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Comparison of the Fishing Power of Two Fisheries Research Vessels

by

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SPECIAL SESSION ON BIOLOGICAL SURVEYS

ABSTRACT

An experiment was conducted to evaluate differences in fishing power between the NOAA research vessels ALBATROSS IV and DELAWARE II. A total of 142 successful pairs of tows were performed with these vessels during Autumn 1982 over a large area that encompassed a variety of depths and bottom types. Subsequent analyses for 32 species of fish and invertebrates indicated significant differences ($P<.05$) in overall catch by number. Differences in overall catch by weight was nearly significant ($.10>P>.05$). Individual species comparisons revealed significant differences for eight species in terms of number and/or weight. The fishing power of the DELAWARE II was generally higher, most notably for demersal species. No significant differences in size composition of the catch were noted, although it is possible that the test was not sufficiently powerful to detect significant differences in selectivity.

INTRODUCTION

The Northeast Fisheries Center (NEFC) has conducted standardized bottom trawl surveys on the Northwest Atlantic Continental Shelf since 1963. The principal objectives of this program are to monitor fluctuations in structure and size of fish populations in a way which is independent of commercial fishery statistics, and to provide data necessary to assess production potential of traditional and underutilized species (Grosslein 1969).

A critical aspect of any long term survey program is standardization of the survey unit (Doubleday 1981, Carrothers 1981). Survey units are composed of the vessel, the captain and crew, and the gear. The NEFC has standardized the construction and use of sampling gears. The number of vessels employed has also been limited. Initially the National Oceanic and Atmospheric Administration (NOAA) R/V ALBATROSS IV was used exclusively for this purpose, but in recent years the NOAA R/V DELAWARE II has also been employed with increasing frequency (Azarovitz 1981). This was necessitated by shifts in Center commitments and priorities (requiring other uses of the R/V ALBATROSS IV). Also, simultaneous use of the two vessels during survey operations has been deemed desirable to reduce survey time requirements, thereby improving synoptic coverage. This in turn introduces the potential for bias due to possible differences in fishing power which may be the result of differences in size, displacement, horsepower or other factors (Byrne et al. 1981; see Table 1).

Sissenwine and Bowman (1978) evaluated the fishing power of the R/V ALBATROSS IV and the R/V BELOGORSK (operated by the Atlantic Research Institute of Marine Fisheries and Oceanography of the USSR) and documented significant vessel and vessel-gear interactions. Koeller and Smith (1983) examined the relative fishing power of the Canadian research vessels A.T. CAMERON and LADY HAMMOND. Comparisons have also been made between the research vessels A.T. CAMERON and the LADY HAMMOND (Fanning 1984). Fanning (1985) described experiments designed to develop fishing power conversion factors between the research vessel LADY HAMMOND and the research vessels ALFRED NEEDLER and WILFRED TEMPLEMAN. These studies clearly document the importance of compensating for differences in research vessel performance to maintain a standardized time series of survey results.

The present study was performed to compare the relative fishing power of the research vessels ALBATROSS IV and DELAWARE II. Noble et al. (MS 1980) described the results of comparative fishing experiments between these vessels conducted during May 1980.

MATERIALS AND METHODS

During October 4-29, 1982, the R/V DELAWARE II accompanied, and made paired tows with, the R/V ALBATROSS IV which was then conducting the annual NEFC autumn bottom trawl survey off southern New England and on Georges Bank (Figure 1). Station locations were preselected using a stratified random sampling design. The rationale and methodology for this sampling scheme are discussed by Grosslein (1969, 1974). Stations were occupied so as to minimize travel distance, operating generally from the south to north. The tow direction was toward the next station unless otherwise dictated by environmental or bottom conditions; and in such cases, tow direction was either into or with the seas and/or along the depth contour in the general direction of the next station.

Tows were 30 minutes in duration, timed beginning when the appropriate amount of trawl wire for the depth had been paid out. Both ships began setting their trawls at approximately the same time, coordinated through the use of ship to ship radio. The scopes used were: 73m of wire in depths less than 18m; 4:1 in depths between 18m and 27m; 3:1 in depths between 27m and 183m, and, 2½:1 in depths between 183m and 366m. Towing speed was designated to be 6.5 km per hour (3.5 knots). Towing speed and distance traveled were determined using doppler speed logs. The R/V ALBATROSS IV is equipped with a Raytheon Doppler Speed Log, Repeater Model (No. DSL-200). The R/V DELAWARE II is equipped with an Amtek Straza Doppler Speed Log (Model No. MRQ 4015A). Paired t-tests indicated a significant difference in distance travelled; however this was small (93m) and within the range of accuracy of the Doppler unit aboard the ALBATROSS IV. Accordingly, adjustment for distance towed was not undertaken in this analysis.

Both ships used standardized Number 36 Yankee otter trawls. These trawls were rigged with nineteen 41 centimeter diameter rollers, 9.1 meter bridles and Type 3A, 545 kg BMV oval trawl doors. The body of these nets is made of 12.7 cm stretched mesh webbing which is made of white 4252 tex (Number 54) virgin braided nylon twine. The codend is made of 11.4 cm stretched mesh, 11,275 tex (Number 132) white virgin braid nylon webbing. Both the upper belly and codend are lined with knotless 1.27 cm stretched mesh, white, 1250 tex (Number 156) knitted nylon webbing. Trawls were exchanged between the ships approximately every 25 tows. A total of 288 tows in matched pairs were accomplished; each vessel employed one trawl for 73 tows and the other for 71 tows. Data for 2 pairs of tows were discarded due to operational difficulties on one of the ships. Analysis of catch data for the remaining 142 matched pairs by Wilcoxon Paired Rank Sum Test indicated no significant differences between individual trawls. Therefore, further examination of potential trawl differences were deemed unnecessary and ignored for all subsequent analyses.

