1975

A study of the archibenthic and abysobenthic fishes of Deep Water Dump Site 106 and the adjacent area : completion report

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Recommended Citation

Musick, J. A., Wenner, C. A., & Sedberry, G. R. (1975) A study of the archibenthic and abysobenthic fishes of Deep Water Dump Site 106 and the adjacent area : completion report. Virginia Institute of Marine Science, William & Mary. https://scholarworks.wm.edu/reports/2578

Completion Report

"A study of the archibenthic and abysobenthic fishes of Deep Water Dump Site 106 and the adjacent area"

submitted to:

U.S. Dept. of Commerce
National Oceanic and Atmospheric Administration
Office of Coastal Environment/ MESA Program
Rockville, MD 20852

in fulfillment of the terms of Sea Grant #04-4-158-31 to the Virginia Institute of Marine Science, Gloucester Point, Virginia 23062

J.A. Musick

J. A. Musick
Principal Investigator

This report is divided into five sections:

Section I: (p. 3) Community structure of demersal fishes at Deep Water Dump Site 106, by J. A. Musick.

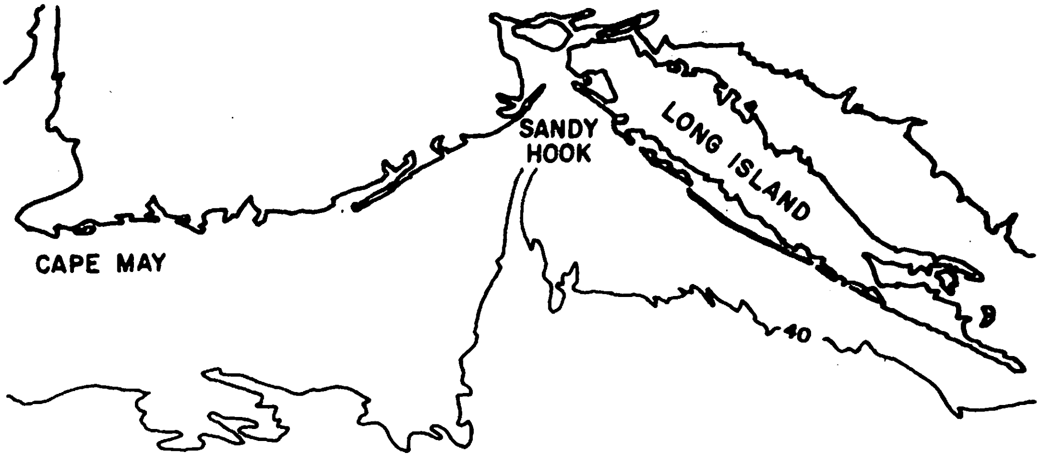
Section II: (p. 45) Reproduction in fishes of DWD 106, by C. A. Wenner.

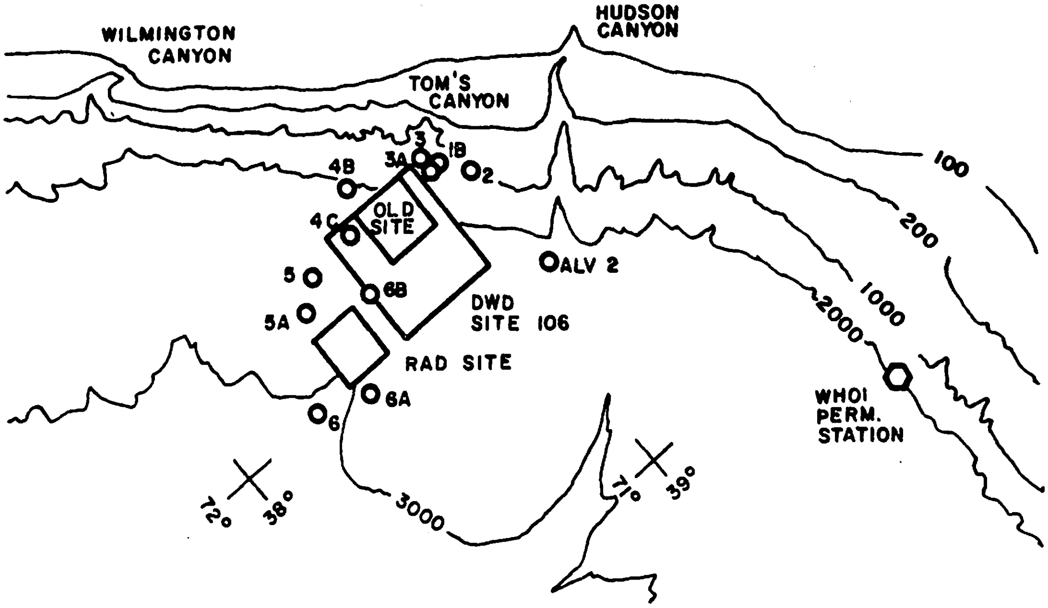
Section III: (p. 52) Food habits of fishes of DWD 106, by G. R. Sedberry.

Section IV: (p. 66) Possible effects of dumping industrial wastes at DWD 106 on demersal fishes.

Section V: (p. 69) Recommendations.

Section II is based in part on a dissertation in progress by C. A. Wenner and Section III on a thesis in progress by G. R. Sedberry, both at the Virginia Institute of Marine Science. Consequently, any reference made to information therein is restricted to the data collected at DWD 106.


SANDY HOOK
LONG ISLAND
CAPE MAY
40


HUDSON CANYON
WILMINGTON CANYON
TOM'S CANYON
3
3A
1B
2
4B
OLD SITE
4C
5
6B
5A
DWD SITE 106
ALV 2
RAD SITE
6A
6
100
200
1000
2000
WHOI PERM. STATION
3000
72°
38°
71°
39°

Section I: Community structure and ecology of demersal fishes at Deep Water Dump Site 106.

by J. A. Musick

INTRODUCTION

Deep water dump site 106 (DWD 106) is located 145 km off the coast of New Jersey and is bounded by the latitudes of 38°40' and 39°00'N and longitudes 72°00' and 72°30'W. The depth of DWD 106 varies from about 1300 m in the northeast corner to 2700 m in the southwest (Fig. 1). Most of the site is deeper than 2000 m. Within DWD 106 is a smaller dump site that has been in use for many years for industrial wastes and munitions. Due south of DWD 106 is an additional dumpsite (Fig. 1) at which the Atomic Energy Commission reported dumping radioactive wastes (rad site). The purpose of this report is to describe the fish fauna in the area of DWD 106 and to provide information on the ecology of dominant species.

Studies of the demersal fishes on the continental slope and rise off the middle Atlantic states began in the latter half of the nineteenth century with the cruises of the Blake and Albatross (Agassiz 1888) that culminated in the publication of Goode & Bean's classic "Oceanic Ichthyology" (1896). These early reports were little more than lists of species (many of which were new to science). Virtually no research was done on demersal slope fishes in this region again until a half century later when Schroeder (1955) reported geographic and depth distribution of several species trawled between Nova Scotia and Virginia as deep as 1335 m. Edwards, Livingston & Hamer (1962) noted the results

Fig. 1. Deep water dump site 106 and adjacent area including bottom trawl station locations for R/V Delaware II cruise 74-2.

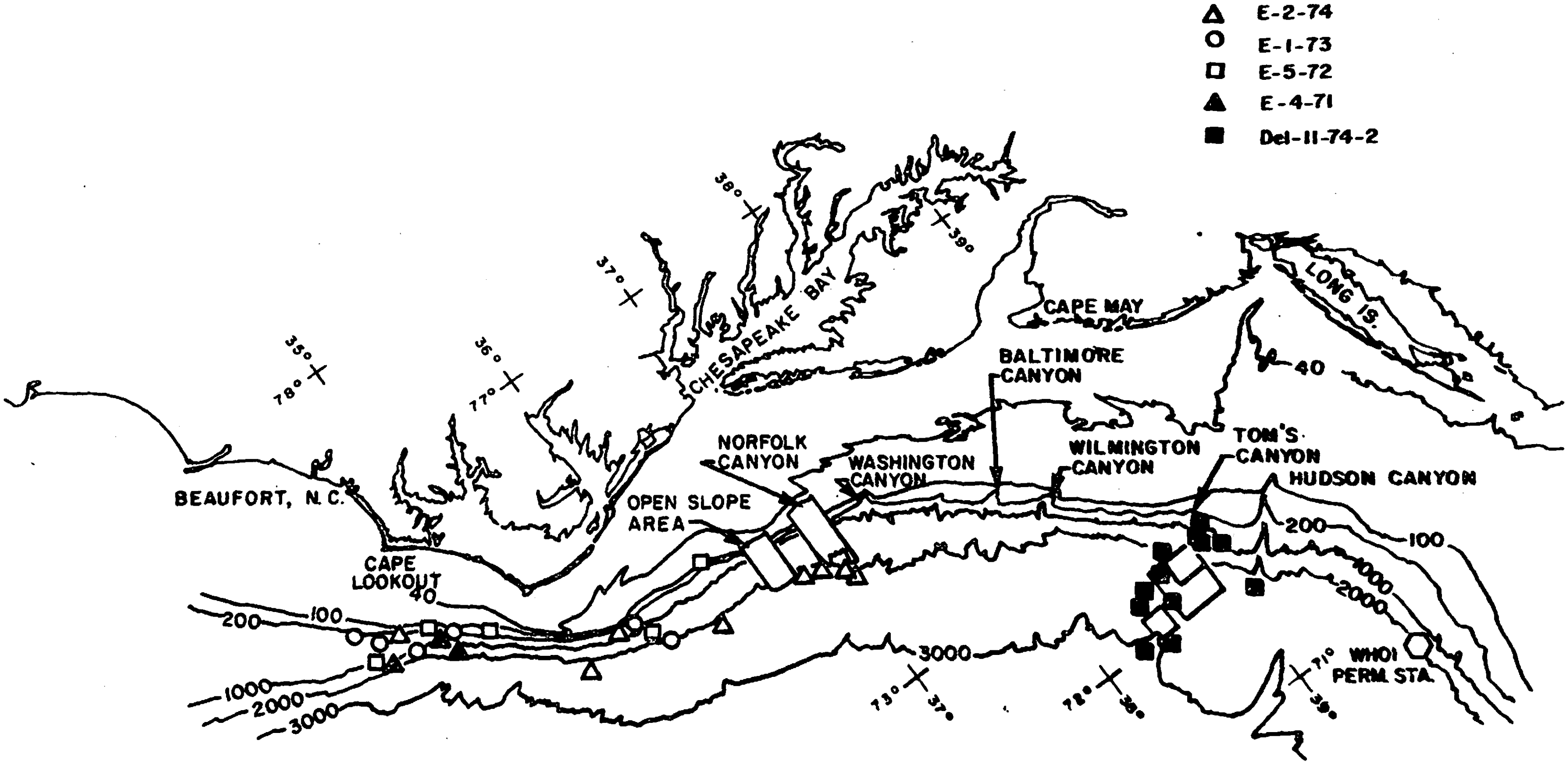
of a series of trawl transects to depths of about 400 m between Cape Hatteras and Nantucket Shoals. Haedrich & Horn (1970) recorded the catch from one trawl station at 1280 m in Hudson Canyon and Haedrich and Polloni (1974) compared that catch to another from a single trawl taken 4 years later at the same place. Markle & Musick (1974) studied demersal fish species associations and diversity in a series of eleven otter trawl catches made at about 900 m between Cape Hatteras and Block Canyon.

METHODS OF DATA COLLECTION

Delaware II data

A trawl reconnaissance was made in and around DWD 106 from R/V Delaware II on cruise D-2-74 from May 14 to 17, 1974, inclusive. Fourteen successful tows of one hour duration each were made at depths of 951 m to 2820 m with a 45' (13.7 m) semi-balloon otter trawl, with 2" (4.45 cm) stretch mesh in wings and body, 1/2" (1.27 cm) stretch mesh liner in the codend, China "V" otter doors and 90' (27.4) bridle and swivel fished from a single trawl warp. All fishes captured were identified, measured and weighed (by species). Digestive tracts were removed from selected dominant species and preserved in 10% formalin for subsequent studies of diet. Also gonads were removed from selected species and preserved in Bouins solution for histological preparation and, in some instances, Gilsons solution for fecundity estimates.

Fig. 2. Trawl stations on the continental slope and rise made on R/V *Eastward* cruises E-4-71, E-5-72, E-1-73, E-2-74 and R/V *Delaware II* cruise 74-2. The locations of R/V *C. O. Iselin* Norfolk Canyon and open slope study areas are also figured.


△ E-2-74
○ E-1-73
□ E-5-72
▲ E-4-71
■ Del-11-74-2
CHESAPEAKE BAY
CAPE MAY
LONG IS.
40
BALTIMORE CANYON
NORFOLK CANYON
WASHINGTON CANYON
WILMINGTON CANYON
TOM'S CANYON
HUDSON CANYON
BEAUFORT, N.C.
OPEN SLOPE AREA
CAPE LOOKOUT
40
100
200
1000
2000
3000
200
100
1000
2000
3000
WHOI PERM. STA.
35°
78°
36°
77°
37°
38°
39°
73°
37°
72°
38°
71°
39°

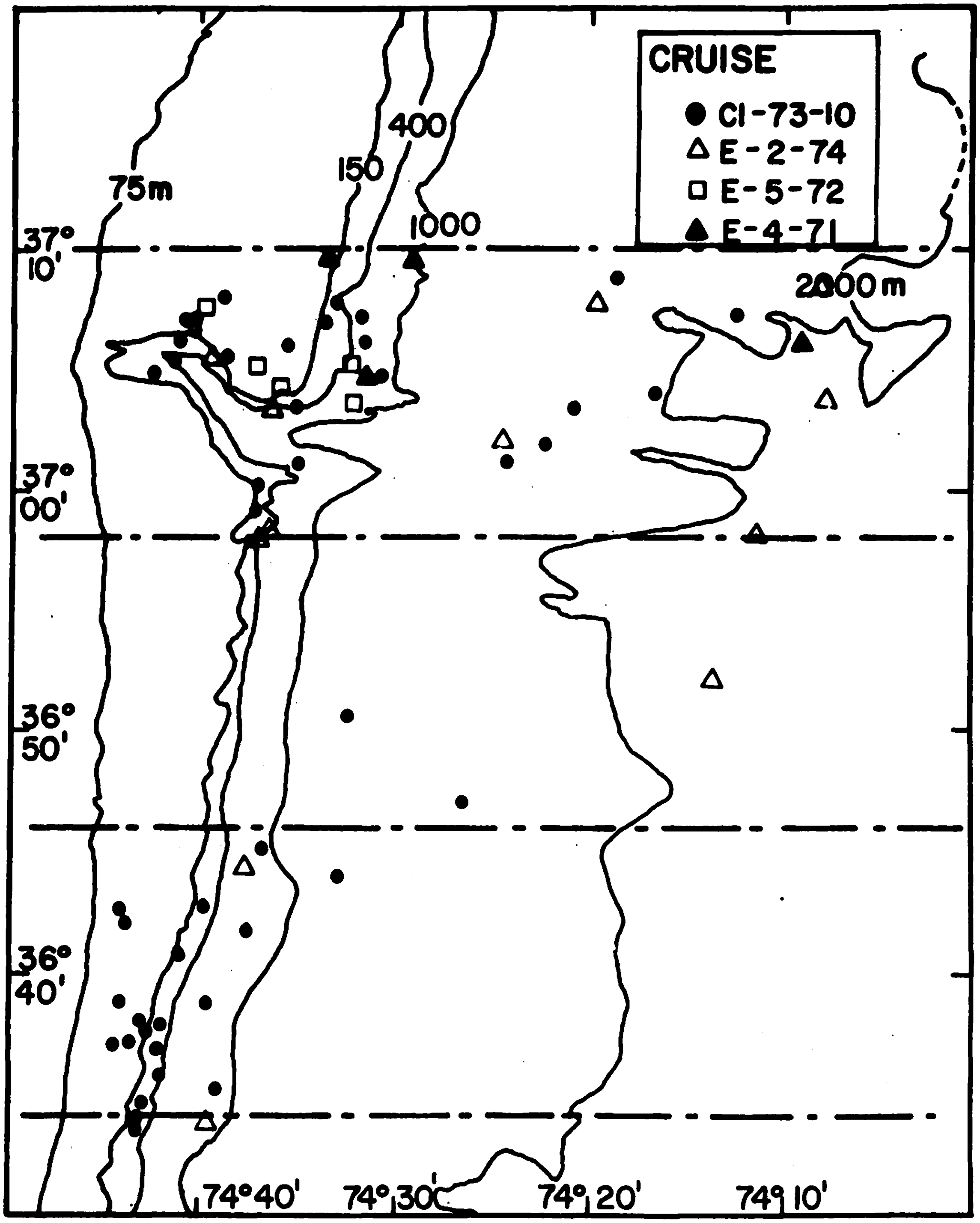
C. O. Iselin and Eastward data

It would not be scientifically prudent to define assemblages of fishes on the lower slope and upper continental rise on the basis of the limited sampling permitted during the Delaware II program. However, comparison of this data with more comprehensive data allows a reasonable description of species assemblages and patterns of diversity and distribution of biomass and related parameters at least as reflected in the animals' availability to the sampling gear. Data for comparison are available from our Norfolk Canyon Slope Study (sponsored in part by the National Science Foundation) and from several training cruises on R/V Eastward. We have selected for comparison data collected primarily in April, May or June (seasonally approximately equivalent to the Delaware II data).

Eastward cruises E-4-71, E-5-72, E-1-73, and E-2-74 included 32 stations on the continental slope or rise (Fig. 2). The net used on these cruises was the 30' (9.1 m) semi-balloon otter trawl with 1-1/2" (3.81 cm) stretch mesh in wings and body, 1/2" (1.27 cm) stretch mesh liner in codend and 90' (27.4 m) bridles. Wooden doors with steel double strap-shoes and solid plastic floats were used for all Eastward cruises except in 1974 when steel china "V" doors and four, two liter gasoline filled floats were used. All tows were of 1/2 hour duration except those deeper than 2000 m which were 1 hour. As part of the Norfolk Canyon study, a spring cruise was made on the R/V C. O. Iselin from June 1-20, 1973, and work was concentrated in Norfolk Canyon and an adjacent "open slope"

Fig. 3. Norfolk Canyon and open slope study areas with locations of stations made on R/V C. O. Iselin cruise CI-73-10, and R/V Eastward cruises E-4-71, E-5-72 and E-2-74. Stations made between the canyon and the slope areas were considered to be part of the open slope.

NORFOLK CANYON AND ADJACENT CONTINENTAL SLOPE



study area (Fig. 2). Intensive random stratified sampling was conducted from 75 m to 2000 m (Fig. 3) with 3 day and 3 night trawls randomly allocated to each of the following depth strata: 75-150 m, 150-400 m, 400-1000 m, 1000-2000 m. Fishing gear was the same as that used in the Delaware II study, but tow duration was 1/2 hour. All catch data in the analyses that followed were converted to a catch per-unit effort of one-half hour. However, Table 1 gives actual catches of demersal fishes at each Delaware II station. The term "demersal fish" as used herein includes so-called benthopelagic fishes (Marshall 1967).

METHODS OF DATA ANALYSIS

Clustering

Assemblages of fishes were defined by computing a distance coefficient, D(j,k), among species and subsequently classifying species into clusters or groups (Sneath & Sokal, 1973). In addition, stations were clustered in the same manner and then species groups were compared to station (site) groups.

The distance coefficient chosen was the Canberra metric, which is particularly of value when the organisms under study are contagiously distributed (W. Stephenson, personal communication) as are most fishes. Also to further reduce the effects of occasional large catches, the transformation, log e (X+1)=y was applied to numerical abundance data before analysis (Taylor 1953). The Canberra metric coefficient was defined by Lance & Williams (1967) as:

$$D_{(j,k)} = \sum_{i=1}^{h} \frac{X_{ij} - X_{ik}}{(X_{ij} + X_{ik})}$$

Table 1. Demersal fishes captured at D.W.D. #106 trawl stations.

