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MEDITERRANEAN BIOLOGICAL STUDIES

FINAL REPORT

VOLUME I OF II

Smithsonian Institution
Washington, D.C. 20560

July 1972

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ERRATA
MEDITERRANEAN BIOLOGICAL STUDIES FINAL REPORT

p. 29, line 14 from top of page, after Table, insert 4.

p. 90, Literature cited, is a duplicate of page 73.

p. 125, 6th line from top of page, change (Sanzo,) to read (Sanzo, 1931)

p. 153 should precede p. 150. Page 153 is the first page of the species account for Electrona rissoi, page 150 the second page of that account.

p. 229, after the citation for Mazzarelli, G., insert:
Nafpaktitis, B. G. 1968. Taxonomy and distribution of the lantern fishes, genera Lobianchia and Diaphus, in the North Atlantic. Dana-Report No. 73: 1-131.

p. 284, paragraph 2, line 2, substitute ...are not for ... is not.

p. 285, Table 23

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13. ABSTRACT

From late August to early October, 1970, biological sampling was conducted at five stations in the Mediterranean Sea to provide material for studies of the composition and vertical distribution of the midwater fauna. The five widely spaced stations provided discrete-depth samples from very different hydrographic regimes from one end of the Mediterranean to the other. Part 1 of the report explains the methods and materials used in collecting and processing the biological samples; Part 2 treats the hydrography of the five stations; Part 3 treats the ecology and vertical distribution of the fishes; Part 4 explains swimbladder structure of the fishes and a method of comparing swimbladder data with acoustic profiles, and Part 5 treats the ecology and vertical distribution of the cephalopods. Appendices 1-4 provide the data upon which the analyses are based.

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Preface

The results presented here will, we believe, serve as a model for future studies of the ecology of the midwater macrofauna. There is nothing startling about the methods employed for sampling and analysis. What is significant is that these methods have all been used in the same study so as to produce a precision and detail that has never, to our knowledge, been accomplished in other studies of the midwater fauna.

Among the significant techniques brought to bear on this study are the following.

1. Sampling with a multiple discrete-depth cod-end sampler. This device permits the collecting of three samples at known depths during a single lowering of the trawl.

2. Shipboard monitoring of net depth, allowing placement of the trawl at a desired depth and control of trawl depth during the sampling period.

3. Specimen data recorded for all individuals of each species. These data include size, sex, and stage of development.

4. Computer methods of data retrieval and analysis.

The body of this report is composed of five parts, each treating a different aspect of this study. Supporting data are included in several appendices.

We are confident that these Mediterranean Biological Studies
ll provide impetus and foundation for many other studies by
rkers interested in the same area and in other waters of the world.

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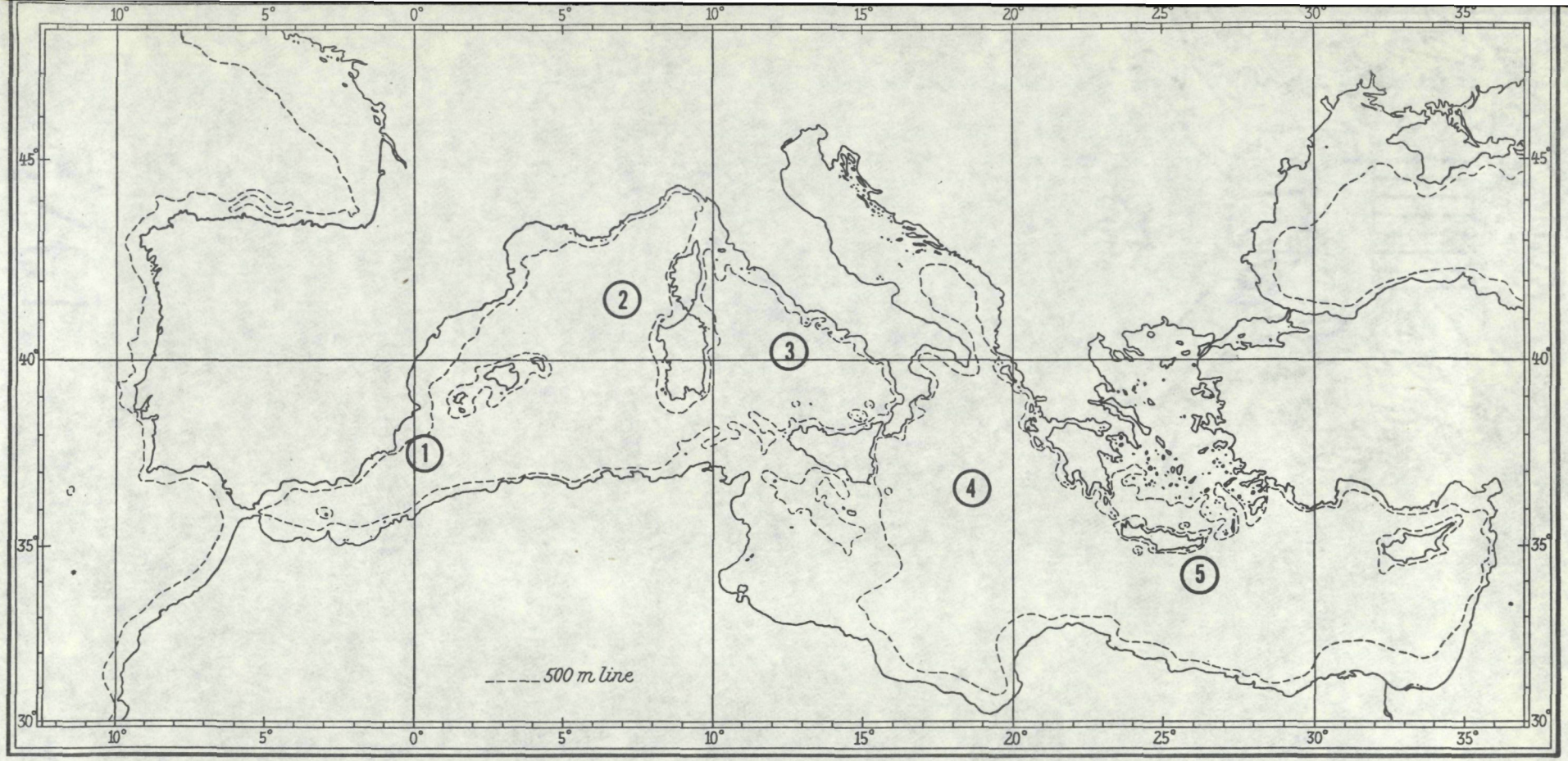


Fig. 1 Location and station number of areas in the Mediterranean Sea where samples used in this report were made.

PART 1

GEAR, SAMPLING METHODS, AND BIOLOGICAL SAMPLE PROCESSING

Robert H. Gibbs, Jr.
Smithsonian Institution

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Introduction

From late August to early October, 1970, biological sampling was conducted at five stations in the Mediterranean Sea to provide material for studies of the composition and vertical distribution of the midwater fauna. The results would then be available for comparison with acoustic measurements made at the same stations during the same time period. The five widely spaced stations provided samples from very different hydrographic regimes from one end of the Mediterranean to the other. The stations (Fig. 1) and the numbers of biological samples from each are given in Table 1. A full listing of data for all samples constitutes Appendix 1.

This introductory section explains the methods and materials used in collecting and processing the biological samples. Other parts of the report will treat the following subjects: (2) hydrography of the five stations, (3) ecology and vertical distribution of the fishes, (4) swimbladder structure of the fishes and a method of comparing swimbladder data with acoustic profiles, (5) ecology and vertical distribution of the cephalopods.

Gear

All trawl samples were made with a 10-foot (3-m) Isaacs-Kidd midwater trawl, fully lined with 1/4-inch bar mesh, terminated by a 1-m ring net of 00 nylon and a four-chambered

TABLE 1. STATION AND SAMPLE SUMMARY

Station Number	Station Coordinates	General Area	Sampling Dates 1970	Number of Trawls	Discrete Depth Samples	Oblique Samples	Horizontal Combined With Oblique Samples	Open Net Samples	Neuston (surface) Samples
1	36°55'-37°40'N 00°35'-01°51'E	Southwest Balearic Sea	20-25 August	15	43	15	--	--	--
2	40°44'-41°48'N 06°14'-07°39'E	Northeast Balearic Sea	26 August - 1 September	19	42	11	9	--	34
3	39°53'-40°33'N 11°48'-13°08'E	Tyrrhenian Sea	3-9 September	26	65	21	4	1	66
4	36°39'N 18°26'E	Ionian Sea	20 September	1	2	2	--	--	--
5	33°59'-34°28'N 25°27'-26°42'E	Levantine Sea	24 September - 2 October	8	18	14	--	--	15
Totals				69	170	63	13	1	115

discrete-depth cod-end sampler modified after Aron et al. (1964) and Bourbeau et al. (1966). The trawl was towed with a single-conductor cable, by means of which sensors in the spreader-bar unit transmitted for shipboard readout the depth of the net, ambient temperature, light intensity, and, during part of the cruise, flow of water. The four chambers of the cod-end sampler were closed by means of shipboard controls that sent an electrical current via a stepping switch in the spreader bar to solenoids on the sampler, each of which operated a trigger to release a pair of butterfly doors. The sampler provided 3 discrete-depth samples and one depth-to-surface sample for each lowering of the net.

Neuston samples were made with a 1-m ring net of 00 nylon with a three-legged bridle and a length of rope attached to a short boom. The net was fished so that its opening was half submerged. All neuston samples were made concomitantly with trawls.

Sampling Regime

The method of using the IKMT and the four chambers of the cod-end sampler was different at the first three stations than at the last two. At stations 1, 2, and 3 the R/V TRIDENT was employed for biological studies only. At these three stations, the trawl was placed at the selected depth, and the three discrete-depth chambers were closed sequentially

at that depth, usually at intervals of one hour. Only when sampling near dawn or dusk migration periods were sampling times shortened. Three samples thus were collected at the same depth with each lowering of the net.

At stations 4 and 5, biological sampling was severely limited, because the available time aboard the USNS SANDS was shared with acoustics programs. At these two stations the trawl was placed at a selected depth and a collection made at that depth in the first chamber; the second chamber sampled during an oblique haul to a second selected depth, and the third chamber sampled the second depth. In this manner, two horizontal discrete-depth samples were made with each lowering of the net. Two trawls were made with all three samples at the same depth.

Depths Sampled

A series of depths was selected to be sampled by IKMT both night and day at each station: (in meters) 50, 100, 150, 200, 300, 400, 500, 600, 800, and 1000. It had been hoped that samples could be made below 1000 m, but time did not permit this. It was also planned, time permitting, to sample several depths in the upper 100 m at night, but this was possible on a few occasions only. Table 2 summarizes the night and day sampling effort accomplished at each station.

The closest approach to accomplishing the sampling of all the basic depths both day and night was at station 3, where only the 1000 m night sample could not be made. Lack

TABLE 2. SUMMARY OF DAY AND NIGHT DISCRETE-DEPTH SAMPLING EFFORT (IN HOURS).

Samples within 1.5 hours of sunrise or sunset excluded.
No night samples taken at station 4.

epths mpled m	Day Station					Night Station			
	1	2	3	4	5	1	2	3	5
rface		2.0					11.9	29.0	7.8
12							1.5		
25						1.1			
40						1.0			
45							2.0		
50			2.0					1.1	1.0
70						1.0			
80									1.0
00		2.0	6.0				1.0	1.0	
35									1.0
50	3.0	1.0	2.0			3.0	3.0	3.0	
55									1.0
60					1.0				
90						1.0			
00		2.0	6.0				3.0	2.0	
35	2.0					3.0			
50					1.0				1.0
00		2.0	2.0					3.0	
25									1.0
40					1.0				
75	3.0								
00		3.0	3.0			3.0	2.1	3.1	
10					1.0				
25									1.0
95					1.0				
00	2.0		3.0	1.0				3.0	
10									1.0
00			3.0				1.0	3.0	
75					2.0				
00	3.0			1.0		3.0			
50			2.0					3.0	
00		2.0					3.0		
40	3.0								
00		1.0	3.0				3.0		

of time forced compromises at stations 1 and 2, and the incomparability of all three stations (1, 2, and 3) has been a source of difficulties in analyzing the samples. Stations 4 (only one trawl) and 5 (eight trawls) are comparable to the first three stations only with very great latitude for error.

Processing Biological Samples

Shipboard procedures. Specimens were fixed in a 10 percent solution of commercial formalin (i.e., 4 percent formaldehyde solution). After standing to harden for at least one hour, the organisms in each sample were sorted into four components: (1) fishes, (2) leptocephali, (3) cephalopods, (4) invertebrates other than cephalopods. Wet displacement volumes were measured for each of the four components. Fishes (including leptocephali) and cephalopods were shipped to the Smithsonian Institution for the studies reported here. Invertebrates other than cephalopods were sent to the Mediterranean Marine Sorting Center, Khereddine, Tunisia, where they were sorted into broad taxonomic categories and returned to the Smithsonian Institution. They are now being stored at the Smithsonian Oceanographic Sorting Center in Washington, D.C.

Laboratory procedures. Collections of fishes and cephalopods were leached in water to remove the formalin, and transferred through gradually increasing concentrations

into 70 percent ethyl alcohol. Each sample was sorted and the species identified. Each individual specimen was measured and its sex and stage (postlarva, juvenile, subadult, adult, etc.) determined. These data were recorded on a standard form designed for computer entry, using a coding system developed for this study. Computer methods of tabulation and analysis were developed by Richard H. Goodyear and Dail W. Brown.

Acknowledgments

These biological studies were a cooperative effort involving personnel of the Smithsonian Institution, University of Rhode Island, and the Naval Oceanographic Office.

Captain Barnes Collinson and the officers and crew of the R/V TRIDENT provided the finest possible support, often under trying circumstances. University of Rhode Island technicians William Hahn and Jack Knee made the hydro casts, analyzed the water samples, maintained the satellite navigation and echo-sounding systems, and particiapted in the biological collecting. All phases of participation by the University of Rhode Island were coordinated by Robert Sexton.

Navoceano personnel (other than those who helped prepare these reports) who contributed greatly to the success of the cruises include G. Brooke Farquhar, who was scientific coordinator aboard the TRIDENT, and James Taylor, who installed and checked out the electronic components of the discrete-depth sampling system while underway to the first station.

Jay Bercaw and Wayne Hoffman of the Santa Barbara General Motors Laboratory both aided in the installation of the sampling system, and Bercaw's participation throughout stations 1-3 was a major factor that assured the success of the work at those stations. George Alley, of the National Oceanographic Instrumentation Center aided in gear handling and maintenance.

Shipboard support in all phases of the biological studies was provided by Smithsonian technicians Charles Karnella, Michael Keene and Ronald Gatton.

Literature Cited

Aron, W., N. Raxter, R. Noel, and W. Andrews. 1964
A description of a discrete depth plankton sampler with some notes on the towing behavior of a 6-foot Isaacs-Kidd midwater trawl and a one-meter ring net. Limnology and Oceanography 9(3):324-333.

Bourbeau, F., W.D. Clarke, and W. Aron. 1966
Improvements in the discrete depth plankton sampler system. Ibid. 11(3):422-426.

APPENDIX I.

Station Data Summary. The depth recorded for discrete-depth samples is the depth at which the trawl fished during most, if not all, of the time. Dissimilar depths from a single trawl that were grouped for analysis and listed in tabulations under a single depth designation are indicated by an asterisk (*). The Time of Day column indicates whether a sample was considered as night (N) or day (D), or fell within the 1½-hour period on either side of sunrise or sunset (T). Letter designations following sample numbers are as follows: A, B, C -- discrete-depth samples; M - oblique sample from depth to surface; Z - sample combining oblique portion from surface to depth and one or more horizontal chambers; P - sample combining one or more horizontal chambers and oblique portion from depth to surface; N - sample combining horizontal and both oblique portions; S - neuston (surface) sample.

tation hamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
				10' IKMT			
1-1A	20.VIII	37°40'	01°43'	40	N	0245-0345	
1-1B	"	"		40	T	0345-0445	
1-1C	"	"		40	T	0445-0545	
1-1M	"	"		0-40		oblique	0545-0600
1-2A	20.VIII	37°24'	01°17'	235	D	1606-1706	
1-2B	"	"		235	D	1706-1806	
1-2C	"	"		235	T	1806-1906	
1-2M	"	"		0-235		oblique	1906-1940
1-3A	20.VIII	37°17'	01°04'	235*	N	2208-2308	
1-3B	"	"		235*	N	2308-0008	
1-3C	21.VIII	"		230*	N	0008-0108	
1-3M	"	"		0-225		oblique	0108-0222
1-4A	21.VIII	37°04'	00°51'	70	N	0325-0425	
1-4B	"	"		70	T	0425-0525	
1-4C	"	"		70	T	0525-0625	
1-4M	"	"		0-70		oblique	0625-0640
1-5A	21.VIII	36°57'	00°35'	360*	D	1000-1100	
1-5B	"	"		375*	D	1100-1200	
1-5C	"	"		390*	D	1200-1300	
1-5M	"	"		0-400		oblique	1300-1420
1-6A	21.VIII	36°55'	01°04'	150	N	2209-2309	
1-6B	"	"		150	N	2309-0009	
1-6C	22.VIII	"		150	N	0009-0109	
1-6M	"	"		0-150		oblique	0109-0140
1-7A	22.VIII	37°01'	01°07'	190	N	0250-0350	

tion mber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
7B	22.VIII	37°01'	01°07'	190	T	0350-0450	
7C	"	"		190	T	0450-0550	
7M	"	"		0-190		oblique	0550-0615
8A	22.VIII	37°12'	01°11'	925*	D	1015-1115	
8B	"	"		940*	D	1115-1215	
8C	"	"		940*	D	1215-1315	
8M	"	"		0-900		oblique	1315-1440
9B	22.VIII	37°26'	01°14'	25	T	1916-1946	
9C	"	"		25	T	1946-2016	
9M	"	"		0-25		oblique	2016-2030
10A	22.VIII	37°25'	01°07'	25	T	2100-2132	
10B	"	"		25*	N	2132-2211	
10C	"	"		30*	N	2211-2241	
10M	"	"		0-30		oblique	2241-2300
11A	23.VIII	37°28'	01°07'	400	N	0110-0210	
11B	"	"		400	N	0210-0310	
11C	"	"		400	N	0310-0410	
11M	"	"		0-400		oblique	0410-0450
12B	23.VIII	37°39'	01°09'	500	D	0815-0915	
12C	"	"		500	D	0915-1015	
12M	"	"		0-500		oblique	1015-1105
13A	23.VIII	37°40'	01°29'	700	D	1340-1441	
13B	"	"		700	D	1441-1542	
13C	"	"		700	D	1542-1641	
13M	"	"		0-700		oblique	1641-1740
14A	23.VIII	37°32'	01°51'	700	N	2250-2352	
14B	"	"		700	N	2352-0050	
14C	24.VIII	"		700	N	0050-0150	
14M	"	"		0-700		oblique	0150-0255
15A	24.VIII	37°09'	01°21'	150	D	1312-1412	
15B	"	"		150	D	1412-1512	
15C	"	"		150	D	1512-1612	
15M	"	"		0-150		oblique	1612-1628
				10' IKMT			
1A	26.VIII	40°44'	06°20'	100	T	2035-2135	
1B	"	"		100	N	2135-2235	
1P	"	"		0-100		2235-2335	2235-2350
2A	27.VIII	40°47'	06°24'	45	N	0029-0229	
2P	"	"		0-45		0229-0329	0229-0337
3A	27.VIII	41°00'	06°53'	100	D	1040-1140	
3B	"	"		100	D	1140-1240	
3P	"	"		0-100		1240-1340	1240-1405

Station Chamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
2-4A	27.VIII	41°14'	07°06'	200	D	1525-1625	
2-4B	"	"		200	D	1625-1725	
2-4P	"	"		0-200		1725-1827	1725-1901
2-5A	27.VIII	41°12'	07°11'	200	N	2045-2145	
2-5B	"	"		200	N	2145-2245	
2-5C	"	"		200	N	2245-2345	
2-5M	"	"		0-200		oblique	2345-0005
2-6A	28.VIII	41°10'	07°07'	400	N	0150-0250	
2-6B	"	"		400	N	0250-0353	
2-6C	"	"		400	T	0353-0453	
2-6M	"	"		0-400		oblique	0453-0530
2-7A	28.VIII	41°26'	07°00'	400	D	1235-1335	
2-7B	"	"		400	D	1335-1435	
2-7C	"	"		400	D	1435-1535	
2-7M	"	"		0-400		oblique	1535-1600
2-8A	28.VIII	41°21'	07°07'	1000	N	2200-2300	
2-8B	"	"		1000	N	2300-0000	
2-8C	29.VIII	"		1000	N	0000-0100	
2-8M	"	"		0-1000		oblique	0100-0255
2-9A	29.VIII	41°21'	07°18'	25	T	0342-0427	
2-9B	"	"		25	T	0427-0512	
2-9C	"	"		25	T	0512-0557	
2-9M	"	"		0-25		oblique	0557-0605
2-10A	29.VIII	41°22'	07°23'	1000	D	0915-1015	
2-10P	"	"		0-1000		1015-1215	1015-1407
2-11A	29.VIII	41°24'	07°08'	300	D	1530-1630	
2-11B	"	"		300	D	1630-1730	
2-11P	"	"		0-300		1730-1830	1730-1900
2-12A	29.VIII	41°15'	07°12'	600	T	2040-2140	
2-12B	"	"		600	N	2140-2240	
2-12P	"	"		0-600		oblique	2240-0045
2-13A	30.VIII	41°48'	07°39'	150	D	1225-1325	
2-13P	"	"		0-150		1325-1525	1325-1550
2-14A	30.VIII	41°31'	07°24'	15	T	1743-1845	
2-14B	"	"		15	T	1845-1945	
2-14C	"	"		15	T	1945-2045	
2-14M	"	"		0-15		oblique	2045-2055
2-15A	30.VIII	41°15'	07°12'	150	N	2148-2248	
2-15B	"	"		150	N	2248-2349	
2-15C	"	"		150	N	2349-0049	
2-15M	31.VIII	"		0-150		oblique	0049-0125
2-16A	31.VIII	41°28'	07°14'	800	N	2155-2257	
2-16B	"	"		800	N	2257-2357	
2-16C	"	"		800	N	2357-0057	
2-16M	1.IX	"		0-800		oblique	0057-0230

tation hamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
2-17A	1.IX	41°15'	06°51'	12	N	0252-0330	
2-17B	"	"		12	N	0330-0352	
2-17C	"	"		12	N	0352-0422	
2-17M	"	"		0-12		oblique	0422-0431
2-18Z	1.IX	41°16'	06°48'	0-800		0812-0912	0448-0912
2-18B	"	"		800	D	0912-1112	
2-18M	"	"		0-800		oblique	1112-1250
2-19A	1.IX	41°18'	06°14'	600	T	1512-1818	
2-19M	"	"		0-600		oblique	1818-1925
				1m ring net			
2-1S	29.VIII	41°21'	07°07'	surface	N	0045-0115	
2-2S	"	"		"	N	0120-0150	
2-3S	"	"		"	N	0153-0223	
2-4S	"	"		"	N	0226-0246	
2-5S	"	41°21'	07°18'	"	N	0346-0416	
2-6S	"	"		"	T	0420-0450	
2-7S	"	"		"	T	0452-0522	
2-8S	"	41°22'	07°23'	"	D	0840-0942	
2-9S	"	"		"	D	0954-1054	
2-10S	29.VIII	41°15'	07°12'	surface	T	1930-2000	
2-11S	"	"		"	T	2003-2033	
2-12S	"	"		"	T	2038-2108	
2-13S	"	"		"	N	2112-2142	
2-14S	"	"		"	N	2200-2230	
2-15S	"	"		"	N	2242-2312	
2-16S	"	"		"	N	2320-2350	
2-17S	30.VIII	"		"	N	2355-0025	
2-18S	"	41°15'	07°12'	"	N	2220-2250	
2-19S	"	"		"	N	2300-2330	
2-20S	"	"		"	N	2335-0005	
2-21S	"	"		"	N	0010-0045	
2-22S	31.VIII	41°28'	07°14'	"	T	1935-2005	
2-23S	"	"		"	T	2010-2040	
2-24S	"	"		"	N	2045-2115	
2-25S	"	"		"	N	2120-2150	
2-26S	"	"		"	N	2155-2225	
2-27S	"	"		"	N	2230-2300	
2-28S	"	"		"	N	2305-2335	
2-29S	"	"		"	N	2340-0010	
2-30S	1.IX	"		"	N	0012-0042	
2-31S	"	"		"	N	0045-0115	
2-32S	"	"		"	N	0153-0223	
2-33S	"	"		"	N	0339-0409	
2-34S	"	"		"	T	0455-0525	

tation hamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
				10' IKMT			
3-1A	3.IX	40°21'	12°31'	750	D	1438-1538	
3-1B	"	"		750	D	1538-1638	
3-1C	"	"		750	T	1638-1738	
3-1M	"	"		0-750		oblique	1738-1855
3-2A	3.IX	40°21'	13°00'	750	N	2140-2244	
3-2B	"	"		750	N	2244-2340	
3-2C	"	"		750	N	2340-0040	
3-2M	4.IX	"		0-750		oblique	0040-0215
3-3A	4.IX	40°27'	12°52'	100	N	0305-0405	
3-3B	"	"		100	T	0405-0505	
3-3C	"	"		100	T	0505-0605	
3-3M	"	"		0-100		oblique	0605-0626
3-4A	4.IX	40°24'	12°52'	600	D	0839-0941	
3-4B	"	"		600	D	0941-1041	
3-4C	"	"		600	D	1041-1141	
3-4M	"	"		0-600		oblique	1141-1255
3-5A	5.IX	40°06'	12°32'	600	N	0106-0206	
3-5B	"	"		600	N	0206-0306	
3-5C	"	"		600	N	0306-0406	
3-5M	"	"		0-600		oblique	0406-0508
3-6A	5.IX	39°58'	12°24'	400	D	0715-0815	
3-6B	"	"		400	D	0815-0915	
3-6C	"	"		400	D	0915-1015	
3-6M	"	"		0-400		oblique	1015-1050
3-7A	5.IX	39°53'	12°04'	200	D	1221-1321	
3-7B	"	"		200	D	1321-1421	
3-7C	"	"		200	D	1421-1521	
3-7M	"	"		0-200		oblique	1521-1550
3-8A	5.IX	40°05'	12°12'	400	N	2020-2120	
3-8B	"	"		400	N	2120-2225	
3-8C	"	"		400	N	2225-2325	
3-8M	"	"		0-400		oblique	2325-0004
3-9P	6.IX	40°08'	11°48'	0-200		0100-0400	0100-0428
3-10A	6.IX	40°17'	12°24'	100	D	1035-1135	
3-10B	"	"		100	D	1135-1235	
3-10C	"	"		100	D	1235-1335	
3-10M	"	"		0-100		oblique	1335-1352
3-11A	6.IX	40°16'	12°42'	50	D	1500-1600	
3-11B	"	"		50	D	1600-1700	
3-11C	"	"		50	T	1700-1800	
3-11M	"	"		0-50		oblique	1800-1810
3-12N	6.IX	39°58'	12°24'	0-500		2030-2330	1820-0015

Station Chamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
3-13A	7.IX	40°17'	12°33'	200	N	0155-0255	
3-13B	"	"		200	N	0255-0355	
3-13C	"	"		200	T	0355-0455	
3-13M	"	"		0-200		oblique	0455-0520
3-14A	7.IX	40°23'	12°49'	500	D	0720-0820	
3-14B	"	"		500	D	0820-0920	
3-14C	"	"		500	D	0920-1020	
3-14M	"	"		0-500		oblique	1020-1135
3-15A	7.IX	40°33'	12°45'	300	D	1325-1425	
3-15B	"	"		300	D	1425-1525	
3-15P	"	"		0-300		1525-1625	1525-1650
3-16A	7.IX	40°25'	12°55'	50	T	1725-1810	
3-16B	"	"		50	T	1810-1855	
3-16C	"	"		50	T	1855-2000	
3-16M	"	"		0-50		oblique	2000-2010
3-17A	7.IX	40°25'	12°55'	150	N	2106-2206	
3-17B	"	"		150	N	2206-2306	
3-17C	"	"		150	N	2306-0006	
3-17M	8.IX	"		0-150		oblique	0006-0024
3-18A	8.IX	40°26'	12°33'	50	N	0100-0205	
3-18P	"	"		0-50		0205-0400	0300-0419
3-19A	8.IX	40°24'	12°51'	1000	D	0838-1039	
3-19C	"	"		1000	D	1039-1141	
3-19M	"	"		0-1000		oblique	1141-1340
3-20A	8.IX	40°32'	12°28'	150	D	1445-1545	
3-20B	"	"		150	D	1545-1645	
3-20C	"	"		150	T	1645-1745	
3-20M	"	"		0-150		oblique	1745-1805
3-21A	8.IX	40°17'	12°51'	500	N	2135-2235	
3-21B	"	"		500	N	2235-2335	
3-21C	"	"		500	N	2335-0035	
3-21M	9.IX	"		0-500		oblique	0035-0135
3-22P	9.IX	40°28'	12°49'	0-25		0306-0506	0306-0520
3-23A	9.IX	40°23'	12°55'	200	D	0820-0920	
3-23B	"	"		200	D	0920-1020	
3-23C	"	"		200	D	1020-1120	
3-23M	"	"		0-200		oblique	1120-1155
3-24A	9.IX	40°23'	12°43'	100	D	1300-1400	
3-24B	"	"		100	D	1400-1500	
3-24C	"	"		100	D	1500-1600	
3-24M	"	"		0-100		oblique	1600-1616
3-25A	9.IX	40°10'	12°49'	25	T	1700-1830	
3-25B	"	"		25	T	1830-1930	
3-25C	"	"		25	T	1930-2030	
3-25M	"	"		0-25		oblique	2030-2036

