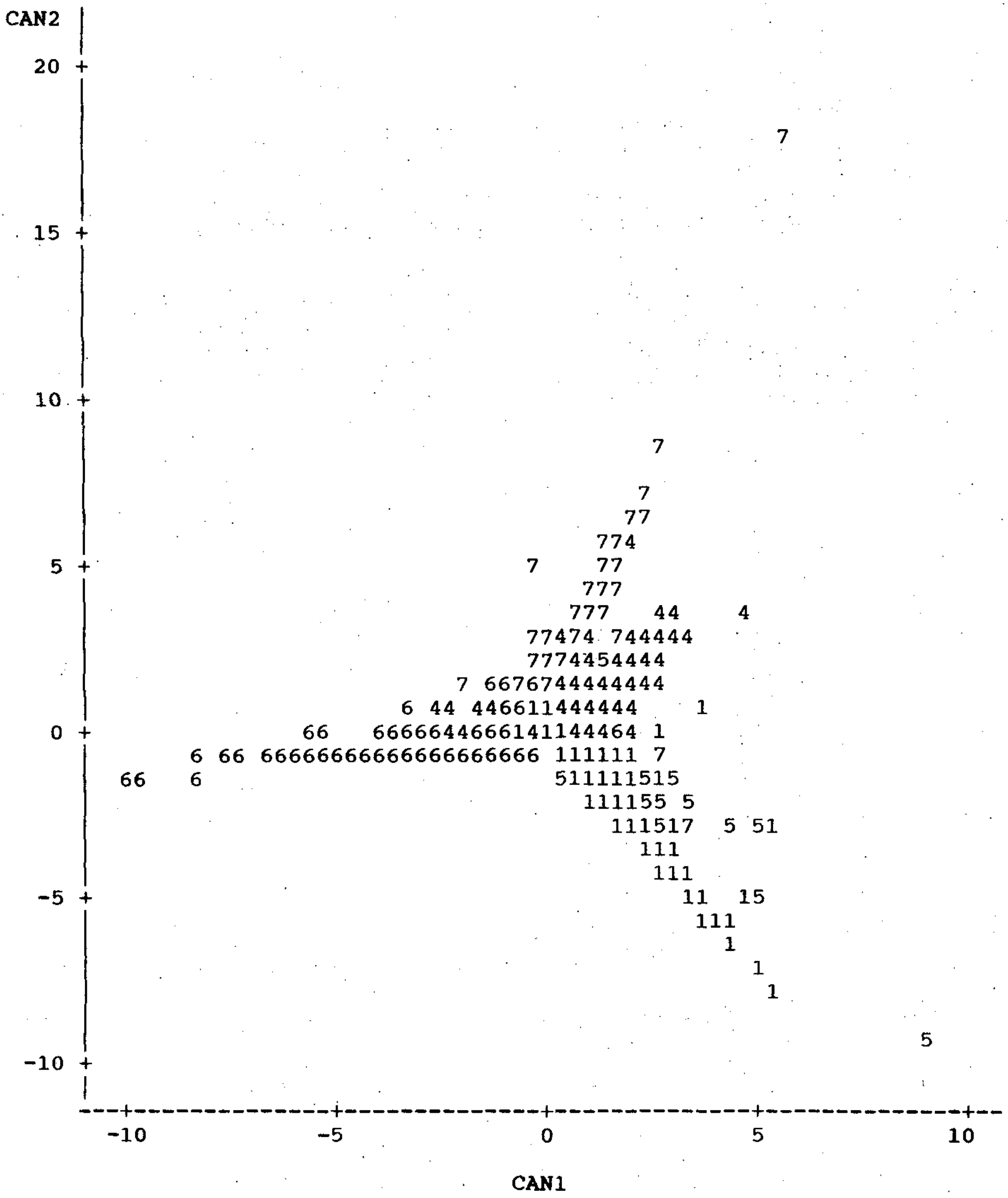

Fig. 3. Scores from first vs. second canonical variables from canonical discriminant analysis of tow catch composition to identify primary species sought. Scores from tows are numbered by species sought: 1 = cod, 4 = silver hake, 5 = yellowtail flounder, 6 = summer flounder, 7 = squid. Scores from additional tows are hidder.