Station # Depth (m) Taxon	2 951	3 1143	3B 1207	3A 1353	4B 2130	ALV2 2286	4C 2377	5 2620	6B 2700	6A 2745	5A 2745	6 2745
Chimaeridae												
Hydrolagus affinis						1						
Rhinochimaeridae												
Harriotta raleighana	2		6				1					
Squalidae												
Centroscyllium fabricii		1	2									
Centroscymnus coelolepis	1	1										
Rajidae												
Raja bathyphila		1		2	1							
Raja jenseni					1							
Bathyraja richardsoni							1				1	
Synaphobranchidae												
Synaphobranchus kaupi	321	20	40	12	5							
Ilyophis brunneus		3			1					1		
Nettastomatidae												
Venefica procera		1				1						
Simenchelyidae												
Simenchelys parasiticus			1									
Halosauridae												
Halosaurus guentheri	2											
Halosauropsis macrochir					19	7	5		3			
Aldrovandia affinis			3									
Aldrovandia phalacra	3	35	3									
Aldrovandia rostrata		5										
Notacanthidae												
Polyacanthonotus africanus		1										
Notacanthus chemnitzi					1							

Table 1. (Continued)

Station # Depth (m) Taxon	2 951	3 1143	3B 1207	3A 1353	4B 2130	ALV2 2286	4C 2377	5 2620	6B 2700	6A 2745	5A 2745	6 2745
Alepocephalidae												
Alepocephalus agassizii	4	12	29	1	1	3						
Grimatroctes bullisii					1							
Narcetes stomias					2							
Synodontidae												
Bathysaurus agassizii					2	1						
Bathypteroidae												
Benthosaurus grallator					2							
Ogocephalidae												
Dibranchus atlanticus		1										
Chaunacidae												
Chaunax sp.					1							
Gadidae												
Urophycis tenuis	2											
Phycis chesteri	4	5										
Ophidiidae												
Dicrolene intronigra	4	16	27									
Monomitopus agassizii	1											
Xyelacyba myersi								1				
Porogadus miles					8		2					
Macrouridae												
Nezumia bairdii	73	37	69	6								
Nezumia aegualis	2											
Nezumia cyrano			1									
Coryphaenoides rupestris	13	8		1								
Coryphaenoides armatus					4	8	8	7	16	8		1
Coryphaenoides leptolepis									1			
Coryphaenoides carapinus		31	3	2	27	4	1	1	3			

Table 1. (Continued)

Station #	2	3	3B	3A	4B	ALV2	4C	5	6B	6A	5A	6
Depth (m)	951	1143	1207	1353	2130	2286	2377	2620	2700	2745	2745	2745
Taxon												
Moridae												
Antimora rostrata		15	28	17	72	14	2	1	3			
Halargyreus johnsonii		1	2		2							
Lotella sp. A	1											
Zoarcidae												
Lycodes atlanticus	5	1	2		1							
Lycenchelys paxillus	22		1									
Lycodonus mirabilis	1	1										
Cottidae												
Cottonculus thompsoni	1		2									
Cyclopteridae												
Paraliparis garmani			1									
Pleuronectidae												
Glyptocephalus cynoglossus	60	9	3									

where in species analysis (inverse analysis) X = the number of species j and k at station i, and in station analysis (normal analysis) X = the number of species i at stations j and k.

The Canberra metric is a dissimilarity function, but in practice the complement is used to yield a similarity function before clustering (Williams, 1971). The clustering strategy used herein is flexible with β =-0.25 (Lance & Williams, 1967b), and is an agglomerative hierarchical procedure which avoids chaining and is space conserving (Sneath & Sokol, 1973).

RESULTS

Cluster analysis

Site Clusters:

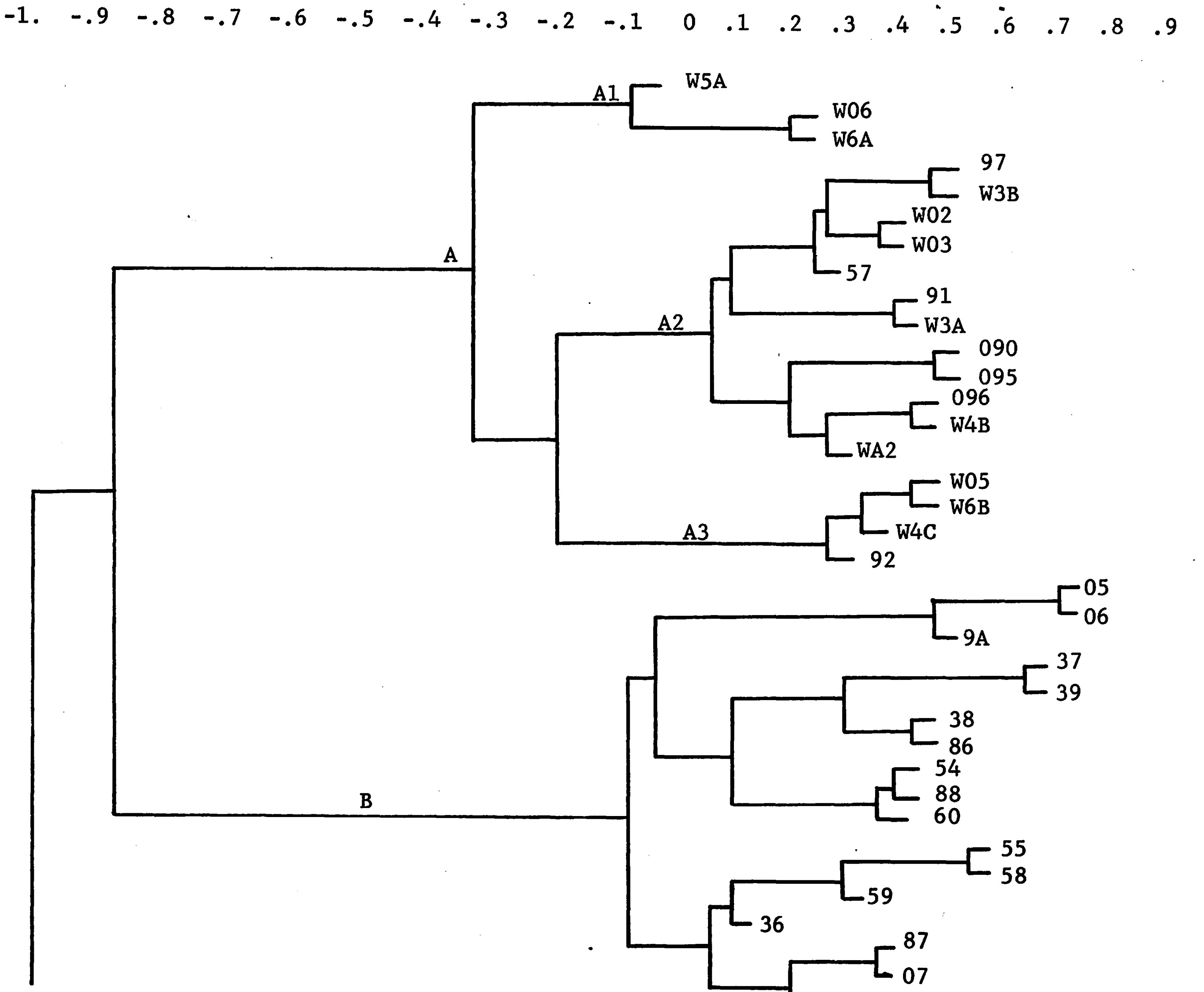
Examination of the dendrogram (Figs. 4 & 5) depicting the results of the site group cluster analysis shows four major site groups, A-D. Group B includes Iselin stations made at 37 to 136 m, C includes stations from 403 to 986 m, and D, stations from 166 to 390 m. Group A is the most relevant to the present report because within it are included all of the Delaware II stations as well as Iselin stations with high similarity to the DWD stations.

Site group A may be further divided into three subgroups A^1, A^2, A^3.

Species Clusters:

Six species groups, A-F, are evident in Figs. 6, 7 & 8. Of these, D-F include species assemblages from the upper slope

Fig. 4. Upper section of dendrogram depicting site group clusters. D.W.D. stations are noted with the prefix "W". All other stations are from R/V C. O. Iselin cruise 73-10.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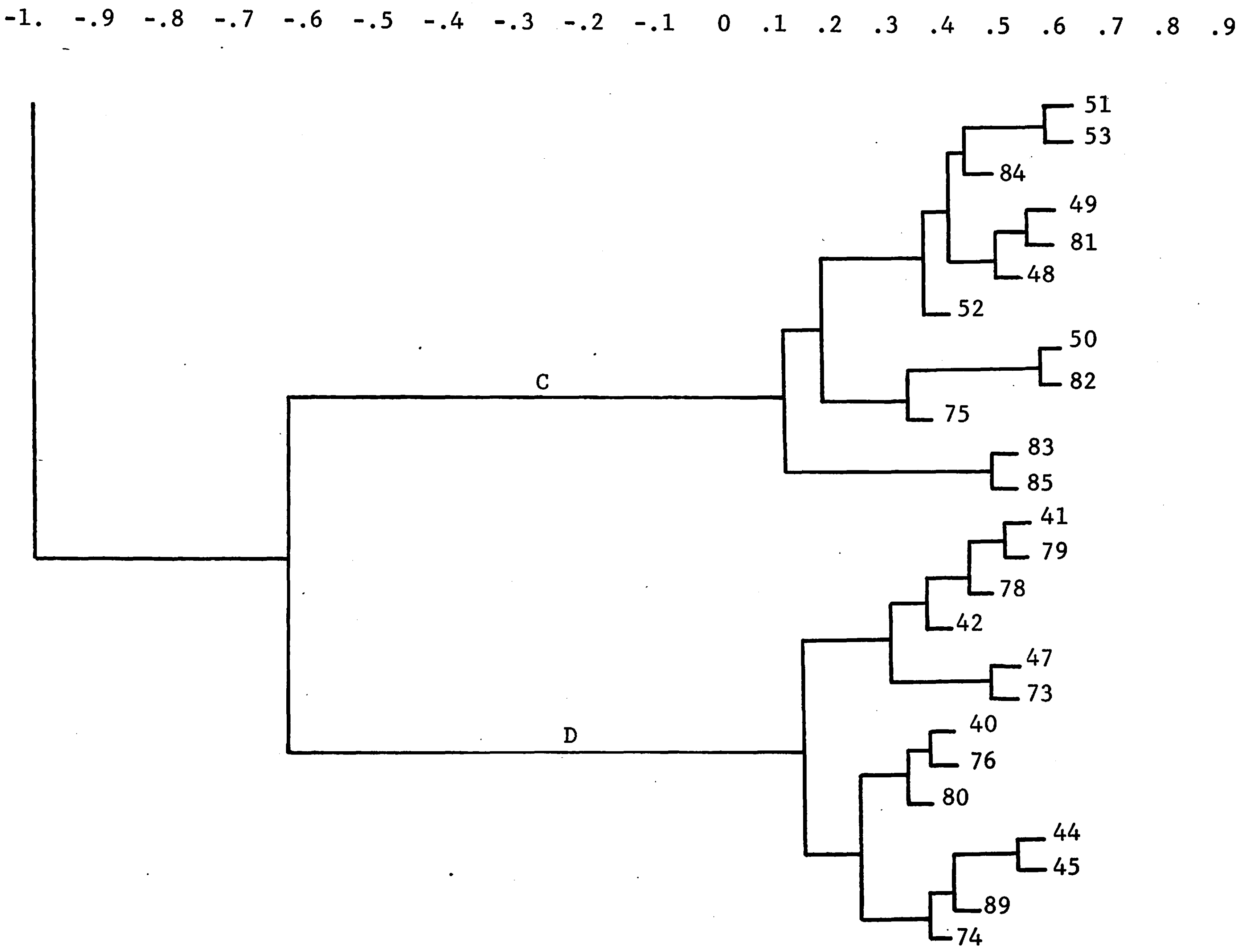
.6
.7
.8
.9
A1
W5A
W06
W6A
97
W3B
W02
W03
57
A
91
W3A
A2
090
095
096
W4B
WA2
W05
W6B
W4C
A3
92
05
06
9A
37
39
38
86
54
88
60
B
55
58
59
36
87
07
08

Fig. 5. Lower section of dendrogram depicting site group clusters. D.W.D. stations are noted with the prefix "W". All other stations are from R/V C. O. Iselin cruise 73-10.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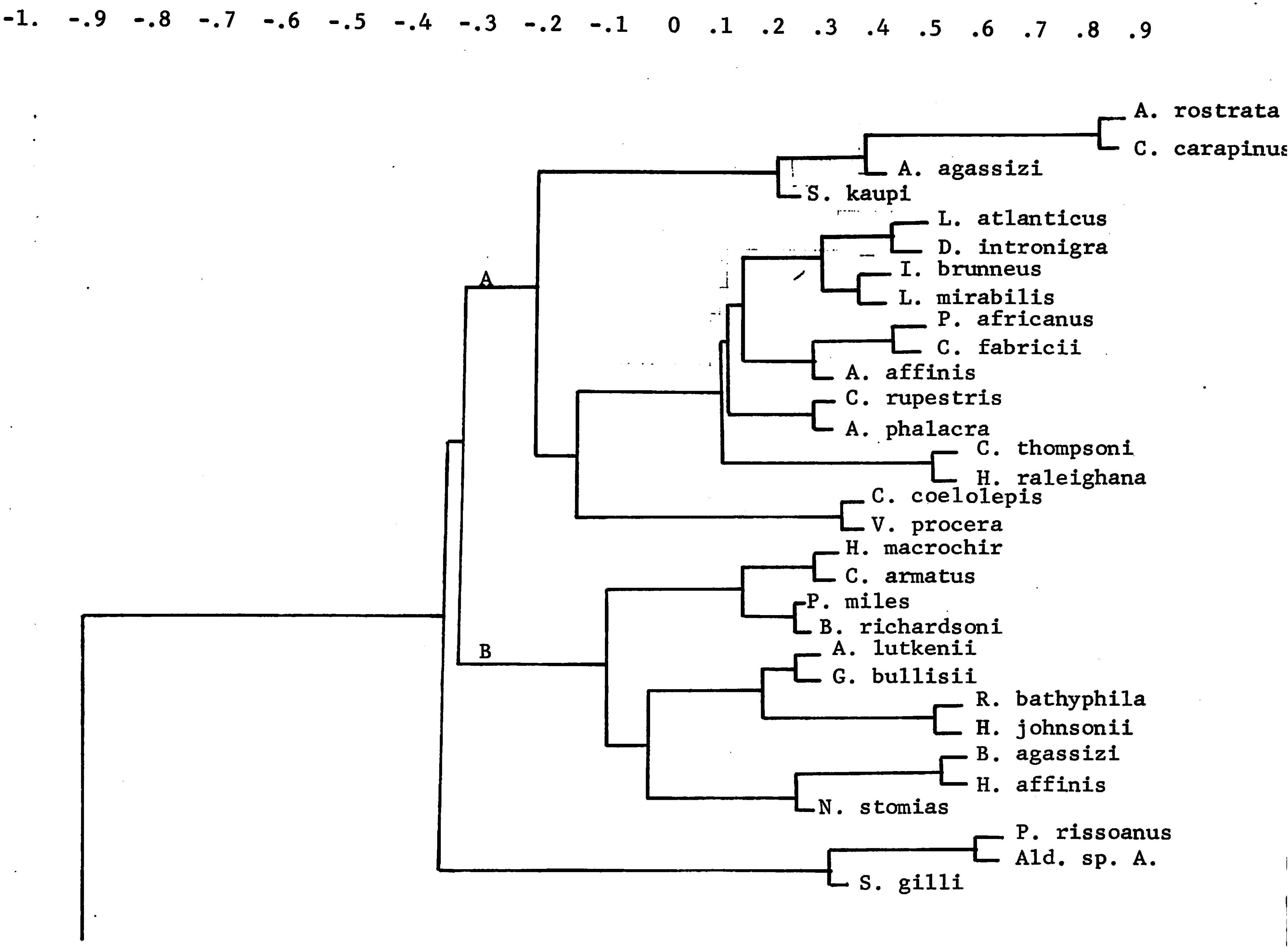
.8
.9
C
D
51
53
84
49
81
48
52
50
82
75
83
85
41
79
78
42
47
73
40
76
80
44
45
89
74

Fig. 6. Upper section of dendrogram depicting species group clusters constructed from a data matrix including trawl catches from D.W.D. 106 and R/V C. O. Iselin cruise 73-10.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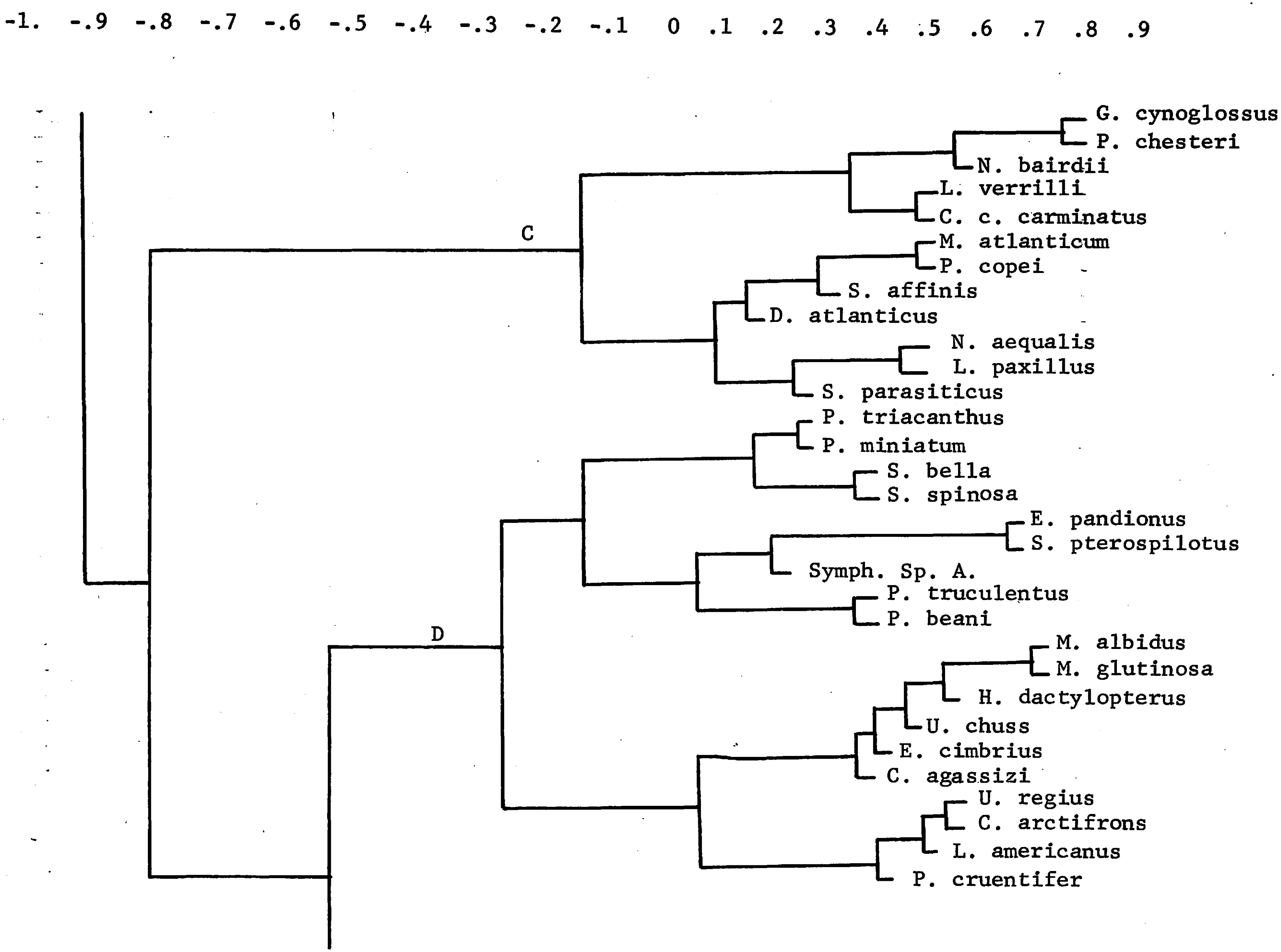
.9
A. rostrata
C. carapinus
A. agassizi
S. kaupi
L. atlanticus
D. intronigra
I. brunneus
L. mirabilis
P. africanus
C. fabricii
A. affinis
C. rupestris
A. phalacra
C. thompsoni
H. raleighana
C. coelolepis
V. procera
H. macrochir
C. armatus
P. miles
B. richardsoni
A. lutkenii
G. bullisii
R. bathyphila
H. johnsonii
B. agassizi
H. affinis
N. stomias
P. rissoanus
Ald. sp. A.
S. gilli
A
B