Station Chamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
3-26A	9.IX	40°05'	12°56'	300	N	2152-2252	
3-26B	"	"		300	N	2252-2352	
3-26C	"	"		300	N	2352-0052	
3-26M	10.IX	"		0-300		oblique	0052-0120
				1m ring net			
3-1S	3.IX	40°21'	13°00'	surface	T	1938-2008	
3-2S	"	"		"	N	2012-2042	
3-3S	"	"		"	N	2046-2116	
3-4S	"	"		"	N	2122-2154	
3-5S	"	"		"	N	2158-2228	
3-6S	"	"		"	N	2230-2300	
3-7S	"	"		"	N	2304-2334	
3-8S	"	"		"	N	2338-0008	
3-9S	4.IX	"		"	N	0015-0045	
3-10S	"	"		"	N	0050-0120	
3-11S	"	"		"	N	0125-0205	
3-12S	"	40°27'	12°52'	"	N	0245-0315	
3-13S	"	"		"	N	0320-0355	
3-14S	"	"		"	T	0435-0505	
3-15S	"	40°06'	12°32'	"	N	2340-0010	
3-16S	5.IX	"		"	N	0012-0044	
3-17S	"	"		"	N	0046-0116	
3-18S	"	"		"	N	0118-0148	
3-19S	"	"		"	N	0152-0224	
3-20S	"	"		"	N	0226-0258	
3-21S	"	"		"	N	0300-0332	
3-22S	"	"		"	N	0335-0407	
3-23S	"	"		"	T	0409-0440	
3-24S	5.IX	40°05'	12°12'	surface	T	1905-1935	
3-25S	"	"		"	T	1940-2010	
3-26S	"	"		"	N	2027-2057	
3-27S	"	"		"	N	2103-2133	
3-28S	"	"		"	N	2135-2205	
3-29S	"	"		"	N	2207-2238	
3-30S	"	"		"	N	2240-2310	
3-31S	"	"		"	N	2312-2342	
3-32S	"	"		"	N	2347-2400	
3-33S	6.IX	40°08'	11°48'	"	N	0120-0150	
3-34S	"	"		"	N	0152-0222	
3-35S	"	"		"	N	0225-0257	
3-36S	"	"		"	N	0300-0330	
3-37S	"	"		"	N	0332-0350	
3-38S	7.IX	40°17'	12°33'	"	N	0200-0230	
3-39S	"	"		"	N	0235-0305	

Station Chamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+1	Total Time
3-40S	7.IX	40°17'	12°33'	surface	N	0310-0340	
3-41S	"	"	"	"	N	0345-0410	
3-42S	"	"	"	"	T	0415-0445	
3-43S	"	40°25'	12°55'	"	T	1900-1945	
3-44S	"	"	"	"	N	2040-2110	
3-45S	"	"	"	"	N	2115-2145	
3-46S	"	"	"	"	N	2150-2220	
3-47S	"	"	"	"	N	2225-2250	
3-48S	"	"	"	"	N	2255-2325	
3-49S	"	"	"	"	N	2330-2400	
3-50S	8.IX	40°26'	12°33'	"	N	0058-0132	
3-51S	"	"	"	"	N	0135-0205	
3-52S	"	"	"	"	N	0210-0240	
3-53S	"	"	"	"	N	0244-0314	
3-54S	"	"	"	"	N	0320-0350	
3-55S	"	40°17'	12°51'	"	N	2050-2120	
3-56S	"	"	"	"	N	2125-2157	
3-57S	"	"	"	"	N	2159-2230	
3-58S	"	"	"	"	N	2233-2303	
3-59S	"	"	"	"	N	2305-2335	
3-60S	"	"	"	"	N	2335-0013	
3-61S	9.IX	"	"	"	N	0016-0037	
3-62S	"	"	"	"	N	0040-0110	
3-63S	"	40°28'	12°49'	"	N	0211-0241	
3-64S	"	"	"	"	N	0244-0316	
3-65S	"	"	"	"	N	0320-0353	
3-66S	"	"	"	"	T	0358-0432	

Station Chamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+2	Total Time
				10' IKMT			
4-1A	20.IX	36°39'	18°26'	700	D	1330-1430	
4-1B	"	"		700-500		oblique	1430-1545
4-1C	"	"		500	D	1545-1645	
4-1M	"	"		0-512		oblique	1645-1720
5-1A	24.IX	34°13'	25°46'	660*	D	1432-1532	
5-1B	"	"		675*	D	1532-1632	
5-1C	"	"		660	T	1632-1702	
5-1M	"	"		0-652		oblique	1702-1802
5-2A	"	34°12'	25°42'	325	N	2105-2205	
5-2B	"	"		325-250		oblique	2205-2255
5-2C	"	"		250	N	2255-2355	
5-2M	"	"		0-248		oblique	2355-0030
5-3A	25.IX	34°17'	25°27'	155	N	0120-0220	
5-3B	"	"		155-80		oblique	0220-0255
5-3C	"	"		80	N	0255-0355	
5-3M	"	"		0-80		oblique	0355-0415
5-4A	"	34°08'	26°28'	340	D	1410-1510	
5-4B	"	"		340-250		oblique	1510-1535
5-4C	"	"		250	D	1535-1634	
5-4M	"	"		0-238		oblique	1635-1700
5-5A	"	34°14'	26°40'	510	N	2130-2230	
5-5B	"	"		510-425		oblique	2230-2315
5-5C	"	"		425	N	2315-0015	
5-5M	26.IX	"		0-427		oblique	0015-0045
5-6A	1.IX	34°00'	26°30'	495	D	1445-1545	
5-6B	"	"		490	T	1545-1645	
5-6C	"	"		505	T	1645-1745	
5-6M	"	"		0-520		oblique	1745-1820
5-7A	"	33°59'	26°42'	135	N	2010-2110	
5-7B	"	"		135-54		oblique	2110-2130
5-7B	"	"		54	N	2130-2230	
5-7M	"	"		0-52		oblique	2230-2242
5-8A	2.X	34°28'	26°30'	410	D	1025-1125	
5-8B	"	"		410-160		oblique	1125-1210
5-8C	"	"		160	D	1210-1310	
5-8M	"	"		0-165		oblique	1310-1330
				1m ring net			
5-1S	24.IX	34°12'	25°42'	surface	N	2135-2205	
5-2S	"	"		"	N	2215-2245	
5-3S	"	"		"	N	2250-2320	
5-4S	"	"		"	N	2325-2355	

Station Chamber	Date 1970	Beginning Coordinates N	E	Depth in Meters	Time of Day	Time at Depth GMT+2	Total Time
5-5S	25.IX	34°17'	25°27'	surface	N	0100-0130	
5-6S	"	"	"	"	N	0135-0205	
5-7S	"	"	"	"	N	0215-0245	
5-8S	"	"	"	"	N	0250-0320	
5-9S	"	"	"	"	N	0325-0355	
5-10S	"	34°14'	26°40'	"	N	2025-2110	
5-11S	"	"	"	"	N	2115-2145	
5-12S	"	"	"	"	N	2150-2220	
5-13S	"	"	"	"	N	2225-2255	
5-14S	"	"	"	"	N	2300-2330	
5-15S	"	"	"	"	N	2335-0005	

PART 2

HYDROGRAPHY

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Introduction

Hydrographic measurements were made to supplement biological and acoustical studies at five stations in the Mediterranean Sea during August and September, 1970 (Fig. 1). Station 1 was located in the far southwestern portion of the Balearic Sea and the remaining four in the larger basins of the Mediterranean: northeast Balearic Basin (Sta. 2), Tyrrhenian Basin (Sta. 3), Ionian Basin (Sta. 4), and Levantine Basin (Sta. 5). Expendable bathythermograph (XBT) casts were taken at four stations (1, 2, 3, and 5) and standard hydrographic casts were made at two stations (2 and 3). No hydrographic sampling occurred at station 4. Temperature was recorded at net depth by a sensor mounted on the spreader bar during most trawls, and data from calibration lowerings of that sensor are available. These data were used in this account only at station 4 where XBT and hydro-cast data were not available.

The water masses of the Mediterranean have been widely studied, in part because the sea is almost entirely surrounded by land, and its outflow has a profound effect on the Atlantic Ocean. Nielsen (1912) presented an extensive review of the literature dealing with Mediterranean hydrographic investigations prior to the Danish Oceanographic Expedition of 1908-1910, which he analyzed in detail. Wust (1961) analyzed approximately 600 stations (400 summer and 200 winter) in determining water-mass circulation. The physical oceanographic data from several cruises

of the R/V CHAIN and R/V ATLANTIS were reported by Miller (1963) and, more extensively, by Miller, Tchernia and Charnock (1970). Studies of the sources and circulation of the deep water were reported by Pollak (1951) and Ovchinnikov and Plakhin (1965).

Methods and Acknowledgments

Hydro casts were made at stations 2 and 3 using Niskin bottles and reversing thermometers. No hydrographic casts were made at station 1 because of rough weather. Three successive sets of bottles were used at station 2: the first, from 0 to 979 m (15 bottles); the second, three bottles at 786, 983 and 1477 m; and the third, three bottles at 1979, 2471 and 2669 meters. Station 3 consisted of two lowerings: 15 bottles from 0 to 982 m and six bottles from 738 to 2299 m. A list of the reduced data from stations 2 and 3 is found in Table

XBT casts were made near the midway point of each biological trawl using 750 meter expendable bathythermographs. The number of casts at stations 1, 2, 3, and 5 were 19, 25, 32 and 5, respectively. Because the XBT casts were made during each trawl, the profiles represent a number of sub-stations rather than one single hydrographic station; therefore, some differences in the water column may be evident.

Chemical analyses were carried out aboard ship by Joel Knee, oceanographic technician from the University of Rhode Island. Computer readouts of corrected and reduced hydrographic data were

furnished to us by Robert Sexton of the University of Rhode Island. Computer analyses of the XBT traces were furnished by the National Oceanographic Data Center.

Morphology, Circulation, and Water Masses

The Mediterranean Sea is almost land-locked and is divided into several semi-isolated seas, resulting in varied hydrographic characteristics for the separate areas. The eastern and western basins are separated by the narrow passage at the Strait of Messina and by the shallow sill at the Strait of Sicily. The continental slope averages less than 25 miles in width in the Mediterranean but exceeds this figure between Sicily and eastern Tunisia, adding to the restriction of circulation between east-west sections.

The western Mediterranean is composed of three basins: 1) the Alboran Sea from the Strait of Gibraltar east to Valencia, Spain; 2) the Balearic Sea from the north-south line at Valencia east approximately to Sardinia and Corsica; 3) the Tyrrhenian Sea, between Italy, Sardinia and Corsica, and south to Sicily. Abyssal plains are predominant in these western basins, as opposed to ridges and troughs in the eastern basins.

The eastern Mediterranean is composed of four basins: the Adriatic Sea, from the Straits of Otranto northwestward; the Aegean Sea, from Crete northward; the Ionian Sea, from the Strait of Sicily to a north-south line at the eastern end of Crete; and

the Levantine Sea from the eastern tip of Crete to the eastern-most coast. This eastern region is generally characterized by east-west fractured ridges and deep depressions parallel to the Hellenic Trough, with small abyssal plains in the Ionian and Adriatic Seas.

The Mediterranean circulation is dominated by the influx of water from the North Atlantic Ocean. This surface water forms several counter-clockwise circulation patterns in both the western and eastern halves (see Nielsen, 1912, for specific patterns). Evaporation in the warmer areas and cooling by dry polar air masses in the northern areas result in sinking of the surface water due to its increased density. Intermediate water, flowing out of the Mediterranean at approximately 300 meters through the Strait of Gibraltar, is much denser, because of its higher salinity, than Atlantic water at the same depth, even though the temperature of the Mediterranean water is higher. Therefore, it sinks until a level of equal density is found at approximately 1000 m and then flows north, west, and south in the Atlantic as a distinctive layer. The loss of intermediate water is balanced by the inflow of Atlantic surface water into the Mediterranean.

There are four water masses in the Mediterranean: surface, intermediate, deep and bottom (Sverdrup et. al., 1942; Wust, 1961). The surface water extends to 100 or 200 m, with its lower limits characterized by a temperature minimum. The intermediate water is found from the lower limit of the surface

water to a depth of approximately 600 meters. This layer is characterized by a maximum salinity reading. In the western half of the Mediterranean there is also a maximum temperature reading in this layer, but in the eastern half temperature decreases throughout this layer. The lower boundary for the intermediate water is indicated by a rapid decrease in both temperature and salinity. The transition between this water mass and the deep water is characterized by a continuation of the temperature and salinity decrease. The deep water mass is found at depths between 1500-3000 m and is characterized by a minimum temperature and a deep oxygen maximum. Bottom water formation is intermittent and its sources apparently are different in the west than in the east.

Hydrography at Stations 1 - 5

Temperature -

Nineteen XBT casts were made at station 1. A composite of the XBT profiles (Fig. 2) shows two, possibly three, separate patterns below the thermocline, which may represent changes in the location of the ship over the sampling period. The trace with a surface temperature nearly 2 degrees above average (27.6°C) and unusually high temperature to 540 m probably is inaccurate.

Fig. 3 graphs the minimum, average and maximum XBT temperatures at station 1. The curve for averaged temperatures

Fig. 2 Composite of 19 XBT casts at Station 1 (CALCOMP Plot).

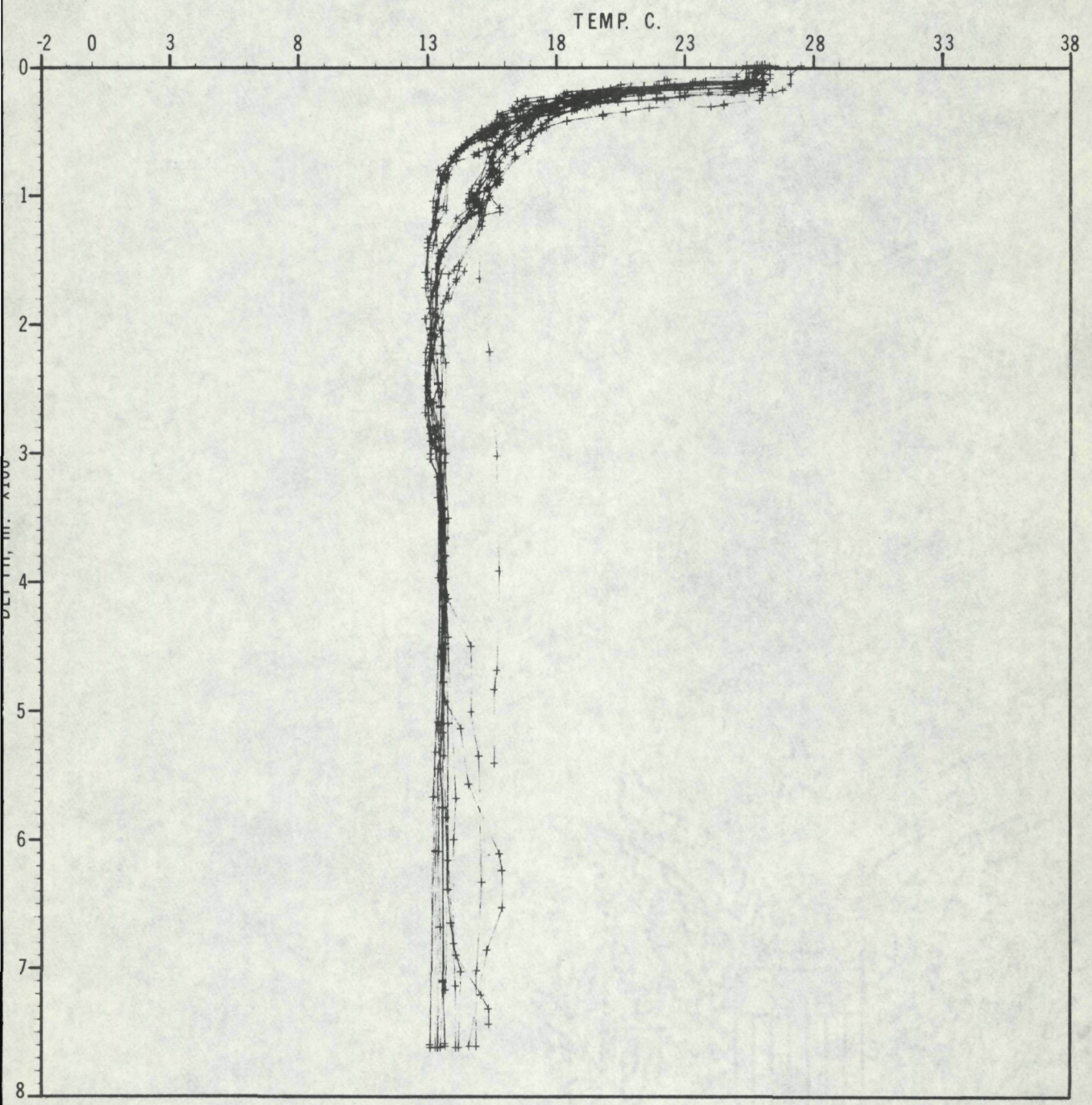
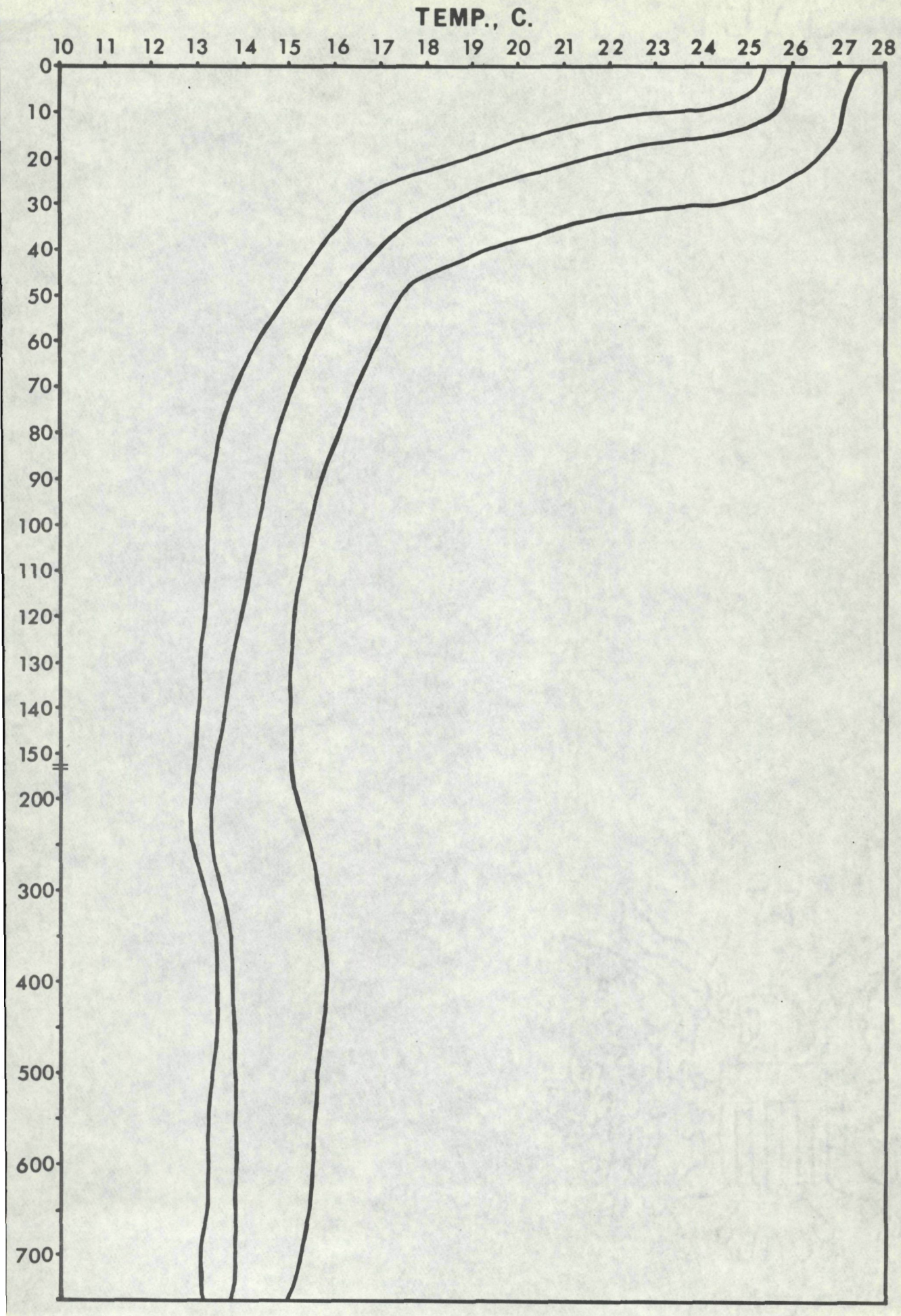

TEMP. C.
-2
0
3
8
13
18
23
28
33
38
0
1
2
3
4
5
6
7
8

Fig. 3 XBT Temperatures (minimum, average, maximum) at Station 1.


TEMP., C.
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
200
300
400
500
600
700

had a surface temperature of 26.0°C followed by a 0.3°C decrease in the upper mixed layer (0-10 m). The thermocline extended from 10-40 m, in which the average temperature decreased 8.7°C at a rate of 0.25°C/m to 17.0°C. The decline in temperature continued at a slower rate to a minimum average of 13.4°C at 185-270 m, the lower boundary of the surface water. Temperature increased to a maximum in the intermediate water of 13.8-13.9°C from 400 m to at least the lower limit of the deepest XBT (760 m).

One series of hydro casts and 34 XBT casts were made at station 2. Fig. 4 graphs the minimum, average and maximum XBT temperatures at station 2. The average surface temperature was 22.6°C and, as at station 1, a 0.3°C decrease occurred in the upper mixed layer (0-10 m). The thermocline extended from 10-70 m, in which the average temperature dropped at a rate of 0.13°C/m to 14.5°C. The decline in temperature continued at a slower rate to a minimum average of 13.3°C at 110-215 m, the lower boundary of the surface water. Temperature increased below this depth. The maximum temperature in the intermediate water (13.5-13.6°C) was located from 260 m to at least the lower limit of the deepest XBT cast (760 m).

The temperatures from the single series of hydro casts (Fig. 6 , Table 4) differed from the average XBT temperatures, but were within the maximum and minimum XBT range. The upper mixed layer and the thermocline were at about the same depths as the XBT averages indicate. The temperature minimum of 13.09°C at 96 m and the increase that began there and became stable at

Fig. 4 XBT Temperatures (minimum, average, maximum) at Station 2.

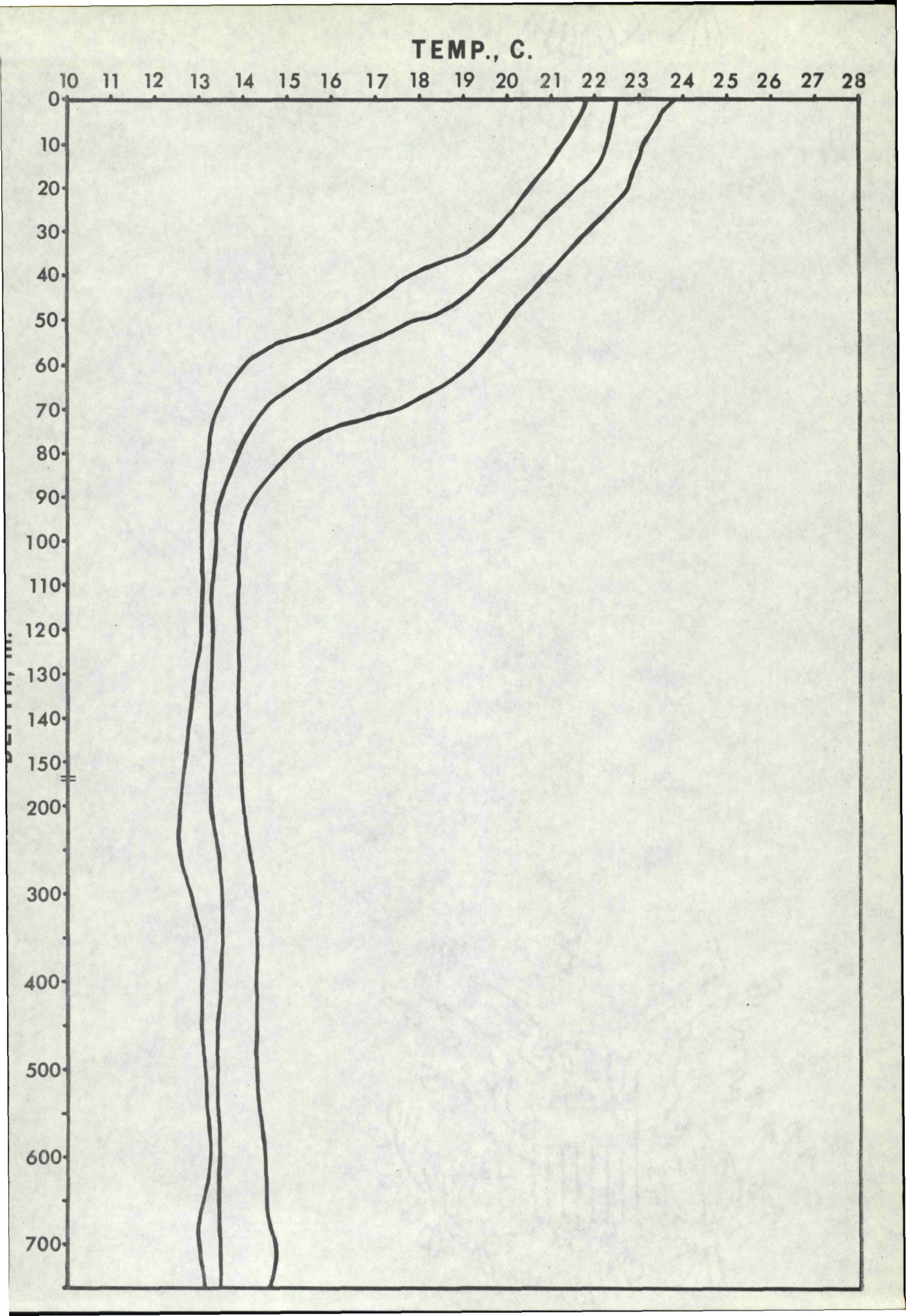

TEMP., C.
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 200 300 400 500 600 700

Fig. 5 Composite of 34 XBT casts at Station 2 (CALCOMP Plot).

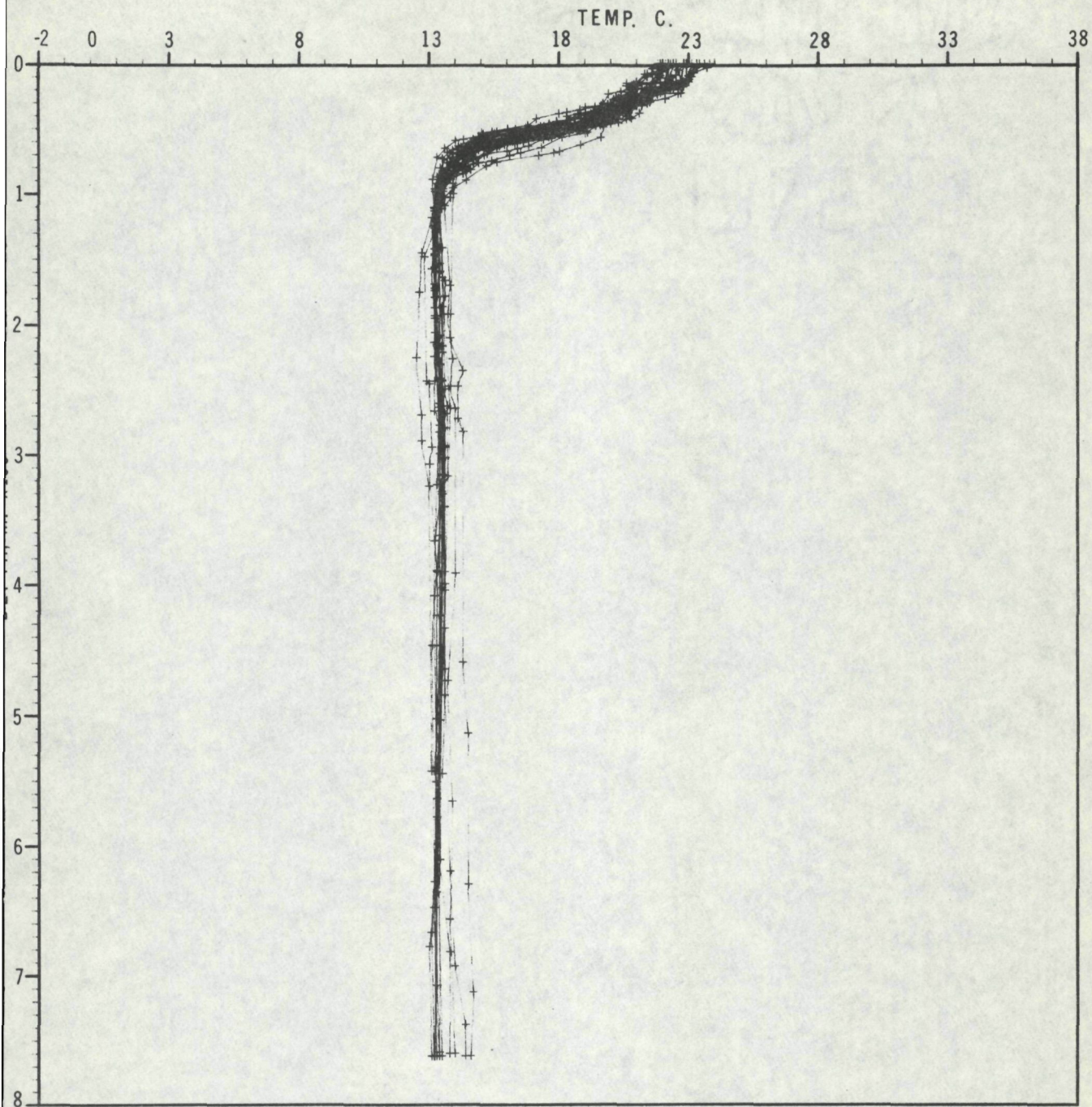
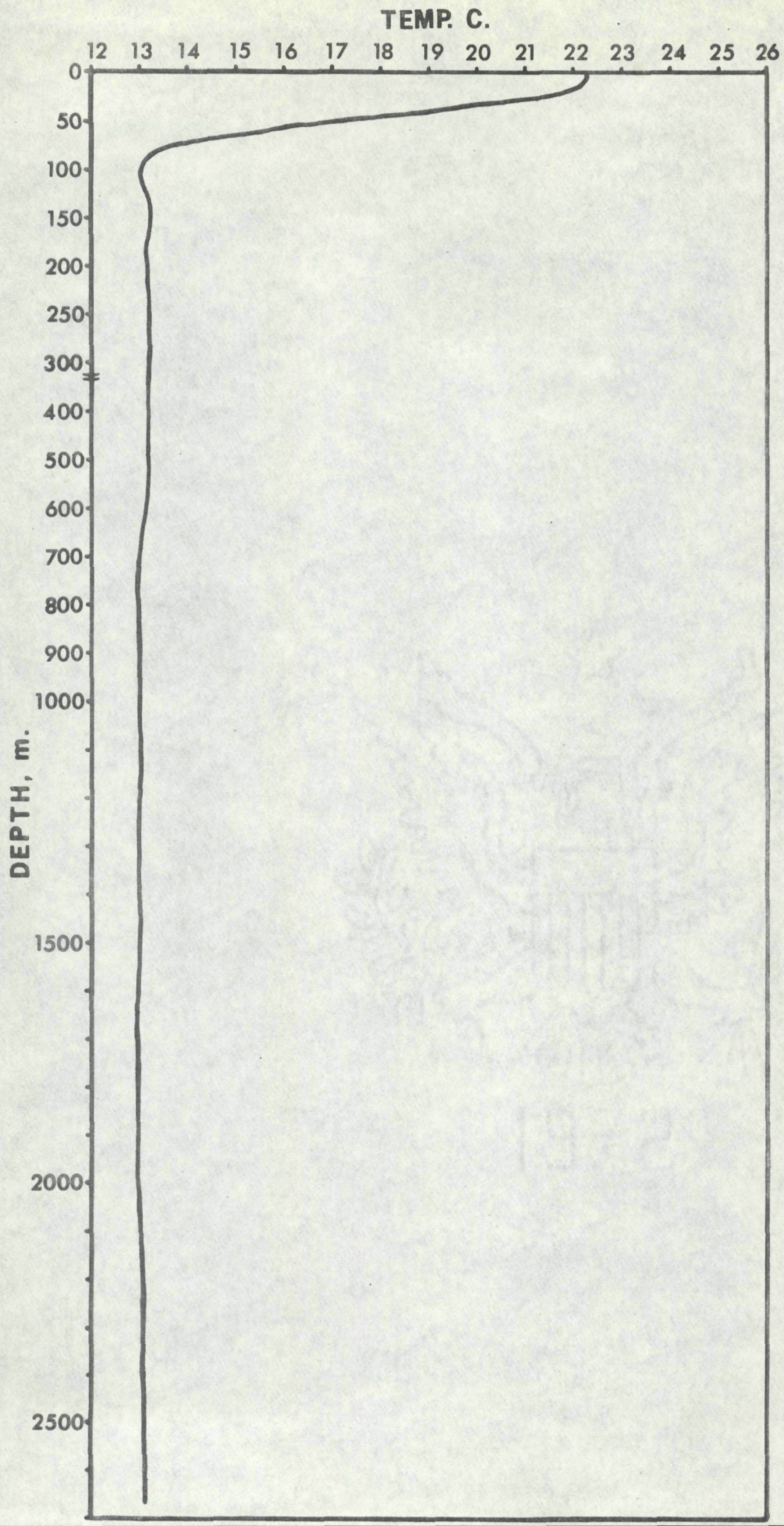

TEMP. C.
-2
0
3
8
13
18
23
28
33
38
0
1
2
3
4
5
6
7
8

Fig. 6 Temperatures at Station 2 from hydro casts


TEMP. C.
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
0
50
100
150
200
250
300
400
500
600
700
800
900
1000
1500
2000
2500
DEPTH, m.

a maximum 13.21-13.26°C between 146-485 m suggest that the intermediate water (characterized at its core by the temperature maximum) was shallower at the hydro station than was indicated by the average XBT temperatures (temperature maximum at 260-760+ m). Below 485 m temperature decreased slightly to 12.98°C at 983-1477 m, below which there occurred an increase to 13.15°C at 2669 m.