At each station, vessels towed parallel courses in as close proximity as possible. Generally, a distance of about 0.6 km (0.3 nautical miles), was maintained, although the distance was increased to about 0.9 km (0.5 nautical miles) during inclement weather. In areas where depths change quickly (for example along the edge of the Continental Shelf), one vessel towed behind the other, and slightly aside, rather than directly parallel to each other. This facilitated sampling within the same depth zone.

Following haulback, catches were sorted to species, weighed, and all individuals (or for large catches a representative subsample) measured. In addition, station data were also recorded. These data were subsequently keypunched, stored and subjected to standard audit procedures.

Analyses were performed using SAS and SPSS-X statistical packages on a VAX 11/785 mainframe computer.

Data Analysis

A total of 137 fish and invertebrate species were collected and recorded during these cruises. Of these, 32 species (listed in Table 2) accounted for approximately 93-94% of both the total weight and number of individuals taken by each vessel. Data for bay and striped anchovy (*Anchoa mitchilli*; *A. hepsetus*) were combined for analysis. Table 3 lists both the total weight and number for all species by vessel, and the totals for the 32 species collectively.

Paired comparisons for differences in catch in numbers and weight between vessels were made for these species. Due to the highly contagious distribution patterns involved, nonparametric methods were employed. For comparative purposes, analyses were also made using equivalent parametric tests on $\log_e (x+1)$ transformed data. As the effectiveness of such transforms is influenced considerably by high zero catches (Pennington 1983), we considered the nonparametric tests to be preferable (note also that the power of nonparametric tests may exceed that of parametric ones if the underlying assumptions of the latter cannot be met). In any case results from both types of tests were consistent, and accordingly only the results of nonparametric testing are presented here.

In tests for overall vessel differences, we considered the catch of the above 32 species as a multivariate response vector. A Hotelling T^2 test for paired data (Srivastava and Carter 1983) was carried out on rank transformed observations. (Conover 1980). Although alternative nonparametric methods are available (Gerig 1969, Puri and Sen 1971), the application of the Hotelling T^2 test on rank transformed data was computationally convenient and may be considered equivalent for large sample sizes[1]. Friedman's tests were conducted to evaluate vessel differences for individual species.

RESULTS AND DISCUSSION

Catch Rates

Analysis of data for the 32 species considered indicated significant overall differences between vessels in catch in numbers (T^2=91.13; P<.05) and overall differences in catch in weight approached significance (T^2=58.39; .10>P>.05). High correlations among catches of certain species necessitated the use of a multivariate approach to evaluating differences in vessel performance. This result is consistent with the observations of Overholtz (1982) who demonstrated spatially and temporally persistent assemblages of fish species on Georges Bank from NEFC survey results. Preliminary analyses indicate that distinct assemblages may be identified throughout the survey region based on cluster analyses[2] which implies a lack of independence among the response variables (catch-per-tow by species). Accordingly, the results cannot be considered as 32 independent tests in evaluating overall differences in fishing power. To determine which species were responsible for the significant differences, we conducted Friedman's test on an individual species basis.

Mean differences in catch between the ALBATROSS IV and DELAWARE II in which a given species was caught by at least one vessel are provided in Table 2. Also indicated is the number of occurrences of a species on at least one vessel with the 142 pairs of tows studied. It is noteworthy that many species are characterized by a high proportion of zero catches.

To further evaluate vessel differences on an individual species basis, Friedman's tests were conducted for each of the 32 species (Table 2). Station location was used as the blocking factor. Significant differences in catch in number and weight were observed for four species: yellowtail flounder (*Limanda ferruginea*), windowpane (*Scopthalmus aquosus*), scup (*Stenotomus chrysops* and American sand lance (*Ammodytes americanus*). Catch in weight was higher on the DELAWARE II for each of these species and catch in number was higher on DELAWARE II for all but scup (Table 2). Significant differences in catch in number but not weight were also noted for little skate (*Raja erinacea*), shortfin squid (*Illex illecebrosus*), silver hake (*Merluccius bilinearis*) and rock crab (*Cancer irroratus*). Catch in number was higher on

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[1] T. Gerig, Dept. of Statistics, North Carolina State University University. Personal communication.
[2] W. Overholtz, NMFS, NEFC, personal communication.

the DELAWARE II for little skate, shortfin squid, and rock crab. Scatterplots of the catch in weight for the ALBATROSS IV versus the DELAWARE II and the catch in number for species which differed significantly between vessels are provided in Figures 2 and 3 respectively. Considerable variability in catch rates is evident.

Stratified mean catch per tow in weight for the species which differed significantly between vessels are provided in Table 4. The means and standard errors have been estimated using the Delta distribution method (Pennington 1983). In this approach, catches are stratified into zero and non-zero values; means and variances of log-transformed non-zero catches are then computed, weighted by the proportion of non-zero catches in the samples, and retransformed. The standard errors of the estimates are relatively high, indicating that large sample sizes would be required to detect significant differences between the vessels if the paired-tows approach were not taken.

Noble et al. (MS 1980) reported significant differences between these vessels for yellowtail flounder and Atlantic cod in catch in number and for winter flounder for catch in both number and weight. A total of nine species were analyzed. With the exception of yellowtail flounder catch in number, catch rates for these species were higher on the R/V DELAWARE II. No significant differences were observed in total catch, however. It should be noted that the test procedures used were not equivalent to that performed in the present analyses.

The results of these experiments indicated some evidence for differences in fishing power between the ALBATROSS IV and DELAWARE II. Where significant differences were observed, catch rates of the DELAWARE II were typically higher, most notably for demersal species. Despite the smaller displacement of the DELAWARE II, the horsepower of this vessel exceeds that of the ALBATROSS IV, possibly contributing to a tendency toward higher fishing power for the DELAWARE II.