Fig. 7. Central section of dendrogram depicting species group clusters constructed from a data matrix including trawl catches from D.W.D. 106 and R/V *C. O. Iselin* cruise 73-10.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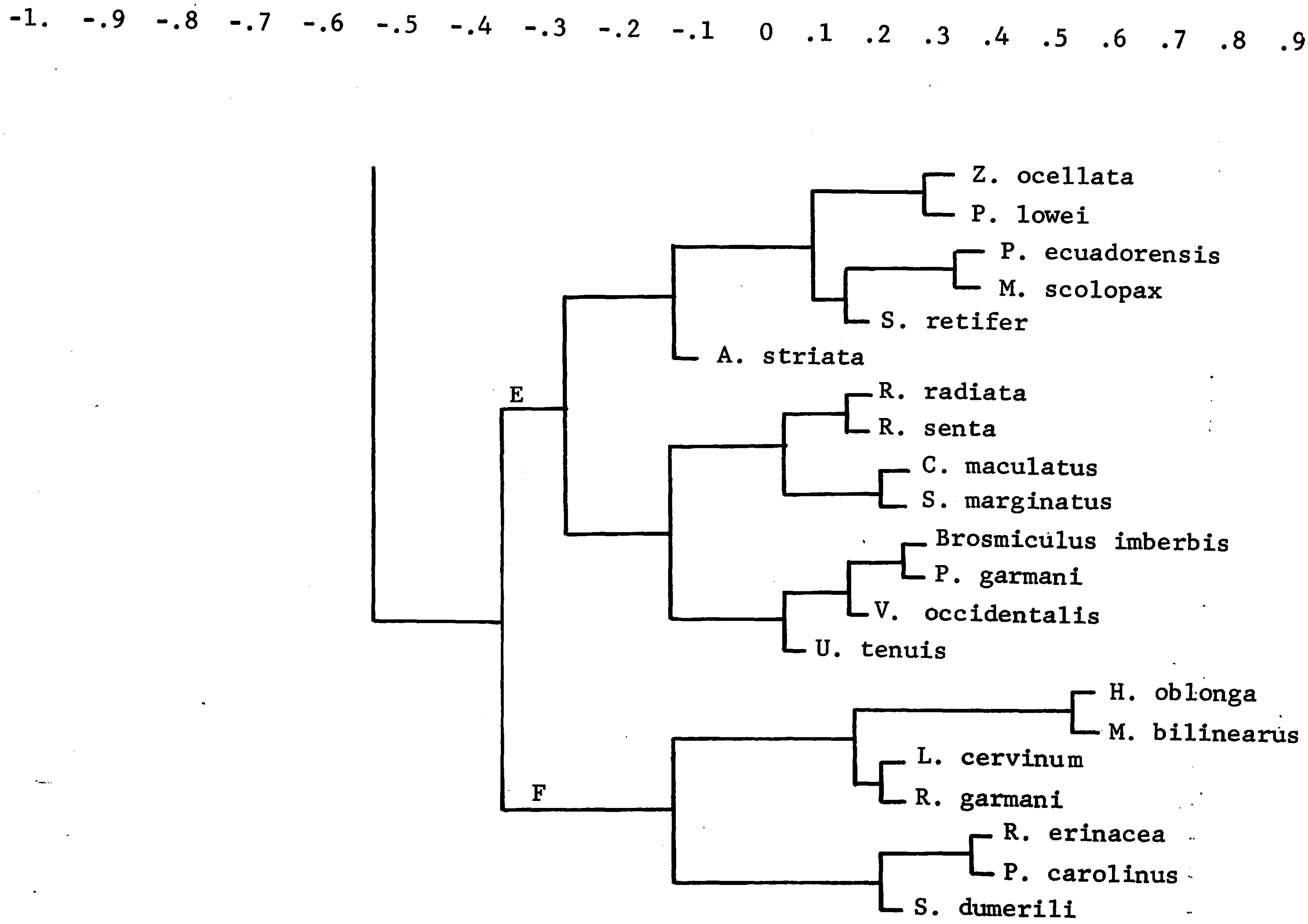
.9
C
D
G. cynoglossus
P. chesteri
N. bairdii
L. verrilli
C. c. carminatus
M. atlanticum
P. copei
S. affinis
D. atlanticus
N. aequalis
L. paxillus
S. parasiticus
P. triacanthus
P. miniatum
S. bella
S. spinosa
E. pandionus
S. pterospilotus
Symph. Sp. A.
P. truculentus
P. beani
M. albidus
M. glutinosa
H. dactylopterus
U. chuss
E. cimbrius
C. agassizi
U. regius
C. arctifrons
L. americanus
P. cruentifer

Fig. 8. Lower section of dendrogram depicting species group clusters constructed from a data matrix including trawl catches from D.W.D. 106 and R/V C. O. Iselin cruise 73-10.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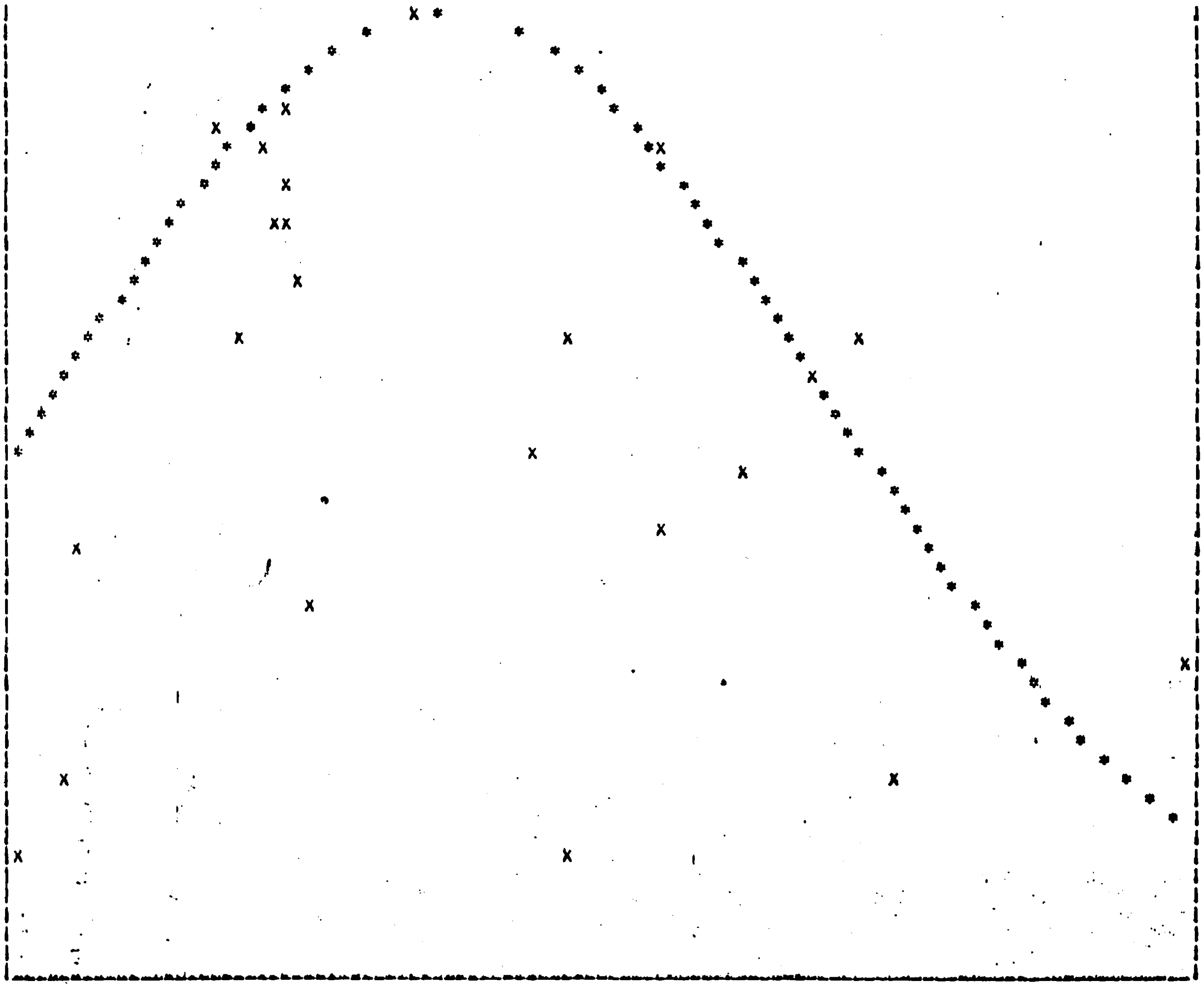
.7
.8
.9
Z. ocellata
P. lowei
P. ecuadorensis
M. scolopax
S. retifer
A. striata
E
R. radiata
R. senta
C. maculatus
S. marginatus
Brosmiculus imberbis
P. garmani
V. occidentalis
U. tenuis
H. oblonga
M. bilinearus
L. cervinum
R. garmani
F
R. erinacea
P. carolinus
S. dumerili

Fig. 9. Distribution of $\log_e$ transformed catches (y axis) of Synaphobranchus kaupi with depth (x axis) and Gaussian curve fitted to data.

NUMBER OF INDIVIDUALS -
DEPTH OF INDIVIDUALS

Synaphobranchus kaupi



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PERCENTAGE OF VARIANCE ACCOUNTED FOR =   28.5982  AVERAGE PERCENT DISPLACEMENT =   30.7192
```

Fig. 10. Distribution of $\log_e$ transformed catches (y axis) of <u>Ilyophis brunneus</u> with depth (x axis) and Gaussian curve fitted to data.

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NUMBER OF INDIVIDUALS
DEPTH OF INDIVIDUALS
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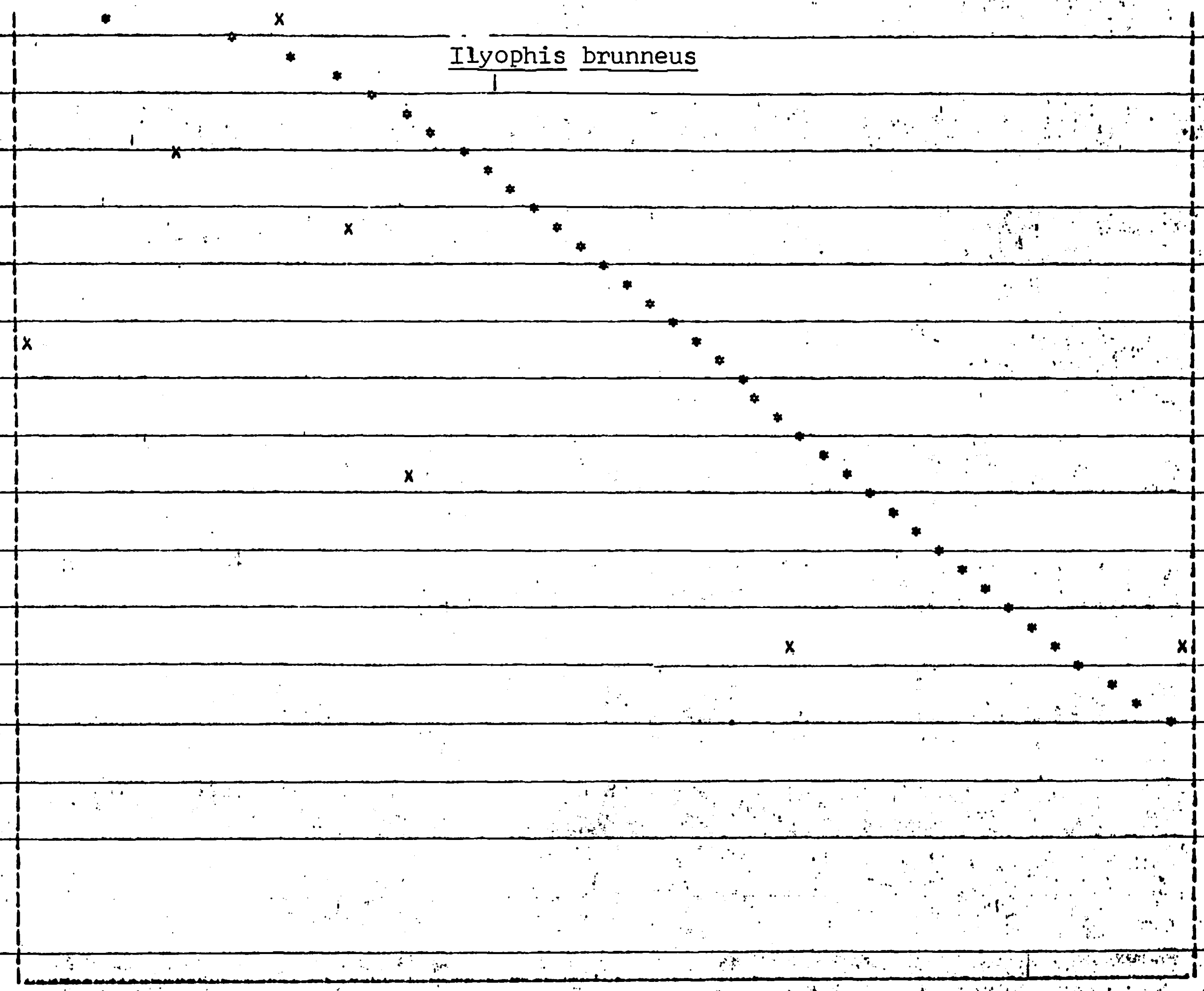

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PERCENTAGE OF VARIANCE ACCOUNTED FOR =   64.3890  AVERAGE PERCENT DISPLACEMENT =   19.8810
```
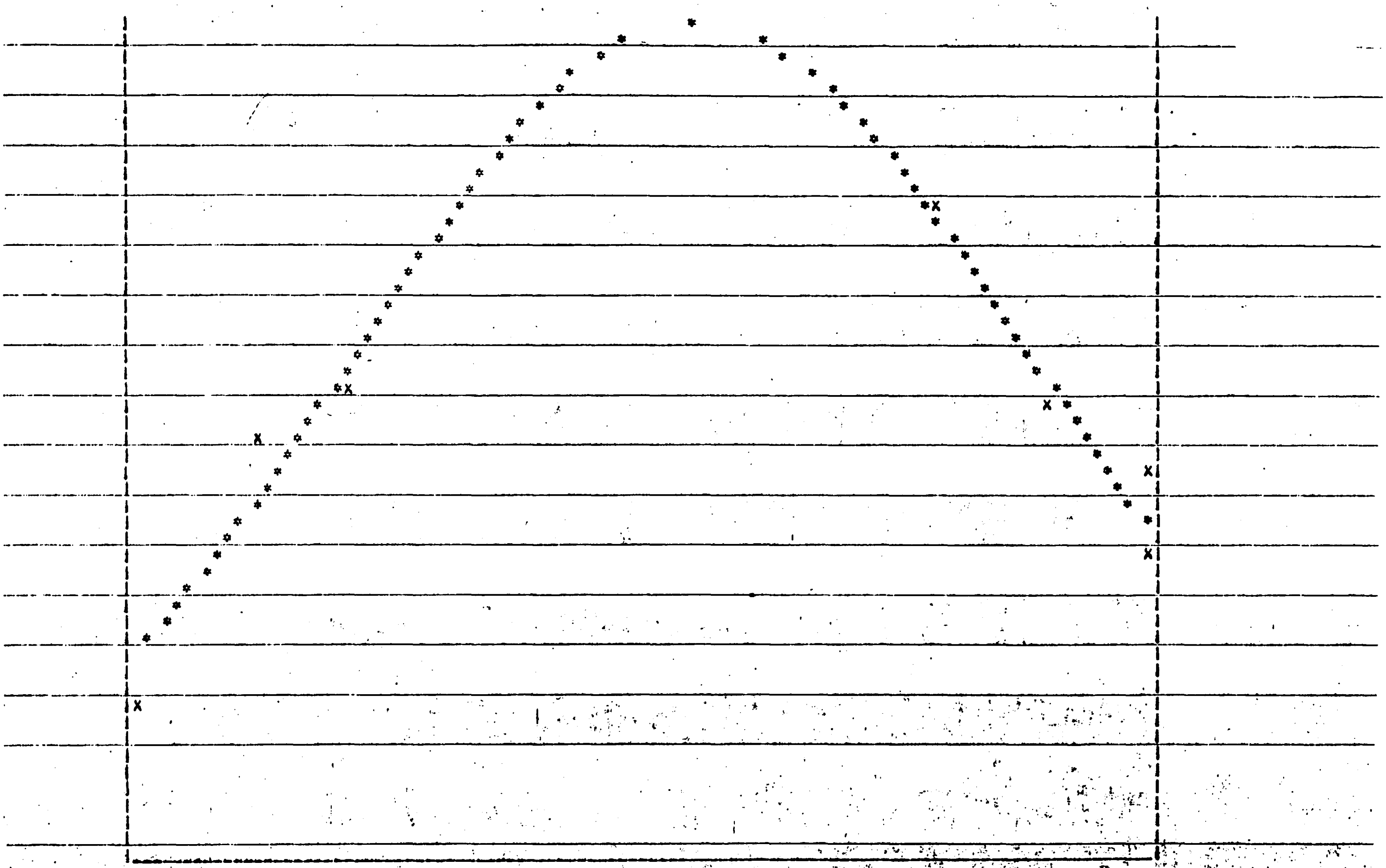

Fig. 11. Distribution of $\log_e$ transformed catches (y axis) of Halosauropsis macrochir with depth (x axis) and Gaussian curve fitted to data.

NUMBER OF INDIVIDUALS
DEPTH OF INDIVIDUALS

Halosauropsis macrochir



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PERCENTAGE OF VARIANCE ACCOUNTED FOR = 90.2034 AVERAGE PERCENT DISPLACEMENT = 9.8241

Fig. 12. Distribution of $\log_e$ transformed catches (y axis) of <u>Alepocephalus</u> <u>agassizi</u> with depth (x axis) and Gaussian curve fitted to data.

```
NUMBER OF INDIVIDUALS
DEPTH OF INDIVIDUALS
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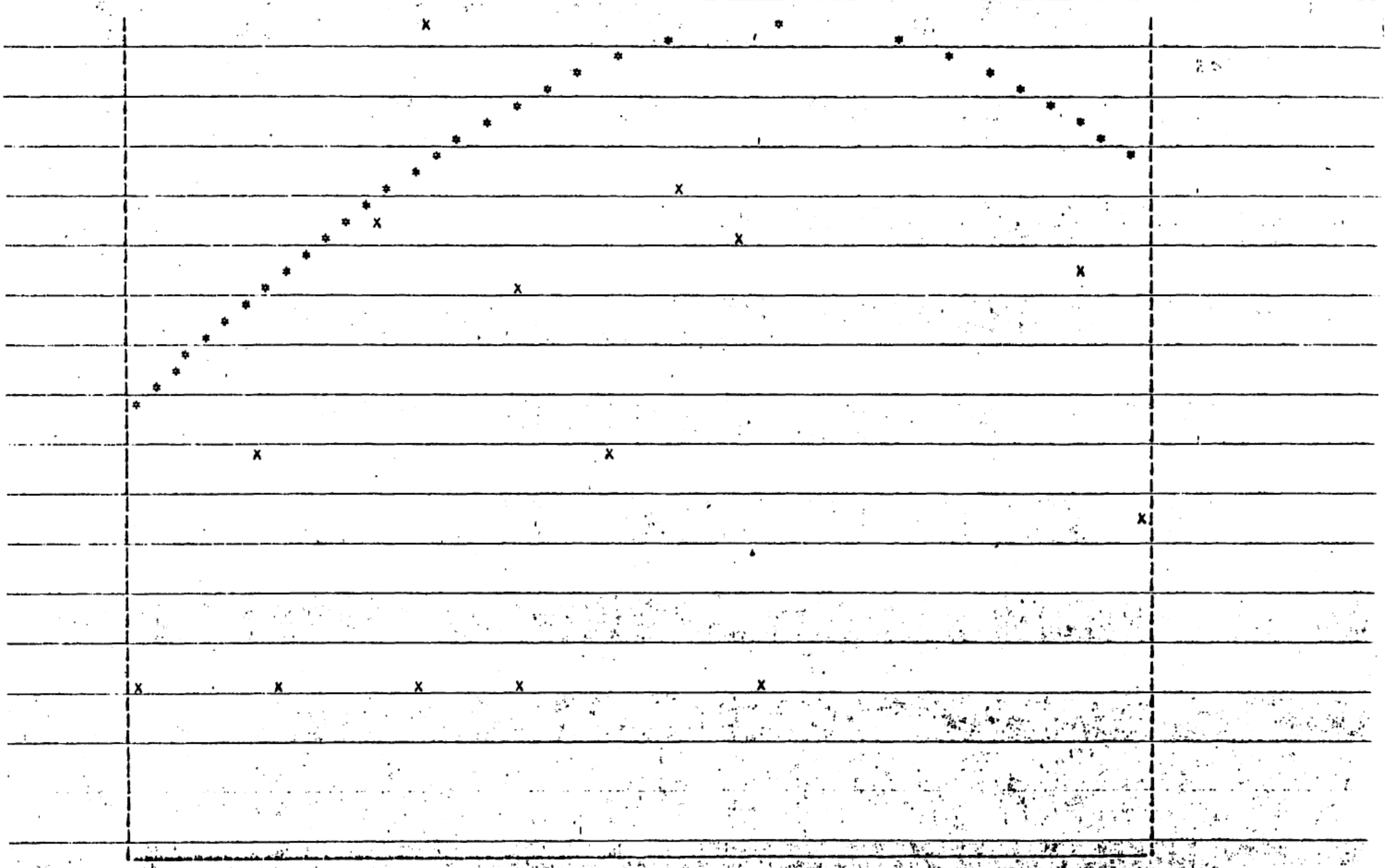
Alepocephalus agassizi



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PERCENTAGE OF VARIANCE ACCOUNTED FOR =   10.0678  AVERAGE PERCENT DISPLACEMENT =  43.4322
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Fig. 13. Distribution of $\log_e$ transformed catches (y axis) of Bathysaurus agassizi with depth (x axis) and Gaussian curve fitted to data.

Bathysaurus agassizi