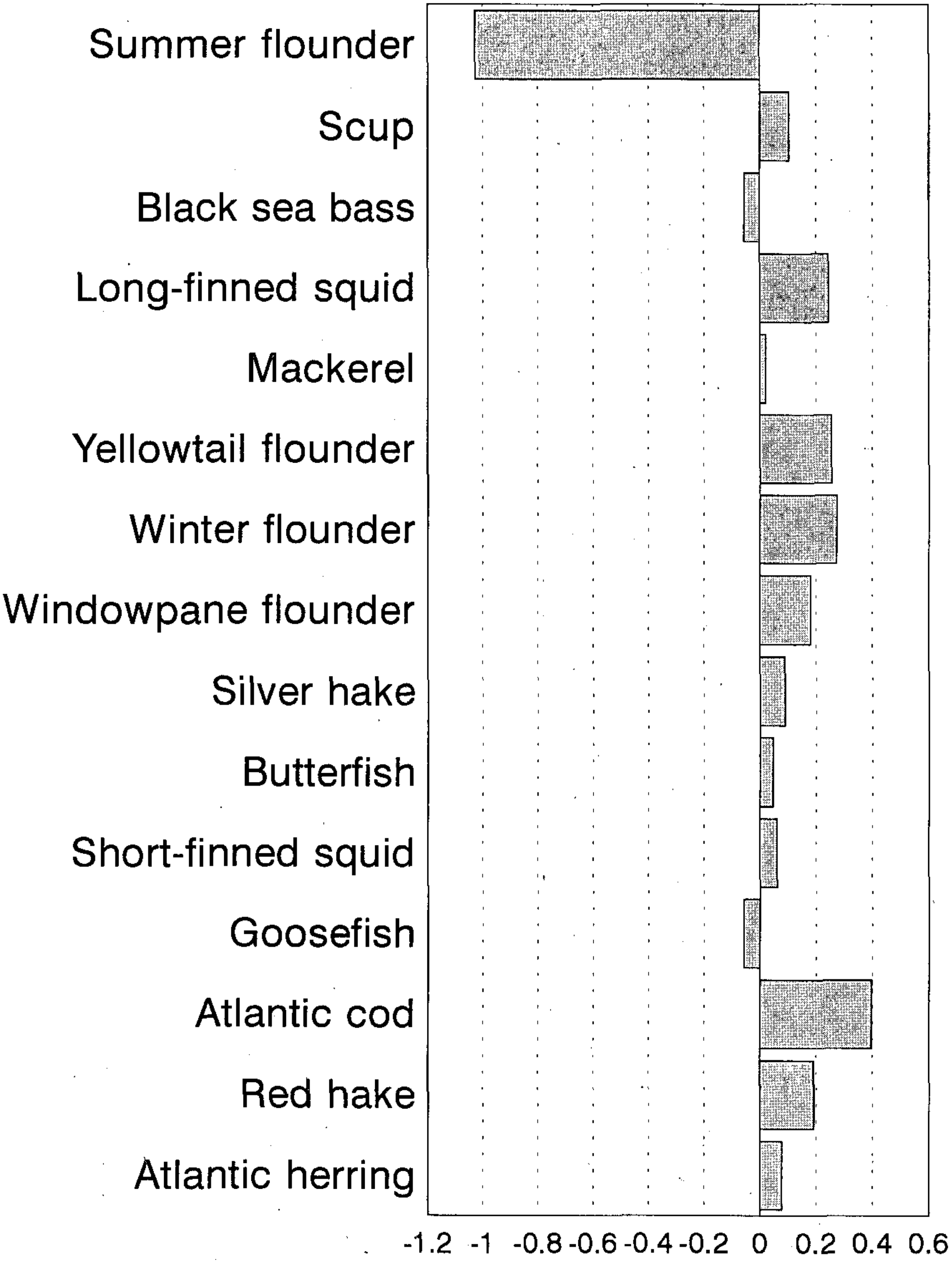

Fig. 4. Canonical coefficients for first canonical variable from canonical discriminant analysis of tow catch composition to indentify primary species sought.