Size Composition

To evaluate the possibility of differences in size selectivity between the two vessels, we compared the size composition of catches using the Kolmogorov-Smirnov two sample test (Conover 1980). Size frequency distributions of the stratified mean number per tow for the eight species which demonstrated significant differences in catch in number and/or weight are provided in Figure 4. No significant differences ($P>.05$) in size distributions were noted using the Kolmogorov-Smirnov two sample test (Table 5) although it is possible that the test was not sufficiently powerful to detect differences.

For species which differed significantly in terms of catch in number but not in weight, it is necessary to account for the discrepancy in test results. We noted a tendency for higher catches of small individuals for silver hake on the ALBATROSS IV (Figure 4); since the weights of small individuals is correspondingly small, sampling variability may have obscured differences in catch in weight between the two vessels. Similarly, for both shortfin squid and rock crab, catches were dominated by small individuals and differences may be more easily detected in number than in weight. The discrepancy for little skate is more difficult to explain, however, we did note a distinct mode at smaller sizes on the DELAWARE II which was less prominent for catches aboard the ALBATROSS IV.

CONCLUSIONS

Comparisons of the fishing power of the research vessels ALBATROSS IV and DELAWARE II indicated no significant differences in overall catch in weight for 32 species. However, significant differences in catch in numbers were demonstrated. The multivariate analysis for overall differences in catch rates was deemed appropriate due to intercorrelations of catches among co-occurring species. This approach differs in evaluating overall differences in catch rates by comparing total catches of all species combined in that the results are not influenced by catches of dominant species alone.

Comparisons on an individual species basis indicated that vessel performance differed for a total of eight species in catch in number and/or weight. We observed a tendency of higher fishing power in the DELAWARE II, particularly for demersal species. No significant differences in size selectivity was obtained although trends were noted which may help explain discrepancies in analyses for catch in number and in weight.

We employed nonparametric tests to evaluate differences in vessel performance due to the highly skewed distribution of catches. Results of the nonparametric tests were consistent in all cases with parametric tests performed on transformed data. The nonparametric tests are considered to be preferable due to the difficulty in normalizing data characterized by a high proportion of zeros. The use of rank transformed data in the context of a multivariate parametric test (Hotelling T^2) proved to be a computationally convenient approach which appears to be valid for large sample sizes.

Noble et al. (MS 1980) made comparisons of catch rates between ALBATROSS IV and DELAWARE II for total catch and for nine indivudual species and concluded that vessel effects were significant for 3 species. No significant differences in total catch in numbers or weight were observed. In spite of differences in experimental design and methods of analysis between these studies, both indicate differences in the fishing power. Further studies would clearly be beneficial; preferably, these should be based on experimental designs permitting paired tows due to natural variability in catch rates.

ACKNOWLEDGEMENTS

We would like to express our sincere appreciation to the officers and crew of the research vessels ALBATROSS IV and DELAWARE II for their cooperation during this study. We are grateful for the assistance of our colleagues at the Northeast Fisheries Center, particularly the scientific party, for their help during this experiment. Janice Forrester provided helpful discussions on statistical issues, and Josef Idoine and Rose Concha provided computational assistance. The critical reviews of Steven Clark and Michael Sissenwine were very helpful.

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Table 1. Characteristics of the National Oceanic and Atmospheric Administration (NOAA) research vessels ALBATROSS IV and DELAWARE II which may contribute to variability in bottom trawl survey data (after Byrne et al. 1981).

	ALBATROSS IV	DELAWARE II
Length	57.0 m	47.2 m
Displacement	987.9 m tons	687.6 m tons
Shaft horsepower	1,130	1,230
Number of main engines	2	1
Propeller type	Variable pitch	Fixed pitch
Rudder	Kort nozzle	Standard
Main winch,		
Type	Free Spool	Direct gear drive
Line pull	7257 kg	9072 kg
Line rate	65.5 m/min	36.3 m/min
Trawl warp diameter	22.2 mm	25.4 mm
Officers	NOAA Corp	Civilian
Towing point	Hydraulic gantry, Approx. 6.1 m above water line	Fixed gallows Approx. 4.3 m above water line

Table 2. Number of occurrences of 32 selected species taken on at least one of the vessels, mean difference in catch (ALBATROSS IV) catch - DELAWARE II catch) for each species, and results of Friedman's test for differences in catch between vessels.