```
GRAPH SCALES: Y = 0.0 TO   0.1386294E 01  AND X =   0.1350000E 04  TO   0.2288000E 04
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PERCENTAGE OF VARIANCE ACCOUNTED FOR =   69.3330  AVERAGE PERCENT DISPLACEMENT =   13.5168
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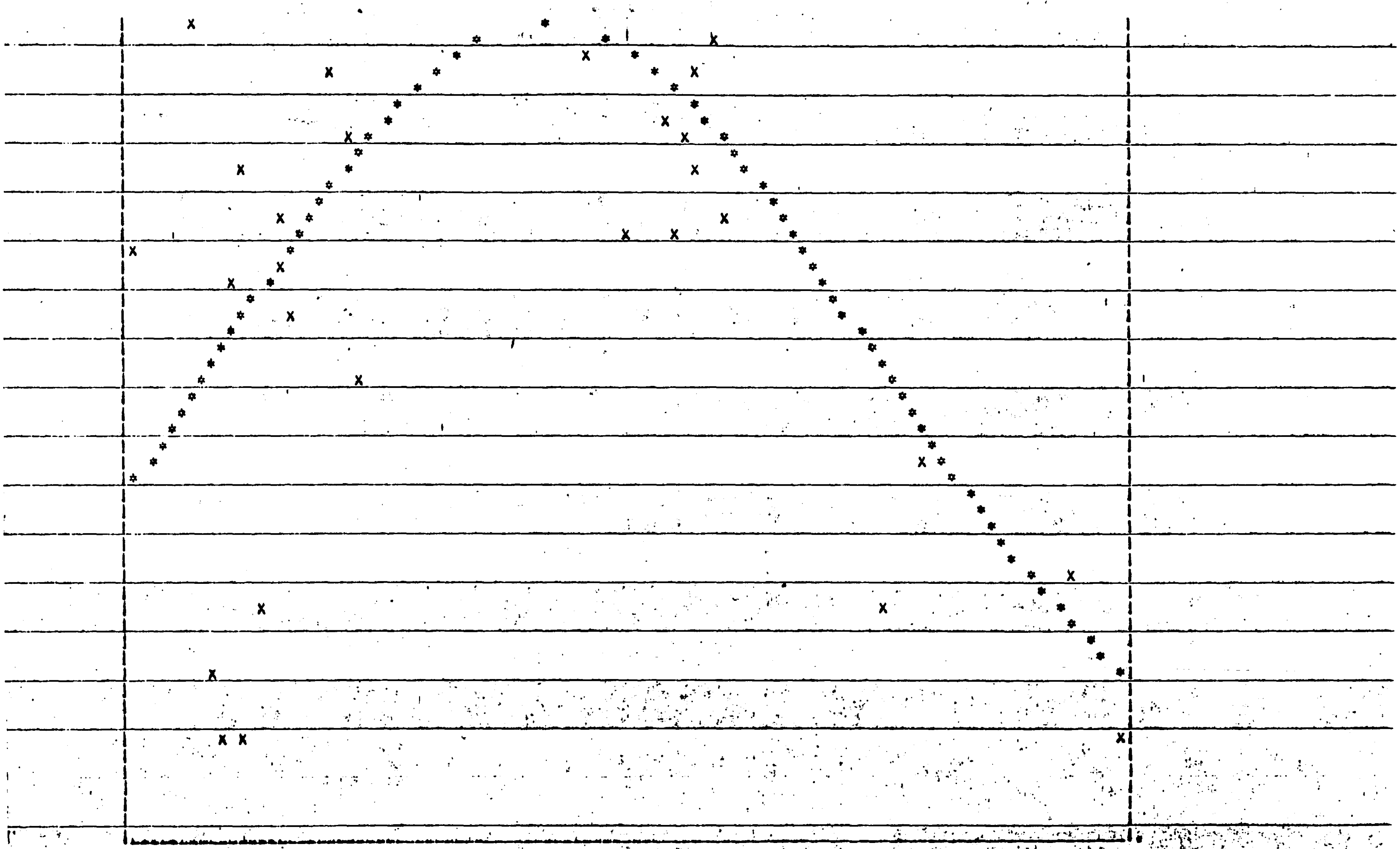
Fig. 14. Distribution of $\log_e$ transformed catches (y axis) of <u>Phycis</u> <u>chesteri</u> with depth (x axis) and Gaussian curve fitted to data.

Phycis chesteri

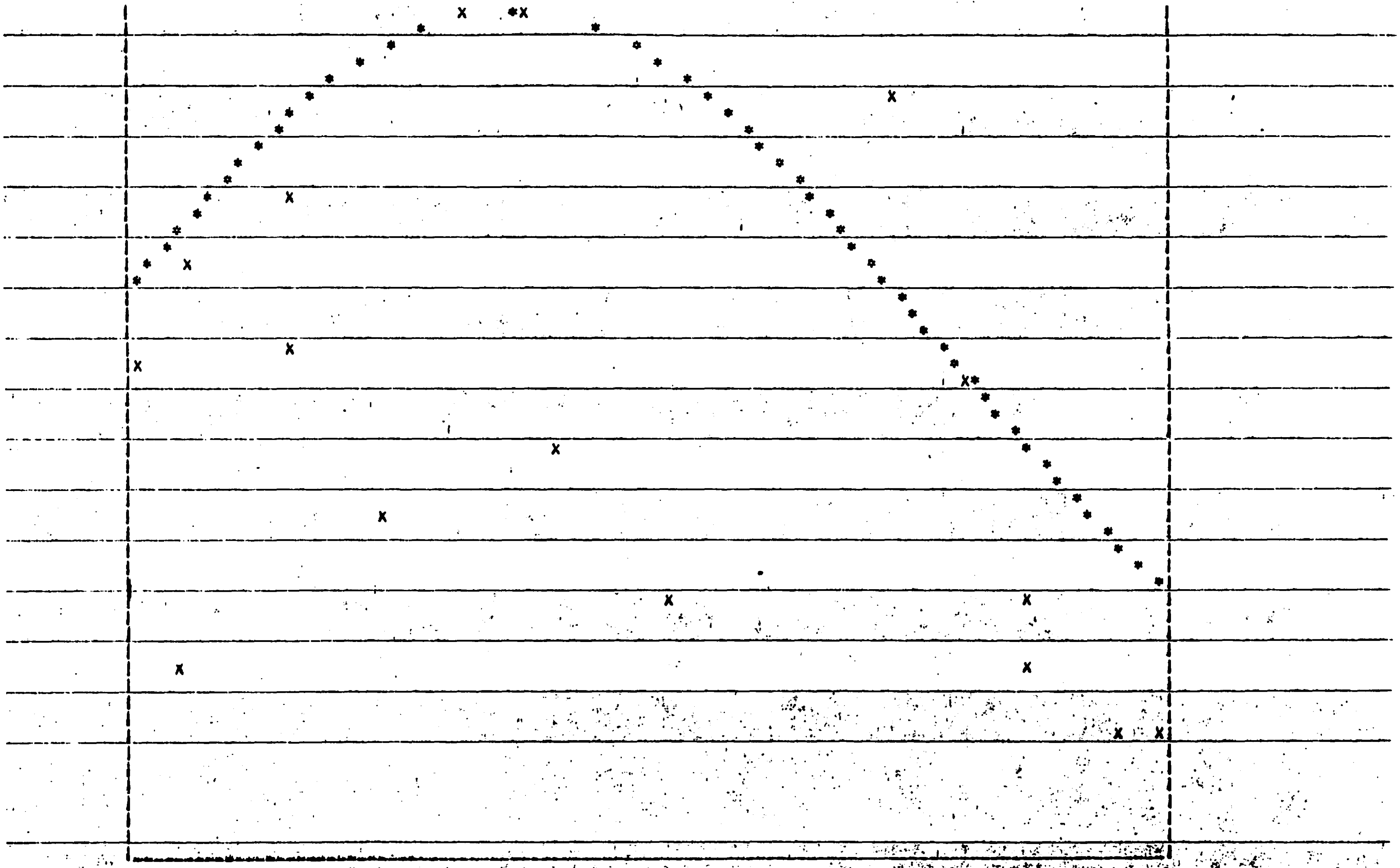


```
GRAPH SCALES:  Y = 0.0 TO  0.5609472E 01  AND X =  0.1660000E 03  TO  0.1194000E 04
MODE =  0.5968396E 03  MAX =  0.5095143E 01  SIG =  0.3325288E 03  SSD =  0.4125555E 02  VAR =  0.6933760E 02
PERCENTAGE OF VARIANCE ACCOUNTED FOR =   40.5004  AVERAGE PERCENT DISPLACEMENT =   26.2462
```

Fig. 15. Distribution of $\log_e$ transformed catches (y axis) of <u>Antimora rostrata</u> with depth (x axis) and Gaussian curve fitted to data.

NUMBER OF INDIVIDUALS
DEPTH OF INDIVIDUALS

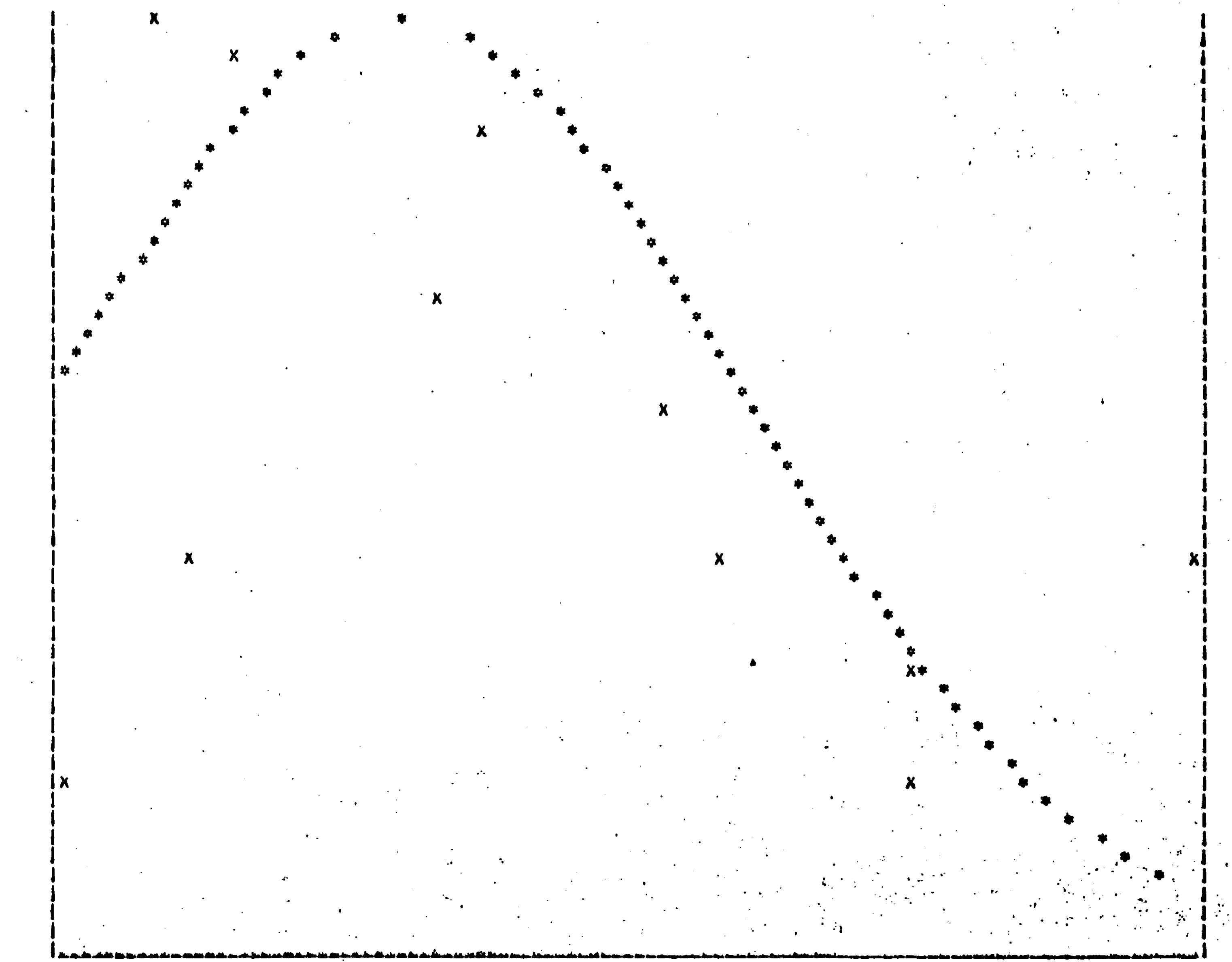
Antimora rostrata



GRAPH SCALES: Y = 0.0 TO 0.4779123E 01 AND X = 0.1142000E 04 TO 0.2562000E 04
MODE = 0.1661237E 04 MAX = 0.3414451E 01 SIG = 0.5942317E 03 SSD = 0.1883707E 02 VAR = 0.2927702E 02
PERCENTAGE OF VARIANCE ACCOUNTED FOR = 35.6592 AVERAGE PERCENT DISPLACEMENT = 37.6187

Fig. 16. Distribution of $\log_e$ transformed catches (y axis) of Coryphaenoides rupestris with depth (x axis) and Gaussian curve fitted to data.

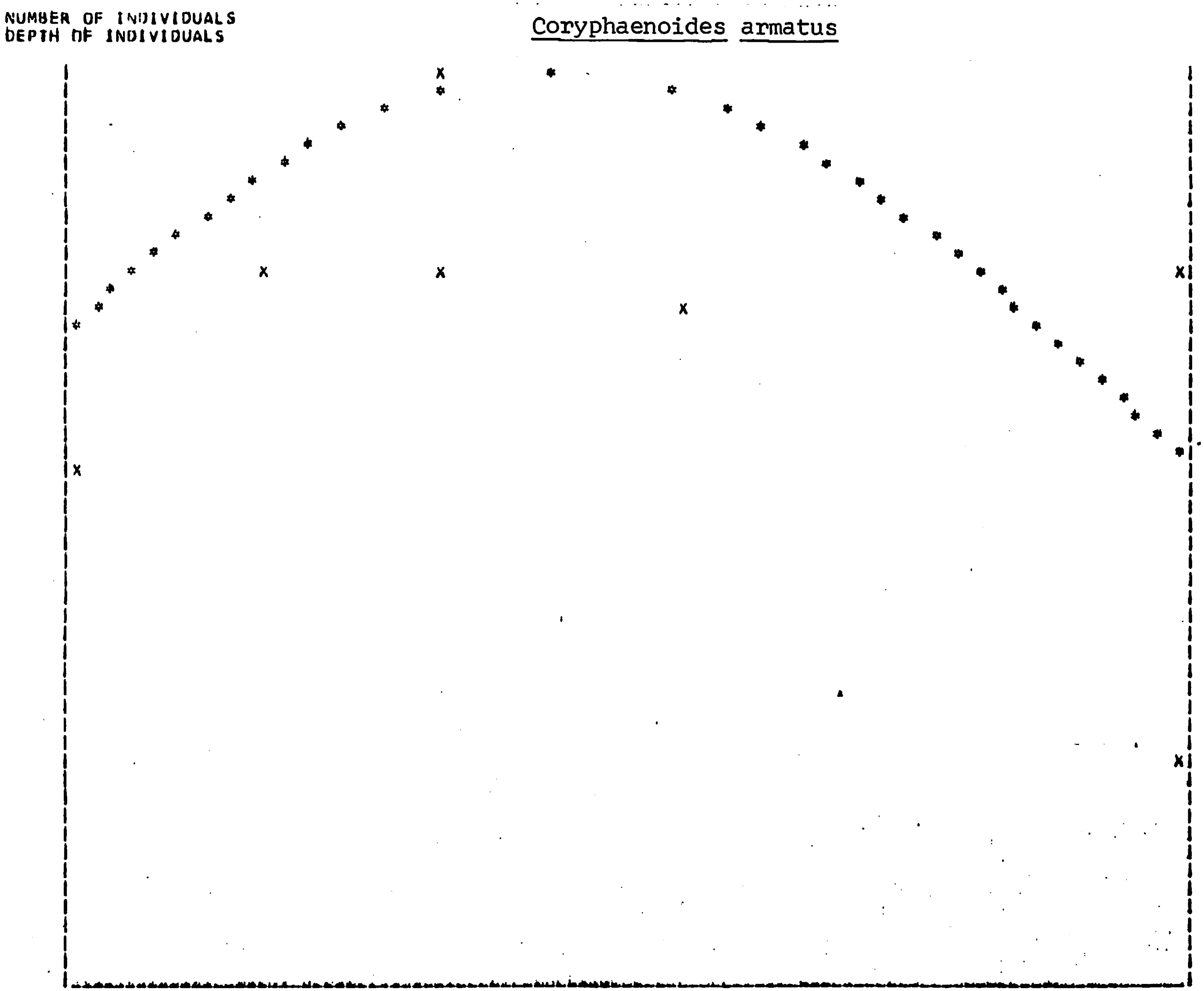
Coryphaenoides rupestris



```
GRAPH SCALES:  Y = 0.0 TO   0.3761200E 01  AND X =   0.6360000E 03  TO   0.1591000E 04
MODE =  0.9206772E 03  MAX =  0.3194145E 01  SIG =  0.2866460E 03  SSD =  0.7498878E 01  VAR =  0.1245917E 02
PERCENTAGE OF VARIANCE ACCOUNTED FOR =   39.7930  AVERAGE PERCENT DISPLACEMENT =   32.7450
```

Fig. 17. Distribution of $\log_e$ transformed catches (y axis) of _Coryphaenoides armatus_ with depth (x axis) and Gaussian curve fitted to data.

Coryphaenoides armatus

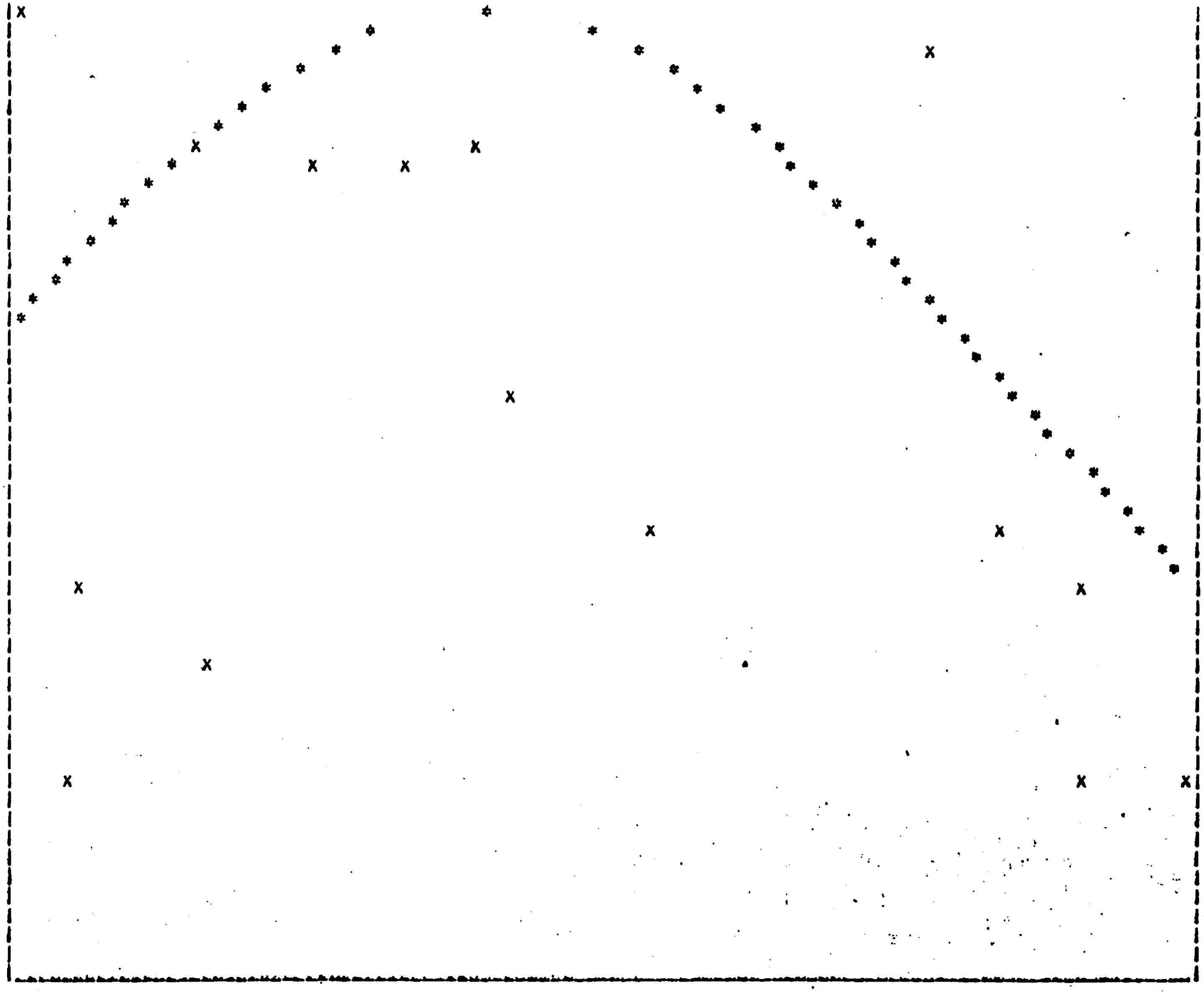


```
GRAPH SCALES:  Y = 0.0 TO   0.2833213E 01   AND X =   0.2196000E 04   TO   0.2745000E 04
MODE =  0.2434648E 04  MAX =  0.2418804E 01  SIG =  0.2968533E 03  SSD =  0.1478152E 01  VAR =  0.2872321E 01
PERCENTAGE OF VARIANCE ACCOUNTED FOR =   44.6866  AVERAGE PERCENT DISPLACEMENT =   18.9705
```

Fig. 18. Distribution of $\log_e$ transformed catches (y axis) of <u>Coryphaenoides</u> <u>carapinus</u> with depth (x axis) and Gaussian curve fitted to data.