One hydrographic series and 32 XBT casts were made at station 3. Average surface temperature from XBT casts (Fig. 7) was 25.4°C. The upper mixed layer extended to 22 m, and within it the temperature decreases about 1°C. Temperature decreased through the thermocline (22-50 m) at 0.38°C/m to 15.9°C, a rate greater than at either station 1 (0.29°C/m) or station 2 (0.13°C/m). The decrease continued to a minimum (14.0°C) at the lower limit of the surface water (100-110 m). Temperature then increased to a maximum of 14.3°C at 230-665 m in the intermediate water.

Temperatures from the hydro casts (Fig. 8 , Table 4) show a temperature minimum of 13.93°C marking the lower boundary of the surface water at 148 m. The increase in temperature in the upper intermediate water reached a maximum of 14.20°C at 245 m, after which there was a slow decrease to 13.82°C at 776 m, a slightly more rapid decrease to 13.17°C at 1328 m, and relative stability at 13.11-13.18°C from 1328-2111 m. A slight adiabatic increase may be indicated at the deepest reading (2299 m).

Temperature data for station 4 (Fig. 10) were obtained from a sensor mounted on the net spreader bar. Surface temperature

Fig. 7 Composite of 32 XBT casts at Station 3 (CALCOMP Plot).

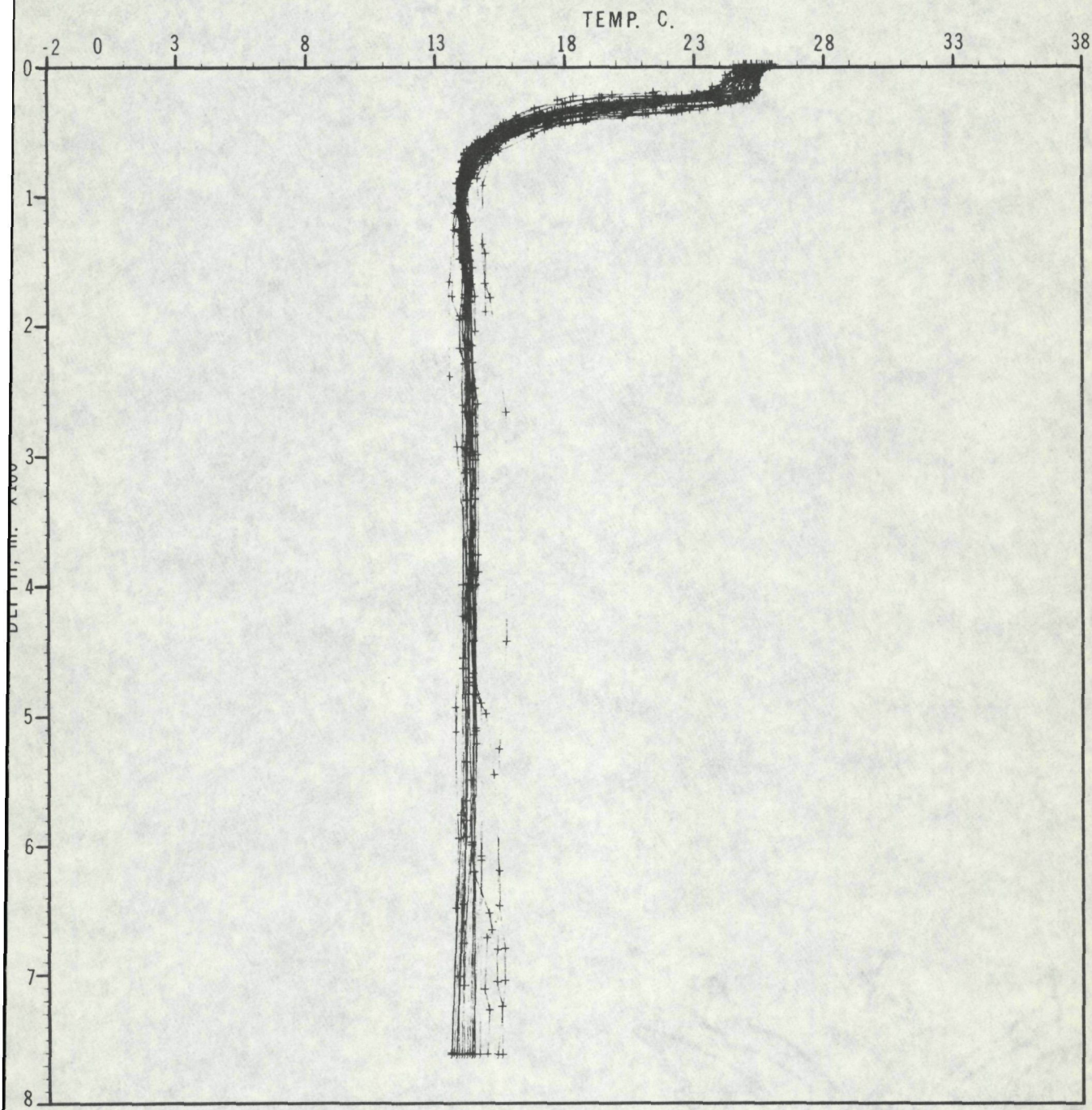

TEMP. C.
-2
0
3
8
13
18
23
28
33
38
0
1
2
3
4
5
6
7
8

Fig. 8 Temperatures at Station 3 from hydro casts

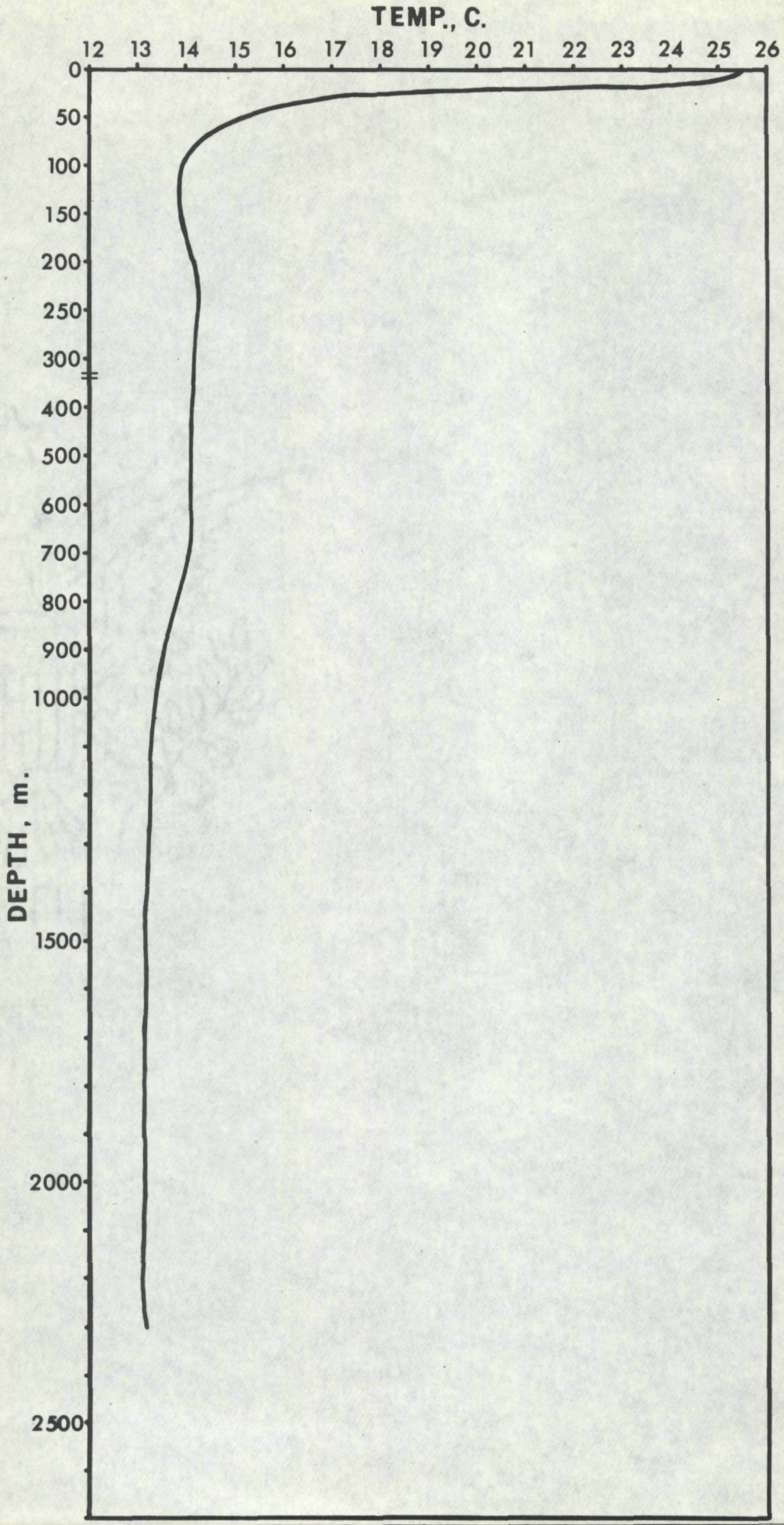

TEMP., C.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
0
50
100
150
200
250
300
400
500
600
700
800
900
1000
1500
2000
2500
DEPTH, m.

Fig. 9 XBT Temperatures (minimum, average, maximum) at Station 3.

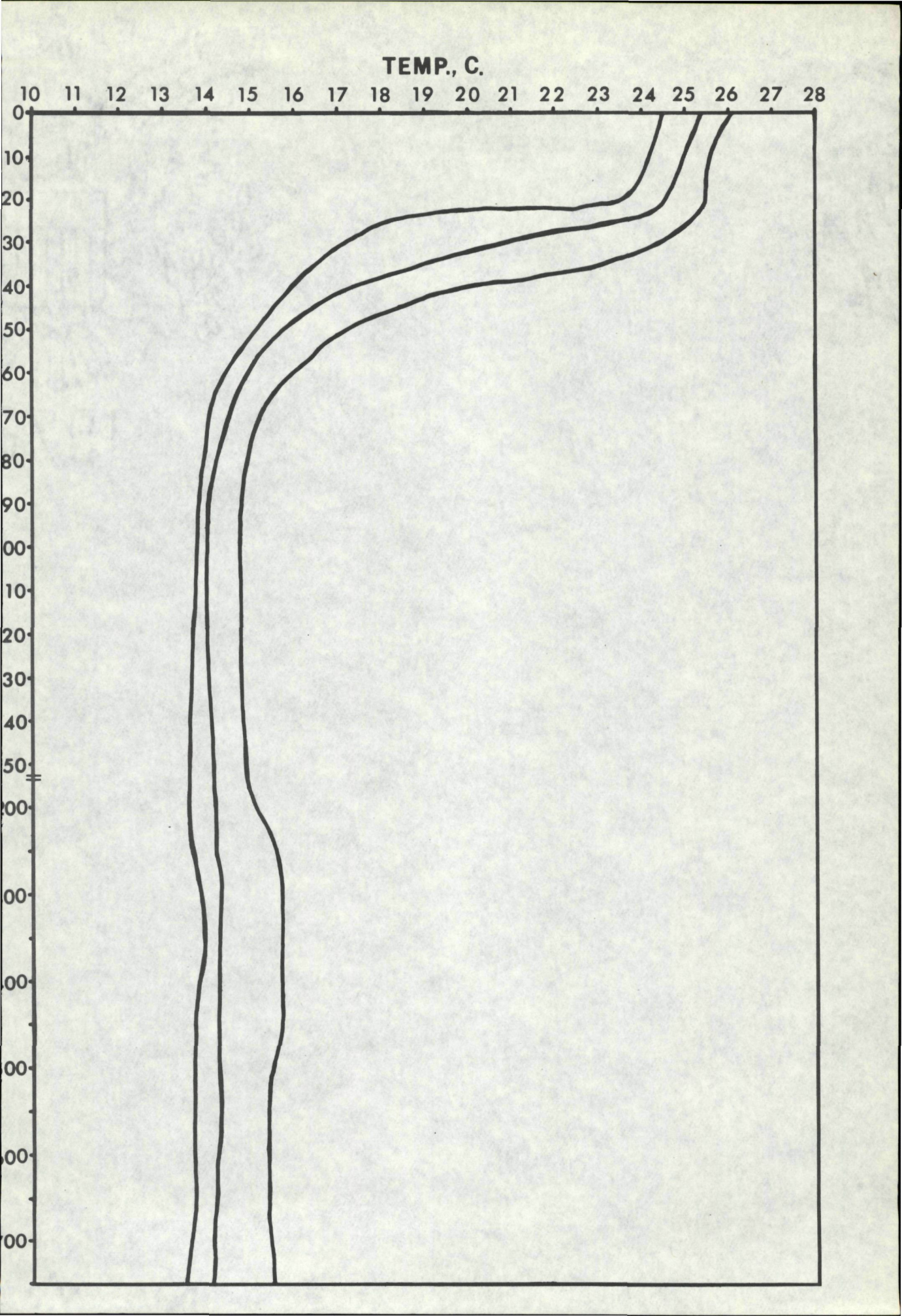
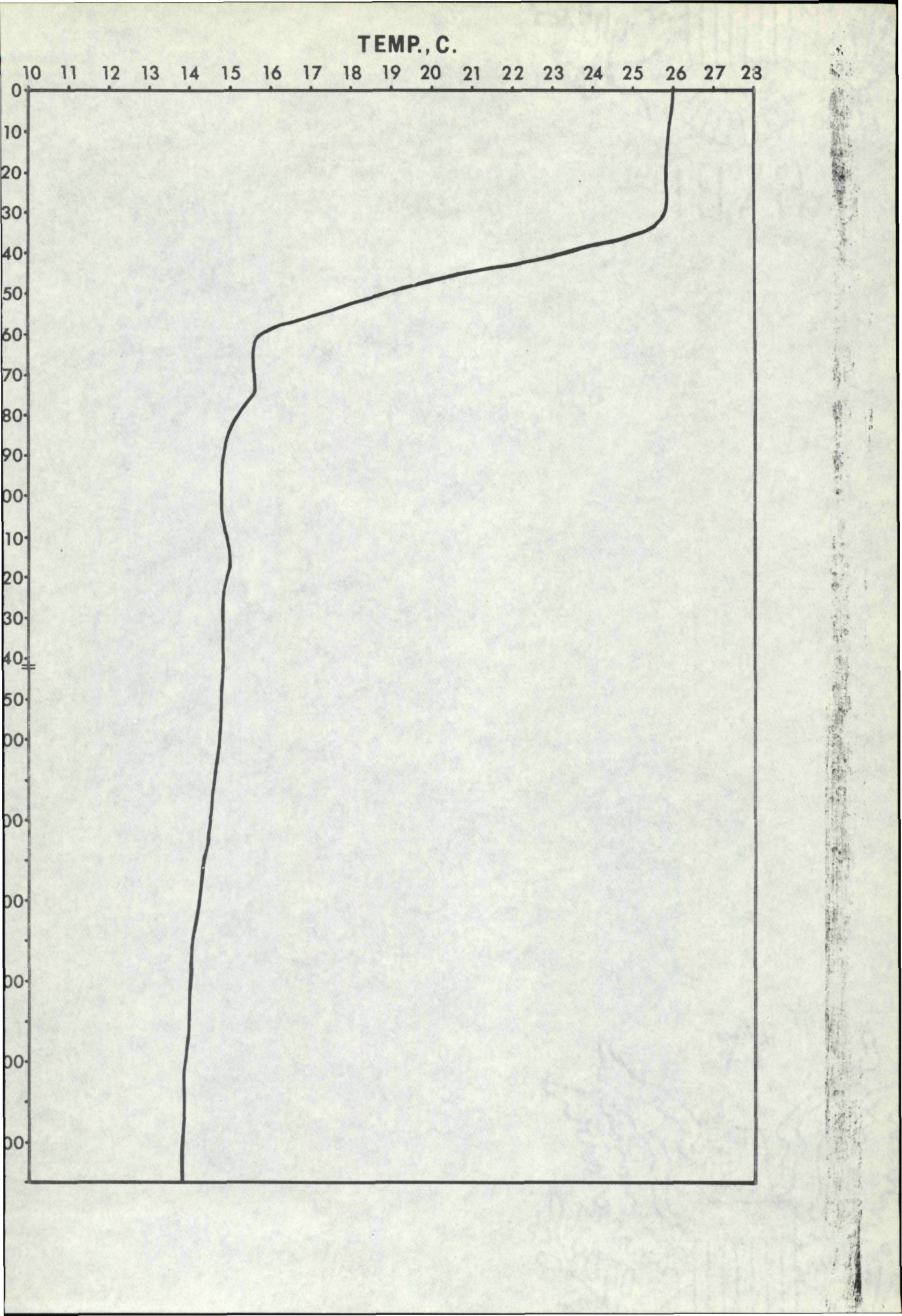

TEMP., C.
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
0
10
20
30
40
50
60
70
80
90
00
10
20
30
40
50
00
00
00
00
00
00

Fig. 10 Temperatures at Station 4 from sensor on trawl.


TEMP., C.
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
0
10
20
30
40
50
60
70
80
90
00
10
20
30
40
50
00
00
00
00
00

was 26.0°C followed by a 0.2°C decrease in the upper mixed layer (0-30 m). The thermocline decrease was rapid (0.33°C/m) with a decrease from 25.8°C (30 m) to 15.7°C (60 m).

Below the thermocline, temperature decreased gradually to the deepest reading at 785 m (13.8°C). There was no obvious distinction between surface water and intermediate water.

XBT casts were the only hydrographic observations conducted at station 5. Five casts were made at two separate locations less than one degree of latitude apart, producing two markedly different temperature curves. Fig. 11 illustrates the profiles for one area, 5a, (two casts, 24 September 1970, 34°13' N 025°42' E). Average surface temperature was 25.7°C and the upper mixed layer extended to 30 m with a 0.5°C decrease to 25.2°C. The thermocline boundaries were 30 m (25.2°C) and 55 m (17.9°C), a rate of decrease of 0.29°C/m. Below the thermocline a steady decrease continued to the termination of the XBT at 760 m (14.0°C). There was no obvious distinction between surface water and intermediate water.

In contrast, the second area, 5b, (Fig. 12 , three casts, 25 September 1970, 34°08' N 026°32' E) had a lower average surface temperature (24.2°C) and a 0.7°C decrease through a thicker upper mixed layer (0-135 m). The thermocline occurred deeper than at sub-station 5a, with the upper limit at 135 m (23.5°C) and the lower limit at 175 m (17.8°C), a rate of decrease of 0.14°C/m. A steady decrease occurred below the thermocline, as in sub-station 5a, to the XBT termination at

Fig. 11 Composite of 2 XBT casts at Station 5a, (CALCOMP Plot).

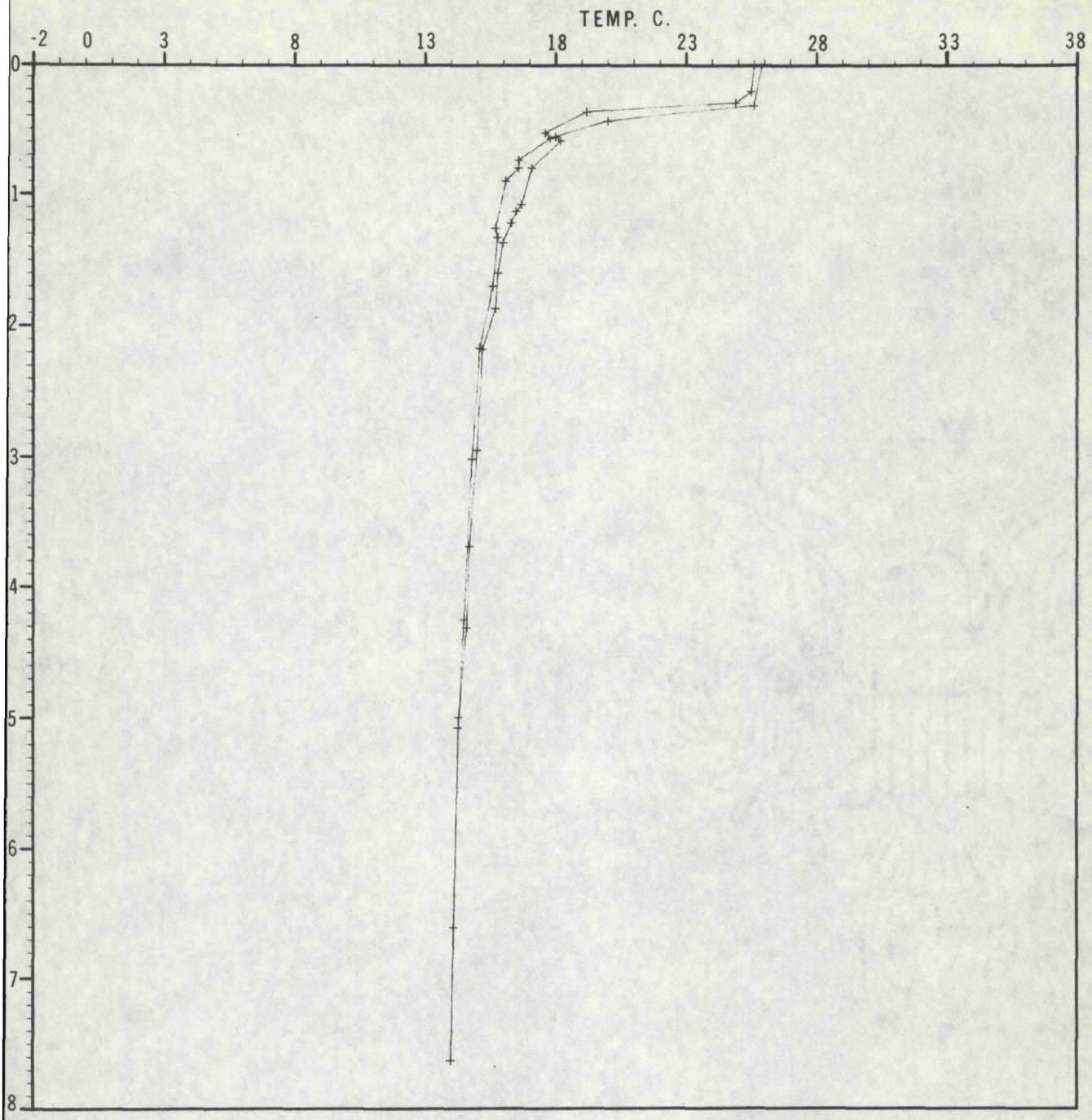
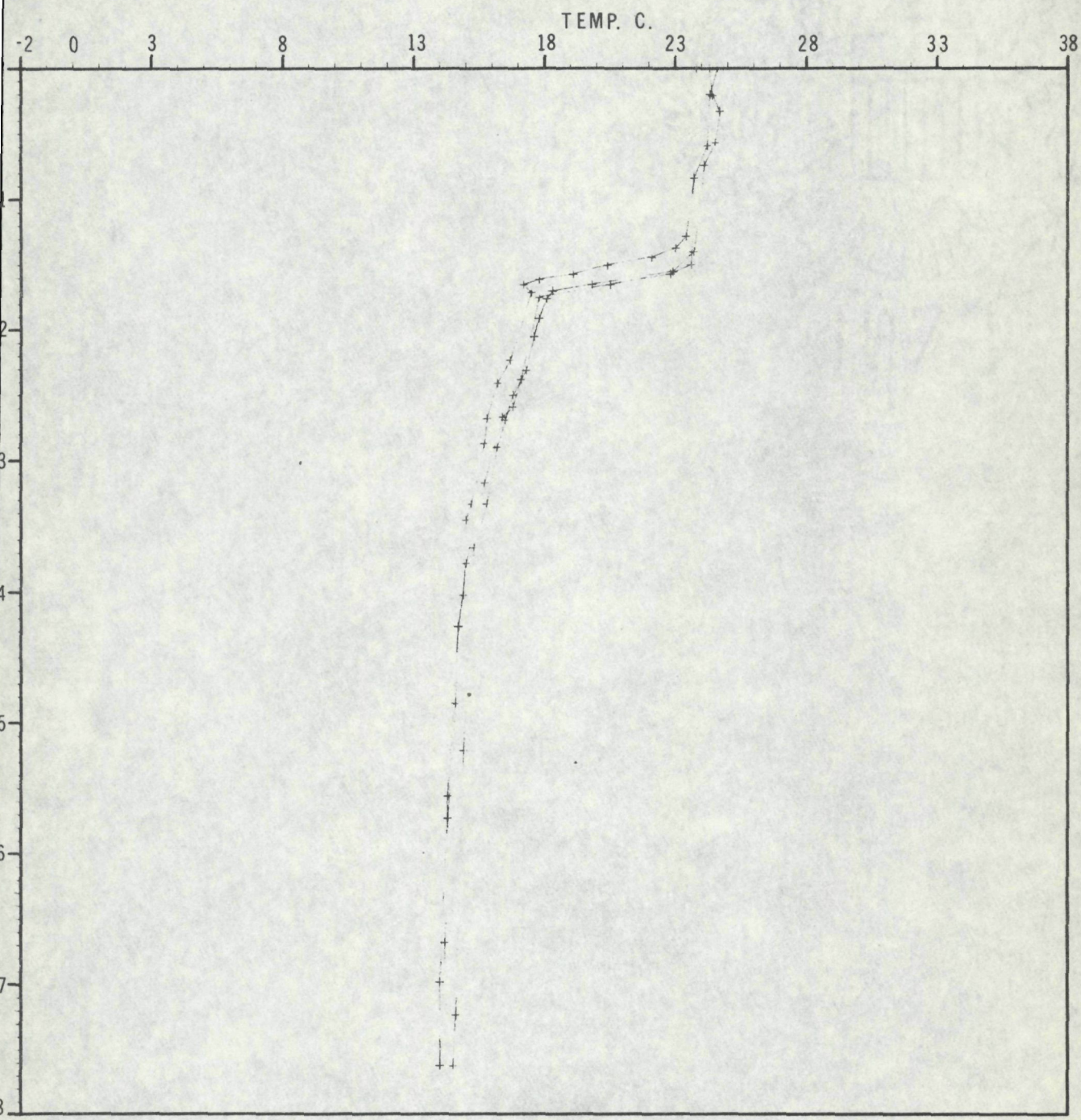

TEMP. C.
-2
0
3
8
13
18
23
28
33
38
0
1
2
3
4
5
6
7
8

Fig. 12 Composite of 3 XBT casts at Station 5b, (CALCOMP Plot).