Species	Number of Occurrences	Mean Difference in Catch		Friedman's Test for Differences			
				Weight		Number	
		Weight (kg)	Number	Chi-Square	Significance	Chi-Square	Significance
Fish							
Smooth dogfish *(Mustelus canis)*	24	0.241	-0.125	.1667	.6831	.0417	.8382
Spiny dogfish *(Squalus acanthias)*	54	-44.952	-27.833	.6667	.4142	.4630	.4962
Little skate *(Raja erinacea)*	93	-4.542	-0.607	2.4194	.1198	3.8817	.0488
Winter skate *(Raja ocellata)*	62	-0.629	4.032	.1451	.7032	1.6129	.2041
Bay and striped anchovies *(Anchoa mitchilli, A. hepsetus)*	23	2.300	2415.652	.0435	.8348	1.0870	.2971
Goosefish *(Lophius americanus)*	48	-1.709	-1.167	3.5208	.0606	3.0000	.0833
Atlantic cod *(Gadus morhua)*	20	0.415	1.300	.0500	.8231	.8000	.3711
Haddock *(Melanogrammus aeglefinus)*	19	0.195	-0.895	3.3684	.0665	1.8947	.1687
Silver hake *(Merluccius bilinearis)*	124	4.385	63.976	.9758	.3232	7.7500	.0054
Red hake *(Urophysis chuss)*	68	-0.747	-4.162	.5294	.4669	1.1912	.2751
Spotted hake *(Urophysis regius)*	32	-0.096	-2.719	1.1250	.2888	2.0000	.1573
White hake *(Urophysis tenuis)*	32	-0.482	-1.500	.2813	.5959	.5000	.4795
Ocean pout *(Macrozoarces americanus)*	24	-0.075	-1.708	.6667	.4142	.3750	.5403
Bluefish *(Pomatomus saltatrix)*	38	0.747	0.789	.4211	.5164	.1053	.7456
Scup *(Stenotomus chrysops)*	43	-0.047	24.488	6.7209	.0095	3.9302	.0474
American sand lance *(Ammodytes americanus)*	42	-0.250	-41.762	5.3572	.0206	4.6667	.0308
Butterfish *(Peprilus triacanthus)*	112	-0.388	29.116	.3215	.5707	.0090	.9245
Northern searobin *(Prionotus carolinus)*	32	0.150	-3.063	1.5130	.2159	.5000	.4795
Sea raven *(Hemitripterus americanus)*	43	-0.091	0.209	.0233	.8788	.0930	.7604
Longhorn sculpin *(Myoxocephalus octodecemspinosus)*	49	-1.100	-2.918	-.0000	1.0000	.0816	.7751
Summer flounder *(Paralichthys dentatus)*	45	0.447	0.622	.2000	.6547	1.4222	.2330
Fourspot flounder *(Paralichthys oblonga)*	80	-0.264	-1.100	.6125	.4338	.8000	.3711
Windowpane *(Scophthalmus aquosus)*	71	-0.515	-2.451	5.6338	.0176	4.0704	.0436
American plaice *(Hippoglossoides platessoides)*	13	-2.923	-4.385	.6923	.4054	.0769	.7815
Yellowtail flounder *(Limanda ferruginea)*	55	-2.575	-9.073	4.0909	.0431	5.8909	.0152
Winter flounder *(Pseudopleuronectes americanus)*	65	0.332	0.446	.0154	.9013	.5538	.4568
Invertebrates							
Sea scallop *(Placopecten magellanicus)*	34	0.224	0.853	.4706	.4927	3.5588	.0592
Shortfin squid *(Illex illecebrosus)*	90	-0.862	-9.078	-1.6000	.2059	5.3778	.0204
Longfin squid *(Loligo pealei)*	110	0.041	96.827	.4454	.5045	.5818	.4456
American lobster *(Homarus americanus)*	80	-0.066	-0.013	2.8125	.0935	1.0125	.3143
Jonah crab *(Cancer borealis)*	48	-0.102	-0.563	1.3333	.2482	2.5208	.1124
Rock crab *(Cancer irroratus)*	77	-0.037	-3.013	3.3247	.0682	7.4805	.0062

Table 3. Total number and weight (kg) for all species combined and for 32 selected species taken aboard R/V ALBATROSS IV and R/V DELAWARE II during vessel comparison trials, 4-29 October 1982.

Vessel	Total No.	Total Wt. (kg)	Total No. of 32 Selected Species	Total Wt. (kg) of 32 Selected Species
ALBATROSS IV	207,756	11,025.0	195,684	10,297.7
DELAWARE II	132,971	13,848.4	123,860	13,122.5

Table 4. Stratified mean catch per tow in weight and number and standard error of each, for eight species with significantly different catch rates between R/V ALBATROSS IV and R/V DELAWARE II.

	ALBATROSS IV		DELAWARE II	
Species	Stratified Mean	Standard Error	Stratified Mean	Standard Error
		Catch in Weight		
Little skate	9.077	15.334	13.960	7.192
Silver hake	4.239	1.877	1.938	0.338
Scup	0.742	0.254	0.374	0.194
American sand lance	0.003	0.001	0.074	0.291
Windowpane	1.293	0.382	1.075	0.254
Yellowtail flounder	3.341	1.206	5.450	2.126
Shortfin squid	0.461	0.066	0.609	0.978
Rock crab	0.059	0.012	0.131	0.464
		Catch in Numbers		
Little skate	28.311	14.945	37.036	20.912
Silver hake	88.170	23.010	35.848	8.627
Scup	12.882	5.531	8.569	5.318
American sand lance	0.673	0.164	11.792	5.412
Windowpane	6.757	2.371	5.624	1.496
Yellowtail flounder	15.540	6.174	23.237	9.344
Shortfin squid	4.292	0.933	6.175	1.054
Rock crab	1.409	0.510	3.311	1.052

Table 5. Estimated mean length and Kolmogorov-Smirnov 2 - Sample test statistics.

Species	Mean Length (cm)		K-S Test	2-Tailed P
	ALBATROSS IV	DELAWARE II		
Little skate	36.854	37.002	1.323	0.060
Silver hake	12.813	12.720	1.030	0.239
Scup	10.364	9.668	0.783	0.573
American sand lance	13.304	12.406	1.155	0.139
Windowpane	23.877	23.151	0.679	0.745
Yellowtail flounder	28.206	28.962	0.600	0.864
Shortfin squid	15.060	13.450	0.788	0.564
Rock crab	5.719	5.640	0.833	0.491