NUMBER OF INDIVIDUALS
DEPTH OF INDIVIDUALS

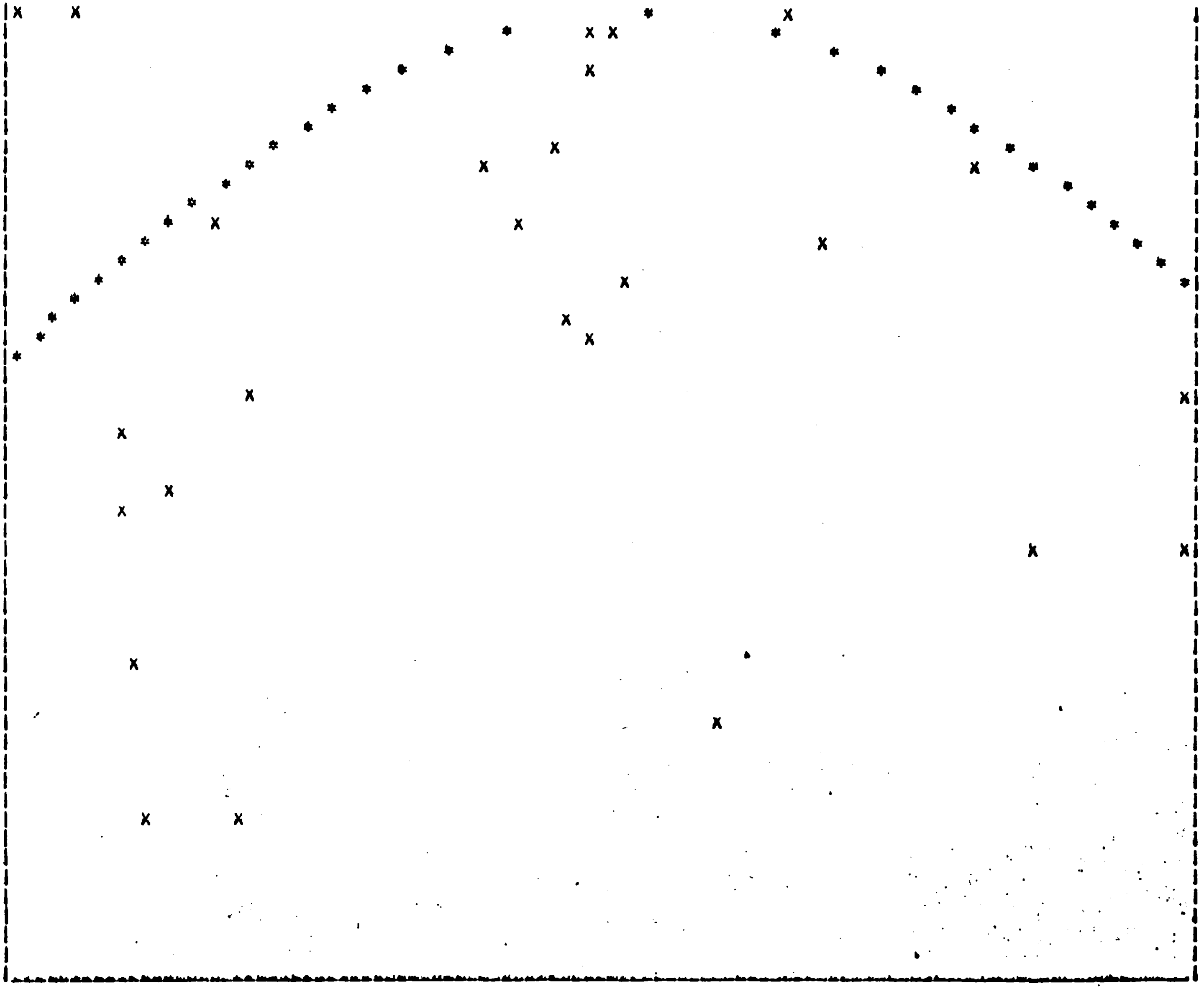
Coryphaenoides carapinus



GRAPH SCALES: Y = 0.0 TO 0.3465735E 01 AND X = 0.1142000E 04 TO 0.2500000E 04
MODE = 0.1679427E 04 MAX = 0.2585457E 01 SIG = 0.6168618E 03 SSD = 0.1090184E 02 VAR = 0.1469043E 02
PERCENTAGE OF VARIANCE ACCOUNTED FOR = 25.7895 AVERAGE PERCENT DISPLACEMENT = 35.3236

Fig. 19. Distribution of $\log_e$ transformed catches (y axis) of Nezumia bairdii with depth (x axis) and Gaussian curve fitted to data.

Nezumia bairdi

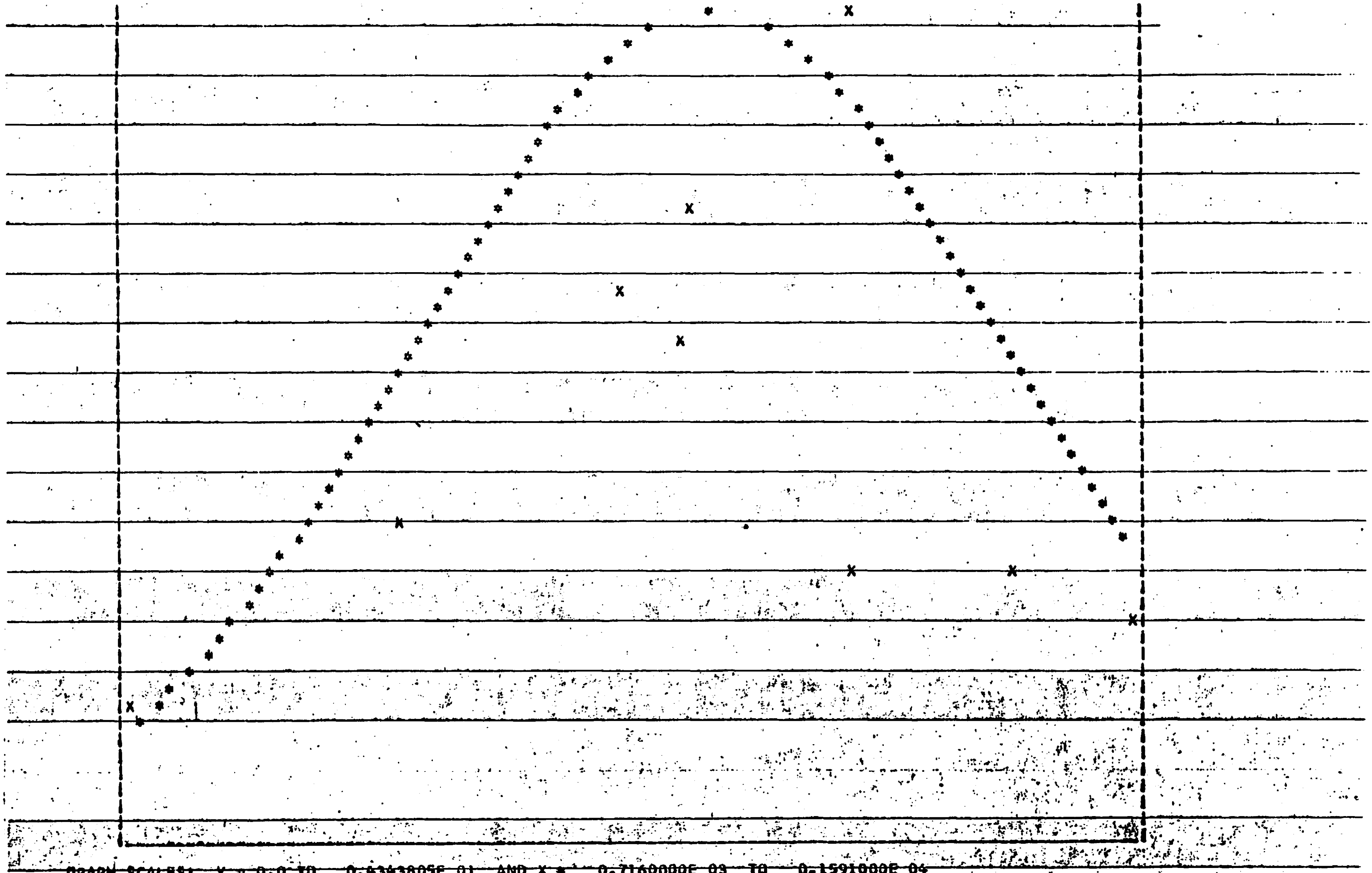


```
GRAPH SCALES:  Y = 0.0 TO   0.4348805E 01  AND X =   0.1660000E 03  TO   0.1354000E 04
MODE =  0.8022095E 03  MAX =  0.3305799E 01  SIG =  0.6780959E 03  SSD =  0.2901678E 02  VAR =  0.3269899E 02
PERCENTAGE OF VARIANCE ACCOUNTED FOR =   11.2609  AVERAGE PERCENT DISPLACEMENT =   87.5440
```

Fig. 20. Distribution of $\log_e$ transformed catches (y axis) of <u>Dicrolene</u> <u>intronigra</u> with depth (x axis) and Gaussian curve fitted to data.

NUMBER OF INDIVIDUALS
DEPTH OF INDIVIDUALS

Dicrolene intronigra

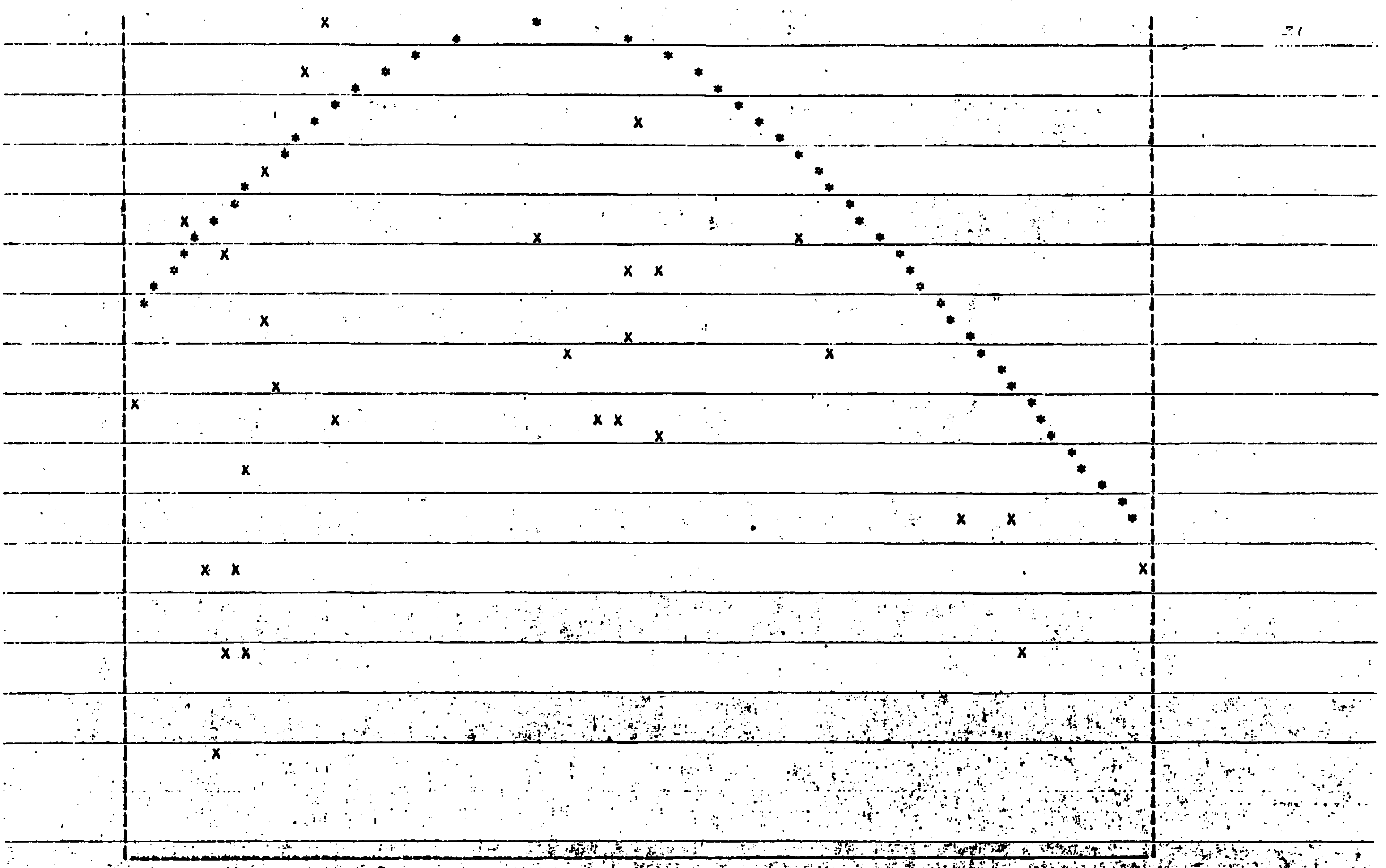


```
GRAPH SCALES:  Y = 0.0 TO   0.4343805E 01  AND X =   0.7160000E 03  TO   0.1591000E 04
MODE =  0.1223270E 04  MAX =  0.3039569E 01  SIG =  0.2533526E 03  SSD =  0.4972116E 01  VAR =  0.1153472E 02
PERCENTAGE OF VARIANCE ACCOUNTED FOR =   56.8943  AVERAGE PERCENT DISPLACEMENT =   23.7190
```

Fig. 21. Distribution of $\log_e$ transformed catches (y axis) of <u>Glyptocephalus</u> <u>cynoglossus</u> with depth (x axis) and Gaussian curve fitted to data.

NUMBER OF INDIVIDUALS
DEPTH OF INDIVIDUALS

Glyptocephalus cynoglossus



```
GRAPH SCALES:  Y = 0.0 TO   0.5627621E 01  AND X =   0.1660000E 03  TO   0.1350000E 04
MODE =  0.6426033E 03  MAX =  0.3846314E 01  SIG =  0.5151108E 03  SSD =  0.3367090E 02  VAR =  0.4341188E 02
PERCENTAGE OF VARIANCE ACCOUNTED FOR =   22.4385  AVERAGE PERCENT DISPLACEMENT =   27.3151
```

Figure 22. Diversity (H^1) plotted against depth for trawl stations made on R.V. C. O. Iselin cruise 73-10, R.V. Eastward cruises E-4-71, E-5-72, and E-2-74 and R.V. Delaware II cruise 74-2.

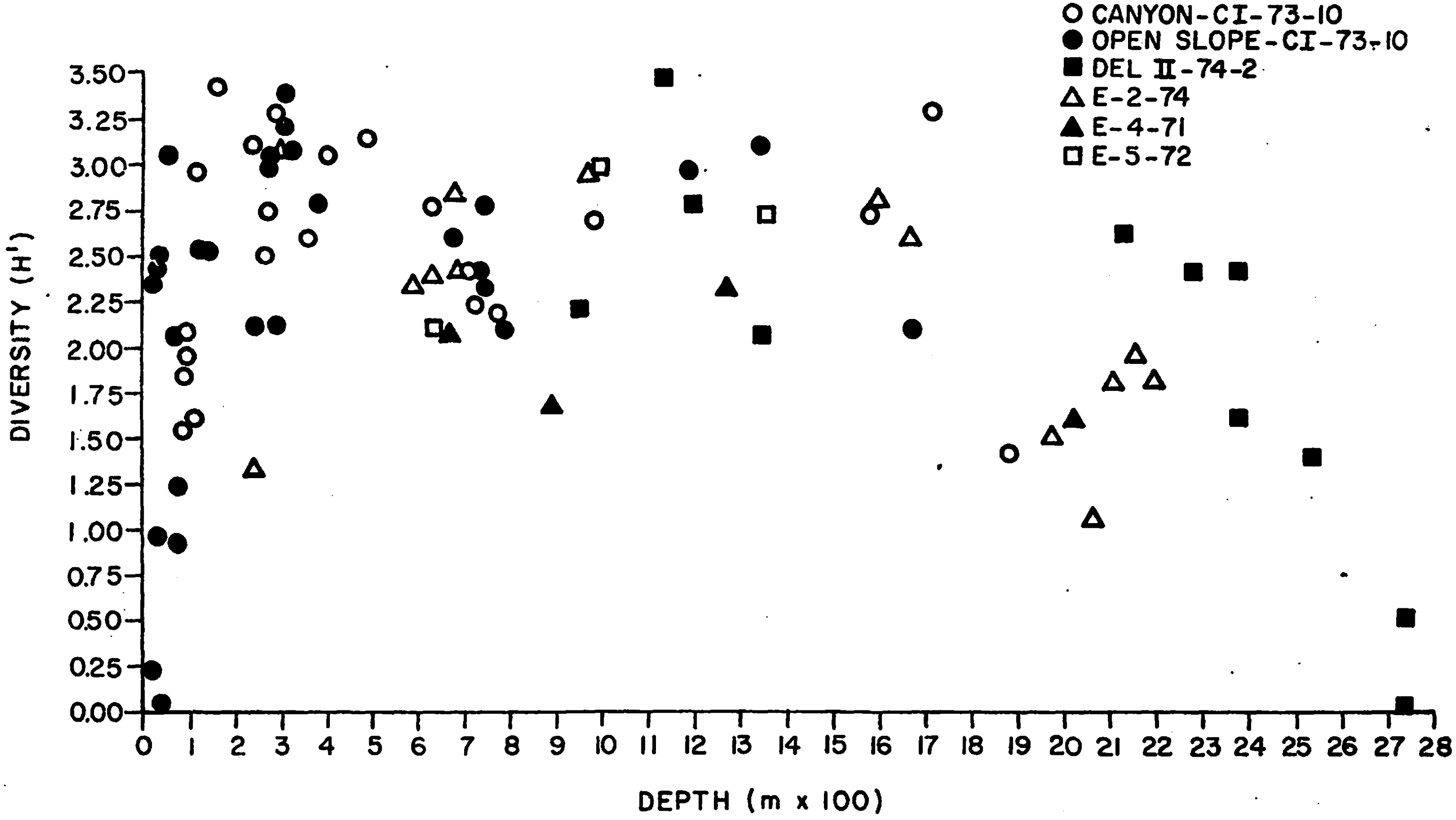
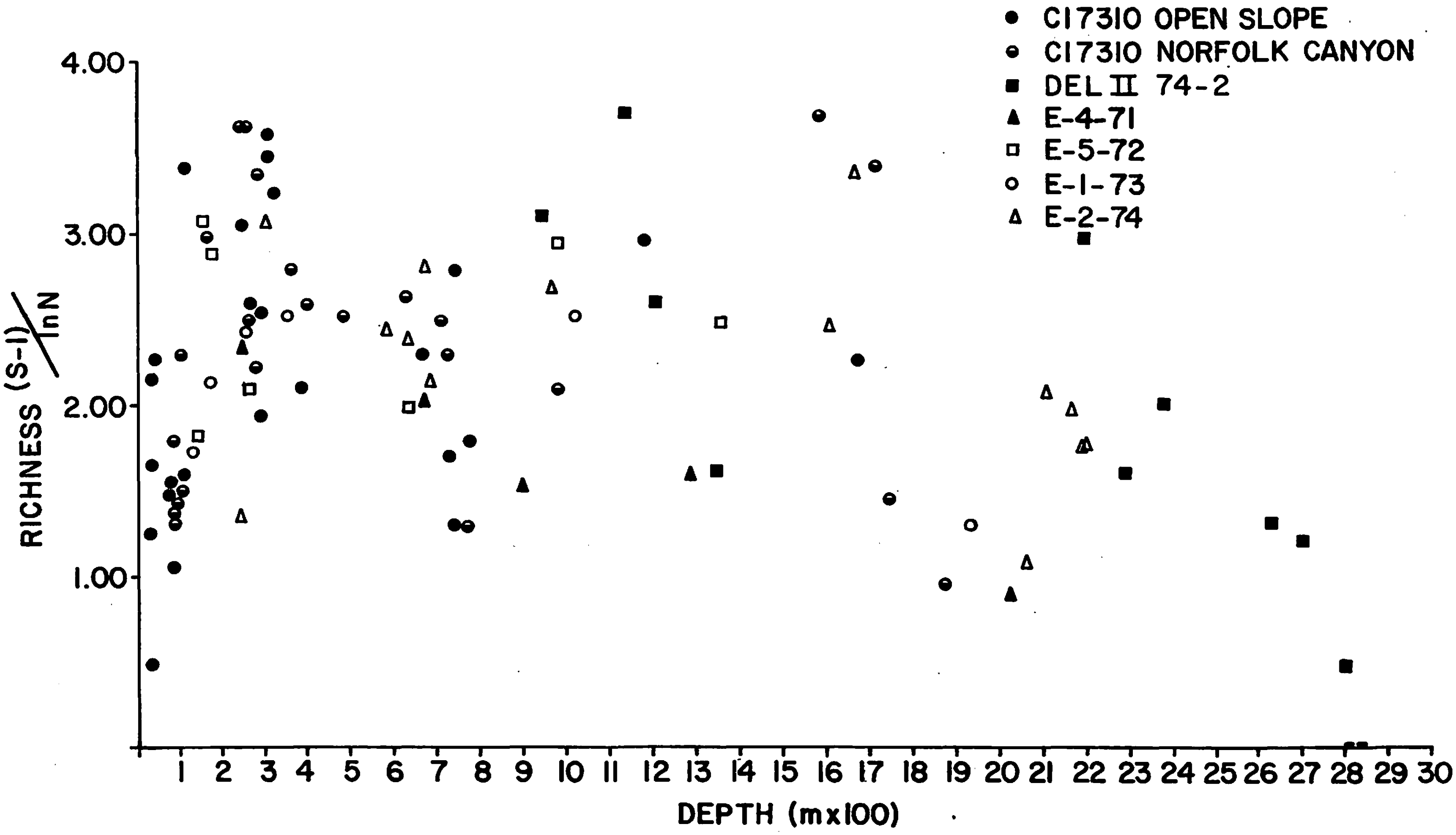

○ CANYON-CI-73-10
● OPEN SLOPE-CI-73-10
■ DEL II-74-2
△ E-2-74
▲ E-4-71
□ E-5-72
DIVERSITY (H')
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
DEPTH (m x 100)

Figure 23. Species richness plotted against depth for trawl stations made on R.V. C. O. Iselin cruise 73-10, R.V. Eastward cruises E-4-71, E-5-72, E-1-73 and E-2-74 and R.V. Delaware II cruise 74-2.