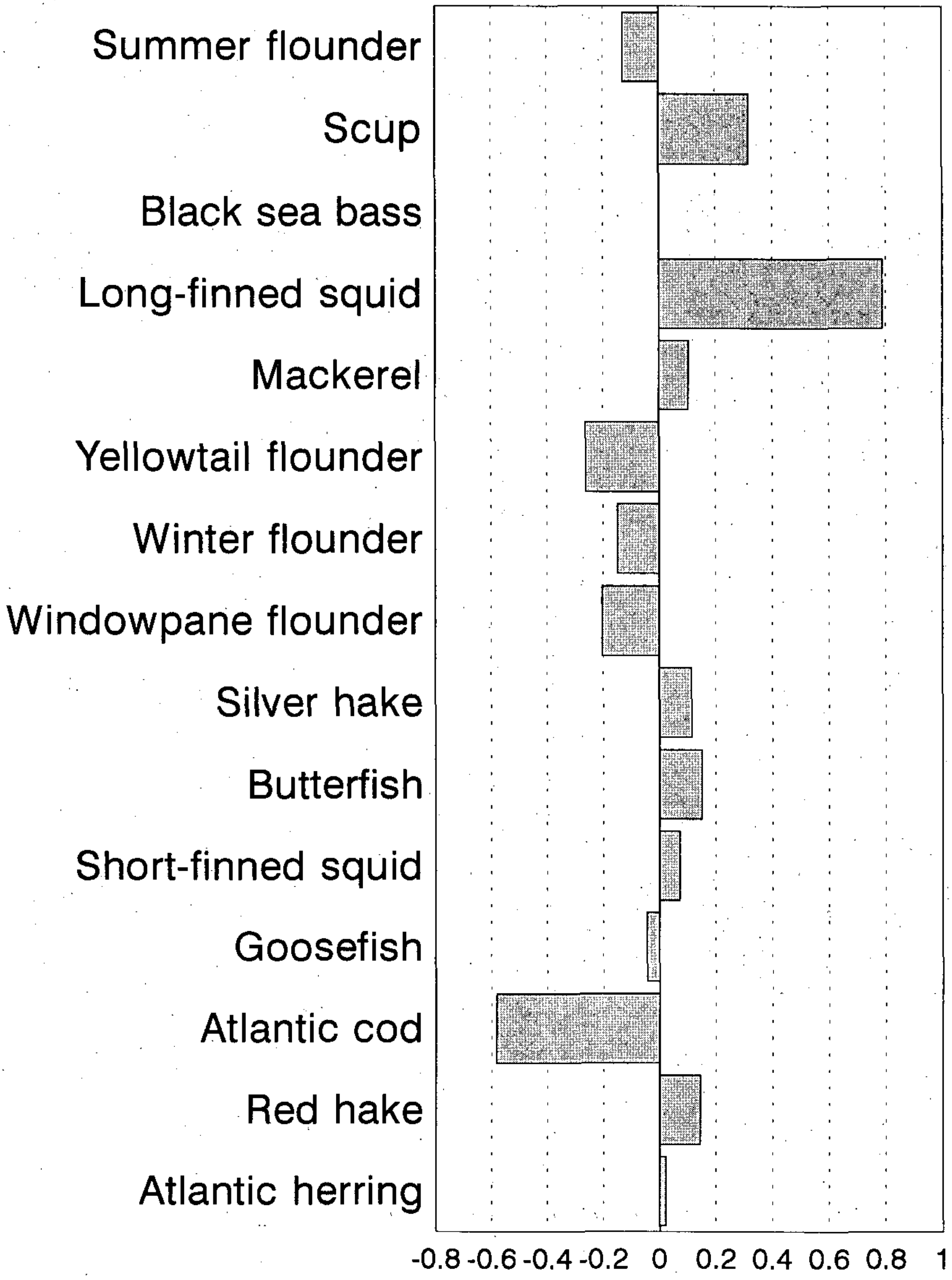

Fig. 5. Canonical coefficients for second canonical variable from canonical discriminant analysis of tow catch composition to identify primary species sought.