TEMP. C.
-2
0
3
8
13
18
23
28
33
38
1
2
3
4
5
6
7
8

760 m (14.2°C). Again, there was no clear distinction between surface water and intermediate water.

Salinity -

The surface salinity at station 2 (Fig. 13, Table 4) was 38.08°/oo; salinity decreased rapidly to a minimum of 37.66°/oo at 48 meters. Evaporation presumably caused the high salinity in the surface waters. Below 48 m the profile showed an increase in salinity to a maximum of 38.68°/oo at 485 m in the intermediate water mass. Salinity remained high from 485-786 m, below which it decreased gradually to 38.39°/oo at the deepest reading at 2669 m.

At station 3 (Fig. 13 , Table 4) salinity at the surface (38.05°/oo) was similar to that of station 2 (38.08°/oo). The similarity ceased, however, immediately below the surface. A distinct salinity peak (38.18°/oo) was recorded at 24 m followed by a decrease to 38.07°/oo at 49 m. Below 49 m salinity increased to a maximum of 38.51°/oo at 483 m in the intermediate water mass and then decreased gradually to the deepest reading of 38.42 at 2299 m.

Density -

The surface density (sigma-t) at station 2 (Fig. 14 , Table 4) was 26.49. After a slight decrease in the upper 10 meters, density increased to a maximum of 29.23 at 786 m. Below 786 m a steady decrease occurred to 29.00 at the greatest depth sampled (2669 m). These data indicate an unstable situation

Fig. 13 Salinity at Station 2 and Station 3 from hydro casts

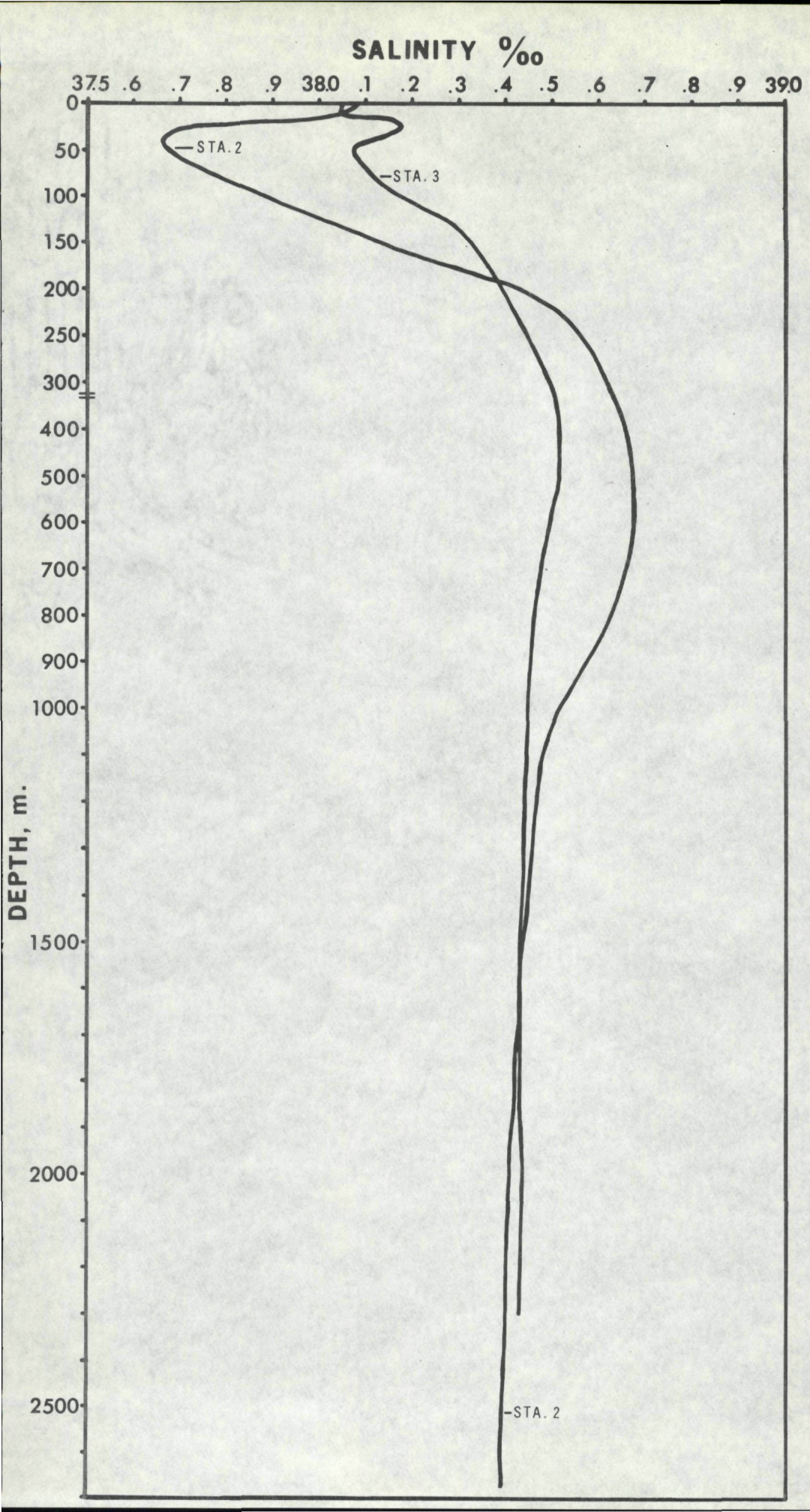
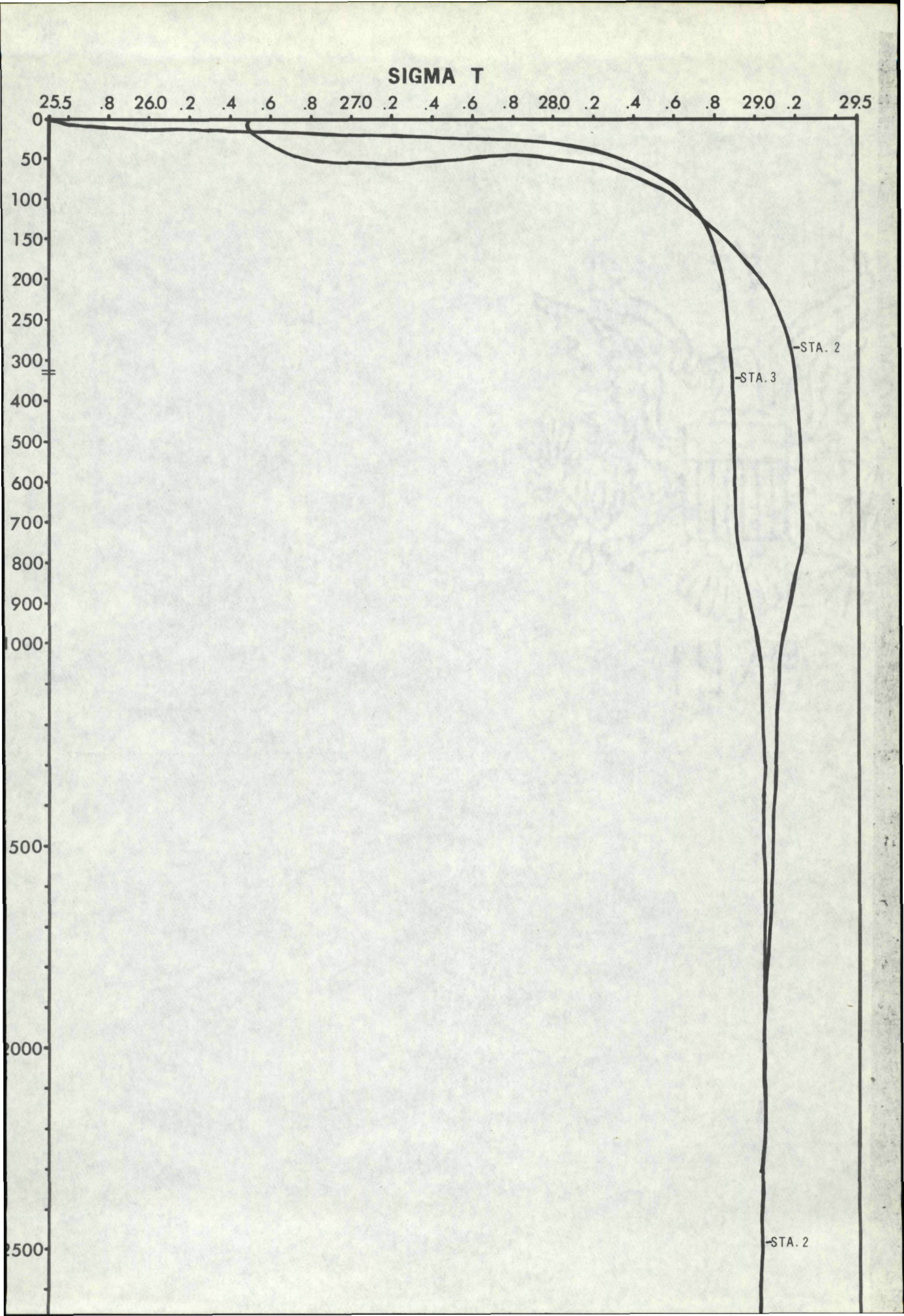

SALINITY ‰
37.5 .6 .7 .8 .9 38.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 39.0
0
50
100
150
200
250
300
400
500
600
700
800
900
1000
1500
2000
2500
DEPTH, m.
STA. 2
STA. 3
STA. 2

Fig. 14 Density at Station 2 and Station 3 from hydro casts


SIGMA T
25.5
.8
26.0
.2
.4
.6
.8
27.0
.2
.4
.6
.8
28.0
.2
.4
.6
.8
29.0
.2
29.5
0
50
100
150
200
250
300
400
500
600
700
800
900
1000
500
2000
2500
STA. 2
STA. 3
STA. 2

and the probability of vertical circulation at that time.

At station 3 density at the surface (Fig. 14) was 25.49 and there was a sharp increase from 10 to 24 m and a somewhat less sharp increase from 24 to 49 m. This reflects the salinity peak at 24 m (Fig. 13). Density then increased gradually throughout the water column to the deepest sample at 2299 m (29.02).

Dissolved Oxygen -

Oxygen concentration at the surface on station 2 was 4.99 ml/l and slightly less at 10 m (Fig. 15 , Table 4). No data were obtained at 24 and 48 m, but probably a rapid increase took place to a maximum at these depths similar to that at station 3 (see below). The maximum recorded oxygen concentration of 5.68 ml/l at 72 m was considerably less than the maximum at station 3, giving further credence to the probability of a maximum at 24-48 m. Below 72 m oxygen concentration decreased to a minimum at 485 m. A slight increase was recorded at 789 m, and this increase continued to 1477 m, at which level oxygen concentration reached a stable level of 4.54-4.59 ml/l that extended to the deepest sample at 2669 m.

Surface oxygen concentration at station 3 (Fig. 16 , Table 4) was 4.77 ml/l. An oxygen maximum of 6.07-6.12 ml/l was recorded at 24-49 m, below which the concentration decreased to a minimum of 4.32 ml/l at 982 m, followed by a slight increase to 4.43-4.44 at 2111-2299 m.

Fig. 15 Dissolved Oxygen at Station 2 from hydro casts

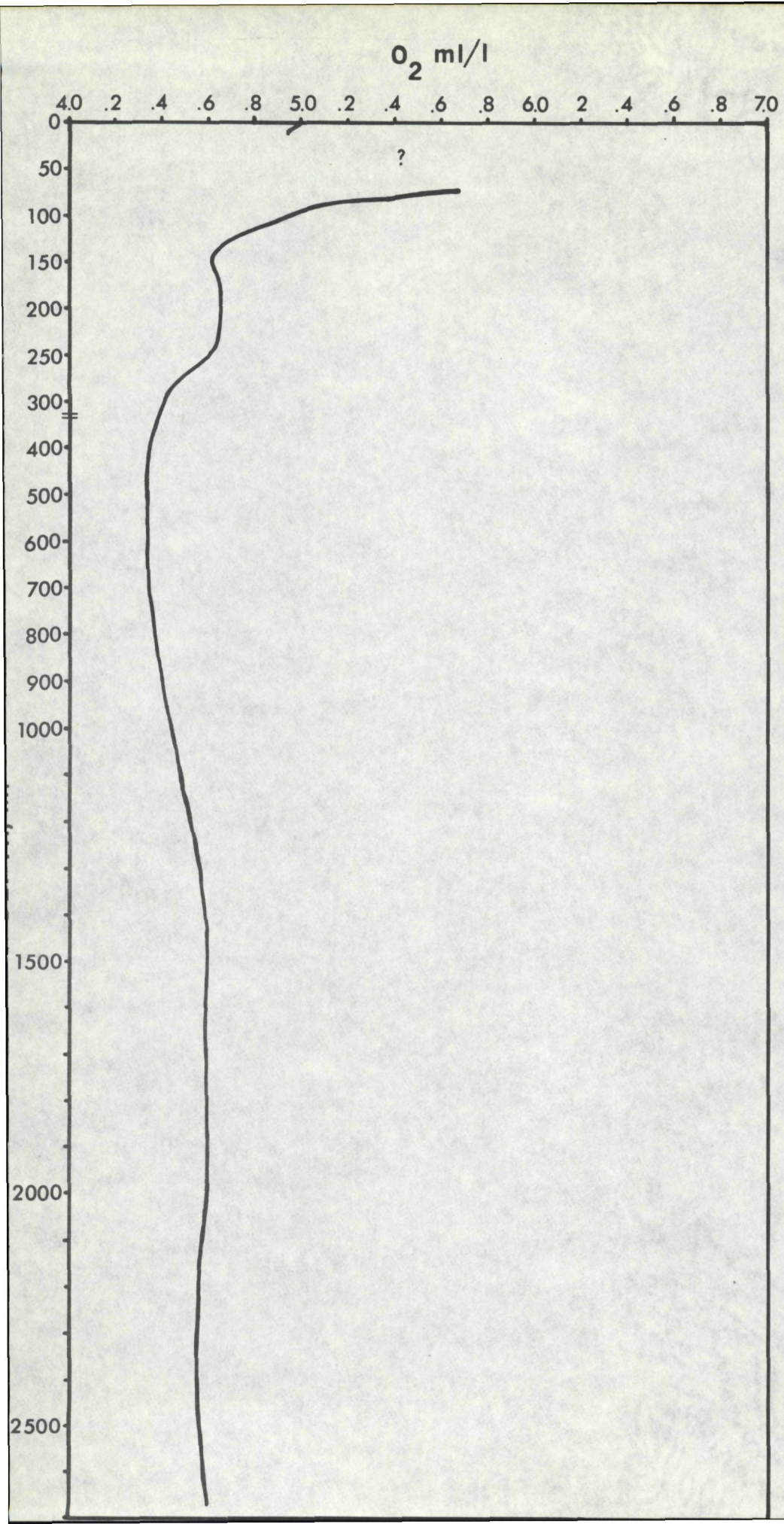
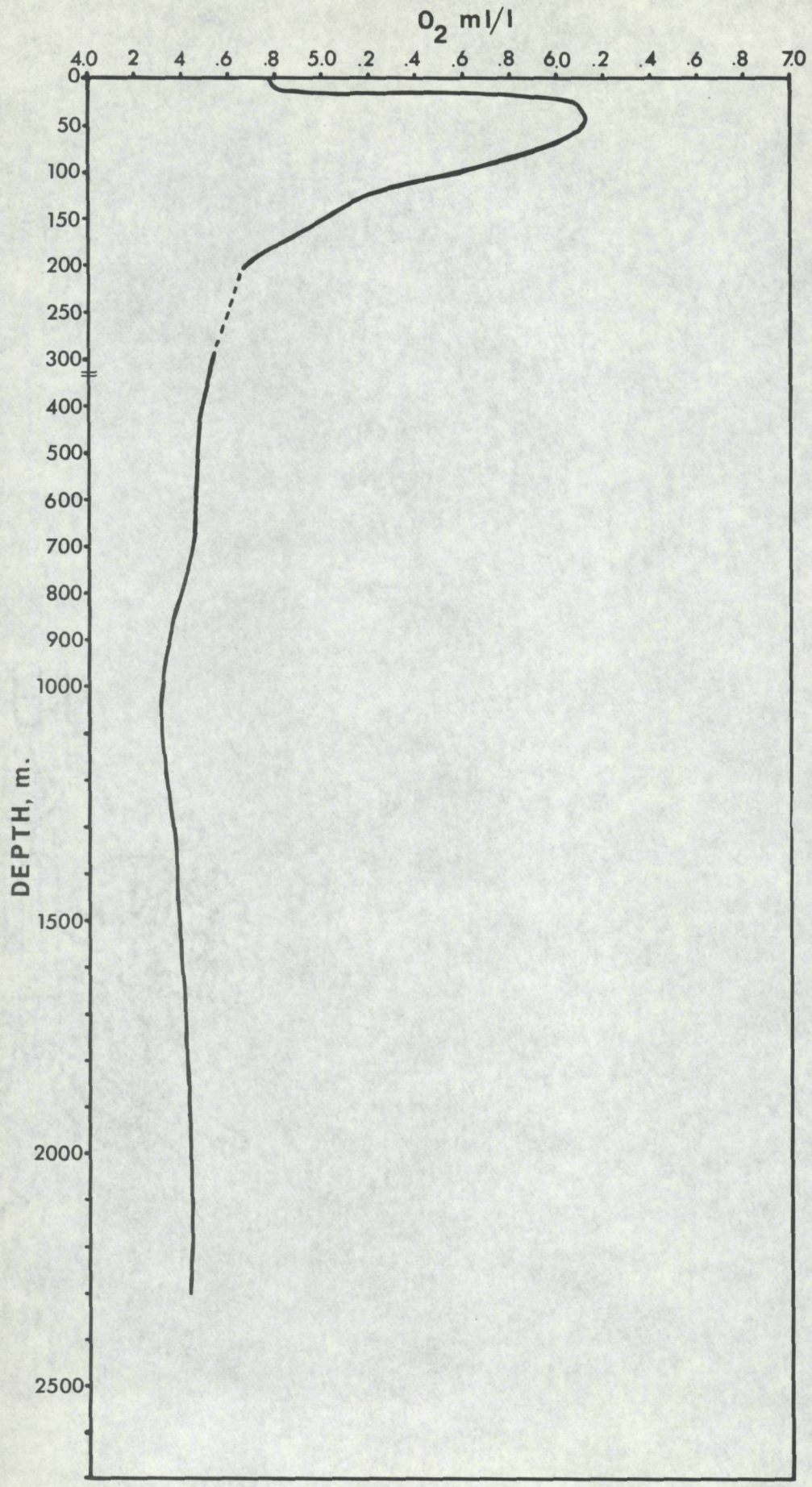

O_2 ml/l
4.0 .2 .4 .6 .8 5.0 .2 .4 .6 .8 6.0 2 .4 .6 .8 7.0
0
50
100
150
200
250
300
400
500
600
700
800
900
1000
1500
2000
2500
?

Fig. 16 Dissolved Oxygen at Station 3 from hydro casts


O_2 ml/l
4.0 2 4 .6 .8 5.0 .2 .4 .6 .8 6.0 .2 .4 .6 .8 7.0
0
50
100
150
200
250
300
400
500
600
700
800
900
1000
1500
2000
2500
DEPTH, m.

Comparison of Stations

This general summary of hydrographic conclusions is slanted toward factors that might explain differences in vertical distribution and diel migratory behavior of the midwater organisms at different stations. Pertinent comparative data are given in Table 3 . These show a number of trends, mainly associated with the Atlantic surface water that moves generally from west to east and the Levantine intermediate water that is formed in the east and moves to the westward. Station 2 has an unstable water structure and is at an extreme in several characteristics.

Oxygen concentration, salinity, and density were measured only at stations 2 and 3, which precludes comparison among stations.

Eastern Stations -- The surface water in the eastern stations (4 and 5) had been modified by the several processes, especially evaporation, that result in the formation of the intermediate water mass. At these eastern stations, the temperature decreased throughout the upper 750 m, whereas at the western stations, the lower boundary of the surface water was marked by a minimum temperature that was followed by an increase to a maximum, always shallower than 750 m, that represented the core of the intermediate water. Thus, the entire upper 750 m at stations 4 and 5 could probably be regarded as intermediate water.

The highly localized character of the influences on intermediate water formation were vividly shown by the differences

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5a	Sta. 5b
Temperature, surface	26.0°C	22.6°C	25.4°C	26.0°C	25.7°C	24.2°C
Upper mixed layer	0-10 m	0-10 m	0-22 m	0-30 m	0-30 m	0-135 m
Thermocline depth	10-40 m	10-70 m	22-50 m	30-60 m	30-55 m	135-175 m
Temperature at thermocline limits	25.7-17.0°C	22.3-14.5°C	24.3-15.9°C	25.8-15.7°C	25.2-17.9°C	23.5-17.8°C
Temperature decline in thermocline	0.29°C/m	0.13°C/m	0.38°C/m	0.33°C/m	0.29°C/m	0.14°C/m
Surface water						
Temp. min.	13.4°C	13.3°C	14.0°C	*15.7°C	*17.9°C	*17.8°C
Lower boundary	185-270 m	110-215 m	100-110 m	*60 m	*55 m	*175 m
Intermediate water						
Temp. max.	13.8-13.9°C	13.5-13.6°C	14.3°C			
Depth	400-760+ m	260-760+ m	230-665 m			
Temperature @ 250 m	13.4°C	13.4°C	14.3°C	14.6°C	15.0°C	16.6°C
" @ 500 m	13.8°C	13.4°C	14.3°C	14.0°C	14.3°C	14.7°C
" @ 750 m	13.8°C	13.6°C	14.1°C	13.8°C	14.0°C	14.2°C
Salinity, surface		38.08°/oo	38.05°/oo			
Surface water,						
Sal. min.		37.66°/oo	38.04°/oo			
Depth		48 m	10 m			
Intermediate water						
Sal. max.		38.67°/oo	38.51°/oo			
Depth		485 m	483 m			
Density, surface		26.49	25.49			
Density max.		29.23				
Density max. depth		786 m	2299 m+			
Oxygen, surface		4.99 ml/l	4.77 ml/l			
Oxygen max. conc.			6.12 ml/l			
Oxygen max. depth			49 m			
Oxygen min. layer		485-786 m	934-1328 m			
Oxygen min. conc.		4.33-4.39 ml/l	4.32-4.37 ml/l			

* At stations 4 and 5, the bottom of the thermocline, not the temperature minimum, was arbitrarily considered the lower boundary of the surface water. The entire zone from below the thermocline to the deepest XBT reading was regarded as intermediate water.

between the two substations of station 5 (Levantine Sea). The bottom of the thermocline had approximately the same temperature at both substations, but was at 55 m at 5a and at 175 m at 5b. Since the two substations had similar temperatures again at 750 m, the rate of decrease in temperature below the thermocline was more gradual at station 5a than at 5b.

Station 5b was extreme in its temperature regime, but stations 4 (Ionian Sea) and 5a were quite similar. Surface temperatures, thermocline depths, and thermocline temperatures were almost the same, except for a more rapid decrease in the thermocline at station 4. Temperatures at comparable depths from the bottom of the thermocline to 750 m were slightly lower at 4 than at 5a, which was to be expected, with intermediate water being influenced more by Atlantic surface water entering from the western basin.

Western Stations -- The temperature regime at station 3 (Tyrrhenian Sea) more closely resembled that at station 4 (Ionian Sea) than it did those at either of the other stations in the western basin. The surface water mass was well marked, in contrast to station 4, but was shallow, extending only to 100-110 m. Surface temperature, thermocline depth, and thermocline temperature were all quite similar to those at station 4. The intermediate water mass here was shallower and its core temperature of 14.3°C higher than at either of the more western stations. Temperatures at comparable depths from the bottom of the thermocline to 750 m

followed the east to west cooling trend that was discernible from stations 5 to 4 to 3.

Station 1, as would be expected, showed the greatest influence of Atlantic surface water, which was deepest at this station, extending to about 270 m. The intermediate water mass was deepest here, and its core temperature of 13.8-13.9°C was lower than at station 3. Temperatures at comparable depths from below the thermocline to 750 m were cooler than at station 3.

Station 2, intermediate in longitude between stations 1 and 3, was intermediate in some of the east-west trends, but was extreme or unique in several respects. It was intermediate in the extent of its surface water, which reached 215 m, and its intermediate water was deeper than at station 3 but shallower than at station 1. It was extreme in its temperature regime, with temperatures at comparable depths consistently lower than at any other station from the surface to 750 m and probably to 2000 m or more. The thermocline was twice as thick with a rate of temperature decline less than half those of any other station (except for 5b). This temperature regime, together with the presence of a density inversion, whereby density decreases from below 786 m to 2669 m, suggest that a downward convection circulation was in progress at station 2.

Summary -- Atlantic surface water, present to 270 m at station 1 became a gradually thinner layer at stations 2 and 3. At stations 4 and 5, where Levantine intermediate water is formed and predominated, no clear boundary between the surface and

intermediate water was distinguished. The intermediate water, shallowest at stations 4 and 5, became gradually deeper at stations 3, 2, and 1. Temperatures within the intermediate water gradually decreased from east to west except at station 2. Station 2 was extreme in having the coldest temperatures throughout the water column, a broad thermocline with a smaller rate of temperature decrease, and a density inversion below 786 m. These factors indicate instability in the water column and are believed to be manifestations of a downward convection circulation.

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TABLE 4 : HYDROGRAPHIC DATA FOR STATIONS 2 & 3

Station 2:

Depth (m)	Temp. °C	Salinity °/oo	Sigma T	Oxygen ml/l
0	22.28	38.078	26.494	4.99
10	22.26	38.051	26.479	4.94
24	21.05	37.719	26.567	--
48	17.03	37.661	27.564	--
72	13.88	37.771	28.372	5.68
96	13.09	37.846	28.595	4.99
121	13.12	37.980	28.693	4.74
146	13.23	38.105	28.767	4.61
170	13.21	38.237	28.874	4.65
194	13.20	38.400	29.002	4.65
242	13.22	38.553	29.117	4.63
290	13.26	38.601	29.146	4.42
485	13.21	38.673	29.211	4.34
781	13.03	38.618	29.207	4.39
*786	13.02	38.643	29.228	4.33
979	13.00	38.511	29.129	4.44
*983	12.98	38.541	29.158	4.42
*1477	12.98	38.440	29.080	4.58
*1979	13.03	38.410	29.045	4.59
*2471	13.10	38.395	29.019	4.54
*2669	13.15	38.392	29.007	4.59

tation 3:

0	25.57	38.049	25.489	4.77
10	24.99	38.046	25.666	4.79
24	18.76	38.176	27.527	6.07
49	15.12	38.074	28.331	6.12
74	14.32	38.107	28.535	5.91
98	13.95	38.167	28.661	5.57
123	13.95	38.264	28.737	5.19
148	13.93	38.323	28.787	5.08
172	13.98	38.354	28.800	4.89
197	14.18	38.362	28.763	4.67
245	14.20	38.398	28.878	--
293	14.18	38.488	28.860	4.54
483	14.10	38.511	28.895	4.46
*738	13.92	38.469	28.902	4.44
776	13.82	38.467	28.922	4.41
*934	13.56	38.417+	28.952	4.34
982	13.38	38.452	29.004	4.32
*1328	13.17	38.433	29.034	4.37
*1724	13.11	38.432	29.045	4.41
*2111	13.11	38.430	29.045	4.44
*2299	13.18	38.424	29.025	4.43

* denotes second cast of station
** denotes third cast of station
\+ possible incorrect reading

TABLE 5 : EXPENDABLE BATHYTHERMOGRAPH DATA - STATION 1

TEMPERATURE						GRADIENT			
DEPTH	MAX	AVG	MIN	NUM	SDEV	MAX	AVG	MIN	DEPTH
0	27.5	26.0	25.4	17	0.5	0.0	0.0	0.0	0
5	27.2	25.9	25.2	17	0.4	0.0	-0.02	-0.08	5
10	27.1	25.7	23.6	17	0.7	0.12	-0.03	-0.32	10
15	27.0	24.6	20.5	17	1.7	0.0	-0.23	-0.72	15
20	26.6	21.8	19.1	17	2.4	0.0	-0.56	-0.96	20
25	25.9	19.8	17.4	17	2.0	-0.02	-0.40	-0.92	25
30	24.5	18.6	16.4	17	1.7	-0.08	-0.25	-0.74	30
35	21.0	17.6	16.2	17	1.2	0.0	-0.20	-0.70	35
40	19.4	17.0	15.7	17	0.9	0.0	-0.12	-0.32	40
45	18.1	16.6	15.6	17	0.7	-0.02	-0.08	-0.26	45
50	17.4	16.2	15.0	17	0.8	-0.02	-0.08	-0.18	50
55	17.1	15.8	14.7	17	0.8	-0.02	-0.07	-0.16	55
60	17.0	15.5	14.4	17	0.8	0.12	-0.06	-0.16	60
65	16.9	15.3	14.1	17	0.9	-0.02	-0.05	-0.08	65
70	16.6	15.1	13.9	17	0.9	0.02	-0.04	-0.06	70
75	16.3	14.9	13.7	17	0.9	0.0	-0.04	-0.20	75
80	16.1	14.8	13.4	17	1.0	0.06	-0.03	-0.08	80
85	15.9	14.7	13.4	17	0.9	0.0	-0.03	-0.06	85
90	15.8	14.6	13.3	17	0.9	0.08	-0.01	-0.04	90
95	15.6	14.5	13.3	17	0.9	0.0	-0.02	-0.10	95
100	15.4	14.4	13.2	17	0.8	0.02	-0.02	-0.10	100
105	15.6	14.4	13.2	17	0.8	0.04	-0.01	-0.06	105
110	15.8	14.4	13.2	17	0.9	0.04	0.00	-0.04	110
115	15.3	14.2	13.2	17	0.8	0.0	-0.03	-0.10	115
120	15.1	14.1	13.2	17	0.7	0.0	-0.02	-0.08	120
125	15.1	14.0	13.1	17	0.7	0.0	-0.02	-0.04	125
130	15.0	13.9	13.1	17	0.7	0.0	-0.02	-0.06	130
135	15.0	13.8	13.0	17	0.7	0.02	-0.02	-0.04	135
140	15.0	13.7	13.0	17	0.7	0.0	-0.02	-0.04	140
145	15.0	13.7	13.0	17	0.6	0.0	-0.01	-0.02	145
150	15.0	13.6	13.0	17	0.6	0.0	-0.01	-0.04	150
155	15.0	13.5	12.9	17	0.6	0.02	-0.01	-0.04	155
160	15.0	13.5	12.9	16	0.6	0.02	-0.00	-0.04	160
165	15.0	13.5	12.9	16	0.5	0.0	-0.01	-0.04	165
170	15.0	13.5	12.9	16	0.5	0.02	-0.01	-0.04	170
175	15.1	13.5	12.9	16	0.5	0.02	-0.00	-0.02	175
180	15.1	13.5	13.0	16	0.5	0.02	0.0	-0.02	180
185	15.1	13.4	13.1	16	0.5	0.02	-0.00	-0.04	185
190	15.2	13.4	13.0	16	0.5	0.02	-0.00	-0.02	190
195	15.2	13.4	12.9	16	0.5	0.0	-0.00	-0.02	195
200	15.2	13.4	12.9	16	0.5	0.02	-0.01	-0.02	200
205	15.3	13.4	13.0	16	0.5	0.02	0.00	-0.02	205
210	15.3	13.4	13.0	16	0.5	0.02	-0.00	-0.04	210
215	15.4	13.4	13.0	16	0.6	0.02	0.00	-0.02	215
220	15.4	13.4	12.9	16	0.6	0.02	0.00	-0.02	220
225	15.4	13.4	12.9	16	0.6	0.02	-0.00	-0.02	225
230	15.4	13.4	12.9	16	0.6	0.02	-0.00	-0.02	230
235	15.4	13.4	12.9	16	0.6	0.02	0.00	0.0	235
240	15.5	13.4	12.9	16	0.6	0.02	0.00	-0.02	240
245	15.5	13.4	12.9	16	0.6	0.02	0.00	-0.02	245
250	15.5	13.4	12.9	16	0.6	0.02	0.00	-0.02	250