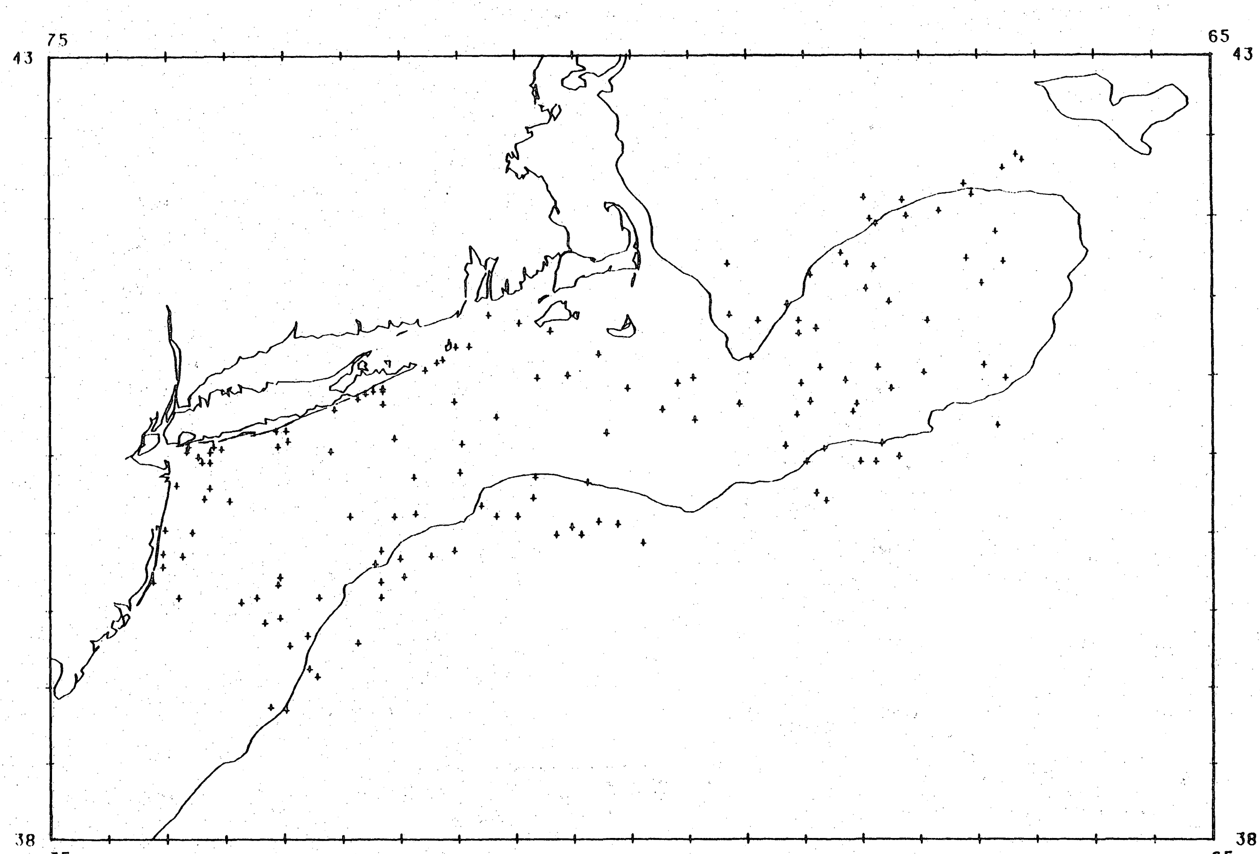

Figure 1. Approximate location of stations occupied during the 4-29 October 1982 research vessel (ALBATROSS IV - DELAWARE II) fishing power experiment.