● C17310 OPEN SLOPE
⊖ C17310 NORFOLK CANYON
■ DEL II 74-2
▲ E-4-71
□ E-5-72
○ E-1-73
△ E-2-74
RICHNESS (S-1)/lnN
4.00
3.00
2.00
1.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
DEPTH (m x 100)

Figure 24. Log $_{10}$ of biomass (wet weight) of trawl catches made on R.V. C. O. Iselin cruise 73-10, R.V. Eastward cruise E-2-74 and R.V. Delaware II cruise 74-2.

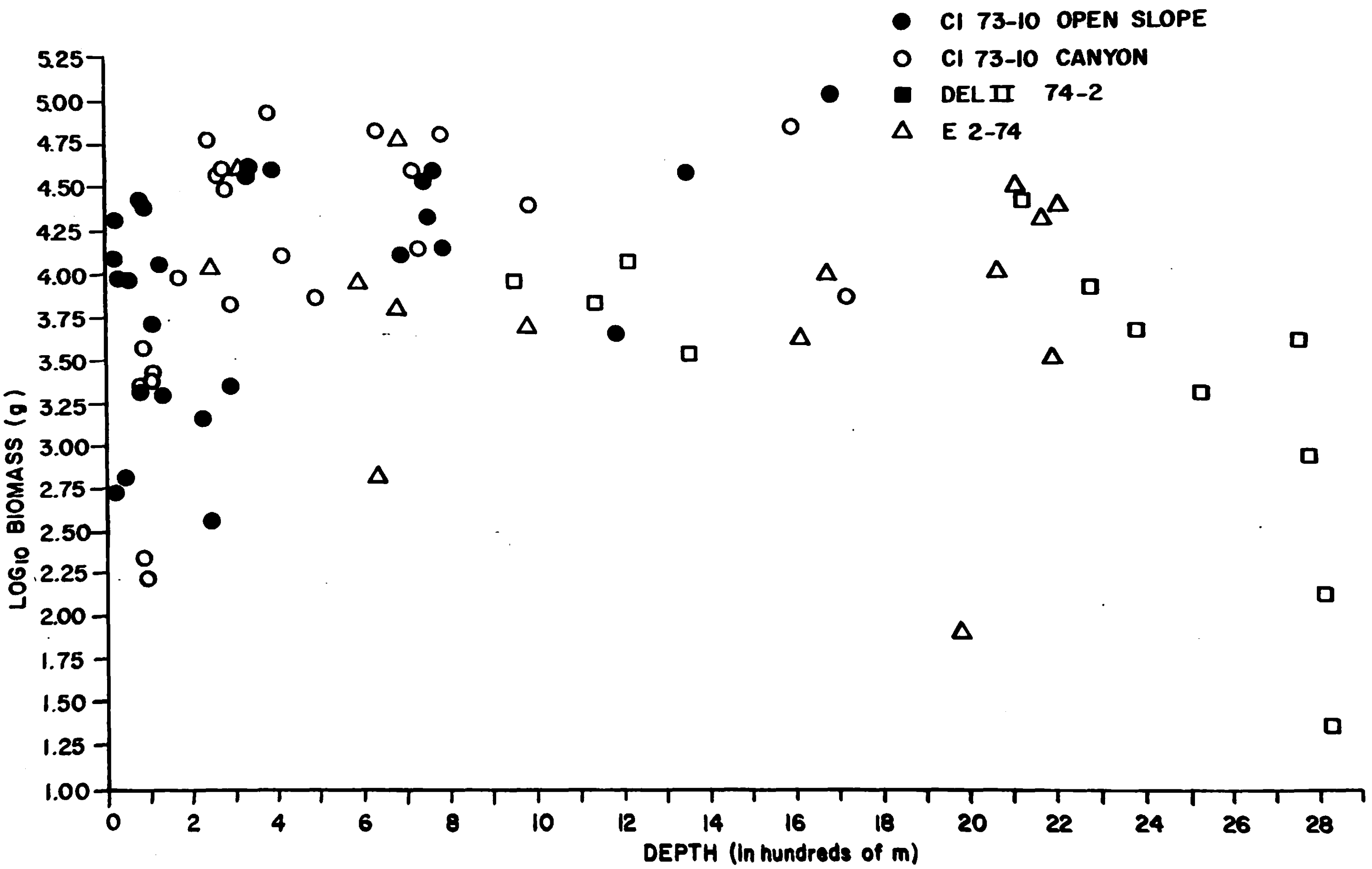

● CI 73-10 OPEN SLOPE
○ CI 73-10 CANYON
■ DEL II 74-2
△ E 2-74
LOG10 BIOMASS (g)
5.25
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
DEPTH (in hundreds of m)

Figure 25. Numerical abundance expressed as $\log_{10}(X + 1)$ where X = total numbers of individuals captured at each station plotted against depth for R.V. <u>C. O. Iselin</u> cruise 73-10, R. V. <u>Eastward</u> cruises E-4-71, E-5-72, E-1-73, and E-2-74 and R. V. <u>Delaware II</u> cruise 74-2.

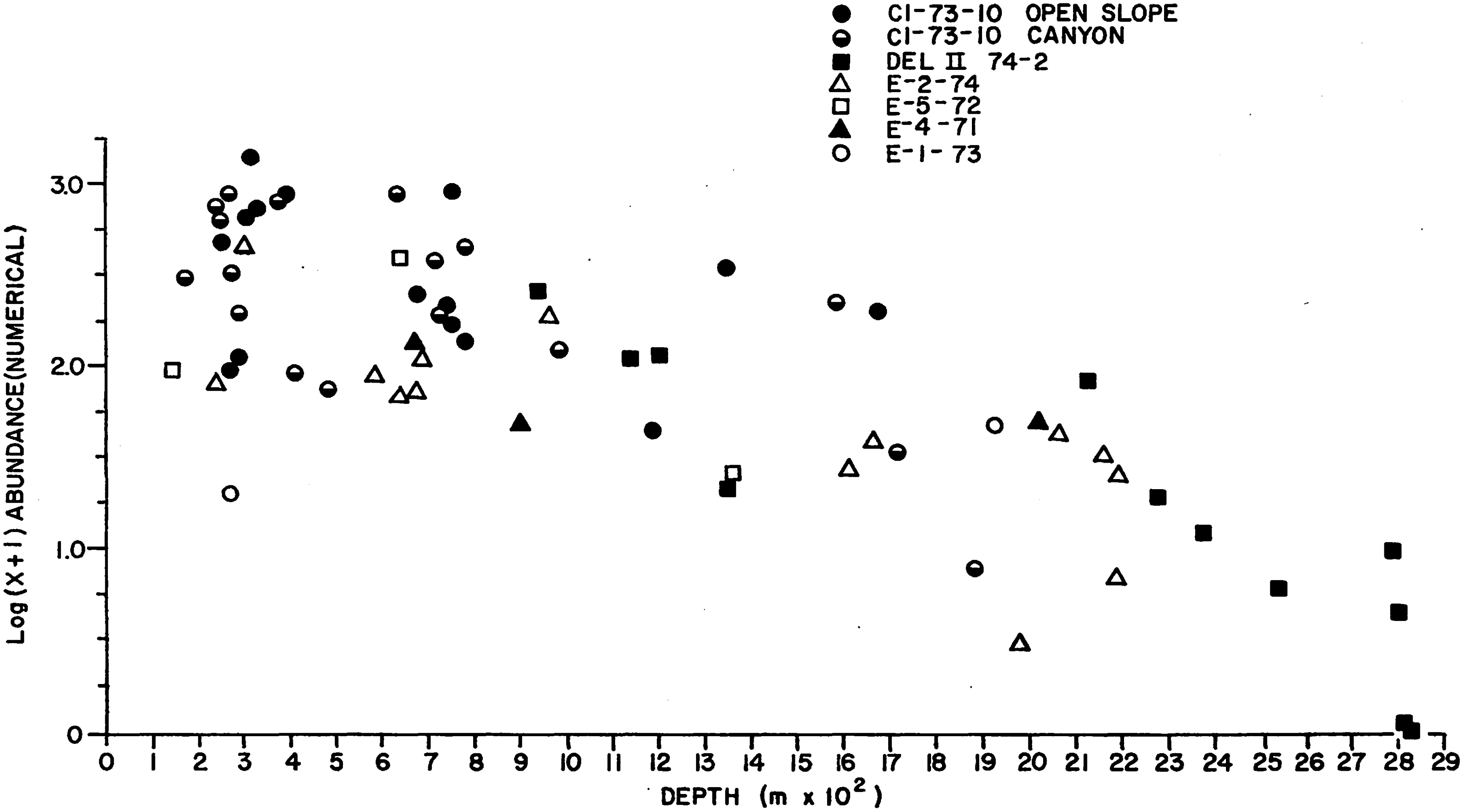

● CI-73-10 OPEN SLOPE
◒ CI-73-10 CANYON
■ DEL II 74-2
△ E-2-74
□ E-5-72
▲ E-4-71
○ E-1-73
Log (X+1) ABUNDANCE(NUMERICAL)
3.0
2.0
1.0
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
DEPTH (m x 10^2)

Table 2. Rank by numerical abundance of the five most dominant species at each D.W.D. #106 trawl station. Stations arranged by increasing depth.

Sta	1	%	2	%	3	%	4	%	5	%	Number of Specimens	Number of Species
2	S. kaupi	.28	N. bairdii	.15	G. cynoglossus	.13	L. paxillus	.02	C. rupestris	.01	526	19
3	N. bairdii	.18	A. phalacra	.17	C. carapinus	.15	S. kaupi	.10	D. intronigra	.08	205	21
3B	N. bairdii	.31	S. kaupi	.18	A. agassizii	.13	A. rostrata	.13	D. intronigra	.12	223	18
3A	A. rostrata	.41	S. kaupi	.29	N. bairdii	.14	R. bathyphila	.05	C. carapinus	.05	42	8
4B	A. rostrata	.45	C. carapinus	.17	H. macrochir	.12	A. agassizii	.06	P. miles	.05	160	18
ALV2	A. rostrata	.36	C. armatus	.21	H. macrochir	.18	C. carapinus	.10	A. agassizii	.08	39	8
4C	C. armatus	.38	H. macrochir	.24	A. rostrata	.10	P. miles	.10	several	.05	21	8
5	C. armatus	.64	C. carapinus	.03	A. rostrata	.08	X. myersi	.08			11	4
6B	C. armatus	.62	C. carapinus	.12	H. macrochir	.12	A. rostrata	.12	C. leptolepis	.04	26	5
6A	C. armatus	.89	I. brunneus	.11							9	2
5A	B. richardsoni	1.0									1	1
6	C. armatus	1.0									1	1

Table 3. Rank by biomass (fresh wet weight) of the five most dominant species at each D.W.D. #106 trawl station. Stations arranged by increasing depth.

Sta	1	%	2	%	3	%	4	%	5	%	Total Biomass (kg)
2	S. kaupi	.43	U. tenuis	.14	C. rupestris	.14	G. cynoglossus	.09	N. bairdii	.09	19,459
3	A. rostrata	.24	N. bairdii	.20	C. rupestris	.15	A. agassizii	.14	S. kaupi	.12	12,958
3B	N. bairdii	.26	A. rostrata	.23	A. agassizii	.22	S. kaupi	.12	D. intronigra	.05	24,365
3A	A. rostrata	.49	S. kaupi	.23	C. rupestris	.18	N. bairdii	.07	A. agassizi	.02	6,827
4B	A. rostrata	.69	A. agassizi	.08	H. macrochir	.08	N. stomias	.05	C. armatus	.02	55,523
ALV2	A. rostrata	.49	C. armatus	.15	A. agassizi	.10	H. macrochir	.10	H. affinis	.08	16,610
4C	C. armatus	.47	A. rostrata	.25	H. macrochir	.19	H. raleighana	.04	B. richardsoni	.02	9,004
5	C. armatus	.80	A. rostrata	.16	C. carapinus	.03	X. myersi				3,982
6B	C. armatus	.50	A. rostrata	.29	H. macrochir	.11	C. leptolepis	.06	C. carapinus	.05	8,650
6A	C. armatus	.98	I. brunneus	.02							1,625
5A	B. richardsoni	1.00									426
6	C. armatus	1.00									400

Table 4. Rank by numerical abundance of the five most dominant species at trawl stations deeper than 900 m from cruise CI-73-10.

Depth (m)	Sta.	1	%	2	%	3	%	4	%	5	%	Number of Specimens	Number of Species
986	83	G. cynoglossus	.23	C. rupestris	.23	N. bairdii	.21	N. aequalis	.10	P. chesteri	.10	120	11
1194	57	D. intronigra	.27	C. cynoglossus	.21	N. bairdii	.14	C. rupestris	.09	A. phalacra	.07	44	12
1350	97	S. kaupi	.34	D. intronigra	.23	A. rostrata	.12	C. carapinus	.06	N. bairdii	.04	330	24
1488	90	C. carapina	.24	S. kaupi	.23	L. atlanticus	.11	I. brunneus	.10	A. rostrata	.08	74	12
1591	95	A. rostrata	.52	S. kaupi	.13	C. carapinus	.07	A. agassizii	.06	H. macrochir	.03	229	21
1578	96	rostrata	.56	S. kaupi	.18	C. carapinus	.04	A. agassizii	.06	H. macrochir	.04	202	13
1719	91	A. rostrata	.27	C. carapinus	.21	S. kaupi	.06	F. bathyphila	.06	others	.06	34	13
1876	92	C. carapinus	.50	A. rostrata	3	A. lutkeni	.13					8	3

Table 5. Rank by numerical abundance of the five most dominant species at trawl stations deeper than 900 m, north of Cape Hatteras, from R. V. Eastward cruises, E-5-72, E-1-73 and E-2-74.

Depth (m)	Sta.	Cruise Year	1	%	2	%	3	%	4	%	5	%	Number of Specimens	Number of Species
900	30	71	S. kaupi	.48	G. cynoglossus	.40	N. bairdii	.02	P. chesteri	.02	L. paxillus	.02	48	7
969	38	74	S. kaupi	.37	N. bairdii	.15	D. intronigra	.14	G. cynoglossus	.07	A. phalacra	.07	166	15
1360	7	72	A. rostrata	.37	C. carapinus	.37	S. kaupi	.21	G. cynoglossus	.11	L. atlanticus	.11	19	9
1607	28	74	S. kaupi	.39	A. rostrata	.23	D. intronigra	.08	C. carapinus	.08	A. agassizii	.08	26	9
1670	27	74	S. kaupi	.36	A. rostrata	.32	C. carapinus	.05	N. bairdii	.05	D. intronigra	.04	72	15
1935	46	73	A. rostrata	.52	C. carapinus	.23	H. macrochir	.18	A. agassizii	.06	L. atlanticus	.02	48	6
1983	30	74	A. rostrata	.50	C. carapinus	.25	A.	.25					4	3
2025	34A	71	C. carapinus	.46	A. rostrata	.40	H. macrochir	.10	N. stomias	.02	B. agassizii	.02	50	5
2065	39	74	A. rostrata	.81	C. armatus	.10	H. macrochir	.04	L. atlanticus	.01	D. intronigra	.01	83	5
2165	33	74	A. rostrata	.72	C. carapinus	.13	H. macrochir	.06	Porogadus sp.	.05	C. armatus	.03	60	7
2195	41	74	A. rostrata	.56	H. macrochir	.19	C. armatus	.19	Porogadus sp.	.06			16	4
2200	34	74	A. rostrata	.71	C. carapinus	.10	H. macrochir	.08	C. armatus	.08	Porogadus sp.	.02	52	6

Table 6. Percent of total number that individuals of species groups A, B & C contributed to each station in three site groups. Station numbers with the prefix "W" are from *Delaware II* 74-2; other stations are from CI-73-10.

Site Group	Sta.	% Species Group A	% Species Group B	% Species Group C	Depth (M)
	W02	.69	-	.31	951
	W03	.73	.01	.26	1143
	57	.59	-	.41	1194
A2	W3B	.65	.03	.32	1207
(upper)	97	.91	.01	.07	1350
	W3A	.78	.04	.12	1353
	91	.74	.03	.06	-
A2	90	.90	.10	-	1488
(lower)	95	.91	.09	-	1591
	96	.92	.08	-	1678
	W4B	.68	.26	<.01	2130
	WA2	.56	.44	-	2286
	92	.88	.12	-	1876
A3	W4C	.24	.76	-	2372
	W05	.30	.70	-	2620
	W6B	.34	.66	-	2700
	W6A	.11	.89		2750
A1	W5A		1.00		2750
	W06		1.00		2750

(Percentages do not add up to 100 at all stations because very rare species had to be eliminated from the cluster analysis and a few small clusters of remaining rare species were not designated with a species group letter.)

and outer continental shelf, and occur well above the bathymetric limits of DWD 106. Species groups A, B and C occur within the bathymetric limits of DWD 106.

Percent Dominance

The five most dominant fishes at each DWD station are ranked by numerical abundance in Table 2 and by biomass (wet weight) in Table 3. Stations are arranged according to depth.

The five most dominant species at CI-74-10 stations deeper than 900 m are similarly listed in Table 4. Those from Eastward stations deeper than 900 m and north of Cape Hatteras are included in Table 5.

Depth ranges of dominant species

When sufficient data were available, log-transformed abundance of selected dominant species were plotted against depth (Figs. 9-21) and the data were fitted to Gaussian curves using a computer algorithm developed by Gauch (1974). Both DWD and *Iselin* data are included.

Patterns of Diversity, Species Richness and Biomass Distribution

Species diversity as measured by the information theoretical measure H^1 (Lloyd, Zar and Karr 1968) has been computed for DWD 106, *Iselin*, and *Eastward* trawl catches and plotted against depth in Fig. 22. Diversity on the slope was higher and less variable than on the continental shelf.

Species richness as measured by Margalef's (1951) index

$$d = S-1)/\log_e N$$

has been plotted against depth in Fig. 23. The pattern of species richness was very similar to that of H^1 diversity.

Biomass as expressed by the $\log_{10}$ of the total weight (gm) of each catch has been plotted in Fig. 24. There was a marked increase in biomass at the shelf-slope break (ca. 200 m) and also a decrease in variability of biomass. There was a marked decrease in biomass below 2000 m.

Numerical abundance, expressed as $\log_{10}$ (X+1) (where X = total number of individuals captured) has been plotted in Fig. 25 for those stations deeper than 150 m. There is a pronounced trend toward a proportional decrease in numerical abundance with depth.

Ancillary information

Pelagic fishes incidentally captured at DWD 106 bottom trawl stations are listed in Appendix 1.

DISCUSSION

Faunal assemblages

The cluster analyses show that with the exception of the three deepest, most DWD stations clustered closely with Iselin stations, indicating that similar faunal assemblages were sampled. Sub group A_1 included the three deepest DWD stations which were located outside the dump site in deeper water. They were unique because of their depauperate nature, although the species captured, Coryphaenoides armatus, Illyophis brunneus and Bathyraja richardsoni, occur in shallower water on the lower slope and are clustered with species group B (or A for I. brunneus). The question is whether the apparent depauperate nature of the fauna below 2700 m is real or whether it is an artifact of sampling error. None of the Eastward or Iselin stations were made at these depths (2700 m), but on a recent cruise of R/V Gilliss in Norfolk Canyon in November 1974 (Musick, unpublished data) stations were made at 2624, 2650, and 2752 m (sta. no. 87, 75 and 86 respectively). The species composition, diversity and biomass at these stations were quite similar to those recorded at DWD stations between 2300 and 2700 m. The question must remain unanswered, and is compounded because DWD 5A, 6 and 6A were made on the periphery of the rad. dump site. It is possible that the depaurarate catches there were related in some way to radiation but not probable because during the cruise Dr. Robert Dyer could find no appreciable radiation above background from parts of fishes and sediments in the area. Perhaps his final report will provide more information on the subject.