XBT DATA - STA. 1, continued:

TEMPERATURE						GRADIENT			
255	15.5	13.4	12.9	16	0.6	0.02	-0.00	-0.02	255
260	15.5	13.4	12.9	16	0.6	0.04	0.00	-0.02	260
265	15.6	13.4	12.9	16	0.6	0.02	0.00	0.0	265
270	15.6	13.4	12.9	16	0.6	0.02	0.00	0.0	270
275	15.6	13.5	13.0	16	0.6	0.02	0.01	0.0	275
280	15.6	13.5	13.0	16	0.6	0.02	0.00	0.0	280
285	15.6	13.5	13.0	16	0.6	0.04	0.00	-0.02	285
290	15.7	13.5	13.1	16	0.6	0.02	0.01	0.0	290
295	15.7	13.6	13.1	16	0.6	0.02	0.00	-0.02	295
300	15.7	13.6	13.1	16	0.6	0.04	0.01	0.0	300
305	15.7	13.6	13.1	16	0.6	0.02	0.00	0.0	305
310	15.7	13.6	13.2	16	0.6	0.02	0.00	0.0	310
315	15.7	13.6	13.3	16	0.6	0.02	0.00	-0.02	315
320	15.7	13.7	13.4	16	0.5	0.04	0.01	0.0	320
325	15.7	13.7	13.4	16	0.6	0.0	-0.00	-0.02	325
330	15.7	13.7	13.4	16	0.5	0.02	0.00	0.0	330
335	15.7	13.7	13.4	16	0.5	0.02	0.00	0.0	335
340	15.7	13.7	13.4	16	0.5	0.02	0.00	0.0	340
345	15.7	13.7	13.4	16	0.5	0.02	0.00	0.0	345
350	15.8	13.7	13.4	16	0.6	0.02	-0.00	-0.02	350
355	15.8	13.7	13.4	16	0.6	0.02	0.00	0.0	355
360	15.8	13.7	13.4	16	0.6	0.02	0.00	0.0	360
365	15.8	13.7	13.4	16	0.6	0.02	0.00	0.0	365
370	15.8	13.7	13.4	16	0.6	0.02	0.00	-0.02	370
375	15.8	13.7	13.4	16	0.6	0.0	-0.00	-0.02	375
380	15.8	13.7	13.4	16	0.6	0.02	0.00	0.0	380
385	15.8	13.7	13.4	16	0.6	0.0	-0.00	-0.02	385
390	15.8	13.7	13.4	16	0.6	0.02	0.00	0.0	390
395	15.8	13.7	13.4	16	0.6	0.0	0.0	0.0	395
400	15.8	13.8	13.5	15	0.6	0.0	-0.00	-0.02	400
405	15.8	13.8	13.5	15	0.6	0.0	0.0	0.0	405
410	15.8	13.8	13.5	15	0.6	0.02	0.00	0.0	410
415	15.8	13.8	13.4	15	0.6	0.0	-0.00	-0.02	415
420	15.8	13.8	13.4	15	0.6	0.04	0.01	0.0	420
425	15.8	13.8	13.4	15	0.6	0.02	0.0	-0.02	425
430	15.8	13.8	13.4	15	0.6	0.02	0.00	0.0	430
435	15.7	13.8	13.4	15	0.6	0.02	0.0	-0.02	435
440	15.7	13.8	13.4	15	0.6	0.04	0.00	-0.02	440
445	15.7	13.8	13.4	15	0.6	0.02	0.00	0.0	445
450	15.7	13.8	13.4	15	0.6	0.02	0.00	0.0	450
455	15.7	13.8	13.4	15	0.6	0.0	-0.00	-0.02	455
460	15.7	13.8	13.4	15	0.6	0.0	-0.00	-0.02	460
465	15.7	13.8	13.4	15	0.6	0.0	0.0	0.0	465
470	15.7	13.8	13.4	15	0.6	0.02	0.00	-0.02	470
475	15.7	13.8	13.4	15	0.6	0.0	0.0	0.0	475
480	15.6	13.8	13.3	15	0.6	0.02	-0.00	-0.02	480
485	15.6	13.8	13.3	15	0.6	0.0	-0.00	-0.02	485
490	15.6	13.8	13.3	15	0.6	0.02	0.00	0.0	490
495	15.6	13.8	13.3	15	0.6	0.02	-0.00	-0.02	495
500	15.6	13.8	13.3	15	0.6	0.02	-0.00	-0.02	500

XBT DATA - STA. 1, continued:

	TEMPERATURE					GRADIENT			
505	15.6	13.8	13.3	15	0.6	0.02	0.0	-0.02	505
510	15.6	13.8	13.3	15	0.6	0.04	0.01	0.0	510
515	15.6	13.8	13.3	15	0.6	0.02	0.00	0.0	515
520	15.6	13.8	13.3	15	0.6	0.02	0.00	0.0	520
525	15.6	13.8	13.3	15	0.7	0.02	0.00	-0.02	525
530	15.6	13.9	13.3	15	0.7	0.02	0.00	0.0	530
535	15.6	13.9	13.3	15	0.7	0.0	0.0	0.0	535
540	15.6	13.9	13.2	15	0.7	0.02	-0.00	-0.02	540
545	15.0	13.7	13.2	14	0.5	0.0	0.0	0.0	545
550	15.0	13.7	13.2	14	0.5	0.02	0.00	0.0	550
555	15.0	13.7	13.2	14	0.5	0.0	0.0	0.0	555
560	15.0	13.8	13.2	14	0.5	0.02	0.00	0.0	560
565	15.0	13.8	13.2	14	0.5	0.02	0.00	0.0	565
570	15.0	13.8	13.2	14	0.6	0.02	0.0	-0.02	570
575	15.0	13.8	13.2	14	0.6	0.02	0.00	-0.02	575
580	15.1	13.8	13.2	14	0.6	0.02	0.00	0.0	580
585	15.2	13.8	13.2	14	0.6	0.02	0.00	-0.02	585
590	15.3	13.8	13.2	14	0.6	0.02	0.0	-0.02	590
595	15.4	13.8	13.2	14	0.7	0.02	0.00	0.0	595
600	15.6	13.8	13.2	14	0.7	0.04	0.00	0.0	600
605	15.7	13.8	13.2	14	0.7	0.02	0.00	0.0	605
610	15.8	13.8	13.2	14	0.7	0.02	0.00	0.0	610
615	15.8	13.8	13.2	14	0.7	0.02	0.00	0.0	615
620	15.9	13.8	13.2	14	0.8	0.02	0.00	0.0	620
625	15.9	13.8	13.2	14	0.8	0.0	0.0	0.0	625
630	15.9	13.8	13.2	14	0.8	0.0	0.0	0.0	630
635	15.9	13.8	13.2	14	0.8	0.02	0.00	0.0	635
640	15.9	13.8	13.2	14	0.8	0.0	0.0	0.0	640
645	15.9	13.8	13.2	14	0.8	0.0	0.0	0.0	645
650	15.9	13.8	13.2	14	0.8	0.0	0.0	0.0	650
655	15.9	13.8	13.2	14	0.7	0.02	0.00	-0.02	655
660	15.8	13.8	13.2	14	0.7	0.0	-0.00	-0.02	660
665	15.7	13.8	13.1	14	0.7	0.0	-0.00	-0.02	665
670	15.6	13.8	13.1	14	0.7	0.02	0.0	-0.02	670
675	15.5	13.8	13.1	14	0.7	0.02	0.00	-0.02	675
680	15.4	13.8	13.1	14	0.7	0.0	-0.00	-0.02	680
685	15.3	13.8	13.1	14	0.6	0.02	-0.00	-0.02	685
690	15.3	13.8	13.1	14	0.6	0.0	0.0	0.0	690
695	15.2	13.8	13.1	14	0.6	0.04	0.00	-0.02	695
700	15.2	13.9	13.1	14	0.6	0.02	0.01	0.0	700
705	15.1	13.9	13.1	14	0.6	0.04	-0.00	-0.02	705
710	15.1	13.9	13.1	14	0.7	0.02	0.00	0.0	710
715	15.0	13.9	13.1	14	0.7	0.04	0.00	-0.02	715
720	15.1	13.9	13.1	13	0.7	0.04	0.00	0.0	720
725	15.2	13.9	13.1	13	0.7	0.02	0.0	-0.02	725
730	15.3	13.9	13.1	13	0.7	0.02	0.00	0.0	730
735	15.4	13.9	13.1	13	0.7	0.02	-0.00	-0.02	735
740	15.4	13.9	13.1	13	0.7	0.02	0.00	-0.02	740
745	14.9	13.8	13.1	12	0.6	0.0	-0.00	-0.02	745
750	14.9	13.8	13.1	12	0.6	0.0	0.0	0.0	750
755	14.9	13.8	13.1	12	0.6	0.0	0.0	0.0	755
760	14.9	13.8	13.1	10	0.6	0.0	-0.00	-0.02	760

TABLE 6 : EXPENDABLE BATHYTHERMOGRAPH DATA - STATION 2

TEMPERATURE						GRADIENT			
DEPTH	MAX	AVG	MIN	NUM	SDEV	MAX	AVG	MIN	DEPTH
0	23.8	22.6	21.8	24	0.6	0.0	0.0	0.0	0
5	23.4	22.5	21.6	24	0.5	0.0	-0.02	-0.08	5
10	23.1	22.3	21.2	24	0.6	0.02	-0.03	-0.14	10
15	22.9	22.0	20.6	24	0.7	0.02	-0.06	-0.46	15
20	22.8	21.6	20.6	24	0.6	0.06	-0.09	-0.44	20
25	22.3	21.1	19.9	24	0.5	0.02	-0.09	-0.26	25
30	21.5	20.7	19.7	24	0.5	-0.02	-0.08	-0.28	30
35	21.1	20.2	18.9	24	0.5	0.04	-0.09	-0.30	35
40	20.9	19.6	17.8	24	0.8	-0.02	-0.12	-0.36	40
45	20.4	19.0	17.0	24	0.8	0.04	-0.12	-0.40	45
50	19.7	18.0	16.3	24	1.0	-0.06	-0.20	-0.40	50
55	19.6	16.8	14.9	24	1.3	-0.02	-0.24	-0.44	55
60	19.2	15.8	14.0	24	1.1	-0.06	-0.19	-0.36	60
65	18.5	15.1	13.7	24	1.1	-0.04	-0.15	-0.28	65
70	17.5	14.5	13.4	24	0.9	-0.02	-0.11	-0.28	70
75	15.9	14.2	13.3	24	0.6	0.06	-0.07	-0.32	75
80	15.1	13.9	13.2	24	0.4	0.02	-0.05	-0.16	80
85	14.8	13.8	13.2	24	0.4	0.0	-0.04	-0.08	85
90	14.4	13.6	13.1	24	0.3	0.0	-0.04	-0.10	90
95	14.0	13.5	13.1	24	0.2	0.0	-0.02	-0.08	95
100	13.9	13.4	13.1	24	0.2	0.0	-0.01	-0.06	100
105	13.9	13.4	13.2	24	0.2	0.02	-0.01	-0.02	105
110	13.9	13.3	13.2	24	0.2	0.02	-0.01	-0.04	110
115	13.9	13.3	13.1	23	0.2	0.02	-0.00	-0.02	115
120	13.9	13.3	13.1	23	0.2	0.0	-0.00	-0.02	120
125	13.9	13.3	13.0	23	0.2	0.0	-0.00	-0.02	125
130	13.9	13.3	12.9	23	0.2	0.02	0.00	-0.02	130
135	13.9	13.3	12.9	23	0.2	0.02	-0.00	-0.02	135
140	13.9	13.3	12.8	23	0.2	0.02	-0.00	-0.02	140
145	13.9	13.3	12.7	23	0.2	0.02	-0.00	-0.02	145
150	13.8	13.3	12.7	23	0.2	0.02	0.0	-0.02	150
155	13.8	13.3	12.7	23	0.2	0.02	0.00	0.0	155
160	13.8	13.3	12.7	23	0.3	0.02	0.00	-0.02	160
165	13.8	13.3	12.6	22	0.3	0.02	-0.00	-0.02	165
170	13.8	13.3	12.6	22	0.3	0.02	-0.00	-0.02	170
175	13.8	13.3	12.6	22	0.3	0.0	0.0	0.0	175
180	13.8	13.3	12.6	22	0.3	0.02	0.00	0.0	180
185	13.8	13.3	12.6	22	0.3	0.02	0.0	-0.02	185
190	13.8	13.3	12.6	22	0.3	0.02	0.0	-0.02	190
195	13.8	13.3	12.6	22	0.3	0.02	0.00	0.0	195
200	13.8	13.3	12.6	22	0.3	0.02	0.00	0.0	200
205	13.8	13.3	12.5	22	0.3	0.02	0.00	-0.02	205
210	13.8	13.3	12.5	22	0.3	0.02	0.00	0.0	210
215	13.9	13.3	12.5	22	0.3	0.02	0.00	0.0	215
220	14.0	13.4	12.5	22	0.3	0.02	0.01	0.0	220
225	14.1	13.4	12.5	22	0.3	0.02	0.00	0.0	225
230	14.2	13.4	12.5	22	0.3	0.02	0.00	0.0	230
235	14.3	13.4	12.5	22	0.3	0.02	0.00	-0.02	235
240	14.2	13.4	12.6	22	0.3	0.02	0.0	-0.02	240
245	14.1	13.4	12.6	22	0.3	0.02	0.00	-0.02	245
250	14.1	13.4	12.6	22	0.3	0.02	0.00	0.0	250

XBT DATA - STA. 2, continued:

TEMPERATURE						GRADIENT			
255	14.1	13.4	12.6	22	0.3	0.02	0.00	0.0	255
260	14.1	13.5	12.7	22	0.3	0.02	0.00	-0.02	260
265	14.1	13.5	12.7	22	0.3	0.02	0.00	0.0	265
270	14.1	13.5	12.7	22	0.3	0.02	0.00	-0.02	270
275	14.1	13.5	12.7	22	0.3	0.02	0.00	0.0	275
280	14.2	13.5	12.7	22	0.3	0.02	0.00	0.0	280
285	14.3	13.5	12.7	22	0.3	0.02	0.00	0.0	285
290	14.3	13.5	12.7	22	0.3	0.02	0.00	0.0	290
295	14.3	13.5	12.7	21	0.3	0.02	0.00	0.0	295
300	14.3	13.5	12.8	21	0.3	0.02	0.0	-0.02	300
305	14.3	13.5	12.8	21	0.3	0.0	-0.00	-0.02	305
310	14.3	13.5	12.9	21	0.3	0.02	0.00	-0.02	310
315	14.3	13.5	12.9	21	0.3	0.0	0.0	0.0	315
320	14.3	13.5	13.0	21	0.3	0.02	0.00	0.0	320
325	14.3	13.5	13.0	20	0.3	0.02	-0.00	-0.02	325
330	14.3	13.5	13.0	20	0.3	0.0	-0.00	-0.02	330
335	14.3	13.5	13.0	20	0.3	0.0	0.0	0.0	335
340	14.3	13.5	13.0	20	0.3	0.0	-0.00	-0.02	340
345	14.3	13.5	13.0	19	0.3	0.02	-0.00	-0.02	345
350	14.3	13.5	13.0	19	0.3	0.02	0.00	0.0	350
355	14.3	13.5	13.0	19	0.3	0.0	0.0	0.0	355
360	14.3	13.5	13.0	19	0.3	0.0	-0.00	-0.02	360
365	14.3	13.5	13.0	19	0.3	0.0	0.0	0.0	365
370	14.3	13.5	13.0	18	0.3	0.02	-0.00	-0.02	370
375	14.3	13.5	13.0	18	0.3	0.0	0.0	0.0	375
380	14.3	13.5	13.0	18	0.3	0.02	-0.00	-0.02	380
385	14.3	13.5	13.0	18	0.3	0.0	0.0	0.0	385
390	14.3	13.5	13.0	18	0.3	0.0	0.0	0.0	390
395	14.3	13.5	13.0	18	0.3	0.0	-0.00	-0.02	395
400	14.3	13.5	13.0	18	0.3	0.0	-0.00	-0.02	400
405	14.3	13.5	13.0	18	0.3	0.0	0.0	0.0	405
410	14.3	13.5	13.0	18	0.3	0.0	-0.00	-0.02	410
415	14.3	13.5	13.0	18	0.3	0.0	-0.00	-0.02	415
420	14.3	13.5	13.0	18	0.3	0.0	0.0	0.0	420
425	14.3	13.5	13.0	17	0.3	0.0	0.0	0.0	425
430	14.3	13.5	13.0	17	0.3	0.0	-0.00	-0.02	430
435	14.3	13.5	13.1	17	0.3	0.02	-0.00	-0.02	435
440	14.3	13.5	13.1	17	0.3	0.0	-0.00	-0.02	440
445	14.3	13.5	13.1	17	0.3	0.0	0.0	0.0	445
450	14.3	13.5	13.1	17	0.3	0.0	0.0	0.0	450
455	14.3	13.5	13.1	17	0.3	0.0	-0.00	-0.02	455
460	14.3	13.5	13.1	17	0.3	0.0	0.0	0.0	460
465	14.3	13.5	13.1	17	0.3	0.0	-0.00	-0.02	465
470	14.3	13.5	13.1	17	0.3	0.0	-0.00	-0.02	470
475	14.4	13.4	13.1	17	0.3	0.02	-0.00	-0.02	475
480	14.4	13.4	13.1	17	0.3	0.0	0.0	0.0	480
485	14.4	13.4	13.1	17	0.3	0.02	-0.00	-0.02	485
490	14.4	13.4	13.1	17	0.3	0.0	-0.00	-0.02	490
495	14.4	13.4	13.1	17	0.3	0.0	-0.00	-0.02	495
500	14.4	13.4	13.1	17	0.3	0.02	0.00	0.0	500

XBT DATA - STA. 2, continued

	TEMPERATURE					GRADIENT			
505	14.5	13.4	13.1	17	0.3	0.02	0.00	-0.02	505
510	14.5	13.4	13.1	17	0.3	0.0	-0.00	-0.02	510
515	14.5	13.4	13.1	17	0.3	0.0	0.0	0.0	515
520	14.5	13.4	13.1	17	0.3	0.02	-0.00	-0.02	520
525	14.5	13.4	13.1	17	0.3	0.02	0.00	0.0	525
530	14.5	13.4	13.1	17	0.3	0.0	0.0	0.0	530
535	14.5	13.4	13.1	17	0.3	0.0	0.0	0.0	535
540	14.5	13.4	13.1	16	0.3	0.02	0.0	-0.02	540
545	14.5	13.5	13.2	13	0.4	0.02	0.0	-0.02	545
550	14.5	13.5	13.2	13	0.4	0.0	-0.00	-0.02	550
555	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	555
560	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	560
565	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	565
570	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	570
575	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	575
580	14.5	13.5	13.2	13	0.4	0.0	-0.00	-0.02	580
585	14.5	13.5	13.2	13	0.4	0.0	-0.00	-0.02	585
590	14.5	13.5	13.2	13	0.4	0.02	0.00	0.0	590
595	14.5	13.5	13.2	13	0.4	0.0	-0.00	-0.02	595
600	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	600
605	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	605
610	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	610
615	14.5	13.5	13.2	13	0.4	0.0	-0.00	-0.02	615
620	14.5	13.5	13.2	13	0.4	0.02	0.00	0.0	620
625	14.5	13.5	13.2	13	0.4	0.02	0.00	0.0	625
630	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	630
635	14.5	13.5	13.2	13	0.4	0.0	0.0	0.0	635
640	14.5	13.5	13.1	13	0.4	0.02	0.00	-0.02	640
645	14.5	13.5	13.1	13	0.4	0.0	-0.00	-0.02	645
650	14.5	13.5	13.1	13	0.4	0.0	0.0	0.0	650
655	14.6	13.5	13.1	13	0.4	0.02	0.00	0.0	655
660	14.6	13.5	13.1	13	0.4	0.02	0.00	0.0	660
665	14.6	13.5	13.1	13	0.4	0.0	-0.00	-0.02	665
670	14.6	13.5	13.0	13	0.4	0.0	-0.00	-0.02	670
675	14.6	13.5	13.0	13	0.4	0.02	0.00	0.0	675
680	14.6	13.5	13.0	13	0.4	0.0	0.0	0.0	680
685	14.6	13.5	13.0	13	0.5	0.02	0.00	0.0	685
690	14.6	13.5	13.0	13	0.5	0.0	-0.00	-0.02	690
695	14.7	13.5	13.0	13	0.5	0.02	0.00	0.0	695
700	14.7	13.5	13.0	13	0.5	0.02	0.00	0.0	700
705	14.7	13.5	13.0	13	0.5	0.0	0.0	0.0	705
710	14.7	13.5	13.0	13	0.5	0.02	0.00	0.0	710
715	14.7	13.5	13.0	13	0.5	0.02	0.00	0.0	715
720	14.7	13.5	13.0	13	0.5	0.02	0.00	0.0	720
725	14.7	13.5	13.1	13	0.5	0.02	0.00	0.0	725
730	14.7	13.5	13.1	13	0.5	0.0	0.0	0.0	730
735	14.7	13.6	13.1	13	0.5	0.02	0.00	0.0	735
740	14.6	13.6	13.1	13	0.5	0.02	0.0	-0.02	740
745	14.6	13.6	13.1	13	0.5	0.0	0.0	0.0	745
750	14.6	13.6	13.1	13	0.5	0.0	0.0	0.0	750
755	14.6	13.6	13.1	13	0.5	0.0	0.0	0.0	755
760	14.6	13.5	13.1	10	0.5	0.0	0.0	0.0	760

TABLE 7 : EXPENDABLE BATHYTHERMOGRAPH DATA - STATION 3

TEMPERATURE						GRADIENT			
DEPTH	MAX	AVG	MIN	NUM	SDEV	MAX	AVG	MIN	DEPTH
0	26.1	25.4	24.5	28	0.4	0.0	0.0	0.0	0
5	25.8	25.2	24.4	28	0.4	0.0	-0.05	-0.12	5
10	25.6	25.0	24.2	28	0.4	0.0	-0.04	-0.08	10
15	25.5	24.8	24.0	28	0.5	0.0	-0.04	-0.16	15
20	25.5	24.7	23.6	28	0.6	0.0	-0.03	-0.08	20
25	25.2	23.3	18.1	28	1.8	0.0	-0.26	-1.34	25
30	24.4	20.8	17.3	28	1.9	-0.04	-0.51	-0.98	30
35	23.2	18.9	16.6	28	1.7	-0.06	-0.37	-0.78	35
40	20.2	17.4	16.0	28	0.9	-0.12	-0.30	-0.78	40
45	18.4	16.5	15.6	28	0.6	-0.06	-0.18	-0.52	45
50	17.2	15.9	15.3	28	0.5	-0.04	-0.12	-0.24	50
55	16.7	15.4	15.0	28	0.4	-0.04	-0.10	-0.16	55
60	16.2	15.0	14.5	28	0.4	-0.04	-0.07	-0.12	60
65	15.6	14.7	14.2	28	0.4	-0.02	-0.06	-0.12	65
70	15.2	14.5	14.1	28	0.3	0.0	-0.04	-0.08	70
75	15.1	14.4	14.0	28	0.3	0.0	-0.03	-0.08	75
80	15.0	14.3	13.9	28	0.3	0.0	-0.02	-0.06	80
85	14.9	14.2	13.9	28	0.2	0.0	-0.02	-0.04	85
90	14.8	14.1	13.8	28	0.2	0.0	-0.01	-0.04	90
95	14.8	14.1	13.8	28	0.2	0.0	-0.01	-0.02	95
100	14.8	14.0	13.8	28	0.2	0.0	-0.01	-0.02	100
105	14.8	14.0	13.8	28	0.2	0.02	-0.00	-0.02	105
110	14.8	14.0	13.8	28	0.2	0.02	0.00	-0.02	110
115	14.8	14.1	13.7	28	0.2	0.02	0.00	-0.02	115
120	14.8	14.1	13.7	28	0.2	0.02	0.00	-0.02	120
125	14.8	14.1	13.7	28	0.2	0.02	0.00	0.0	125
130	14.8	14.1	13.6	28	0.3	0.02	0.00	-0.02	130
135	14.8	14.1	13.6	28	0.3	0.02	0.01	-0.02	135
140	14.8	14.1	13.6	28	0.3	0.04	0.00	-0.02	140
145	14.9	14.2	13.6	28	0.3	0.02	0.00	-0.02	145
150	14.9	14.2	13.6	28	0.3	0.02	0.00	0.0	150
155	14.9	14.2	13.5	28	0.3	0.02	0.00	-0.02	155
160	14.9	14.2	13.5	28	0.3	0.02	-0.00	-0.02	160
165	14.9	14.2	13.5	28	0.3	0.02	0.00	0.0	165
170	14.9	14.2	13.5	28	0.3	0.02	0.00	0.0	170
175	15.0	14.2	13.5	28	0.3	0.02	0.00	-0.02	175
180	15.1	14.2	13.5	27	0.3	0.02	0.00	0.0	180
185	15.1	14.2	13.5	27	0.3	0.02	-0.00	-0.04	185
190	15.2	14.2	13.5	26	0.3	0.02	0.00	-0.02	190
195	15.2	14.2	13.5	25	0.3	0.02	0.00	0.0	195
200	15.2	14.2	13.5	25	0.3	0.0	0.0	0.0	200
205	15.3	14.2	13.5	24	0.3	0.02	0.00	-0.02	205
210	15.3	14.2	13.5	24	0.3	0.02	0.00	0.0	210
215	15.3	14.2	13.5	24	0.3	0.0	0.0	0.0	215
220	15.4	14.2	13.5	24	0.3	0.02	0.00	0.0	220
225	15.4	14.2	13.5	24	0.3	0.02	0.00	-0.02	225
230	15.4	14.3	13.5	24	0.3	0.02	0.00	0.0	230
235	15.5	14.3	13.5	24	0.3	0.02	0.00	-0.02	235
240	15.5	14.3	13.5	24	0.3	0.02	0.00	0.0	240
245	15.5	14.3	13.5	24	0.3	0.02	0.00	0.0	245
250	15.6	14.3	13.6	24	0.3	0.02	0.00	0.0	250

XBT DATA - STA. 3, continued

TEMPERATURE						GRADIENT			
255	15.6	14.3	13.6	24	0.3	0.02	0.00	0.0	255
260	15.7	14.3	13.6	24	0.4	0.02	0.00	-0.02	260
265	15.7	14.3	13.6	24	0.4	0.0	0.0	0.0	265
270	15.7	14.3	13.7	24	0.4	0.02	0.00	-0.02	270
275	15.7	14.3	13.7	24	0.4	0.02	0.00	-0.02	275
280	15.7	14.3	13.7	24	0.4	0.0	-0.00	-0.02	280
285	15.7	14.3	13.7	24	0.4	0.02	0.00	-0.02	285
290	15.7	14.3	13.8	24	0.4	0.02	0.00	0.0	290
295	15.7	14.3	13.8	24	0.4	0.02	0.00	-0.02	295
300	15.7	14.3	13.8	24	0.4	0.02	0.00	0.0	300
305	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	305
310	15.7	14.3	13.9	23	0.4	0.02	0.00	0.0	310
315	15.7	14.3	13.9	23	0.4	0.02	0.00	0.0	315
320	15.7	14.3	13.9	23	0.4	0.02	0.00	0.0	320
325	15.7	14.3	13.9	23	0.4	0.0	-0.00	-0.02	325
330	15.7	14.3	13.9	23	0.4	0.0	0.0	0.0	330
335	15.7	14.3	13.9	23	0.4	0.02	0.00	-0.02	335
340	15.7	14.3	13.9	23	0.4	0.0	-0.00	-0.02	340
345	15.7	14.3	13.9	23	0.4	0.02	0.0	-0.02	345
350	15.7	14.3	13.9	23	0.4	0.0	0.0	0.0	350
355	15.7	14.3	13.9	23	0.4	0.0	0.0	0.0	355
360	15.7	14.3	13.9	23	0.3	0.02	0.00	0.0	360
365	15.7	14.3	13.9	23	0.3	0.0	0.0	0.0	365
370	15.7	14.3	13.9	23	0.4	0.02	-0.00	-0.02	370
375	15.7	14.3	13.9	23	0.4	0.02	0.0	-0.02	375
380	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	380
385	15.7	14.3	13.8	23	0.4	0.02	-0.00	-0.02	385
390	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	390
395	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	395
400	15.7	14.3	13.8	23	0.4	0.0	0.0	0.0	400
405	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	405
410	15.7	14.3	13.8	23	0.4	0.02	0.00	0.0	410
415	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	415
420	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	420
425	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	425
430	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	430
435	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	435
440	15.7	14.3	13.8	23	0.4	0.02	0.00	0.0	440
445	15.7	14.3	13.8	23	0.4	0.02	0.0	-0.02	445
450	15.7	14.3	13.8	23	0.4	0.0	-0.00	-0.02	450
455	15.7	14.3	13.8	23	0.4	0.0	0.0	0.0	455
460	15.6	14.3	13.7	23	0.4	0.02	-0.00	-0.02	460
465	15.6	14.3	13.7	23	0.4	0.0	0.0	0.0	465
470	15.6	14.3	13.7	23	0.4	0.0	0.0	0.0	470
475	15.6	14.3	13.7	23	0.4	0.02	0.00	0.0	475
480	15.6	14.3	13.7	23	0.4	0.02	0.00	0.0	480
485	15.5	14.3	13.7	22	0.4	0.02	0.0	-0.02	485
490	15.5	14.3	13.7	22	0.4	0.04	0.00	0.0	490
495	15.5	14.3	13.7	22	0.4	0.02	0.0	-0.02	495
500	15.5	14.3	13.7	22	0.4	0.02	0.00	0.0	500