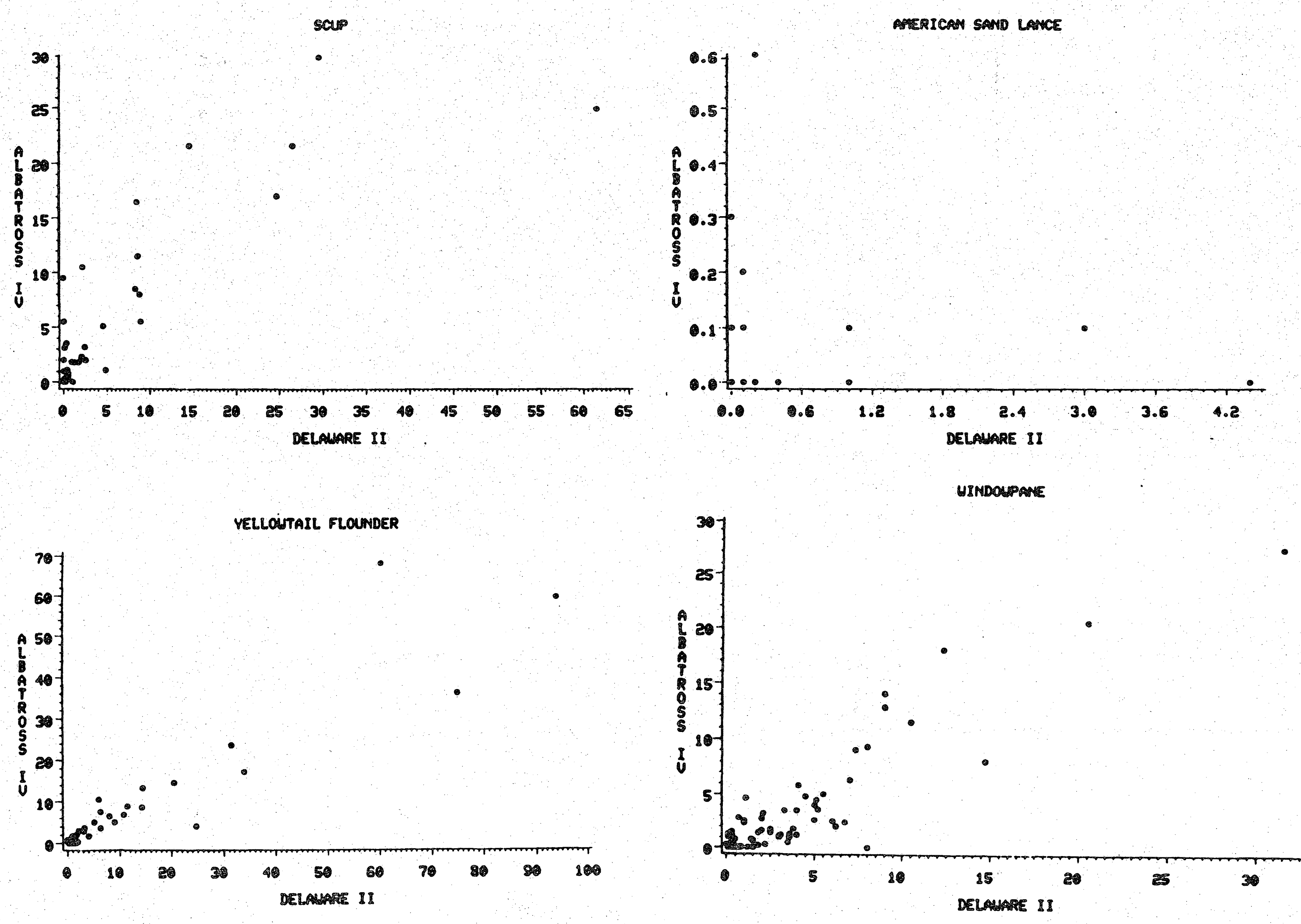

Figure 2. Distribution of catch in weight (kg) for species from which significant differences were detected. R/V ALBATROSS IV catches are plotted against those for R/V DELAWARE II.

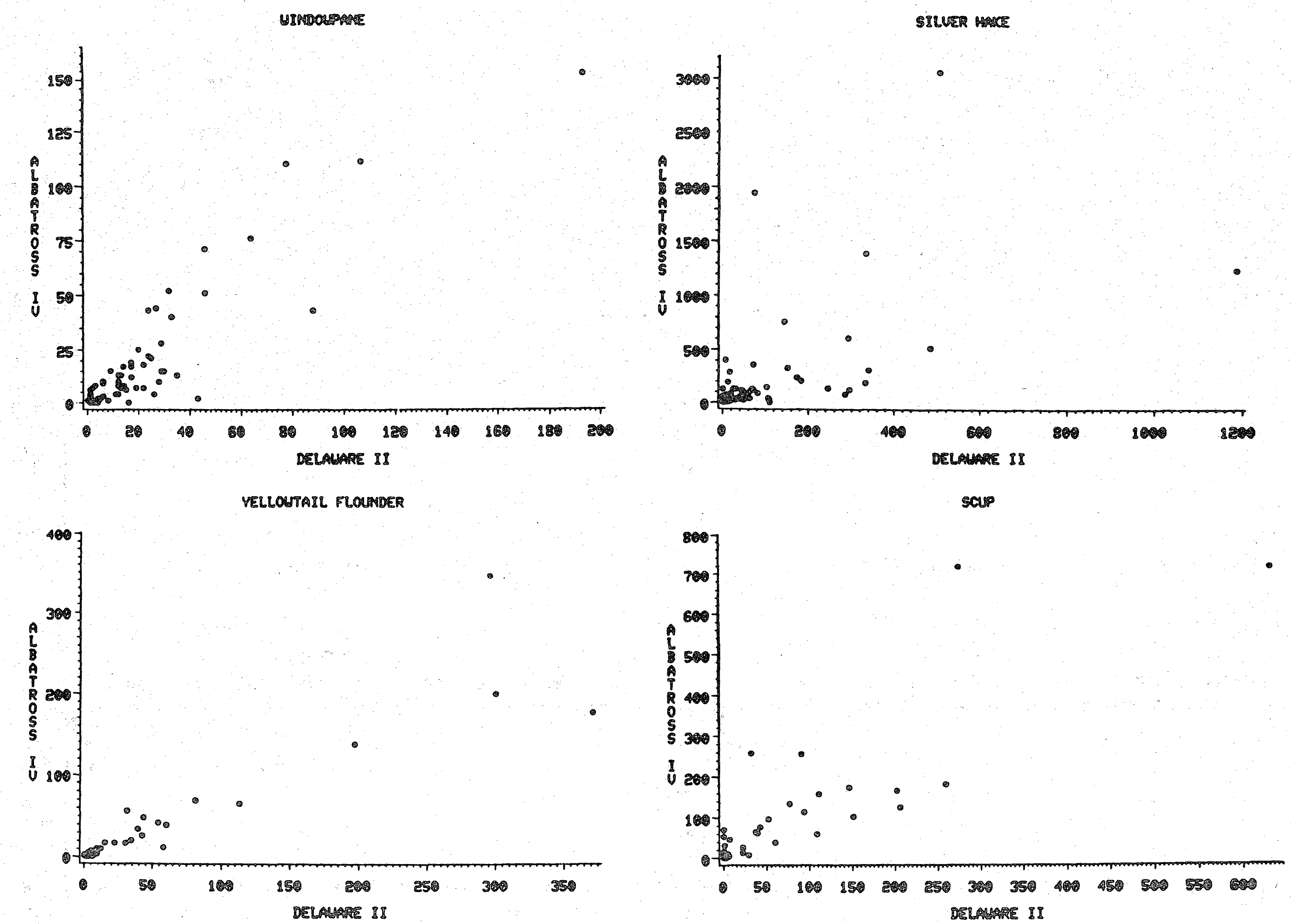

Figure 3. Distribution of catch in numbers for species for which significant differences were detected. R/V ALBATROSS IV catches are plotted against those for R/V DELAWARE II.