Three species groups A, B and C are represented within the sites clustered in Fig. 4. Table 6 shows the percent composition by species group at each station. The stations that clustered within group A_3 contained more than 65% individuals from species group B (with the exception of station 92 which yielded only 8 specimens of demersal fishes and 63 pelagics, suggesting that the net did not fish bottom properly). Site group A_3 contained no species from species group C, but as high as 34% from group A.

Site group A_2 (Fig. 4) branches into two subgroups that correspond closely with the occurrence of species groups and also with bathymetric distribution. The upper subgroup (stations 97, W33, W02, W03, 57, 91, W3A) contains 59-91% of individuals belonging to species in group A, 5% or fewer of "B" species and 6-31% of "C" species. The lower subgroup (stations 90, 95, 96, W4B, WA2) contains a majority (56-92%) of individuals belonging to species group A, 8-44% from group B and virtually none from C.

Comparing site and species cluster patterns with depth (Table 6), species group C contributes about one-third of the individuals to stations from 900 to about 1200 m. Group A contributes about two-thirds and group B contributes less than 5%. Between 1200 and 1400 m, group C declines drastically in importance and group A increases. Beyond 1400 m, group C is virtually absent. Group A contributes about 90% and B about 10% of the individuals between 1400 and 1900 m. Beyond 1900 m group B increases and A decreases in importance to about 2300 m and deeper where individuals in species group B outnumber those in group A.

Similar patterns of faunal distribution are reflected by the numerical dominance (Tables 2-5). At 900 m , *Nezumia bairdii*,*Glyptocephalus cynoglossus*, *Lycenchelys paxillus*, *Phycis chesteri* and *Coryphaenoides rupestris* and *Synaphobranchus kaupi* are the dominant species. *Synaphobranchus kaupi* remains as a dominant to about 1700 m, *N. bairdii* to about 1400 m, *L. paxillus* and *P. chesteri* only to about 1000 m, *G. cynoglossus* to about 1300 m and *C. rupestris* to about 1200 m. *Aldrovandia phalacra* appears as a dominant within a limited bathymetric range of about 950-1200 m. *Dicrolene intronigra* is among the dominant species between 1000 and 1600 m, but reaches higher ranks between 1100 and 1350 m.

Antimora rostrata may appear among the five most dominant species as shallow as about 1000 m and first appears in the top three out of five between 1300 to 1700 m. *Coryphaenoides carapinus* shows a similar pattern. Both species remain among the dominants to depths of at least 2700 m. *Alepocephalus agassizii* becomes a dominant as shallow as 1200 m and occurs among the dominant species regularly to depths of about 2200 m. *Halosauropsis macrochir* appears as a dominant species at about 1600 m and remains so to at least 2700 m. *Coryphaenoides armatus* was the deepest living of the major dominant species encountered in this study, first appearing as a dominant at 2065 m and increasing in importance to about 2300, where it replaced *A. rostrata* as most abundant fish. It remained in this position at all deeper stations excepting DWD station 5A where one specimen or *Raja richardsoni* was captured.

The patterns of dominance shown by the R/V *Eastward* data (Table 5) were remarkably similar to those reflected in the *Iselin* and *DWD* data which were collected with a larger net. This suggests that the relative sampling efficiency for the two nets is about the same for most of the dominant species although because of its smaller size the 30' net usually yielded fewer individuals, lower biomass and a less diverse catch than that of the 45' net at similar depths (Figs. 22, 24, 25).

Coryphaenoides rupestris was rare in the 30' net catches and dominant in some 45' net catches. This species actively migrates into mid-water to feed (Savvatinskii, 1969; Haedrich, 1974) and probably more easily avoids the 30' net which has a lower headrope.

Both the cluster analyses and the numerical dominance data suggest that these species assemblages should not be viewed as discrete communities separated into zones, but rather as parts of a biocoenose that gradually changes along an ecocline. The faunal gradient appears to be steeper between 1200 and 1400 m and between 1900 and 2200 m.

The concept of a biocoenotic gradient is reinforced by the examination of the bathymetric distribution of individual species illustrated in Figs. 9-21. Even though the contagious distribution of catches may be reflected by high variance in some graphs, the curves give a visual depiction of estimated abundance with depth and also the modal depth of capture.

In species group C, the depth range and modal depth of capture for *Nezumia bairdii* were 166 to 1354 m and 802 m respectively (Fig. 19); for *G. cynoglossus* they were 166 to 1350 and 643 m (Fig. 21); and for *P. chesteri*, 166 to

1194 m and 597 m (Fig. 14). In group B, Halosauropsis macrochir had a range of 1488 to 2379 m and a mode of 1979 m (Fig. 11). Bathysaurus agassizi had a range of 1350 to 2288 m, and mode of 1835 m (Fig. 13). Coryphaenoides armatus had a range of 2196 to 2745 m (the deepest station sampled) with a mode of 2435 m (Fig. 17). Within group A, S. kaupi has a range of 316 to 2196 m with mode of 996 m (Fig. 9). Antimora rostrata had a range of 1142 to 2562 m with a mode of 1661 m (Fig. 15) and Coryphaenoides carapinus had a range of 1142 to 2500 m, with mode of 1679 m (Fig. 18). Dicrolene intronigra had a range of 716 to 1591 m, and a mode of 1223 m (Fig. 20).

The concept of a biocoenose in an ecocline is at variance with Menzies George and Rowe (1973) who proposed a rather rigid system of faunal zonation on the slope, rise and abyssal plain off North Carolina. Their conclusions were based primarily on isopods (detritovores) and our differences in concept may be based on the analysis of data from different taxa and different trophic levels. However, Dayton and Hessler (1972) said of detritovores"deep sea species show strong depth zonation with the only major zonal break in community composition occurring at the continental shelf-slope transition band." Otherwise there is a continuous turnover in the species composition of the community as depth increases."

This last interpretation of community change is much closer to ours. Both Menzies, et al. (1973) and Dayton and Hessler (1972) analyzed collections from much deeper areas than sampled by us for fishes.

Distribution of biomass and numerical abundance with depth:

Figure 24 shows that the biomass of fishes increased at the shelf-slope break (ca 200 m) then remained fairly constant down to a depth of about 2000 m beyond which a rapid decrease in biomass occurred. This pattern is similar to that which has been documented many times for the distribution of invertebrates but most recently by Rowe, Polloni and Horner (1974). Hessler (1974) has succinctly paraphrased John Murray's conclusion that standing crop is inversely correlated with depth of water and distance from major land masses, a condition that Rowe et al. have noted is merely a reflection of productivity.

Figure 25, the distribution of numerical abundance of fishes with depth, shows after an initial increase from shelf to slope, a steady decrease in abundance down to about 2000 m where the rate of decrease becomes very pronounced. The difference between the patterns of biomass and numerical abundance distribution above 2000 m is primarily due to the relative decrease in numerical dominance of smaller numerous animals such as *Chlorophthalmus*, *Helicolenis*, *Synagrops*, *Lycenchelys*, etc., as one proceeds down slope and the increasing dominance of larger species *Synaphobranchus*, *Antimora*, etc. Thus fewer individuals may contribute as much biomass. Both biomass and numerical abundance show a sudden decrease at 2000 m.

Distribution of diversity and related parameters;

Diversity (H^1) and species richness both reflect the same pattern shown by the biomass distribution, a marked increase at slope break, relative stability down to about 2000 m and a rapid decline thereafter. Our data substantiate the tentative conclusions reached by Markle and Musick (1974) that diversity of fish communities on the continental slope is higher than that of estuarine and shelf communities. Sanders (1968) and his colleagues have amply demonstrated that the diversity of deposit feeding invertebrates is much higher on the continental slope than on the adjacent continental shelf. Hessler (1974) has shown that high diversity in the benthic infauna continues out onto the abyssal plain, a pattern unlike that shown by fishes. Dayton and Hessler (1972) suggested that high species diversity among deepsea deposit feeders was attributable to cropping pressure from predators that kept infaunal populations low, not resource limited, and less likely to encounter competitive exclusion. As a corollary they suggested that the larger the animal, the greater the probability of resource limitation and therefore the lower the diversity of populations of increasingly large animals. Our data support their contention. At about 2000 m, the approximate boundary between continental slope and rise, biomass, and diversity change rapidly and species dominance and composition also change. This change probably coincides with the region at which the benthic communities become predominantly dependent on food sources of oceanic origin.

Commercial Fisheries:

Currently there are no ongoing fisheries for demersal fishes within the confines of DWD 106 (a seasonal commercial long-line fishery by both Japanese and U. S. fishermen may occur in the area). Of the dominant finfishes, Glyptocephalus cynoglossus supports a fishery elsewhere. This species uses the continental slope for a nursery area and occupies shallower water when adult. Markle (1975) working with data from Norfolk Canyon has suggested that G. cynoglossus off the middle Atlantic states are derived from spawning stocks to the north. It is not known what percent if any of the large number of juveniles that occur off the middle Atlantic states return to the northern spawning (and fishing) areas.

Of the dominant species which occur within DWD 106, the macrourid, Coryphaenoides rupestris has been exploited by Soviet fisheries to the north and alepocephalids (including A. agassizi or close relations) have been experimentally harvested. (Pechenik, Troyanovski, 1970). In addition, C. rupestris and Alepocephalus bairdii have been experimentally harvested off the British Isles by the United Kingdom (Ann,1974). Both the Soviets (Savvatimskii 1969) and the British (Ann,1974) consider the Alepocephalids to be poor quality food fishes because of the high water content of the flesh. Coryphaenoides rupestris, however, is considered to be a high quality food fish. Examination of Norfolk Canyon data suggests that the modal size of C. rupestris in our collections is about 2/3 to 1/2 that of the fish commercially harvested by the Soviets off Newfoundland and Labrador (55-75 cm TL). In addition, the Soviets report average catches in excess of 20 metric tons per trawler hour. The highest catches of C. rupestris recorded from DWD 106 were 2.68 and 1.9 k per hr and from CI-73-10 were 8.0 and 7.0 k per hr.

The difference in catch rates is due to the much larger nets that the Soviets use and also the fact that they were fishing for concentrations of C. rupestris located by echo sounder.

In addition the Soviet fishery was most active in July-Oct when concentrations of larger grenadiers migrated upslope from deep water and became available to their gear (Pechenik and Troyanovski 1971). It is interesting that the Soviets found that in June on the northern Newfoundland Bank and off South Labrador, the C. rupestris are 23-50 cm TL, a size range much closer to that found by us at about the same time of year off the Middle Atlantic states.

Preliminary analysis of the November 1974 cruise on R/V Gilliss (Musick, unpublished data) shows catch rates of C. rupestris in the Norfolk Canyon area as high as 1.6 metric tons per hour even with the 45' trawl and that the modal size was much larger than that in June. These data suggest that C. rupestris off the middle Atlantic states may have a seasonal migratory pattern that is similar to that found by the Soviets to the north. Small C. rupestris are available in May or June at about 700 -1000m. By November much larger individuals in larger numbers are available at about the same depths and there is a strong possibility that commercially harvestable concentrations occur on the slope off the middle Atlantic states at that time.

A potentially important decapod resource, the red crab Geryon quinquedens occurs adjacent to DWD 106. Catch rates of 27.8 k and 3.7 k were recorded at Delaware II stations 2 and 3. The dump site itself is mostly deeper than the normal bathymetric range for the species (Haefner & Musick, 1974).

REPRODUCTION IN FISHES OF DWD #106

by C. A. Wenner

Mead, Bertelsen & Cohen (1964) have pointed out that information concerning modes of reproduction of deep-sea fishes is fragmentary at best. This is due to the paucity of deep-sea trawls both temporally and spatially. This brief account is based on the scant data collected on the "Deep water Dumpsite" cruise plus other cruises made to the Norfolk Canyon area.

Anguilliformes

Synaphobranchus kaupi and *Ilyophis brunneus*, both members of the family Synaphobranchidae, were the eels collected in the greatest numbers on the cruise. Ripe specimens of *Synaphobranchus kaupi* have been captured year round. Females possess distended abdomens which are filled with oocytes 1 mm in diameter. Histological sections show that these are filled with yolk granules, cytoplasmic lipid vesicles and well developed vitelline membranes. Some males possess swollen testicular lobes filled with mature spermatozoa. Nine percent of the specimens of *S. kaupi* collected in May were ripe. Egg counts for 6 females are found in Table 1.

Brunn (1937) found that the smallest of the leptocephalus larvae of *Synaphobranchus kaupi* are most abundant in the Sargasso Sea area. The smallest larvae (20 mm) were collected in January through March so that spawning must take place somewhat earlier.

Table 1. Fecundity estimates of <u>Synaphobranchus kaupi</u> from May 1974.

Total Length	Number of eggs
390	14,118
405	16,821
435	21,104
450	18,141
570	46,506
620	54,767

Based on length frequency distributions, he concluded that the duration of the planktonic larval stage is about 2 years and they obtain a size of about 120 mm.

Since relatively sexually mature individuals have been collected during April, May, June, July and November, it may be that a certain percentage of the population spawns the year round or a certain stage of sexual maturity is reached and arrested until the spawning season. Until more comprehensive seasonal bottom sampling and mid-water trawls for eggs and larvae are carried out, the puzzle cannot be unraveled.

Ilyophis _brunneus_ is a relatively rare synaphobranchid eel and this is reflected in the scant accounts of this species in the literature. Robins (1968) estimated the number of eggs in a 486 mm total length specimen of _I. brunneus_ as 20,000 with a mean egg diameter of 0.78 mm. Ovigerous females were collected by her in January and September, while we have taken them in May, September and November. In both of these species of synaphobranchid eels, the males are smaller than the females at sexual maturity.

Heteromi

The most frequently encountered halosaur, _Halosauropsis machrochir_, like the Anguilliform fishes, has a leptocephalus larvae whose description is yet to be published. The sexes are separate with sexual demiorphism present in the structure of the olfactory apparatus (McDowell, 1973). The Deep-water Dump site cruise resulted in the capture of several gravid and ripening females ranging in gnathoproctal length (GPL) 250 to 280 mm

(GPL = the distance from the tip of the lower jaw to the anus, a measurement used because of the fragility of the caudal region). Two ripe females taken from a cruise in June or 1973 contained 19,225 and 22,620 ova of approximately 1.1 to 1.2 mm in diameter. It appears from other cruise results that this species is a spring-summer spawner.

Salmoniformes

Female specimens of the dominant alepocephalid, Alepocephalus agassizi, were all immature and, to date, none of our cruises has resulted in the capture of mature females. Running ripe males, however, with markedly developed testes were observed in June 1973 (Markle, personal communication). The eggs of A. agassizi are probably large at maturity because Mead et al. (1964) reported that other members of the family have egg diameters of up to 3.0 mm. They also stated that alepocephalids are dioecious and oviparous, producing small numbers of relatively large eggs, with larvae developing directly into adolescent stages.

Gadiformes

The blue hake, Antimora rostrata, was the dominant morid collected during the deep-water dump site cruise. Gross and histological examination of the gonads of A. rostrata have failed to provide evidence on its spawning season. Specimens collected during April, May, June and November all had quiescent gonads with ovaries containing 0.1 mm occytes with no evidence of yolk deposition, vitellogenesis or cytoplasmic activity. Males sampled at these times had inactive testes containing primary and secondary spermatogonia with no spermatogenic activity.

Data from previous cruises points to a predominance of one sex in any given trawl. The results for the deep-dump cruise are tabulated below:

Station	Number of Males	Number of Females
3	5	10
3A	16	1
3B	16	12
6B	0	3
4B	14	55
4C	0	2
ALVIN 2	3	11

The structure of the ovary leads me to believe that *Antimora rostrata* has a relatively high fecundity of small eggs that probably develop and hatch at some depth in the water column.

The dominant rat-tails (Family Macrouridae) were *Nezumia bairdii*, *Coryphenoides armatus*, *C. rupestris* and *C. carapinus*. All specimens of these species were immature or resting (no histological evidence of active gametogenesis). Previous cruises and the November 1974 *Gilliss* cruise have provided the following information on seasonality of three of the species. *Nezumia bairdii* had developing oocytes with some yolk deposition and formation of the egg membranes. The eggs, however, were still very small and spawning probably does not take place until late winter-early spring in the Norfolk Canyon area. Coryphenoides carapinus and C. rupestris had larger, more developed ovaries and testis in November. Counts, histological examination and egg diameter measurements have not as yet been completed on the November material. Mature or ripening individuals of C. armatus have not been encountered so little can be said of this species.

The ophidioid fish, Diciolene intronigra, is an oviparous species (Mead et al., 1964) which has sexual dimorphism in the swimbladder structure (Wenner, unpublished data). Based on gross and histological examination of gonads of specimens from other cruises, this species is probably a late summer-fall spawner. Fecundity estimates have not been made, nor are the larvae known.

The eel-pouts (Family Zoarcidae) form a group of boreal fishes which are frequently encountered in slope and deep-water trawls. The deep-dump trawls collected several specimens of Lycenchelys paxillus. This species had well developed eggs in June 1973 of 3 mm in diameter. The large eggs are few in number (20-40 per individual) and are probably demersal. The sexes show dimorphism in that the males have enlarged cheek muscles and modifications of the cranial osteology which may suggest some type of parental protection of the fertilized eggs. This species probably has direct development with no pelagic larvae.

Pleuronectiformes

The grey sole, *Glyptocephalus cynoglossus*, spawns in the Georges Bank region from May to September (Ensunko & Nevinskiz, 1973). The adults occur on the continental shelf whereas the young occur on the continental slope which provides ecological separation of the two life history stages and eliminates competition between the juveniles and the adults (Powles and Kohler, 1970; and Markle, 1975). The pelagic eggs are small in diameter (1.0-1.2 mm) and hatching takes place in 7 to 8 days (Bigelow and Schroeder, 1953). Since specimens encountered during the DWD 106 cruise were all juveniles, no reproductive information was collected.

In summary, the dominant fishes collected during the DWD 106 cruise have several modes of reproduction, from the suggested parental guarding of a few large eggs of *Lycenchelys paxillus* to the broadcast spawning of the eels and halosaurs. More information will be available on reproduction of fishes from the continental slope of the middle Atlantic states after data collected during the R/V *Columbus Iselin*, the R/V *James T. Gilliss* and the R/V *Eastward* and future scheduled cruises have been fully analyzed.

Section IV: Food habits of fishes of DWD 106

by G. R. Sedberry

INTRODUCTION

Relatively little is known of the food of deeper dwelling demersal fishes of the continental slope and rise and of the abyss (Marshall, 1965; Bright, 1970; Grassle and Sanders, 1973) and few studies have delt with trophic dynamics in the deep sea. Food of some deep living invertebrates and fishes has been reported by Marshall (1954), who reviewed the two main theories of food provision to the deep sea: the rain of dead plankton theory (Agassiz, 1888) and the theory of vertically migrating food chains (Vinogradov, 1953 as cited by Vinogradov, 1961). Sokolova (1957, 1959) reported the food of several deep-sea invertebrates. Barnard (1962) reported on the food of abyssal amphipods. Vinogradov (1961), in looking at the feeding patterns of deep-sea zooplankton, proposed that overlapping vertical migrations were the most likely method of bringing food from the productive surface waters down to great depths. Menzies (1962) again reviewed the theories of sources of food and, from his data on isopods and the literature, proposed that the rain of dead plankton was the most important food source. Additional work on this problem and the food of deep-sea invertebrates has been reported by Krogh (1934), Isaacs (1969), Sanders and Hessler (1969), Harding (1973), Dayton and Hessler (1972), Grassle and Sanders (1973), and others (see Zenkevich and Birstein, 1956 for earlier studies).

Food of deep-sea pelagic fishes has received some attention in recent years (Marshall, 1954; Haedrich, 1964; Haedrich and Nielson, 1966; Duka, 1969; Collard, 1970; Childress and Meek, 1973; and others; see Merrett and Roe, 1974 for review).

As far as benthic and benthopelagic (Marshall, 1967) fishes are concerned, less work has been done. Stomach contents of some species have been reported only in passing in taxonomic and other works (Bigelow and Schroeder, 1953; Marshall, 1954; Cohen, 1958; Nielson, 1964; Marshall, 1965; Bright, 1968; Robins, 1968; Marshall and Iwamoto, 1973; McDowell, 1973), and hence are based on a few specimens and are consequently incomplete. Bright examined the stomachs of many species of deep-sea fish from the Gulf of Mexico and constructed a food web from his data, but his material was limited to 81 small specimens. Clarke and Merrett (1972) discussed the significance of pelagic food in the stomachs of deep living benthic fishes which they examined. Haedrich and Henderson (1974) and Pearcy and Ambler (1974) studied the food habits of macrourids of the genus Coryphaenoides.

Dayton and Hessler (1972) predicted that deep-sea benthic fishes should be extreme food generalists, preying on populations of smaller deposit feeders and thus are responsible for maintaining a high diversity in deposit feeders by reducing the probability of competitive exclusion. Sanders (1968) and Grassle and Sanders (1973) state that deep-sea benthic carnivores are not complete generalists that prey with little selectivity, but would be expected to have specialized feeding habits, although the lack of data on feeding make any statements speculative.

The purpose of this report is to provide information on the food eaten by several species of fishes from the continental slope and rise and to provide a clearer picture of food webs in these habitats and to classify the species examined as opportunists or specialists in order to define their role in maintaining the high diversity of the deep-sea benthic fauna.