XBT DATA - STA. 3, continued

	TEMPERATURE					GRADIENT			
505	15.5	14.3	13.7	22	0.4	0.0	-0.00	-0.02	505
510	15.5	14.3	13.7	22	0.4	0.02	0.00	0.0	510
515	15.4	14.3	13.7	22	0.4	0.02	-0.00	-0.02	515
520	15.4	14.3	13.7	22	0.4	0.0	-0.00	-0.02	520
525	15.4	14.3	13.7	22	0.4	0.02	0.00	0.0	525
530	15.4	14.3	13.7	22	0.4	0.0	0.0	0.0	530
535	15.4	14.3	13.7	22	0.4	0.0	-0.00	-0.02	535
540	15.4	14.3	13.7	22	0.4	0.02	0.00	-0.02	540
545	15.4	14.3	13.7	22	0.4	0.0	0.0	0.0	545
550	15.4	14.3	13.7	22	0.4	0.0	0.0	0.0	550
555	15.4	14.3	13.7	22	0.4	0.02	0.00	0.0	555
560	15.4	14.3	13.7	22	0.4	0.0	-0.00	-0.02	560
565	15.4	14.3	13.7	22	0.4	0.02	-0.00	-0.02	565
570	15.4	14.3	13.7	22	0.4	0.0	0.0	0.0	570
575	15.4	14.3	13.7	22	0.4	0.0	0.0	0.0	575
580	15.4	14.3	13.7	22	0.4	0.0	-0.00	-0.02	580
585	15.4	14.3	13.7	22	0.4	0.0	0.0	0.0	585
590	15.4	14.3	13.7	22	0.4	0.02	0.00	0.0	590
595	15.4	14.3	13.7	22	0.4	0.0	0.0	0.0	595
600	15.4	14.3	13.7	22	0.4	0.0	-0.00	-0.02	600
605	15.4	14.3	13.7	22	0.4	0.02	-0.00	-0.02	605
610	15.4	14.3	13.7	22	0.5	0.02	0.0	-0.02	610
615	15.4	14.3	13.7	22	0.5	0.0	-0.00	-0.02	615
620	15.4	14.3	13.7	22	0.5	0.0	0.0	0.0	620
625	15.4	14.3	13.7	22	0.5	0.02	-0.00	-0.02	625
630	15.4	14.3	13.7	22	0.5	0.02	-0.00	-0.02	630
635	15.4	14.3	13.7	22	0.5	0.02	0.00	0.0	635
640	15.4	14.3	13.7	22	0.5	0.02	-0.00	-0.02	640
645	15.4	14.2	13.7	22	0.5	0.0	-0.00	-0.02	645
650	15.4	14.3	13.7	21	0.5	0.02	-0.00	-0.02	650
655	15.4	14.3	13.7	21	0.5	0.02	-0.00	-0.02	655
660	15.5	14.3	13.7	21	0.5	0.02	0.00	0.0	660
665	15.5	14.3	13.7	21	0.5	0.0	-0.00	-0.02	665
670	15.5	14.2	13.7	21	0.5	0.0	-0.00	-0.02	670
675	15.6	14.2	13.7	21	0.5	0.02	-0.00	-0.02	675
680	15.6	14.2	13.6	21	0.5	0.0	-0.00	-0.02	680
685	15.6	14.2	13.6	21	0.5	0.0	-0.00	-0.02	685
690	15.6	14.2	13.6	21	0.5	0.0	-0.00	-0.02	690
695	15.6	14.2	13.6	21	0.5	0.0	-0.00	-0.02	695
700	15.6	14.2	13.6	21	0.5	0.0	-0.00	-0.02	700
705	15.6	14.2	13.6	21	0.5	0.0	-0.00	-0.02	705
710	15.6	14.2	13.6	20	0.6	0.0	0.0	0.0	710
715	15.5	14.2	13.6	20	0.6	0.02	-0.00	-0.02	715
720	15.5	14.2	13.6	20	0.6	0.02	0.00	0.0	720
725	15.5	14.2	13.6	20	0.6	0.02	0.00	-0.02	725
730	15.5	14.2	13.6	20	0.6	0.0	0.0	0.0	730
735	15.5	14.2	13.5	20	0.6	0.0	-0.00	-0.02	735
740	15.5	14.2	13.5	20	0.6	0.0	-0.00	-0.02	740
745	15.5	14.1	13.5	20	0.6	0.0	-0.00	-0.02	745
750	15.5	14.1	13.5	20	0.6	0.0	0.0	0.0	750
755	15.5	14.1	13.5	20	0.6	0.0	-0.00	-0.02	755
760	15.5	14.1	13.5	20	0.6	0.0	0.0	0.0	760

TABLE 8 : EXPENDABLE BATHYTHERMOGRAPH DATA - STATION 5a

TEMPERATURE						GRADIENT			
DEPTH	MAX	AVG	MIN	NUM	SDEV	MAX	AVG	MIN	DEPTH
0	25.9	25.7	25.6	2	0.2	0.0	0.0	0.0	0
5	25.9	25.7	25.6	2	0.2	0.0	0.0	0.0	5
10	25.8	25.7	25.6	2	0.1	0.0	-0.01	-0.02	10
15	25.8	25.6	25.5	2	0.2	0.0	-0.01	-0.02	15
20	25.7	25.6	25.5	2	0.1	0.0	-0.01	-0.02	20
25	25.7	25.4	25.2	2	0.4	0.0	-0.03	-0.06	25
30	25.6	25.2	24.9	2	0.5	-0.02	-0.04	-0.06	30
35	24.2	22.5	20.8	2	2.4	-0.28	-0.55	-0.82	35
40	21.9	20.4	18.9	2	2.1	-0.38	-0.42	-0.46	40
45	19.8	19.1	18.4	2	1.0	-0.10	-0.26	-0.42	45
50	19.0	18.4	17.9	2	0.8	-0.10	-0.13	-0.16	50
55	18.2	17.9	17.7	2	0.4	-0.04	-0.10	-0.16	55
60	18.1	17.8	17.6	2	0.4	-0.02	-0.02	-0.02	60
65	17.9	17.5	17.2	2	0.5	-0.04	-0.06	-0.08	65
70	17.6	17.2	16.9	2	0.5	-0.06	-0.06	-0.06	70
75	17.4	17.0	16.6	2	0.6	-0.04	-0.05	-0.06	75
80	17.1	16.8	16.6	2	0.4	0.0	-0.03	-0.06	80
85	17.0	16.6	16.3	2	0.5	-0.02	-0.04	-0.06	85
90	17.0	16.5	16.1	2	0.6	0.0	-0.02	-0.04	90
95	16.9	16.4	16.0	2	0.6	-0.02	-0.02	-0.02	95
100	16.8	16.4	16.0	2	0.6	0.0	-0.01	-0.02	100
105	16.7	16.3	15.9	2	0.6	-0.02	-0.02	-0.02	105
110	16.6	16.2	15.9	2	0.5	0.0	-0.01	-0.02	110
115	16.5	16.1	15.8	2	0.5	-0.02	-0.02	-0.02	115
120	16.3	16.0	15.8	2	0.4	0.0	-0.02	-0.04	120
125	16.2	15.9	15.7	2	0.4	-0.02	-0.02	-0.02	125
130	16.1	15.9	15.8	2	0.2	0.02	-0.00	-0.02	130
135	16.0	15.9	15.8	2	0.1	0.0	-0.01	-0.02	135
140	16.0	15.9	15.8	2	0.1	0.0	0.0	0.0	140
145	15.9	15.8	15.7	2	0.1	-0.02	-0.02	-0.02	145
150	15.9	15.8	15.7	2	0.1	0.0	0.0	0.0	150
155	15.8	15.7	15.7	2	0.1	0.0	-0.01	-0.02	155
160	15.8	15.7	15.7	2	0.1	0.0	0.0	0.0	160
165	15.8	15.7	15.6	2	0.1	0.0	-0.01	-0.02	165
170	15.8	15.7	15.6	2	0.1	0.0	0.0	0.0	170
175	15.7	15.6	15.5	2	0.1	-0.02	-0.02	-0.02	175
180	15.7	15.6	15.5	2	0.1	0.0	0.0	0.0	180
185	15.7	15.5	15.4	2	0.2	0.0	-0.01	-0.02	185
190	15.7	15.5	15.4	2	0.2	0.0	0.0	0.0	190
195	15.6	15.4	15.3	2	0.2	-0.02	-0.02	-0.02	195
200	15.5	15.4	15.3	2	0.1	0.0	-0.01	-0.02	200
205	15.4	15.3	15.2	2	0.1	-0.02	-0.02	-0.02	205
210	15.3	15.2	15.2	2	0.1	0.0	-0.01	-0.02	210
215	15.2	15.1	15.1	2	0.1	-0.02	-0.02	-0.02	215
220	15.2	15.1	15.1	2	0.1	0.0	0.0	0.0	220
225	15.2	15.1	15.1	2	0.1	0.0	0.0	0.0	225
230	15.2	15.1	15.1	2	0.1	0.0	0.0	0.0	230
235	15.2	15.1	15.0	2	0.1	0.0	-0.01	-0.02	235
240	15.1	15.0	15.0	2	0.1	0.0	-0.01	-0.02	240
245	15.1	15.0	15.0	2	0.1	0.0	0.0	0.0	245
250	15.1	15.0	15.0	2	0.1	0.0	0.0	0.0	250

XBT DATA - STA. 5a, continued:

TEMPERATURE						GRADIENT			
255	15.1	15.0	15.0	2	0.1	0.0	0.0	0.0	255
260	15.1	15.0	14.9	2	0.1	0.0	-0.01	-0.02	260
265	15.1	15.0	14.9	2	0.1	0.0	0.0	0.0	265
270	15.1	15.0	14.9	2	0.1	0.0	0.0	0.0	270
275	15.1	15.0	14.9	2	0.1	0.0	0.0	0.0	275
280	15.0	14.9	14.9	2	0.1	0.0	-0.01	-0.02	280
285	15.0	14.9	14.9	2	0.1	0.0	0.0	0.0	285
290	15.0	14.9	14.8	2	0.1	0.0	-0.01	-0.02	290
295	15.0	14.9	14.8	2	0.1	0.0	0.0	0.0	295
300	15.0	14.9	14.8	2	0.1	0.0	0.0	0.0	300
305	15.0	14.9	14.8	2	0.1	0.0	0.0	0.0	305
310	14.9	14.8	14.8	2	0.1	0.0	-0.01	-0.02	310
315	14.9	14.8	14.8	2	0.1	0.0	0.0	0.0	315
320	14.9	14.8	14.8	2	0.1	0.0	0.0	0.0	320
325	14.9	14.8	14.7	2	0.1	0.0	-0.01	-0.02	325
330	14.9	14.8	14.7	2	0.1	0.0	0.0	0.0	330
335	14.8	14.7	14.7	2	0.1	0.0	-0.01	-0.02	335
340	14.8	14.7	14.7	2	0.1	0.0	0.0	0.0	340
345	14.8	14.7	14.7	2	0.1	0.0	0.0	0.0	345
350	14.8	14.7	14.7	2	0.1	0.0	0.0	0.0	350
355	14.8	14.7	14.7	2	0.1	0.0	0.0	0.0	355
360	14.7	14.7	14.7	2	0.0	0.0	-0.01	-0.02	360
365	14.7	14.6	14.6	2	0.1	0.0	-0.01	-0.02	365
370	14.7	14.6	14.6	2	0.1	0.0	0.0	0.0	370
375	14.7	14.6	14.6	2	0.1	0.0	0.0	0.0	375
380	14.7	14.6	14.6	2	0.1	0.0	0.0	0.0	380
385	14.7	14.6	14.6	2	0.1	0.0	0.0	0.0	385
390	14.7	14.6	14.6	2	0.1	0.0	0.0	0.0	390
395	14.7	14.6	14.6	2	0.1	0.0	0.0	0.0	395
400	14.6	14.6	14.6	2	0.0	0.0	-0.01	-0.02	400
405	14.6	14.5	14.5	2	0.1	0.0	-0.01	-0.02	405
410	14.6	14.5	14.5	2	0.1	0.0	0.0	0.0	410
415	14.6	14.5	14.5	2	0.1	0.0	0.0	0.0	415
420	14.6	14.5	14.5	2	0.1	0.0	0.0	0.0	420
425	14.6	14.5	14.5	2	0.1	0.0	0.0	0.0	425
430	14.6	14.5	14.5	2	0.1	0.0	0.0	0.0	430
435	14.6	14.5	14.5	2	0.1	0.0	0.0	0.0	435
440	14.6	14.5	14.5	2	0.1	0.0	0.0	0.0	440
445	14.5	14.5	14.5	2	0.0	0.0	-0.01	-0.02	445
450	14.5	14.4	14.4	2	0.1	0.0	-0.01	-0.02	450
455	14.5	14.4	14.4	2	0.1	0.0	0.0	0.0	455
460	14.5	14.4	14.4	2	0.1	0.0	0.0	0.0	460
465	14.4	14.4	14.4	2	0.0	0.0	-0.01	-0.02	465
470	14.4	14.4	14.4	2	0.0	0.0	0.0	0.0	470
475	14.4	14.4	14.4	2	0.0	0.0	0.0	0.0	475
480	14.4	14.4	14.4	2	0.0	0.0	0.0	0.0	480
485	14.4	14.4	14.4	2	0.0	0.0	0.0	0.0	485
490	14.3	14.3	14.3	2	0.0	-0.02	-0.02	-0.02	490
495	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	495
500	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	500

XBT DATA - STA. 5a, continued:

	TEMPERATURE					GRADIENT			
505	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	505
510	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	510
515	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	515
520	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	520
525	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	525
530	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	530
535	14.3	14.3	14.3	2	0.0	0.0	0.0	0.0	535
540	14.3	14.2	14.2	2	0.1	0.0	-0.01	-0.02	540
545	14.3	14.2	14.2	2	0.1	0.0	0.0	0.0	545
550	14.2	14.2	14.2	2	0.0	0.0	-0.01	-0.02	550
555	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	555
560	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	560
565	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	565
570	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	570
575	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	575
580	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	580
585	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	585
590	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	590
595	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	595
600	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	600
605	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	605
610	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	610
615	14.2	14.2	14.2	2	0.0	0.0	0.0	0.0	615
620	14.2	14.1	14.1	2	0.1	0.0	-0.01	-0.02	620
625	14.2	14.1	14.1	2	0.1	0.0	0.0	0.0	625
630	14.2	14.1	14.1	2	0.1	0.0	0.0	0.0	630
635	14.1	14.1	14.1	2	0.0	0.0	-0.01	-0.02	635
640	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	640
645	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	645
650	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	650
655	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	655
660	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	660
665	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	665
670	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	670
675	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	675
680	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	680
685	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	685
690	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	690
695	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	695
700	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	700
705	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	705
710	14.1	14.1	14.1	2	0.0	0.0	0.0	0.0	710
715	14.1	14.0	14.0	2	0.1	0.0	-0.01	-0.02	715
720	14.0	14.0	14.0	2	0.0	0.0	-0.01	-0.02	720
725	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	725
730	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	730
735	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	735
740	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	740
745	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	745
750	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	750
755	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	755
760	14.0	14.0	14.0	2	0.0	0.0	0.0	0.0	760

TABLE 9 : EXPENDABLE BATHYTHERMOGRAPH DATA - STATION 5b

	TEMPERATURE					GRADIENT			
DEPTH	MAX	AVG	MIN	NUM	SDEV	MAX	AVG	MIN	DEPTH
0	24.6	24.2	23.8	3	0.4	0.0	0.0	0.0	0
5	24.5	24.2	23.8	3	0.4	0.0	-0.01	-0.02	5
10	24.4	24.2	23.8	3	0.3	0.0	-0.01	-0.02	10
15	24.4	24.2	23.8	3	0.3	0.02	0.01	0.0	15
20	24.4	24.2	23.8	3	0.3	0.0	-0.01	-0.02	20
25	24.5	24.2	23.8	3	0.4	0.02	0.01	0.0	25
30	24.6	24.2	23.8	3	0.4	0.02	0.01	0.0	30
35	24.7	24.3	23.8	3	0.5	0.02	0.01	0.0	35
40	24.6	24.2	23.7	3	0.5	-0.02	-0.02	-0.02	40
45	24.6	24.2	23.7	3	0.5	0.0	0.0	0.0	45
50	24.6	24.2	23.7	3	0.5	0.0	0.0	0.0	50
55	24.5	24.1	23.7	3	0.4	0.0	-0.01	-0.02	55
60	24.4	24.1	23.7	3	0.4	0.0	-0.01	-0.02	60
65	24.3	24.0	23.7	3	0.3	0.0	-0.01	-0.02	65
70	24.2	24.0	23.7	3	0.3	0.0	-0.01	-0.02	70
75	24.1	23.9	23.7	3	0.2	0.0	-0.01	-0.02	75
80	24.1	23.9	23.7	3	0.2	0.0	-0.01	-0.02	80
85	24.0	23.8	23.7	3	0.2	0.0	-0.01	-0.02	85
90	24.0	23.8	23.7	3	0.2	0.0	0.0	0.0	90
95	24.0	23.8	23.6	3	0.2	0.0	-0.01	-0.02	95
100	23.9	23.7	23.6	3	0.2	0.0	-0.01	-0.02	100
105	23.9	23.7	23.6	3	0.2	0.0	0.0	0.0	105
110	23.9	23.7	23.5	3	0.2	0.0	-0.01	-0.02	110
115	23.9	23.7	23.5	3	0.2	0.0	-0.01	-0.02	115
120	23.8	23.6	23.5	3	0.2	0.0	-0.01	-0.02	120
125	23.8	23.6	23.4	3	0.2	0.0	-0.01	-0.02	125
130	23.8	23.6	23.3	3	0.3	0.0	-0.01	-0.02	130
135	23.7	23.5	23.1	3	0.3	0.0	-0.02	-0.04	135
140	23.7	23.3	22.6	3	0.6	0.0	-0.03	-0.10	140
145	23.6	22.9	21.8	3	1.0	0.0	-0.07	-0.16	145
150	23.6	22.4	20.4	3	1.7	0.0	-0.11	-0.28	150
155	23.0	21.8	19.5	3	2.0	-0.06	-0.12	-0.18	155
160	21.9	20.4	18.1	3	2.0	-0.22	-0.27	-0.32	160
165	20.5	19.2	17.2	3	1.7	-0.18	-0.25	-0.30	165
170	19.1	18.3	17.4	3	0.9	0.04	-0.18	-0.30	170
175	18.1	17.8	17.4	3	0.4	0.0	-0.10	-0.26	175
180	18.0	17.7	17.4	3	0.3	0.0	-0.01	-0.02	180
185	17.9	17.6	17.3	3	0.3	0.0	-0.01	-0.02	185
190	17.8	17.5	17.2	3	0.3	-0.02	-0.02	-0.02	190
195	17.7	17.5	17.1	3	0.3	0.0	-0.01	-0.02	195
200	17.7	17.4	17.1	3	0.3	0.0	-0.01	-0.02	200
205	17.6	17.4	17.0	3	0.3	0.0	-0.01	-0.02	205
210	17.5	17.3	16.9	3	0.3	-0.02	-0.02	-0.02	210
215	17.5	17.2	16.8	3	0.4	0.0	-0.01	-0.02	215
220	17.4	17.1	16.7	3	0.4	-0.02	-0.02	-0.02	220
225	17.4	17.1	16.6	3	0.4	0.0	-0.01	-0.02	225
230	17.3	17.0	16.5	3	0.4	0.0	-0.01	-0.02	230
235	17.2	16.9	16.4	3	0.4	-0.02	-0.02	-0.02	235
240	17.1	16.8	16.2	3	0.5	0.0	-0.02	-0.04	240
245	17.0	16.7	16.1	3	0.5	-0.02	-0.03	-0.04	245
250	16.9	16.6	16.1	3	0.4	0.0	-0.01	-0.02	250

XBT DATA - STA. 5b, continued

TEMPERATURE						GRADIENT			
255	16.9	16.5	16.0	3	0.5	0.0	-0.01	-0.02	255
260	16.8	16.4	15.9	3	0.5	-0.02	-0.02	-0.02	260
265	16.6	16.3	15.8	3	0.4	0.0	-0.03	-0.06	265
270	16.5	16.2	15.8	3	0.4	0.0	-0.01	-0.02	270
275	16.4	16.2	15.8	3	0.3	0.0	-0.01	-0.02	275
280	16.3	16.1	15.7	3	0.3	-0.02	-0.02	-0.02	280
285	16.3	16.0	15.7	3	0.3	0.0	-0.01	-0.02	285
290	16.2	16.0	15.7	3	0.3	0.0	-0.01	-0.02	290
295	16.2	15.9	15.6	3	0.3	0.0	-0.01	-0.02	295
300	16.1	15.9	15.6	3	0.3	0.0	-0.01	-0.02	300
305	16.1	15.8	15.5	3	0.3	0.0	-0.01	-0.02	305
310	16.0	15.7	15.4	3	0.3	-0.02	-0.02	-0.02	310
315	16.0	15.7	15.4	3	0.3	0.0	-0.01	-0.02	315
320	15.9	15.6	15.3	3	0.3	0.0	-0.01	-0.02	320
325	15.9	15.6	15.3	3	0.3	0.0	-0.01	-0.02	325
330	15.8	15.5	15.2	3	0.3	0.0	-0.01	-0.02	330
335	15.8	15.5	15.2	3	0.3	0.0	-0.01	-0.02	335
340	15.7	15.4	15.1	3	0.3	-0.02	-0.02	-0.02	340
345	15.6	15.3	15.0	3	0.3	0.0	-0.01	-0.02	345
350	15.5	15.3	15.0	3	0.3	0.0	-0.01	-0.02	350
355	15.5	15.3	15.0	3	0.3	0.0	0.0	0.0	355
360	15.4	15.2	15.0	3	0.2	0.0	-0.01	-0.02	360
365	15.3	15.1	15.0	3	0.2	0.0	-0.01	-0.02	365
370	15.3	15.1	15.0	3	0.2	0.0	0.0	0.0	370
375	15.3	15.1	14.9	3	0.2	0.0	-0.01	-0.02	375
380	15.3	15.1	14.9	3	0.2	0.0	0.0	0.0	380
385	15.3	15.1	14.9	3	0.2	0.0	0.0	0.0	385
390	15.2	15.0	14.9	3	0.2	0.0	-0.01	-0.02	390
395	15.2	15.0	14.9	3	0.2	0.0	0.0	0.0	395
400	15.2	15.0	14.9	3	0.2	0.0	0.0	0.0	400
405	15.2	15.0	14.8	3	0.2	0.0	-0.01	-0.02	405
410	15.2	14.9	14.8	3	0.2	0.0	-0.01	-0.02	410
415	15.2	14.9	14.8	3	0.2	0.0	0.0	0.0	415
420	15.2	14.9	14.7	3	0.3	0.0	-0.01	-0.02	420
425	15.1	14.8	14.7	3	0.2	0.0	-0.01	-0.02	425
430	15.1	14.8	14.7	3	0.2	0.0	0.0	0.0	430
435	15.1	14.8	14.7	3	0.2	0.0	0.0	0.0	435
440	15.1	14.8	14.7	3	0.2	0.0	0.0	0.0	440
445	15.1	14.8	14.6	3	0.3	0.0	-0.01	-0.02	445
450	15.1	14.8	14.6	3	0.3	0.0	0.0	0.0	450
455	15.1	14.8	14.6	3	0.3	0.0	0.0	0.0	455
460	15.1	14.8	14.6	3	0.3	0.0	-0.01	-0.02	460
465	15.0	14.7	14.6	3	0.2	0.0	-0.01	-0.02	465
470	15.0	14.7	14.6	3	0.2	0.0	0.0	0.0	470
475	15.0	14.7	14.5	3	0.3	0.0	-0.01	-0.02	475
480	15.0	14.7	14.5	3	0.3	0.0	0.0	0.0	480
485	15.0	14.7	14.5	3	0.3	0.0	0.0	0.0	485
490	15.0	14.7	14.5	3	0.3	0.0	0.0	0.0	490
495	15.0	14.7	14.5	3	0.3	0.0	0.0	0.0	495
500	15.0	14.7	14.5	3	0.3	0.0	-0.01	-0.02	500

XBT DATA - STA. 5b, continued

TEMPERATURE						GRADIENT			
505	14.9	14.6	14.5	3	0.2	0.0	-0.01	-0.02	505
510	14.9	14.6	14.4	3	0.3	0.0	-0.01	-0.02	510
515	14.9	14.6	14.4	3	0.3	0.0	0.0	0.0	515
520	14.9	14.6	14.4	3	0.3	0.0	0.0	0.0	520
525	14.9	14.6	14.4	3	0.3	0.0	0.0	0.0	525
530	14.9	14.6	14.4	3	0.3	0.0	-0.01	-0.02	530
535	14.9	14.6	14.4	3	0.3	0.0	0.0	0.0	535
540	14.9	14.5	14.3	3	0.3	0.0	-0.01	-0.02	540
545	14.9	14.5	14.3	3	0.3	0.0	0.0	0.0	545
550	14.9	14.5	14.3	3	0.3	0.0	0.0	0.0	550
555	14.8	14.5	14.3	3	0.3	0.0	-0.01	-0.02	555
560	14.8	14.5	14.3	3	0.3	0.0	-0.01	-0.02	560
565	14.8	14.5	14.3	3	0.3	0.0	0.0	0.0	565
570	14.8	14.5	14.3	3	0.3	0.0	0.0	0.0	570
575	14.8	14.5	14.3	3	0.3	0.0	0.0	0.0	575
580	14.8	14.4	14.2	3	0.3	0.0	-0.01	-0.02	580
585	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	585
590	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	590
595	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	595
600	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	600
605	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	605
610	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	610
615	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	615
620	14.8	14.4	14.2	3	0.3	0.0	0.0	0.0	620
625	14.7	14.4	14.2	3	0.3	0.0	-0.01	-0.02	625
630	14.7	14.3	14.1	3	0.3	0.0	-0.01	-0.02	630
635	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	635
640	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	640
645	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	645
650	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	650
655	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	655
660	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	660
665	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	665
670	14.7	14.3	14.1	3	0.3	0.0	0.0	0.0	670
675	14.7	14.3	14.0	3	0.4	0.0	-0.01	-0.02	675
680	14.7	14.3	14.0	3	0.4	0.0	0.0	0.0	680
685	14.7	14.3	14.0	3	0.4	0.0	0.0	0.0	685
690	14.6	14.3	14.0	3	0.3	0.0	-0.01	-0.02	690
695	14.6	14.2	14.0	3	0.3	0.0	-0.01	-0.02	695
700	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	700
705	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	705
710	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	710
715	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	715
720	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	720
725	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	725
730	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	730
735	14.6	14.2	14.0	3	0.3	0.0	0.0	0.0	735
740	14.6	14.2	14.0	3	0.3	0.0	-0.01	-0.02	740
745	14.5	14.2	14.0	3	0.3	0.0	-0.01	-0.02	745
750	14.5	14.2	14.0	3	0.3	0.0	0.0	0.0	750
755	14.5	14.2	14.0	3	0.3	0.0	0.0	0.0	755
760	14.5	14.2	14.0	3	0.3	0.0	0.0	0.0	760

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PART 3

ECOLOGY AND VERTICAL DISTRIBUTION OF MEDITERRANEAN MIDWATER FISHES

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Introduction

The midwater fish fauna of the Mediterranean Sea is meager when compared with such faunas of the open oceans and provides an opportunity to study the ecology of an entire fauna with only limited resources. This report is the result of such a study. Based on a total of 21,572 specimens of 34 species of midwater fishes collected in horizontal, discrete-depth samples and 2 species taken only in non-discrete samples (Table 10) at 5 representative stations (Fig. 1), this study is concerned with the geographic distribution and abundance of these fishes in the Mediterranean Sea, their life cycles, and their patterns of vertical distribution.

The 36 species of midwater fishes included representatives of 10 families. About half of the species (17) were lanternfishes (Myctophidae). In terms of numbers of individuals, the two species of Cyclothone (family Gonostomatidae) were overwhelmingly dominant, with 15,094 specimens taken in the horizontal discrete-depth samples. Of the remaining 6,480 specimens, about 75% (4,932 specimens) were lanternfishes. These were followed in descending order by the other Gonostomatidae (656 specimens), Sternoptychidae (367), Paralepididae (327), Stomiatidae (100), and Chauliodontidae (86). Four other families were represented by fewer than ten specimens each from all five stations.

Table 10. Species of midwater fishes caught during the Mediterranean Biological Studies Program.