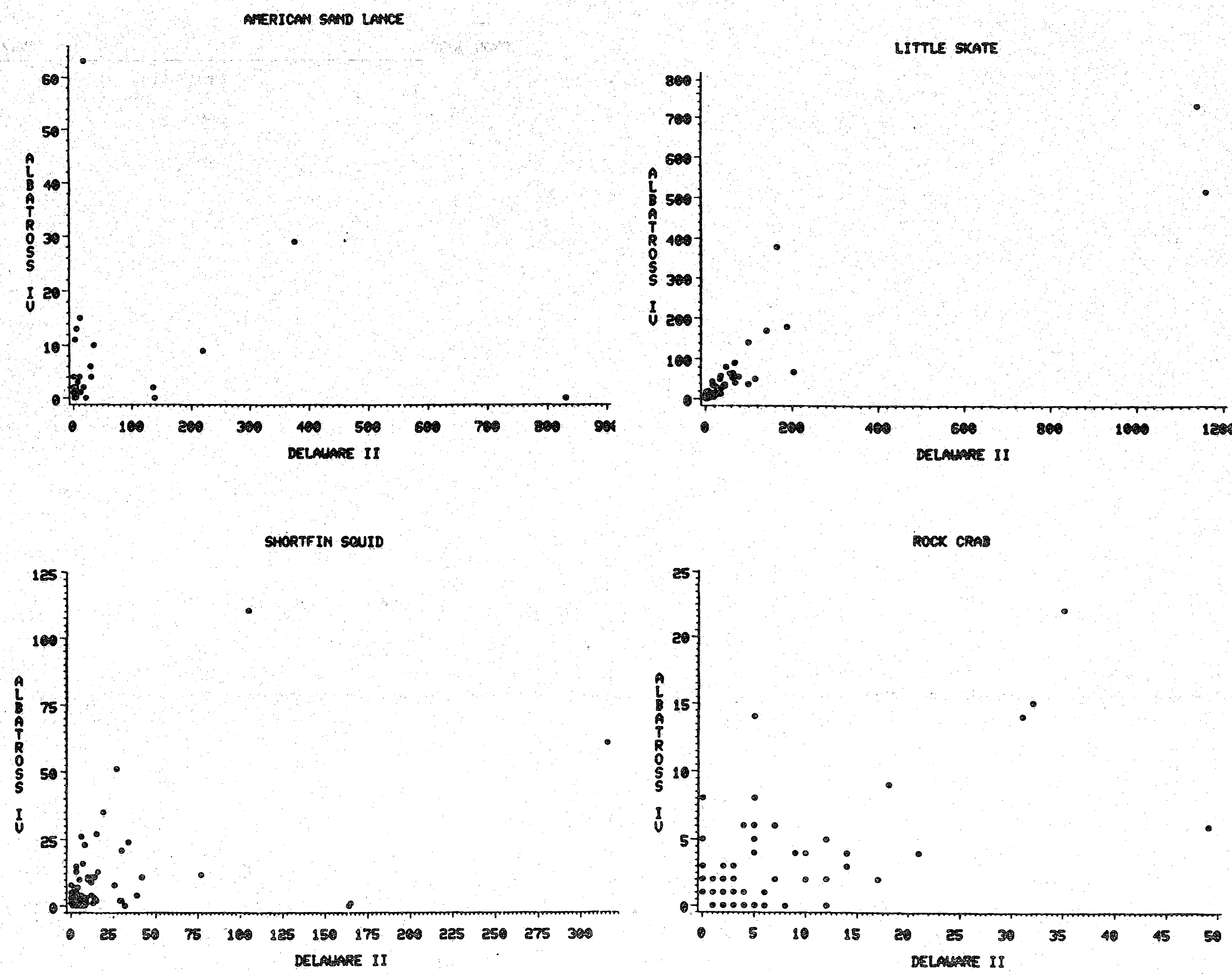

Figure 3. Continued.