FOOD HABITS

METHODS

Stomachs of several specimens of different dominant species were excised onboard and preserved in 10% seawater formalin for later analysis. Fishes and organisms which could possibly serve as food for the fishes were also collected and subjected to radiological analysis by EPA personnel onboard.

Most fishes from these depths regurgitate their food when hauled up because of expansion of gas in the swimbladder. Consequently, only a limited number of stomachs could be examined from Delaware II cruise. In all, nine species of fishes were examined. For each stomach, the contents were emptied, identified, sorted and the number of stomachs in which an item occurred noted and expressed as a percentage of the number of stomachs examined (frequency of occurrence, FO). The number of individuals of a food item were counted and expressed as a percentage of the total number of food items (numerical dominance, ND). Volume of the total number of food items of a given taxon was measured by displacement and expressed as a percentage of the total volume of the stomach contents (volume displacement, VD). Volume displacement of sediment was also noted as an index of the amount of benthic feeding occurring. For purposes of this analysis, fragments of an animal were counted as one organism. For example, if crustacean fragments occurred in a stomach, it would by counted as one unidentified crustacean. A total of 43 stomachs were examined, of which four were completely empty.

RESULTS

Halosauropsis macrochir

Twenty-five stomachs of H. macrochir were collected from three stations (15 from 4B, 3 from 6B, and 7 from ALVIN 2. Only one of them was completely empty. Crustaceans were the dominant food item in frequency of occurrence (64% of stomachs examined), number of individuals (77.4% of the total number of individual food items), and volume displacement (16.9% of the total food volume). Within the crustacean group, unidentified crustacean fragments occurred in the greatest number of stomachs (FO = 28%) followed by amphipods (FO = 24%) and isopods (FO = 20%). Amphipods were the numerically dominant food item (NC = 25.8%), followed by unidentified crustaceans (ND = 22.6%) and isopods (ND = 16.1%). Volumetrically, decapod crustaceans had the greatest volume displacement (VD = 10.9%), followed by unidentified crustaceans (VD = 2.6%) and isopods (VD = 9%).

Other dominant food items included ophiuroideans (FO = 12%, ND = 9.7%, VD = .83%), poriferan (sponge) fragments (FO = 8%, ND = 6.5%, VD = 1.0%), and calanoid (Euchaeta sp.?) copepods (FO = 8%, ND = 6.5%, VD = .4%). Polychate fragments and holothuroidean fragments were of minor importance, appearing in only one stomach.

It is apparent from this data and other studies (McDowell, 1973) that H. macrochir feeds mainly in the sediment. Sediment occurred in 68% of all stomachs examined and comprised 74.9% of the volume of the stomach contents. Some of the amphipods found in the stomachs (Ampelisca, Harpinia, and the Lysianassids) are considered to be infaunal* and fragments of ophiuriodeans, sponges, and holothurians provide evidence for infaunal and epifaunal benthic feeding by H. macrochir. Some pelagic feeding may also occur, as noted by the presence of pelagic shrimps (Hymenopaneus laevis and Sergestes sp.) in two stomachs.

Coryphaenoides armatus

Five stomachs from C. armatus were examined from two stations (1 from 6A, and 4 from ALVIN 2). All five contained identifiable food.

Crustaceans were the most abundant food. All five stomachs contained crustaceans. They comprised 94.6% of all individual food items and constituted 76.4% of the volume of stomach contents. Within the crustaceans, amphipods had the highest frequency of occurrence, as they occurred in all stomachs examined. Unidentified crustacean fragments were next (FO = 80%), followed by decapods (FO = 60%). The remainder of the crustaceans were comprised of calanoid copepods, valviferan isopods, and euphausiids (FO = 40% for each). Amphipods were also numerically dominant (ND = 46.4%), followed by decapods (ND = 21.4%), calanoid copepods(ND = 8.9%), unidentified crustaceans (ND = 7.1%), and euphausiids (ND = 5.4%). Unidentified crustacean fragments comprised the greatest volume of crustacean food (VD = 44.5%), followed by decapods (VD = 26.1%), amphipods (VD = 3.1%), and euphausiids (VD = 1.4%).

The remaining (non-crustacean) stomach contents were mainly cephalopods. Cephalopod remains (Histioteuthis & Thysanoteuthidae) occurred in 40% of the stomachs examined, comprised 5.4% of the total number of food items, and contributed 3.9% to the total volume of food. The remainder of the stomach contents was sediment (VD = 11.3%) and unidentifiable remains, generally a white paste (VD = 5.9%). One stomach also contained pieces of a squid pen.

The stomach contents of Coryphaenoides armatus indicate that they are mainly pelagic feeders. This is evident by the abundance of remains of squids, pelagic hyperiid amphipods, euphausiids (Nematoscelis microps and Thysanopoda acutifrons), branchyuran megalopae (which are initially pelagic), and other crustacean larvae, and also by the relatively small amount of sediment. This is in agreement with the findings of other investigators (Haedrich and Henderson 1974, Pearcy and Ambler 1974).

Lycodes atlanticus

Four stomachs of specimens of L. atlanticus were examined from three stations (1 from 3, 2 from 3B, and 1 from 4B). Bivalve mollusks and ophiuroidean echinoderms were the predominent food found in L. atlanticus stomachs examined. Bivalves (Ayalopecten sp., Limatula sp., Lyonstella sp., Malletia polita) occured in 75% of the stomachs and comprised 72.7% of the total number of food items. Being rather small in size, they comprised only 13.4% of the total volume of stomach contents. Ophiuroideans (Ophiomusium lymani and unidentifiable fragments) occurred in all four stomachs examined and had a numerical dominance of 15.2%. They were the most abundant food item volumetrically with a volume displacement of 22.6%. The remainder of the food was composed of polychaete fragments, an amphipod, and a small pycnogonid (Nymphon macrum). Sediment took up most of the volume of the stomachs examined, with a volume displacement of 62.1%.

The remainder of species examined are represented by only one or two stomachs and will be summarized together. Of the three Aldrovandia phalacra examined, two were empty and the third contained only a white paste similar to that described by McDowell (1973) from specimens of A. phalacra which he examined. He has termed this "shrimp paste" and concluded that it is probably composed of detritus and crustacean remains. A. phalacra feeds on small benthic and pelagic crustaceans.

The one Simenchelys parasiticus stomach examined contained a large amorphous mass of white paste. Nothing could be recognized as fragments of any particular animal. This is probably fish flesh as these eels are believed to feed by boring into the bodies of other dead or living fishes (Goode and Bean 1896, Salomon-Raju and Rosenblatt 1971).

The single stomach of Bathysaurus agassizi examined contained a fish, Halosauropsis macrochir.

The two stomachs of Synaphobranchus kaupi examined contained squid (Histioteuthis) and hyperiid amphipod remains.

The single specimen of Coryphaenoides rupestris examined contained copepods and crustacean remains.

A single stomach of Centroscyllium fabricii was found to be empty.

The limited sampling possible at DWD 106 makes it necessary to include data from other sources in order to describe with any confidence, the food habits and trophic position of the dominant fish species. Consequently in the "Discussion" section of the present report I will refer to the results of the analysis of stomachs of 776 fishes in 21 species collected on other cruises cited in Section I above.

DISCUSSION

Menzies (1962) discusses possible sources of food for deep-sea organisms and ranks these sources in the following order of importance: 1. Rain of Dead Plankton (Agassiz, 1888). 2. Turbidity Currents (Heezen, Ewing, and Menzies, 1955). 3. Living Vertical Migrations (Vinogradov, 1958). 4. Floating Benthic Marine Plants. 5. Floating terrestrial Plants (Agassiz, 1892; Brunn, 1957). He also states that far at sea the rain of plankton may be followed in importance by living vertical migrations, but that in near shore areas there is little doubt that turbidity currents, the rain of dead plankton, and floating terrestrial and marine plants are the major sources of food. He believes that turbidity currents may bring organic rich sediment and near shore estuarine and terrestrial plants and debris to the deeper waters, enriching the food supply. It appears however, that this may not be an important direct source of food for fishes.

Submarine canyons are believed to be high incidence areas for turbidity currents (Heezen, Ewing, and Menzies, 1955), and if they are as important in deep-sea nutrition as Menzies believes, than shallow water plant material and debris should be an important source of food for fishes from canyon areas. There was no shallow water debris in any of the stomachs examined. in this study, although other workers have reported small amounts of neritic algae and tracheophytes from deep-living fishes (Haedrich and Henderson, 1974; Pearcy and Ambler, 1974). This material may have been uprooted by storms and carried out as a "floating benthic marine plant" food source (Menzies, 1962). However, inshore macrophytes are not important in the nutrition of the deep sea (Vinogradov, 1961). Turbidity currents may play an important role indirectly in the nutrition of these fishes by recycling nutrients and increasing productivity of planktonic animals, thus increasing the number of migrating pelagic animals which in turn serve as food for benthic fishes. Populations of detritus feeders such as Meganyctiphanes norvegica, Thysanopoda acutifrons, and other euphausiids (Macdonald, 1927; Einarsson, 1945; Mauchline, 1959, as cited by Raymont, 1963), may be increased by the action of turbidity currents stirring up organic detritus into suspension. These detritus feeders, in turn, are important food items for many deep-sea benthic fishes. Turbidity currents, by bringing organic rich sediments to greater depths, may support a greater number of deposit feeders, increasing the food supply for those species of fish that feed heavily on benthic deposit feeders (Halosauropsis macrochir, Aldrovandia spp., Lycodes atlanticus, Harriota raleighana). However, available evidence indicates that they are only of minor importance in food transport (Sanders and Hessler, 1969). They may even reduce food supply by destroying the habitat and burying deposit feeders under thick layers of sediments (Heezen, Ewing, and Menzies, 1955). It is apparent in the dominant slope species examined (*Synaphobranchus kaupi* and *Phycis chesteri*) and in a dominant abyssal species (*Coryphaenoides armatus*), that living vertical migrators are the most important sources of food. The pelagic myctophids, euphausiids, decapods, and cephalopods are the most important items in the diet of these fishes. On the continental slope, where vertical migrations bring mesopelagic animals down to the bottom, this is a very important food source for the dominant fishes, *Synaphobranchus kaupi* and *Phycis chesteri*. Other dominant benthic slope fishes, such as macrourids, also feed heavily on vertically migrating animals (Okamura, 1970; Marshall and Iwamoto, 1973). Vertical migrations may be an important source of food for abyssal fishes, such as *Antimora rostrata* and *Coryphaenoides armatus*, which had pelagic food items in their guts. Haedrich and Henderson (1974) have also cited *Coryphaenoides armatus* as a possible example of Vinogradov's vertically migrating food chain.

Menzies (1962) is probably correct in asserting that the rain of dead plankton is the most important food source far at sea. Though these small refractory particles are of little use to fishes directly, in the deeper living fishes examined in this study (*Halosauropsis macrochir*, *Lycodes atlanticus*, and in some *Coryphaenoides armatus*), and in stomach contents of fishes reported by other workers (Nielson, 1964; Bright, 1968, 1970), filter and deposit feeding animals are important food items. The dominance of deposit feeders in open areas of the sea is evidence of this type of food supply (Menzies, 1962; Sanders and Hessler, 1969). Rains of small particles thus sustain populations of deposit and filter feeders, which in turn serve as food for many benthic deep-sea fishes, which root in the oozes for food (Halosauridae, Zoarcidae, some Macrouridae, chimaeroids).

This indiscrimant rooting in the ooze and ingesting of sediment and infauna, which many species have exhibited, may also play a role in maintaining the high diversity (Sanders, 1968; Sanders and Hessler, 1969) which is found in deep-sea deposit feeders. Disturbance caused by uprooting and ingestion of infaunal and epifaunal animals by species such as <u>Halosauropsis</u> <u>macrochir</u>, <u>Lycodes</u> <u>atlanticus</u>, and <u>Aldrovandia</u> spp., and some macrourids (Marshall and Bourne, 1964) serves to regulate the population sizes of these prey organisms. This regulation reduces the probability of competitive exclusion, as Dayton and Hessler (1972) have hypothesized. The cropping life style as described by Dayton and Hessler (1972) is seen in the stomach contents found in this study and in the feeding behavior of these fishes, as described by Marshall and Bourne (1964).

Grassle and Sanders (1973) state that deep-sea benthic carnivores are not complete generalists that prey on smaller species with little selectivity. However, in areas where there is a lower abundance of food, such as the deep sea, fishes should be more generalized feeders (Ivlev, 1961; Schoener, 1971).

Studies that have delt in detail with the food of deep-sea benthic fishes have concluded that the species studied are generalists (Haedrich and Henderson, 1974; Pearcy and Ambler, 1974). The cropping benthic feeders examined in this study appear to exhibit little selectivity in their feeding. They consume any item which is small enough for them to eat, although no comparison of stomach contents with the benthic fauna can be made. Larger mouthed species (*Halosauropsis macrochir*, *Lycodes atlanticus*) consume some larger prey than the smaller mouthed species (*Aldrovandia* spp.), but there is much overlap. These croppers consumed a wide variety of food, thus having a generalized diet. The stomach contents of *Halosauropsis macrochir* comprised seven different phyla, many classes and orders within these phyla, and at least 30 species. *Lycodes atlanticus* had consumed five phyla of invertebrates and at least 21 species. *Aldrovandia* spp. fed on four phyla comprising at least 10 species. Stomach analysis of other species of deep living fishes have shown similar results (Bright, 1968, 1970; Haedrich and Henderson, 1974; Pearcy and Ambler, 1974).

Another indication of generalized feeding is the overlap found in the diets of fishes which co-occur. *Phycis chesteri* feeds mainly on fishes, decapods, and euphausiids, and *Synaphobranchus kaupi* feeds mainly on fishes, cephalopods, and euphausiids. Of the fishes eaten, *Ceratoscopelus maderensis* and unidentified myctophids are the most important food for both species of predator. Several species of euphausiids and decapods are common prey to both species. Amphipods are important food items for Halosauropsis macrochir, Aldrovandia spp. Lycodes atlanticus, and Coryphaenoides armatus, with several genera shared as common food.

Benthic fishes which fed mostly on pelagic food items (Synaphobranchus kaupi, Phycis chesteri, Antimora rostrata, Coryphaenoides armatus) also had generalized diets, but since they do not feed on deposit feeders, they would not be important in reducing competitive exclusion at this trophic level. Mobile predators such as these may actually compete for food (dead carcasses as they fall, or live meso and bathypelagic animals) with deposit feeders. They may function in dispersing large falls (Issacs, 1969) by consuming them above or on the bottom and homogenizing these widely spaced falls by spreading them out over the bottom as feces as Dayton and Hessler (1972) have hypothesized. The "shrimp paste" found in many stomachs by myself and other workers (McDowell, 1973) may represent scavenged larger parcels of flesh which are in the process of being dispersed over the bottom. Certainly scavengers such as many of the deep-sea sharks and Simenchelys parasiticus function at this trophic level.

Several species of fish consumed large amounts of sediment. Many specimens of Halosauropsis macrochir, Lycodes atlanticus, Harriota raleighana, Hydrolagus affinis, and some Aldrovandia had a greater volume of sediment than food in their stomachs. It is not known how much nutrition is derived from this sediment. McDowell (1973) believed the sediment he found in halosaurs to be "non-nutritional" but gave no evidence for this conclusion.

Section IV: Possible effects of dumping industrial wastes at DWD 106 on demersal fishes.

by J. A. Musick

During the course of this study we have often heard various collegues comment on the very low probability of demersal fishes being effected by industrial waste dumping at DWD 106 because of dispersal and dilution of such wastes in the upper water column. To this contention we offer the following cautionary comments.

1. Even though several species have demersal eggs, most of the dominant fishes at DWD 106, (S. kaupi, A. rostrata, the holosaurs and macrourids) have pelagic eggs and larval that would be exposed to wastes in the upper water column. Particular attention should be given to wastes which form flocculants that might become suspended in the thermocline, an area of concentration for fish eggs and larvae and other zooplankters.

2. Several of the dominant fishes at DWD 106, (A. rostrata, S. kaupi, C. rupestris, C. armatus) feed primarily on pelagic animals. There is evidence that some of these benthopelogic fishes actively forage in the water column and there is also evidence that some species of mesopelasic fishes spend the daylight hours close to the bottom. These facts suggest that there may be relatively rapid pathways for materials from the surface to the bottom even in areas as deep as DWD 106. Of primary concern should be the transport of persistant biologically active compounds (heavy metals, chlorinated hydrocarbons, etc.) dumped at the surface.

3. Because of the relative constancy of the environment on the lower continental slope and rise the resident fishes are

probably much more stenobiotic than are fishes of the continental shelf. Consequently caution must be exercised in making any attempt to extrapolate the results of shelf dumping studies to the deep-sea.

4. The northwest corner of DWD 106 is located over the mid-slope, an area of steep bottom gradient and only 21.2 km from the 200 m isobath. Prolonged southerly winds after a dump could quite conceivably cause waste materials to drift onto the upper slope, where the developing red crab fishery would be active or even to the outer shelf where there are several seasonally active fisheries (flounder, porgy, butterfish, lobster by U. S. fishermen; squid and butterfish by the Japanese; squid by the Spanish; hakes by the Soviet block).

5. Tom's Canyon, a small submarine canyon, funnels into the northwest corner of DWD 106 (Coast and Geodetic Survey Chart 0807N-53). Rowe (1972) has recently pointed out that such canyons may trap large aggregates of shallow water detritus and funnel sediment movements into the deep-sea. If such is the case with Tom's Canyon, then DWD 106 would be the recipient of accelerated downslope transport of carbon from the shelf. Consequently DWD 106 might support larger populations (at least of mobile megabenthic organism) than adjacent areas. Our studies in Norfolk Canyon suggest that for fishes, larger individuals are found in the canyon than on the adjacent slope, and also seasonally the canyon acts as a focal point for the aggregation of *Coryphaenoides rupestris*. No data exist on the fishes of DWD 106 other than for the Spring but because of the presence of Tom's Canyon, the area

is a more likely place for aggregations of _C. rupestris_ in the Fall than adjacent slope areas.

6. Submarine canyons are areas of active, complex bottom currents (Shepard, Marshal and McLoughlin, 1974). Consequently prediction or interpretation of the dispersal of wastes near the bottom will be more difficult in the northwest corner of DWD 106 than on the adjacent slope.

Section V: Recommendations

It would be naive to assume that contractors transporting wastes to DWD 106 will use the center of the dumpsite for disposal. In order to save time and fuel it is a simple economic fact that most contractors will dump in the shallow northwest corner of DWD 106 closest to land. Consequently dumping will be concentrated in a canyon ecosystem and in an area where there is a likelihood of wind driven dispersal of wastes over the upper slope and outer shelf.

Therefore, we recommend that consideration by given to move the locality of the dumpsite south to about the vicinity of the rad dumpsite. Such a move would place the site entirely on the continental rise away from the influence of Tom's Canyon and the diverse slope ichthyofauna. Diversity and biomass of fishes are lower on the rise. The bottom is well below the mesopelogic zone and even though there still remains the chance of vertical transport through pelagically foraging benthopelagic fishes, the great numbers of the vertically migrating mesopelogic fauna would not reach the bottom. Lastly, macrourids are less important and ophidioids become more important at the depths at which the rad site is located. The ophidioids are viviparous or have demersal eggs. Because fewer species with pelagic eggs and larvae occur in this deeper area than at DWD 106, the potential of industrial wastes effecting benthic fish populations through destruction of eggs and larvae will be reduced. In addition, the chance of encountering pelagic eggs and larvae of commercially important species spawned on the continental shelf will also be reduced.

Appendix 1. (Continued)

Station # Taxon	2	3	3B	3A	4B	ALV2	4C	5	6B	6A	5A	6
Melanocetidae												
Melanocoetus murrayi								1				
Anoplogasteridae												
Anoplogaster cornuta												
Stephanoberycidae												
Acanthochaenus lutkeni							1					
Melamphaidae												
Scopelogadus mizolepis				1			1					
Poromitra crassiceps							1					
Scopeloberyx robustus								1				
Scopeloberyx opisthopterus										1		

Appendix 1. Pelagic fishes incidentally captured at D.W.D. #106 bottom trawl stations.

Station # Taxon	2	3	3B	3A	4B	ALV2	4C	5	6B	6A	5A	6
Nessorhamphidae												
Nessorhamphus ingolfianus							1					
Serrivomeridae												
Serrivomer beanii	4	2		1			1					
Bathylagidae												
Bathylagus berycoides								1		1		
Bathylagus sp. A						1						
Gonostomatidae												
Polymetme corythaeola								1				
Gonostoma elongatum		2				1	3	1				
Gonostoma bathyphilum		1			1			1				
Cyclothone sp.								3				
Sternoptychidae												
Argyropelecus aculeatus			1								1	
Sternoptyx diaphana											2	
Chadliodontidae												
Chauliodus sloanii	2											
Stomiatidae												
Stomias boa ferex	1	1										
Melanostomiatidae												
Melanostomias valdiviae												1
Malacosteidae												
Malacosteus niger		1										
Paralepididae												
Macroparalepis affine	1											
Myctophidae												
Ceratoscopelus maderensis								1	1		1	
Lampanyctus macdonaldi	1				1							

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