Family	Scientific Name
onostomatidae	Cyclothone pygmaea
	C. braueri
	Gonostoma denudatum
	Ichthyococcus ovatus
	Maurolicus muelleri
	Vinciguerria attenuata
	V. poweriae
ternoptychidae	Argyropelecus hemigymnus
elanostomiatidae	Bathophilus nigerrimus
tomiatidae	Stomias boa boa
hauliodontidae	Chauliodus sloani
aralepididae	Lestidiops jayakari pseudosphyraenoides
	L. sphyrenoides
	Notolepis rissoi rissoi
	Paralepis coregonoides
vermannellidae	Evermannella balbo
yctophidae	Electrona rissoi
	Hygophum hygomi
	H. benoiti
	Benthosema glaciale
	Diogenichthys atlanticus
	Myctophum punctatum
	Symbolophorus veranyi
	Gonichthys cocco
	Lobianchia dofleini
	Diaphus rafinesquei
	D. holti
	D. metopoclampus
	Lampanyctus crocodilus
	L. pusillus
	Ceratoscopelus maderensis
	Notoscopelus kroyeri
	N. elongatus
emichthyidae	Nemichthys scolopaceus
	Paravocettinops trilinearis
rachipteridae	Zu cristatus

The discussions first treat each species separately and then generalize on the basis of all species combined. The computer-generated readouts on which the analyses are based may be found in Appendices 2 and 3.

Materials and Methods

Analyses were based on specimens taken in horizontal discrete-depth samples. All discussions pertain to data from such samples only, unless indicated otherwise. Supplemental data from oblique discrete-depth samples (stations 4 and 5) and from non-discrete samples were used occasionally.

Samples were sorted to species, the size (standard length) of each specimen was measured, and its sex and stage of development determined. These data were recorded on a printed form (Fig. 17), from which cards were keypunched for entry into computer storage. The sex codes used were:

0 = undetermined
1 = male
2 = female

The stage codes used were:

0 = undetermined
1 = prolarva
2 = postlarva
3 = juvenile
4 = subadult
5 = adult

Stages were defined as follows:

prolarva - yolk sac not fully resorbed.

Fig. 17. Worksheet for recording stage of development, sex, and standard length of individual fish specimens.

Program _____

Description of Data Ichthyological Data _____ Prepared by _____ Date _____

	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	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	
			TRAWL			CODE				STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE					STAGE						
					SAMPLE					SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE		SEX			SIZE			
1					

postlarva - Yolk sac fully resorbed. Body proportions, pigmentation, and photophore development (if any) markedly different from those of the adult.

juvenile - Body proportions, pigmentation, and photophore development (if any) similar to those of the adult. Gonad thread-like, sex not determinable by gross examination with a dissecting microscope.

subadult female - Ovaries exhibiting regional enlargement, this enlargement forming an ovoid mass with eggs detectable on gross examination. Stage terminating where 90% of the periphery of the ovary is covered with large eggs.

adult female - At least 90% of the periphery of the ovary covered with large eggs.

subadult and adult male - Development of the testis was not marked by abrupt changes in external morphology, and males were coded initially as of undetermined stage of development. Two methods were used to determine a size at which males would be divided into subadults and adults. When the male size-frequency distribution was bimodal or there was an obvious gap in the total size range, a point

between the two size groups was chosen. In all cases, the size-frequencies of males and females were compared, and when the first method of division was not applicable, a size at the middle of the overlap in size of subadult and adult females was chosen for dividing the males. The sizes at which males were separated into subadults and adults are given in Table 11.

The two species of Cyclothone could not be treated in the same way as all other species, because males were not identifiable. Post-juvenile specimens were divided into two categories on the basis of size: intermediates (including some small females and many unsexable specimens) and females. The size range used to delimit each of the two categories was as follows.

	Size mm	
	intermediate	female
Cyclothone braueri	14-17	19 and longer
Cyclothone pygmaea	14-16	18 and longer

The justification for these divisions are given in the species accounts.

Catch rates are expressed in number per hour and were alculated as follows.

1) the catch rate for each sample was calculated by dividing the number of specimens caught by the duration of the sampling (in hours).

Table 11. Sizes at which male specimens were divided into subadult and adult categories. See text for explanation.

Species	Upper Limit of Subadult (mm)
Vinciguerria attenuata	27
Vinciguerria poweriae	26
Argyropelecus hemigymnus	18
Electrona rissoi	30
Hygophum hygomi	all adult
Hygophum benoiti	29
Benthosema glaciale	31
Myctophum punctatum	all subadult
Symbolophorus veranyi	79
Gonichthys cocco	all subadult
Lobianchia dofleini	26
Diaphus rafinesquei	52
Diaphus holti	all adult
Lampanyctus crocodilus	all subadult
Lampanyctus pusillus	32
Ceratoscopelus maderensis	37
Notoscopelus kroyeri	81
Notoscopelus elongatus	all subadult

2) For samples from the same depth or from similar depth that were grouped together, the sum of the catch rates was obtained. Catch rates for negative samples were included.

3) The sum from step 2 was divided by the total number of samples in the group.

The procedure for calculating the catch rate is illustrated by the following example.

During the day at station 1, Argyropelecus hemigymnus was taken in three samples made at 375 m. The number of specimens captured in each sample, the duration of each sample, and the catch rate for each sample were as follows.

ample	No. of specimens	Duration of sample (hrs.)	Catch rate (No./hr.)
A	5	1.0	5.0
B	13	1.0	13.0
C	19	1.0	19.0

The catch rates are then added,

$$\begin{array}{r} 5.0 \\ 13.0 \\ 19.0 \\ \hline 37.0 \end{array}$$

and the total divided by the number of samples

$$37.0/3 = 12.3/\text{hr.}$$

to give the catch rate for that depth.

Computer programs were developed to construct files from, and to sort and summarize trawl collection data and biological data. A description of each program follows.

1) Constructs tape file of species library and trawl collection data, and lists contents of files.

2) Constructs tape file of individual fish data and lists contents of file.

3) Stages males on the basis of size, sexes Cyclothone on the basis of size, and punches a data deck containing the revised codes.

4) Sample Summary. - Summarizes each sample, listing collection data, species obtained, and for each species, the number caught of each stage of development.

5) Stage-Size. - (A) Tabulates size frequency distributions for each stage or stage-sex combination for each species, and (B) tabulates the number of specimens of each species and their size range for each sample.

6) Time-Depth. - Tabulates the number of specimens caught per hour of trawling as a function of time of day and depth of capture. Prints the number zero at coordinates in the table where at least one sample was taken, but no specimens were captured.

7) Depth-Size. - Tabulates the number of specimens caught per hour of trawling as a function of depth of capture and size of the specimen (in 1 mm intervals). Separate tabulations for day and night collections are generated.

8) Stage-Depth. - Tabulates the number of specimens caught per hour of trawling as a function of stage of development and depth of capture. Separate tabulations for day and night collections are generated.

Cyclothone braueri

Appendix 2 Tables 47-65

Distribution and Abundance.

Cyclothone braueri was the most abundant fish species in our collections; almost 10,000 specimens occurred in discrete-depth samples.

Contamination was a problem in analyzing C. braueri. Many specimens remained in the webbing of the net and were dislodged during the succeeding hauls. Contaminant specimens undoubtedly were caught both during the horizontal, discrete-depth portion and during the oblique portion of the haul while the net was being retrieved. When the net was lowered with all sampling chambers open during the next haul, numbers of specimens that had remained in the webbing were dislodged and lost, but some doubtless entered the succeeding discrete-depth samples.

As a check on the probability of contamination in the samples, the depths of sampling and catch rates were listed for each station in the order in which they were made (Table 11). The depths of greatest abundance of C. braueri were known from the analyses discussed below. Many depths at which the occurrence of C. braueri was doubtful could be eliminated and others virtually eliminated because they followed a trawl made in the depths of greatest abundance or towed obliquely through these depths on retrieval. Shallow trawls are most likely to be

Table 11. Cyclothone braueri: number caught per hour of trawling at discrete depths. Depths listed in the order in which they were sampled at each station. Underlined depths are those at which C. braueri would be expected. Underlined catch rates are those believed to be entirely composed of contaminants; these are also indicated by the letter C. Catch rates followed by a (C) in parentheses are believed to be partly, but not significantly, contaminated. Question mark (?) indicates samples from that depth were not discrete.

Sta. 1		Sta. 2		Sta. 3		Sta. 5	
Depth	No./hr.	Depth	No./hr.	Depth	No./hr.	Depth	No./hr.
40	0	100	0	750	9	675	32
235	0	45	0	750	13(C)	325	0
235	1	100	0	100	11(C)	325-250	0
70	0	200	0	600	149	250	0
375	182	200	0	600	145(C)	155	0
150	0	400	11	400	20(C)	155-80	0
190	0	400	71(C)	200	0	80	0
						340	0
940	0	1000	5(C)	400	13	340-250	0
25	0	25	23(C)	200	?	250	0
25	0	1000	9	100	0	510	93
400	179	300	6(C)	50	0	510-425	267(C)
500	485(C)	600	500	500	?	425	107(C)
700	96(C)	150	3C	200	14C	495	120(C)
700	34(C)	15	0	500	499	135	4C
150	0	150	0	300	61(C)	135-50	48C
		800	12	50	7C	50	1C
		12	26C	150	0	410	0
		800	91	50	0	410-160	0
		600	255(C)	1000	1	160	0
				150	2C		
				500	333		
				25	0		
				200	1		
				100	0		
				25	0		
				300	1		

contaminated, because there is less time for the net to be washed out before the sampler is closed.

The depth of maximum concentration appeared to be near 500 m. The number of fish caught per hour at this or adjacent depths, either night or day at all stations is shown in the following table (dash indicates no collections at or near 500 m; overlap into dawn and dusk(*) included for stations 2 and 5):

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	485	500	-	-
2	*255	600	564	600
3	499	500	333	500
4	367	500	-	-
5	*120	495-505	*133	425-510

The species was abundant at stations 1-4 (apparently most abundant at station 2). At station 5, it was much less abundant than at the other four stations.

Growth Stages and Reproductive Condition.

An attempt was made to determine stage of development and sex in 26 specimens from station 1, 181 specimens from station 2, 41 specimens from station 4, and 61 specimens from station 5. All specimens smaller than 14 mm had tiny, undeveloped gonads and were classified as juveniles. All specimens larger than 17 mm were females with distinct eggs. Sex of the intermediate specimens, 14-17 mm, was often difficult to determine. Many tissue squashes for microscopic examination of the gonads, and some histological sections were made. Specimens as small as 14 mm had gonads

containing eggs, but only one specimen could be identified with certainty as a male. A large proportion of the gonads of intermediate specimens lacked the obvious characteristics of either males or females. These might have developed into males.

Among western Mediterranean specimens, smaller females generally had small eggs, while most large females had large, clearly visible ova, and a few appeared to be spent. The single recognized male, 17 mm long, taken at station 2 was considered ripe. These indications suggest that spawning was occurring at the end of August at station 2 and possibly at stations 1 and 3 as well.

None of the females from the eastern Mediterranean that were sexed and staged had well developed eggs or were in a spent condition, and no assured males were found. Spawning was apparently not occurring in the eastern Mediterranean.

Length frequency distributions (Table 12) from stations 1, 2 and 3 (western Mediterranean) show three peaks - one each for large females and juveniles and one for intermediate sized specimens - and the percentage of the total at each peak increases with increasing size. The reason for this increase is unclear but may be related to greater efficiency of the net for capturing larger sized specimens of this species.

The population at station 2 was probably actively spawning, and females were larger than at any other station. Females were slightly smaller at station 1, and the population here probably had not yet reached the stage of spawning activity of

Table 12. Cyclothone braueri: percent of total number represented by each size at stations 1 - 5.

Standard Length mm	Stations 1	2	3	4	5
10	0.1	0.5	0.1	0.4	-
11	1.5	1.5	1.1	0.2	-
12	5.8	0.9	5.9	2.7	1.7
13	3.9	0.3	6.3	7.3	11.1
14	2.2	0.4	5.7	11.2	20.9
15	4.8	2.3	9.2	10.4	23.7
16	8.1	7.4	9.6	7.1	14.6
17	5.6	5.6	8.9	5.5	9.4
18	7.0	5.2	12.3	6.2	5.1
19	10.8	7.8	15.0	13.0	4.6
20	12.5	14.4	13.2	14.8	3.9
21	12.3	16.0	9.0	11.5	2.8
22	8.2	16.2	3.0	5.9	1.5
23	8.1	13.3	0.6	3.1	0.3
24	4.1	5.5	0.1	0.7	0.1
25	1.8	2.3	0.02	-	-
26	0.5	0.5	-	-	-
27	0.1	-	-	-	-
28	-	-	0.02	-	-

station 2. Spawning at station 3, where females were even smaller than at station 1, was still farther behind. The population of station 4 may have had a spawning status intermediate between station 1 and station 3 since the female peak was similar to that at station 1, but fewer large females were taken. At station 5, the population would not have approached a spawning peak for some time.

Vertical Distribution.

Depths of occurrence at stations 1-5 were 235-1000 m, with peak concentrations at 375-600 m. There was little difference between day and night in depths of capture. Specimens occurred in samples made at 12-200 m, but in every case the samples from these shallow depths followed tows made in or through the levels of concentration of the species and the specimens are presumed to be contaminants.

At stations 1, 3, 4 and 5, C. braueri was by far most abundant at or near 500 m, at which depth all sizes were well represented. At station 2 no tows were made at 500 m, but the catch per hour at 600 m was larger than any catch rate recorded elsewhere, indicating that C. braueri was most abundant at this station and had a greater depth of maximum concentration here.

The modal size of females increased with depth from 400 to 800 m at all stations, while few or no juveniles were taken deeper than 600 m. Thus a degree of size stratification is indicated. Similar tendencies were described by Jespersen and Taning (1926).

Cyclothone pygmaea

Appendix 2 Tables 66-83

Distribution and Abundance.

Cyclothone pygmaea was the second most abundant fish species in our collections; more than 5,000 specimens occurred in discrete depth samples. Many of these were contaminants, and a check was made as for C. braueri by listing the depths and catch rates for each station in the order in which they were made (Table 13). Obvious contaminants were thereby easily detected.

The depth of maximum concentration appeared to be 700-800 m. The number of fish caught per hour at these depths is shown in the following table (dash indicates no collections at or near these depths).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	228	700	81	700
2	500	800	181	800
3	43	750 and 1000	47	750
4	22	700	-	-
5	18	675	-	-

The species was most abundant at station 2, abundant at station 1, and much reduced in numbers at stations 3, 4, and 5, apparently decreasing gradually to the eastward.

Growth Stages and Reproductive Condition.

An attempt was made to determine stage of development and sex in 95 specimens from station 1, 187 specimens from station 2,

Table 13. Cyclothone pygmaea: number caught per hour of trawling at discrete depths. Depths listed in the order in which they were sampled at each station. Underlined depths are those at which C. pygmaea would be expected. Underlined catch rates are those believed to be entirely composed of contaminants; these are also indicated by the letter C. Catch rates followed by a (C) in parentheses are believed to be partly, but not significantly, contaminated. Question mark (?) indicates samples from that depth were not discrete.

Sta. 1		Sta. 2		Sta. 3		Sta. 5	
Depth	No./hr.	Depth	No./hr.	Depth	No./hr.	Depth	No./hr.
40	0	100	0	750D	43.4	675	18.0
235	0	45	0	750N	47.0(C)	325	0
235	0	100	0	100	15.0C	325-250	0
70	0	200	0	600	10.3(C)	250	0
375	0	200	0	600	3.0(C)	155	0
150	0	400	0	400	0	155-80	0
190	0	400	0	200	0	80	0
940	55.3	1000	115.7	400	0	340	0
25	0	25	68.0C	200	0	340-250	0
25	0.6C	1000	163.0(C)	100	0	250	0
400	0	300	5.5C	50	0	510	0
500	0	600	16.0(C)	500	0	510-425	0
700	228.1	150	1.0C	200	0	425	0
700	81.0(C)	15	0	500	0	495	0
150	0	150	0	300	0	135	0
		800	180.7	50	0	135-50	0
		12	114.3C	150	0	50	0
		800	500.0	50	0	410	0
		600	285.0(C)	1000	43.4	410-160	0
				150	3.0C	160	0
				500	0		
				25	0		
				200	0		
				100	0		
				25	0		
				300	0		

26 specimens from station 4 and 13 specimens from station 5. The gonads in specimens smaller than about 13 mm were very tiny and the sex could not be determined; these specimens were classified as juveniles. All specimens larger than 19 mm were females with obvious eggs. Many of the intermediate sized specimens also contained eggs, but sex could not be determined in many other specimens. No males could be identified, even when squashes of gonad tissue were examined microscopically. Some of these intermediate specimens might have developed into males.

All but one of the females examined had small or medium sized ovaries with small eggs or eggs of mixed sizes. Only one female, from station 2, had eggs large enough to be considered ripe. This indicates that at the end of August there is very little spawning in the Mediterranean.

Length frequency distributions (Table 14) from all stations each show a single peak, suggesting that the population of C. pygmaea is the result of a single spawning maximum at each station. The population at station 2 is made up of larger specimens, and this population is probably approaching a spawning period. At stations 1 and 3 the specimens average 1.4 mm and 2.5 mm smaller, respectively, than at station 2. Spawning at these stations would occur successively later than at station 1.

In the eastern Mediterranean (stations 4 and 5), the average specimen size is smaller than in any of the western populations, but the modal sizes are equal to or slightly

Table 14. *Cyclothone pygmaea*: percent of total number represented by each size at stations 1 - 5.

Standard Length mm	Stations 1	2	3	4	5
10	0.2	-	0.4	-	-
11	0.6	-	2.2	4.0	8.2
12	1.3	0.3	6.3	13.6	8.2
13	6.5	1.0	17.8	24.1	23.0
14	15.5	3.0	17.1	19.6	32.8
15	15.8	8.3	14.5	24.1	14.8
16	18.3	15.0	14.5	8.5	11.5
17	15.5	17.8	12.6	4.5	1.6
18	10.3	20.0	6.1	1.0	-
19	6.7	17.8	4.0	0.5	-
20	4.8	10.7	2.8	-	-
21	2.9	4.4	1.1	-	-
22	1.3	1.2	0.2	-	-
23	0.3	0.4	0.2	-	-
24	-	0.1	-	-	-
25	-	0.1	-	-	-
Mean mm	16.3	17.7	15.2	14.0	13.8

greater than those at station 3. Maximum spawning at stations 4 and 5, therefore, might be expected to occur at almost the same period as at station 3 and later than at stations 1 or 2. However, because C. pygmaea was sampled presumably only at its shallowest depths of occurrence at stations 4 and 5, the size frequencies are probably biased.

Vertical Distribution.

Depths of occurrence at stations 1-3 were 600 to 1000 m with peak concentrations at 700 to 800 m. Depths of occurrence at stations 4 and 5 were 500 to 700 m with only one tow at each of those stations containing specimens of C. pygmaea. There was little difference between day and night in depth of capture.

The occurrences at 500 m and 600 m may be attributable to contamination, for positive tows at these depths always followed tows made at or through the depths of maximum concentration. Probably C. pygmaea occurs in very small numbers as shallow as 600 m. Its only occurrence at 500 m was in a sample from the single tow at station 4. The net was towed at 700 m for one sample; the second sample was oblique from 700 to 500 m, presumably causing specimens in the body of the net to become dislodged and resulting in a catch rate (108/hr.) higher than either the preceeding (22/hr.) or following depths (42/hr.); the third sample, at 500 m, probably contains only contaminants. Specimens in samples made at 12-300 m are undoubtedly contaminants.

Larger specimens tended to be slightly more numerous in deeper (800-1000 m) hauls than in shallower ones (700-750 m), but this tendency was not very pronounced.

Gonostoma denudatum

Appendix 2 Tables 84-91

Distribution and Abundance.

This medium-sized species was relatively rare in our collections. It was collected at stations 2, 3, and 4, was uncommon at station 3, and rare at stations 2 and 4. At station 3, the highest rate of capture for any sample was 5.0/hr. in a sample taken at dawn (0405-0505 hrs.) at 100 m. One specimen was taken at each of the other positive stations (2 and 4). Almost all of the specimens reported by Jespersen and Taning (1926) from the Mediterranean were collected in the Tyrrhenian Sea and eastern Mediterranean.

Growth Stages and Reproductive Condition.

Postlarvae and juveniles of G. denudatum predominate in our collections (14 of 16 specimens). Two post-juveniles, both unstagable males, were collected. The number of specimens of each stage, followed by size range (mm) in parentheses, is as follows:

Station	Postlarvae	Juvenile	Unstaged Male
2	1(16)	0	0
3	8(13-19)	4(33-40)	2(65-97)
4	0	1(28)	0
2-4	9(13-19)	5(28-40)	2(65-97)

The presence of postlarvae and the gap in size between postlarvae and juveniles suggest spawning periods in spring and summer. The limited data preclude predictions of spawning activity at other times of the year.

Vertical Distribution.

Daytime depths of occurrence at station 3 were at 500-600 m; at station 4, one specimen was collected in an oblique sample between 700-500 m. None were taken during the day at station 2. Night depths of occurrence at stations 2 and 3 were 100-150 m; no night samples were made at station 4.

At station 3 at 500 m during the day, 3 juveniles (1.0/hr.) and one of the males (65 mm, 0.3/hr.) were taken, and at 600 m the 97 mm male (0.3/hr.) was collected.

At night at station 2, a postlarva (0.3/hr.) was taken at 150 m and at station 3, 2 postlarvae (2.0/hr.) were collected at 100 m and 1 juvenile (0.3/hr.) at 150 m.

Ichthyococcus ovatus

Appendix 2 Tables 92-98

Distribution and Abundance.

This small species was rare in our collections. Of the 10 specimens collected, two were taken at station 2 and 8 at station 3. Jespersen and Taning (1926) reported this species to occur predominantly in the Tyrrhenian Sea and the eastern Mediterranean. Most of our specimens were collected in the Tyrrhenian Sea, none in the eastern Mediterranean.

Growth Stages and Reproductive Condition.

Of the 10 specimens, one is a postlarva (16 mm), four are juveniles (12-17 mm), and five are adult females (27-39 mm); both specimens from station 2 are adult females (30-36 mm). No specimens 18-26 mm were taken. The absence of subadults and presence of about equal numbers of juveniles and adults may indicate a post-spawning situation in August and September, with adults dying at 1+ years of age, following spawning.

Vertical Distribution.

During the day, adults were taken at 400 m at stations 2 and 3 (0.7/hr. and 0.7/hr.); at station 3, a juvenile was taken at 500 m (0.3/hr.) and the postlarva at 750 m(0.5/hr.).

At night at station 3, three juveniles were taken at 500 m (1.0/hr.) and an adult at 150 m (0.3/hr.). No specimens were taken at night at station 2.

These data suggest that juveniles live deeper than adults and may not undergo diel migrations, while adults migrate some 250 m. The postlarva at 750 m may be in the metamorphosis stage.

Maurolicus muelleri

Appendix 2 Tables 99-101

Distribution and Abundance.

This small species was rare in our collections; four specimens were taken at station 2, none at the other stations. Jespersen and Taning (1926) reported that M. muelleri was abundant in the Alboran Sea, and rare to the east, particularly in the eastern Mediterranean. Their distribution map of stations negative and positive for catches of this species indicates that few captures were made in open sea areas; most positive stations were near land or over relatively shallow bottom. Most of our samples were made in open sea areas, a fact which may explain the small numbers of M. muelleri captured.

Growth Stages and Reproductive Condition.

Of the four specimens captured, two, 22-30 mm, are subadult females, one,32 mm, is a male, and one, 17 mm, is of undetermined stage of development.

Vertical Distribution.

None were taken during the day. At night, at station 2, the 17 mm specimen was captured at 45 m (0.5/hr.), and the male and the 30 mm female at 100 m (2.0/hr.). The 22 mm female was taken in a sample made at dusk at 100 m (2035-2135 hrs.).

Vinciguerria attenuata

Appendix 2 Tables 102-119

Distribution and Abundance.

This small species was moderately abundant in our collections, and, after the two species of Cyclothone, was the most abundant gonostomatid. It was taken at all five stations, was most abundant at station 2, and moderately abundant at stations 1, 3, 4, and 5. The maximum catch rates for day and night samples, and the depths of capture are listed in the following table (no night samples were taken at station 4).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	5.0	500	2.7	400
2	44.0	300	18.0	200
3	6.0	400	9.0	300
4	7.0	500	-	-
5	1.0	495	6.0	250

Growth Stages and Reproductive Condition.

Specimens in the 15-20 mm size range were difficult to sex and stage in a uniform manner. For this reason, all specimens other than postlarvae were assigned to a stage on the basis of size. Size limits of the stages were based on a series of sexed and staged specimens from station 2 and are as follows:

juveniles -- less than 17 mm

subadults -- 17-27 mm

adults -- greater than 27 mm

Juveniles predominate in our collections followed by subadults and postlarvae (226, 148, and 119 specimens respectively of 516); only 23 adults were caught. The number of specimens of each stage, followed by size range (mm) in parentheses, is as follows.

Sta.	Postlarvae	Juvenile	Subadult	Adult
1	10(12-18)	21(13-16)	4(18-24)	1(33)
2	49(13-18)	100(11-16)	96(17-26)	15(29-36)
3	59(10-17)	73(10-16)	30(17-23)	6(28-36)
4	0	7(13-15)	7(17-19)	0
5	1(14)	25(11-16)	11(17-27)	1(28)
1-5	119(10-18)	226(10-16)	148(17-27)	23(28-36)

The large numbers of pre-adult stages in contrast to the numbers of adults, indicates a post-spawning condition in an annual species. Most of the adults have spawned and died. The last of the postlarvae are entering the population, while many of those spawned earlier in the season have reached the subadult stage. Size-frequency distributions indicate that the juvenile-subadult population is formed of one spawning period; there is only one peak in size frequency for each station (excluding postlarvae). The population at station 2 apparently spawned earlier than at the other stations, for the size frequencies peak at 16-17 mm. At stations 1, 3, and 5 they peak at 13-14 mm. The larger sizes at station 2 are reflected in the higher ratio of subadults to juveniles, which approaches 1:1 at station 2, but is less than 0.5:1 at stations 1, 3, and 5. At station 4, data are sparse, but the population is presumed to be at about

the same stage as those of stations 3 and 5.

Spawning thus is presumed to occur in the spring and summer. Jespersen and Taning (1926) reported postlarvae very numerous in summer samples, but sparse in samples taken during winter.

Vertical Distribution.

Daytime depths of occurrence were 100-800 m with greatest concentrations at 300-500 m. Night depths of occurrence were 45-800 m with greatest abundance at 200-400 m and with a secondary peak of abundance at 45-50 m at stations 2 and 3.

During the day, juveniles, subadults and adults were concentrated in the 300-500 m layer (164 of the 175 specimens caught). Postlarvae occurred mainly above (100 m) and below (600-800 m) the 300-500 m layer; only 1 of the 31 postlarvae collected during the day was taken in that layer (300 m at station 2). Catch rates of postlarvae in the shallow and deep layers were about equal (0.5 and 0.5/hr. at station 2 and 2.5 and 3.3/hr. at station 3).

At night, postlarvae in the shallow layer apparently migrated from the day depth of about 100 m up to about 50 m, while in the deep layer they remained stationary at about 600 m. Juveniles, subadults, and adults migrate upward and occupy the 80-400 m depth interval, with juveniles in the lower part of the range, and subadults and adults in the upper .

Vinciguerria poweriae

Appendix 2 Tables 120-130

Distribution and Abundance.

This small species is present in moderate numbers in our collections. It was taken at stations 3, 4, and 5, and was most abundant at station 3. It was not taken at stations 1 and 2.

Depths judged to be near those of maximum concentration of V. poweriae were sampled either day or night (or both) at stations 3, 4, and 5. The number of specimens caught per hour at these depths is as follows (no night samples were taken at station 4):

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
3	4.7	500	12.0	50
4	6.0	500	-	-
5	0.0	495	7.0	80

Growth Stages and Reproductive Condition.

At station 3, postlarvae predominated, followed by juveniles (35 and 24 specimens respectively of a total of 76). Juveniles predominated at stations 4 and 5 (21 of a combined total of 34 specimens). The number of specimens of each stage, followed by size range (mm) in parentheses is as follows:

Sta.	Postlarva	Juvenile	Subadult		Adult	
			Male	Female	Male	Female
3	35(9-18)	24(12-18)	7(19-21)	5(21-24)	2(29-29)	3(22-30)
4	0	10(14-15)	1(18)	0	0	0
5	2(14-15)	11(13-16)	5(17-20)	3(16-20)	0	0
3-5	37(9-18)	45(12-18)	13(17-21)	8(16-24)	2(29-29)	3(22-30)

In addition, two specimens (17-18 mm) collected at station 5 could not be sexed or staged.

The smallest adult female is 22 mm long, and all females longer than 24 mm are adult. Males are about the same size as females.

Reduction in length during larval metamorphosis has been documented for this species (Sanzo,). This is indicated in our data by the wide overlap in the size ranges of postlarvae and juveniles, and by the fact that the largest juveniles and the largest postlarvae are the same size. The following table shows that at station 3, where the species was most abundant, the average size of postlarvae was larger than that of juveniles.

Depth m	Time of Day	Postlarvae		Juveniles	
		Number	SL(mm)	Number	SL(mm)
50	Night	1	14.0	0	
100	Day	4	14.3	0	
200	Night	1	9.0	0	
300	Night	0		2	13.5
500	Day	4	15.3	10	13.9
600	Night	6	15.0	0	

The large numbers of postlarvae and juveniles, compared to the small numbers of subadults and adults at station 3 indicate a post-spawning population. Most of the larger individuals have spawned and died, and many of the young have progressed to the juvenile stage. Spawning appears to have occurred earlier at stations 4 and 5; almost all the young specimens captured had developed to the juvenile stage.

Spawning, then, occurs mainly in summer (and perhaps spring). Jespersen and Taning (1926) found postlarvae of V. poweriae

throughout the year, but reported they were present in largest numbers during the summer.

Vertical Distribution.