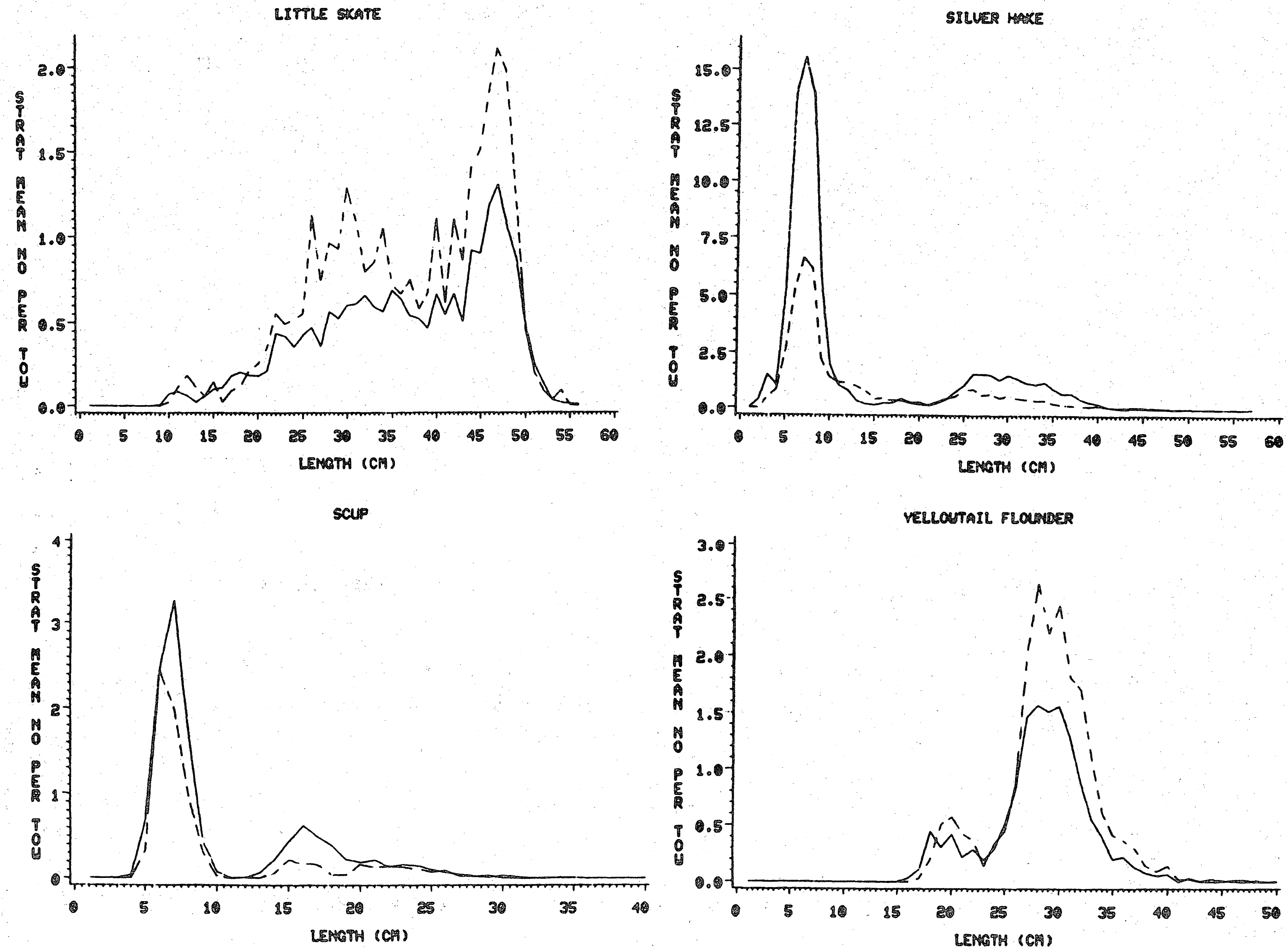

Figure 4. Length distributions for species for which differences in either weight and/or number were detected. (Solid line R/V ALBATROSS IV; dashed line R/V DELAWARE II).

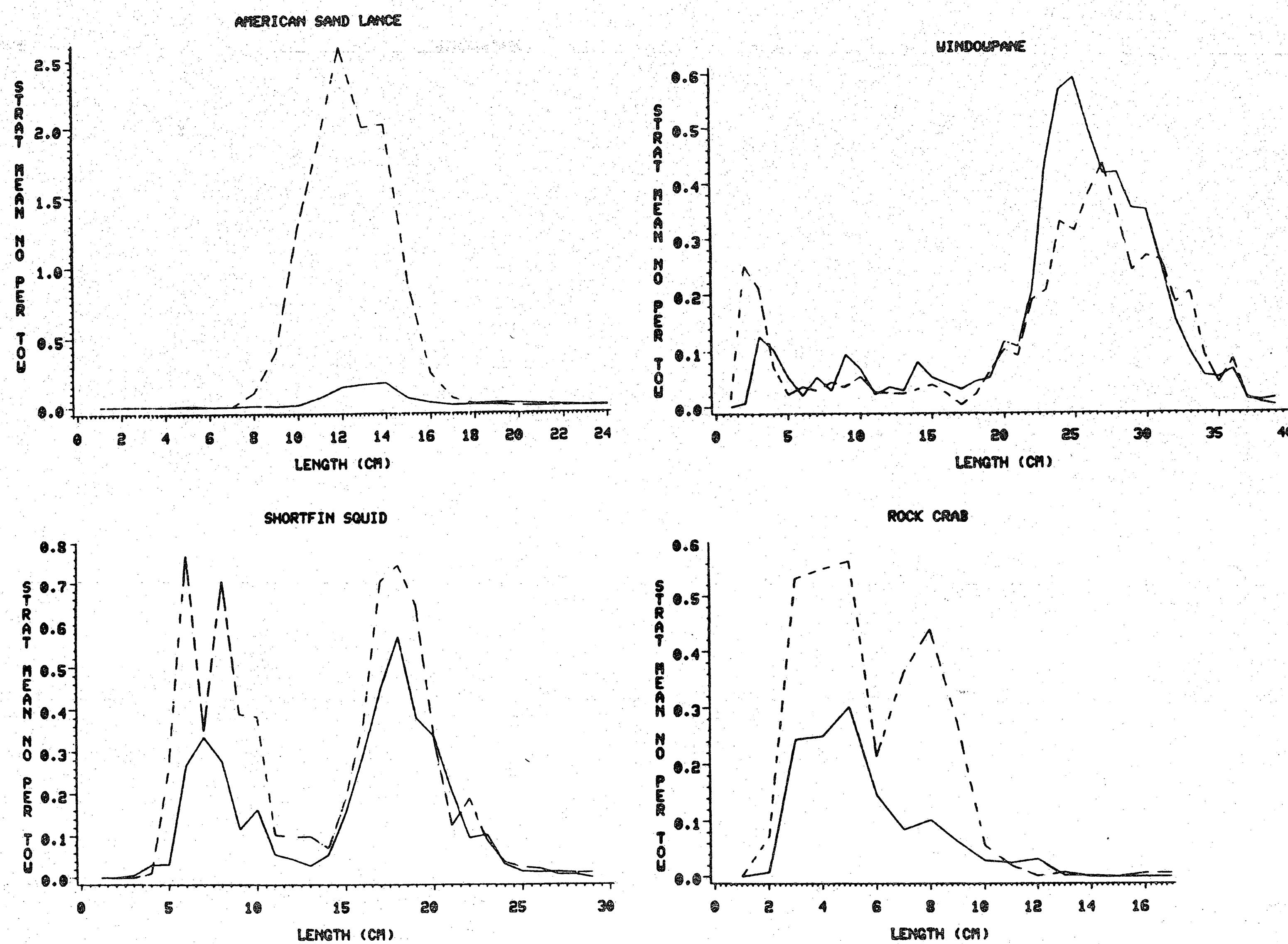

Figure 4. Continued.