During the day, V. poweriae was collected at 100-250 m (stations 3 and 5), and at 500 m (stations 3 and 4), with highest concentrations at 500 m. No specimens were taken between 250 and 500 m. Night depths of occurrence at stations 3 and 5 were 50-600 m, with peak abundance at 50-80 m. At station 4, no night samples were taken.

Smaller postlarvae apparently inhabit the 50-100 m stratum, possibly migrating from 100 m during the day to 50 m at night (one 9 mm postlarva was taken at 200 m at night). Larger postlarvae were taken only at 500 m during the day and only at 425 (station 5) and 600 m (station 3) at night, indicating that they move downward to occupy the deeper stratum prior to metamorphosis. They apparently migrate downward at night from 500 m to 600 m, but the catch rate at night was much lower than during the day, indicating that the depth of greatest abundance at night may not have been sampled.

Juveniles were taken only at 500 m during the day, at stations 3 and 4. They were taken at night at 300 m at station 3, where the average size was 13.5 mm, and at 80 m at station 5, where the average size was 14.6 mm. Juveniles, then, migrate upward at night, the larger individuals more extensively than the smaller.

Only one subadult was taken during the day, at 200 m (0.2/hr.). Subadults were taken at night at 50 m (9.2/hr., station 3) and at

155 m (2.0/hr., station 5). Adults were collected only at night and only at station 3, at 50 m (1.8/hr.) and 100 m (1.0/hr).

The virtual lack of advanced juveniles, subadults, and adults in daytime collections prevents delineation of the vertical migration patterns. These larger individuals either avoided our nets during the day or were living below our sampling depths.

Argyropelecus hemigymnus

Appendix 2 Tables 131-149

Distribution and Abundance.

This small hatchetfish was moderately abundant at all five stations. The maximum rates of capture (at night) and their depths are listed in the following table.

Station	Depth (m)	No./hr.
1	235	9.0
2	400	17.5
3	400	9.5
5	425	15.0

At station 4, 2 specimens were taken during the day at 700 m, and no night samples were taken. This low catch rate, however, does not necessarily indicate low abundance, for at station 5, only 1 specimen was taken during the day, while at night the catch rates were comparable to those at stations in the western Mediterranean. Probably A. hemigymnus is about as abundant at station 4 as at the other four stations.

Growth Stages and Reproductive Condition.

Adults dominate the catch at stations 1, 2, and 3 (176 of 314 specimens), while at station 5, juveniles predominate (26 of 49 specimens). Only four specimens were taken at station 4. The number of specimens of each stage, followed by size range (mm) in parentheses, is as follows:

Sta.	Postlarva	Juvenile	Subadult	Adult
1	20(5-8)	5(7-11)	11(11-18)	75(20-29)
2	41(7-9)	8(8-11)	5(9-12)	51(19-39)
3	14(6-9)	22(9-13)	12(15-24)	50(20-32)
4	1(7)	1(13)	0	2(26-27)
5	8(6-7)	26(7-13)	3(16-17)	12(23-36)
1-5	84(5-9)	62(7-13)	31(9-24)	190(19-39)

The smallest adult females in our collections are 20 mm long, and all females larger than 24 mm are adult. The largest specimen collected is a 39 mm male taken in a neuston (surface) sample at station 2; all other specimens collected in the western Mediterranean are smaller than 33 mm. In the eastern Mediterranean, the largest specimen collected is a 36 mm female.

Adult males are slightly smaller than adult females. This is shown by the following table, which lists the mean standard lengths of adult males and adult females collected at stations 1, 2, 3, and 5. The 39 mm male from station 2 is not included.

	Mean SL	
Sta.	males	females
1	22.1	24.3
2	24.0	25.4
3	25.0	27.0
5	27.9	31.0

Both adult males and adult females progressively increase in average size from station 1 to station 5 (west to east). This trend indicates that A. hemigymnus has a fairly restricted breeding season and spawns earliest in the east, progressively later to the west. The following table of the ratios of juveniles to subadults to adults supports this conclusion.

Sta.	Juv:	Subadult:	Adult
1	0.1:	0.1:	1
2	0.2:	0.1:	1
3	0.4:	0.1:	1
5	2.2:	0.3:	1

The abundances of juveniles relative to adults increases to the east. At station 5, adults are assumed to have spawned to be dying; juveniles constitute the bulk of the population. At stations 1, 2, and 3, spawning is probably near its peak, and juveniles will soon become dominant in the population. The 39 mm specimen from station 2 is an adult that probably did not die immediately after the previous spawning period. Its capture at the surface suggests that it may have been in poor condition -- no other specimens of A. hemigymnus were captured in neuston tows.

Vertical Distribution.

Daytime depths of occurrence at all 5 stations combined, were 150-800 m with peak concentrations at 300-500 m. Night depths of occurrence at stations 1, 2, 3, and 5, were 70-600 m (3 specimens were taken between 600 and 1000 m) with greatest abundance at 235-600 m. At station 4, no samples were taken at night.

Greatest daytime concentrations at stations 1, 2, and 3 were at 375 m (12.3/hr.), 400 m (9.3/hr.), and 400-500 m (3.7/hr.), respectively. Only two specimens were taken at station 4 (at 700 m), and one specimen at station 5 (495 m) during the day.

Some daytime size stratification is suggested at stations 1, 2, and 3, with mainly small specimens occurring above the

levels of greatest conecntration and mainly large specimens occurring below that level. At station 1, the only specimens taken deeper than the depth of greatest abundance (375 m) were two postlarvae, a single subadult, and three adults at 500 m, and two adults at 700 m; only one specimen, an adult, was taken shallower than 375 m. At station 2, no collections were made between the depth of greatest abundance (400 m) and 800 m; above 400 m a single postlarva and all seven day-caught juveniles were taken at 300 m, and a single 15 mm subadult was taken at 150 m. At station 3, a single 29 mm adult, taken at 600 m, was the only specimen caught below the depths of greatest concentration (400 and 500 m), while an 11 mm juvenile and a 22 mm adult were taken above these depths at 300 m. The only two daytime specimens taken at station 4, 7 and 13 mm, were caught at 700 m and do not agree with the conclusions on size stratification based on stations 1, 2, and 3.

At night, the vertical distributions of postlarvae, juveniles, and subadults were much the same as during the day, being centered at or near 400 m and ranging from 235-600 m. Adults, however, appeared to migrate upward to a limited extent. Adults were taken at 200 m or shallower at all four stations that were sampled at night (1, 2, 3, and 5); at station 5, one was taken at 135 m, and at station 1, one was taken at 70 m. Except at station 1, however, the greatest concentrations of adults were still at or near 400 m, suggesting that most do not migrate. At station 1, adults were most abundant at 235 m, suggesting that most may have migrated upward at this station.

The suggestion that at least a portion of the adult population migrates upward at night is somewhat dampened by the possibility of daytime net avoidance. The following table compares day and night capture rates for all sizes combined at depths that were sampled during both periods at any station. At virtually every level, the catch rate is considerably greater at night than during daylight hours.

Sta.	Depth (m)	Catch rate (No/hr) Day	Night
1	150	0.3	0.3
	235	0.0	9.0
	375-400	12.3	7.0
	700	0.7	0.3
2	200	0.0	1.3
	400	9.3	17.5
3	200	0.0	0.5
	300	1.0	4.0
	400	3.7	9.5
	500	3.7	3.3
	600	0.3	3.0
5	160-155	0.0	1.0
	340-325	0.0	2.0
	410-425	0.0	15.0
	495-510	1.0	4.0

Almost the entire increase in catch rate at night above 400 m is attributable to adults. At station 1, there was a considerable decrease at night in the adult catch rate at 400 m, while at stations 2, 3, and 5, there was little difference between the day and night catch rates of adults. Assuming daytime net avoidance, this strengthens the conclusion that most adults at station 1 were migrating upward at night, while at the other stations, only a few were doing so.

Increases in catch rate at 400 m at night reflect the abundances of each growth stage at each station. The following

table gives the number per hour of each growth stage taken during day and night at stations 1, 2, 3, and 5.

	Postlarva		Juvenile		Subadult		Adult	
ion	day	night	day	night	day	night	day	night
	3.3	2.7	0.7	0.7	1.0	0.7	7.3	3.0
	2.7	8.8	0.0	0.5	0.7	0.5	6.0	7.8
	0.7	3.7	0.0	3.6	1.0	0.0	2.0	2.3
	0.0	5.0	0.0	7.0	0.0	1.0	0.0	2.0

Adults were most abundant at station 1, and the greatest difference in catch rate was the decrease in adults that was mentioned above. At all other stations, the similarity of adult catch rates, in spite of daytime net avoidance, is attributed to upward migration of a smaller part of the adult population than at station 1. At station 2, the greatest night increase was in the postlarvae, which were most abundant there. At stations 3 and 5 increases were in both postlarvae and juveniles; at these stations juveniles formed an increasingly large proportion of the population.

In summary, postlarvae, juveniles, and subadults were concentrated at or near 400 m both day and night, and all three growth stages avoided the net to some extent during the day. Adults were also most abundant at or near 400 m during the day and apparently avoided the net during daylight. At night, most adults at station 1 and a smaller portion at the other stations migrated upward, most of them to 200-300 m, but a few to as high as 70 m.

Bathophilus nigerrimus

Appendix 2 Tables 150-155

Distribution and Abundance.

This moderate-sized species was rare in our collections. One specimen was taken at station 2, and one at station 3. Both specimens were adult females (81 mm at station 2 and 68 mm at station 3). The specimen from station 3 was captured during the day at 600 m. The specimen from station 2 was taken at night at 45 m.

Stomias boa boa

Appendix 2 Tables 156-171

Distribution and Abundance.

This species was collected in small numbers at stations 1, 2, 3, and 5. Catch rates among stations did not differ markedly.

The maximum catch rates (and their depths) for day and night samples are listed in the following table.

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	2.0	700	3.0	190
2	2.5	100	4.5	45
3	3.6	600	2.0	100
5	1.0	250	2.0	50

Growth Stages and Reproductive Condition.

Most of the specimens in our collections were juveniles (90 of 100 specimens), no postlarvae or adults were taken. The number of specimens of each stage, followed by size range (mm) in parentheses, is as follows.

Station	Juvenile	Subadult		
		Male	Female	Unsexed
1	29(22-86)	0	0	2(117-120)
2	28(34-74)	1(127)	0	0
3	30(25-79)	2(96-118)	0	2(97-121)
5	3(48-58)	0	1(89)	2(90-90)
1-5	90(22-86)	3(96-127)	1(89)	6(90-121)

The large number of juveniles suggests that spawning occurs in the spring, at least, and perhaps during the summer. Ege (1918)

reported postlarvae of S. boa boa in the Mediterranean in the fall, winter, and spring, but none in July or August. The number of postlarvae collected in February was about the same as the number taken in June. Ege (1918) concluded that spawning takes place at about a constant rate from September through June, and at reduced levels, or not at all, in July and August.

Vertical Distribution.

Daytime depths of occurrence for this species were 100-250 m (stations 1, 2, 3, and 5) and 375-1000 m (stations 1 and 3), with peak concentrations at 100-250 m and 600-700 m; catch rates in the two layers were similar. Night depths of occurrence at stations 1, 2, 3, and 5 were 12-300 m and 400-750 m, with greatest abundances at 45-190 m and 400-750 m; catch rates in the shallow layer were greater than those in the deep layer.

The few subadults captured were taken both deep and shallow, night and day. The juveniles, however, exhibited upward migration at night of at least part of the population. The following table summarizes the maximum day and night catch rates in the shallow and deep layers.

	Shallow		Deep	
Station	Day	Night	Day	Night
1	1.0	3.0	1.7	1.0
2	2.5	4.5	0.0	0.5
3	1.5	2.0	3.6	1.0
5	1.0	2.0	0.0	1.0

The catch rates in the shallow layer were higher at night than during the day, while the night rates in the deep layer were lower than (stations 1 and 3), or similar (stations 2 and 5) to the day rates.

Chauliodus sloani

Appendix 2 Tables 172-190

Distribution and Abundance.

This species was taken in small numbers at each of the 5 stations. It was most abundant at station 3 and least abundant at station 1.

The maximum capture rates (and their depths) for day and night samples are listed in the following table (no night samples at station 4):

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	0.7	700	0.7	700
2	1.0	100	1.5	45
3	4.6	600	3.0	100
4	2.0	500	-	-
5	0.5	675	2.0	135

Growth Stages and Reproductive Condition.

More than 90% of the specimens in our collections were juveniles. No postlarvae were collected. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

Station	Juvenile	Subadult		Adult	
		Male	Female	Male	Female
1	2(36-61)	1(86)	0	1(190)	1(169)
2	15(38-66)	0	1(134)	0	0
3	46(26-60)	1(111)	0	0	0
4	2(24-29)	1(105)	0	0	0
5	13(23-55)	1(102)	0	0	0
1-5	78(23-66)	4(86-111)	1(134)	1(190)	1(169)

In addition, a 93 mm specimen of undetermined sex and stage was collected at station 1. The large numbers of juveniles suggests that spawning occurs at least in the spring and possibly during the summer.

Vertical Distribution.

Daytime depths of occurrence at all stations combined were 400-940 m with peak abundance at 500-800 m; at stations 2 and 3 specimens were taken also at 100-200 m with highest catch rates at 100-150 m. Night depths of occurrence were 45-135 m and 425-700; highest catch rates occurred in the shallow layer.

Catches of C. sloani indicate that part of the juvenile population undergoes vertical migration, while subadults and adults remain in the deep layer. All post-juveniles in our collections were caught at 675-1000 m both day and night. The migration of juveniles is best illustrated by the collections from station 3, where this species was most abundant. The following table summarizes all catches of juveniles at station 3.

Depth (m)	Day (No./hr.)	Night (No./hr.)
100	0.0	3.0
150	0.5	0.0
200	0.2	0.0
500	2.7	2.0
600	4.6	1.3
750	1.5	0.0

Catch rates in the deep layer decrease at each depth sampled, while in the shallow layer slight decreases are evident at 150 m and 200 m, but there is a marked increase at 100 m.

Lestidiops jayakari pseudosphyraenoides

Appendix 2 Tables 191-200

Distribution and Abundance.

Lestidiops jayakari pseudosphyraenoides was uncommon in our collections, having been found only at stations 2, 3, and 5. It was most abundant at station 2, moderately abundant at station 3 and rare at station 5. Depths judged to be near those of maximum concentration were sampled either during the day or at night (or both) at all three of these stations. The number of specimens per hour taken at these depths was as follows (dash indicates depth of maximum concentration was not sampled).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
2	1.0	300	6.3	12
	1.0	800		
3	1.0	300		
	0.5	750		
5	-	-	2.0	135

The absence of this species from station 1 cannot be explained. Ege (1930) reported taking numerous specimens during shallow night collections in that vicinity during September.

Growth Stages and Reproductive Condition.

All of the 42 specimens taken were postlarvae (15-69 mm). Only one postlarva smaller than 22 mm was taken, indicating

that spawning is probably not occurring or is at a low level in late August and early September. Ege (1930) reported that spawning probably takes place the year around, and Rofen (1966) stated that this species spawns primarily from May to August with a peak in July. The absence of large specimens is probably due to net avoidance.

Vertical Distribution.

This species occurred at two levels during the day at stations 2 and 3: 150-300 m and 750-800 m. As the rates of capture listed in the above table indicate, there is no marked difference in abundance between the two levels. No size stratification was apparent. At these same stations, the only specimens taken at night were from 12 m at station 2. Others were taken during twilight hours from 15 m at station 2 and from 25 and 50 m at station 3. A considerable vertical migration is indicated.

No specimens of L. jayakari were taken at station 4, and the only two specimens from station 5 were caught at 135 m at night. Because no specimens were taken deeper than 50 m at night at stations 2 and 3, both of which were well sampled, it is possible that the species does not migrate as far toward the surface at station 5.

Lestidiops sphyrenoides

Appendix 2 Tables 201-208

Distribution and Abundance.

This species was the rarest of the barracudinas in our collections. A total of 5 specimens was taken at stations 1, 2, and 4. The single specimen taken at station 4 may have been a stray, for Ege (1930) reported that the range for this species did not extend to the area of our stations 4 and 5.

Growth Stages and Reproductive Condition.

All five specimens were postlarvae (36-61 mm). The absence of postlarvae smaller than 36 mm indicates a post-spawning situation. Ege (1930), however, reported that L. sphyrenoides probably spawns the year around in the Mediterranean. The absence of the larger growth stages is probably due to net avoidance.

Vertical Distribution.

Two specimens were taken during the day, one of 36 mm from 100 m at station 2 and one of 59 mm from 700 m at station 4. At sunrise, a single 43 mm specimen was taken at 70 m at station 1, and at night two of 47 and 61 mm were taken at 45 m at station 2. Ege (1930) reported taking numerous specimens near our station 1 in non-closing nets fished to depths of about 40 to 180 m at night in September, with a peak of abundance at about 60-80 m.

Therefore, the three specimens taken at sunrise and at night at our stations 1 and 2 may well be near the depth of maximum concentration at their respective stations (70 m at station 1 and 45 m at station 2). Because no specimens were taken shallower than 100 m during the day and at night none were taken deeper than 70 m, diel vertical migration is suggested.

Notolepis rissoi rissoi

Appendix 2 Tables 209-225

Distribution and Abundance.

Notolepis rissoi rissoi was the most abundant paralepidid in our collections. It was taken at all five stations, was most abundant at station 2, moderately abundant at station 3 and rare at stations 1, 4, and 5.

Depths judged to be near those of maximum concentration in the upper 1000 m were sampled during the day and at night at stations 1, 2, and 3. The data from stations 4 and 5 are too few to allow comparisons. The number of specimens per hour taken at these depths was as follows.

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	0.3	700	1.0	150
2	8.0	800	20.0	100
3	4.5	750	3.0	100

As shown above, N. r. rissoi was considerably more abundant at station 2 than at stations 1 and 3.

Growth Stages and Reproductive Condition.

Of the 150 specimens of N. r. rissoi taken, all but 4 were postlarvae (18-61 mm). Two were subadult females (90 and 124 mm) and two were subadult males (98 and 114 mm).

This relatively high incidence of postlarvae indicates that this species was spawning in the Mediterranean in the summer and

may still have been spawning through August. Ege (1930) reported that N. r. rissoi probably spawns throughout the year in the Mediterranean Sea. The scarcity of juveniles and subadults and the complete absence of adults is probably due to net avoidance.

Vertical Distribution.

Daytime depths of occurrence at stations 1, 2, and 3 were 100-800 m with peaks of abundance at 100-150 m and 700-800 m. At station 4, there was a tow made at 700 m, the depth judged to be near the maximum concentration at stations 1, 2, and 3, but no specimens were taken. Therefore, the only two specimens taken at station 4, in an oblique tow between 700 and 500 m, suggest that the depth of maximum concentration during the day at this station may be somewhat shallower than at stations 1-3. Only a single specimen, a subadult, was taken during the day at station 5, at 340 m.

Night depths of occurrence at stations 1, 2, and 3 were 12-1000 m with peaks of abundance at 100-150 m and 600-800 m. No night tows were made at station 4, while at station 5 only one specimen was taken, at 50 m.

The vertical distribution of N. r. rissoi is marked by size stratification. During both day and night, almost all specimens taken in the upper 200 m were smaller than 25 mm, while almost all taken deeper than 200 m were 25 mm or larger. Apparently the smaller specimens inhabit shallower depths, where they exhibit little or no vertical migration. When they reach a size of about 25 mm, they migrate downward, the vast majority to

depths of 700-800 m, where they remain both day and night, at least through the postlarval stage.

The considerable difference between catch rates for night and day at 700-800 m (stations 2 and 3) suggests that a part of the daytime population at those depths may migrate at night, but there is no indication of where it goes. These catch rates for stations 1, 2, and 3 are shown in the following table:

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	0.3	700	0.7	700
2	8.0	800	1.7	800
3	4.5	850	1.0	750

The difference at station 1 is not very meaningful, but those at stations 2 and 3 are. No suspicious differences in catch rates at 200-600 m are present to suggest an upward movement at night, and the species was not taken at 940-1000 m.

One possible explanation for the differences could be patchiness, the occurrence of well-separated aggregations of the species. This explanation is bolstered by the night catch of 20.0/hour at 100 m at station 2, which was not approached at any other depth at any of the five stations. The sample preceding the 20.0/hr. catch was taken at dusk at the same depth and produced 7.0 specimens/hour. Our conclusion remains that the species does not undertake extensive diel vertical migrations.

Paralepis coregonoides coregonoides

Appendix 2 Tables 226-240

Distribution and Abundance.

This species was the second most abundant paralepidid in our collections. It was most abundant at station 2, slightly less abundant at station 3, and moderately abundant at station 1. Only one specimen was taken at station 5 and none at station 4.

Depths judged to be near those of maximum concentration in the upper 1000 m were sampled during the day and at night only at stations 1, 2, and 3. The number of specimens per hour taken at these depths is as follows:

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	3.3	940	1.7	700
2	14.0	1000	3.7	800
3	7.6	1000	5.0	750

Growth Stages and Reproductive Condition.

All but one of the 130 specimens of P. c. coregonoides taken were postlarvae (16-36 mm). A 153 mm subadult female from station 5 was the largest specimen taken. This large number of postlarvae indicates that this species has recently spawned and may still be spawning through August in the western Mediterranean. Ege (1930) reported that this species probably spawns the year around in the Mediterranean. The absence of postlarvae in the eastern Mediterranean at stations

4 and 5 probably reflects the incomplete deep sampling at those stations, particularly since Ege (1930) reported that postlarvae were found evenly distributed between the eastern and western Mediterranean within the species range. The virtual absence of adults and subadults is probably due to net avoidance.

Vertical Distribution.

Postlarvae of P. c. coregonoides were both day and night at depths from 500 to 1000 m at stations 1, 2, and 3. Concentrations increased with depth during daytime, with greatest abundances being found at 940-1000 m. A few specimens were taken at 100-150 m during the day at station 3.

The picture at night is less clear, because depths near 1000 m were not sampled at night at stations 1 and 3. At station 2, at 1000 m, this species was far less abundant (in terms of catch per hour) at night than during the day, while there was no sign of increased concentrations at 600 and 800 m. A few specimens were taken at station 2 between 12 and 100 m, whereas none were taken at these depths during the day, but these are too few to account for the decrease at 1000 m. At station 1, there was no apparent change in abundance at 700 m, the greatest depth sampled at night, and no specimens were taken at shallower depths. At station 3, however, although 1000 m was not sampled at night, there was notably increased concentration at 750 m (5.0 per hour vs. 0.5); no changes in abundance were apparent at 500-600 m, and only a single specimen was taken shallow, at 100 m.

Size stratification during the day at stations 1, 2, and 3 is indicated by two peaks in the length frequency distribution. The shallowest peak, between 700-800 m, is composed mostly of specimens 16-20 mm long, while a deeper peak at about 1000 m is mostly composed of specimens larger than 20 mm. At station 2, the only station with samples from 1000 m at night, the nighttime situation was similar to the day, and this may be assumed to be true of stations 1 and 3 as well.

It appears that some of the small postlarvae living deeper than 700-800 m may migrate upward to these depths at night, but this is suggested convincingly only by the data from station 3. Most of these small individuals apparently remain at 700-800 m both day and night. The larger postlarvae, however, may be migrating at night from their daytime levels near 1000 m to deeper depths. This is strongly suggested by the decrease in catch rate at station 2 and the lack of a corresponding increase at shallower depths. Confirmation must await sampling deeper than 1000 m.

Presumably the smallest stages occur in the upper 150 m, and the few specimens taken during night or day at those depths probably had not yet moved to their permanent deeper habitat levels.

Evermannella balbo

Appendix 2 Tables 241-248

Distribution and Abundance.

This moderate-sized species was rare in our collections. Of the six specimens collected, three were taken at station 2, and one each at stations 3, 4, and 5.

Growth Stages and Reproductive Condition.

One of the specimens taken at station 2, and each of the specimens taken at stations 3, 4, and 5, were juveniles. Also at station 2, 1 postlarva and 1 subadult female (87 mm) were collected.

Vertical Distribution.

Two juveniles were taken during daytime, one (32 mm) at 200 m at station 3, the other (24 mm) between 700-500 m in an oblique sample at station 4. A third juvenile (21 mm) was taken at station 2 at 600 m in a 3-hour sample that ended shortly before sunset.

At night, a postlarva (15 mm) and a subadult (87 mm) were collected at 200 m at station 2, and a juvenile (44 mm) was taken at station 5 in an oblique sample between 325-250 m.

These catches suggest, if anything, that this species may occupy a wide vertical range during the daytime, and, perhaps, also at night.

		Subadult		Adult	
Postlarvae	Juveniles	Males	Females	Males	Females
2(7-10)	9(8-11)	1(13)	0	0	0
1(9)	6(9-11)	3(11-16)	2(17)	1(40)	0
2(7-9)	3(9-11)	3(23-28)	4(18-28)	0	3(31-45)
5(7-10)	18(8-11)	7(11-28)	6(17-28)	1(40)	3(31-45)

In addition, a 16 mm subadult (unsexable) was taken at station 1, and a 10 mm specimen of undetermined sex or stage at station 2. There was no overlap in sizes of subadult and adult females in our collections.

The stage composition of the specimens taken at the three stations suggests that E. rissoi spawns in the summer and fall, earliest at station 3, and progressively later to the west. The percentage composition of juveniles, subadults, and adults at each station are summarized in the following table.

	Percent of Total		
Station	Juvenile	Subadult	Adult
1	90	10	0
2	50	42	8
3	23	54	23

Only 1 or 2 postlarvae were captured at each of the three stations. The percentage of juveniles at each station increases from station 3 to station 1, while the percentages of subadults and adults decreases. The population at station 3, then, spawned earliest and a large proportion of individuals had progressed to the subadult and adult stages, while at station 1 almost all specimens were juveniles.

Vertical Distribution.

Daytime depths of occurrence at stations 1 and 3 were 150-200 m and 700-750 m with peak concentrations at 700-750 m; no specimens were taken during the day at station 2. Night depths of occurrence at stations 2 and 3 were 150-500 m with greatest abundance at 200 m; at stations 1 and 3, a few specimens were taken at 700-750 m.

Small postlarvae apparently remain at depths of 50-150 m. One of 7 mm was taken at station 1 at 150 m during the day, and another 7 mm specimen was taken at 50 m at dusk at station 3. A 9-mm postlarva was taken at 150 m at night at station 2.

Larger postlarvae (9-12 mm) move downward to inhabit a deeper layer at 700-750 m. Here they undergo transformation to the juvenile stage. They do not seem to migrate vertically, but these larger postlarvae were taken only during the day in the deep layer, while none were caught at night at any depth.

Vertical migration does not appear to begin until juvenile metamorphosis has been completed for a while. At stations 1 and 3 juveniles were small (mean size 8.7 and 9.0 mm, respectively) and were taken only at 700-750 m both night and day. (At station 3 a single 11 mm specimen was taken during the day at 200 m). Juveniles at station 2 were larger (mean size 11.7 mm) and were taken at 200 m at night; the 700-750 m depth was not sampled during the day.

The extent of vertical migration appears to become smaller as the individuals become larger. All juveniles taken in shallow

depths at night were from 200 m (station 2), and all subadults were also taken at 200 m at night (stations 2 and 3). Depth of capture of adults at night was deeper than for juveniles and subadults and progressively deeper with size of fish: two specimens 40-42 mm at 400 m, one specimen 45 mm at 500 m. The daytime depths of subadults and adults are assumed to be the same as those of juveniles (700-750 m) or a little deeper, although none was caught during the day.

Electrona rissoi

Appendix 2 Tables 249-259

Distribution and Abundance.

This small species was uncommon in our collections. It was taken at stations 1, 2, and 3, in about equal abundance at each station, and was not collected at stations 4 and 5.

Depths judged to be near those of maximum concentration of E. rissoi were sampled either day or night (or both) at stations 1, 2, and 3. The number of specimens caught per hour at these depths is as follows (dash indicates depth of maximum concentration not sampled).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	2.3	700	0.0	190
2	-	-	4.0	200
3	1.0	750	3.5	200

The lack of specimens taken at (or even near) 190 m at station 1 at night may reflect the growth stage composition of the population and will be discussed later.

Growth Stages and Reproductive Condition.

Juvenile and subadult stages predominate in our collections, with relative proportions varying widely among stations. The number of specimens of each stage, followed by size range (mm) in parentheses is as follows:

Hygophum hygomi

Appendix 2 Tables 260-275

Distribution and Abundance.

This moderate-sized species was present, but rare in our collections from stations 1, 2, 3, 4, and 5. The highest rate of capture in a discrete depth chamber was 3.0/hr.

Depths judged to be near those of maximum concentration of H. hygomi were sampled during the day at stations 1, 3, 4, and 5. The number of specimens caught per hour at these depths is as follows.

Station	Day No./hr.	Depth (m)
1	0.3	700
3	1.3	600
4	1.0	700
5	1.5	675

Growth Stages and Reproductive Condition.

Adults predominate in our collections (25 of 31 specimens) and most of the rest (5) are juveniles. The number of specimens of each stage, followed by size range (mm) in parentheses, is as follows.

Station	Postlarva	Juvenile	Adult Male	Adult Female
1	1(10)	2(13-13)	4(42-44)	1(47)
2	0	0	2(41-50)	2(48-53)
3	0	0	7(36-49)	2(54-58)
4	0	0	2(37-43)	0
5	0	3(11-21)	5(36-46)	0
1-5	1(10)	5(11-21)	20(36-50)	5(47-58)

The data indicate that H. hygomi is an annual with a pronounced spawning peak in the late summer and fall, and that there is sexual dimorphism in growth rates, with females growing faster and becoming larger than males. Six specimens (postlarvae and juveniles) are 10-21 mm long and 25 are 36-58 mm. None are 20-35 mm, leaving a considerable gap in size range.

All of the specimens 36-46 mm collected (18) are males. Of the remaining 7 fish, 47-58 mm, 2 are males and 5 are females. Taning (1918:55) presented a size frequency table for H. hygomi collected in the Mediterranean Sea in December, January, February, April, June, July and August. The sizes fall into two groups (all months combined): 60 specimens 11-24 mm and 5 specimens, all males, 37-46 mm. In our collections, all specimens in the 37-46 mm size range are also males, and we similarly find a lack of individuals 25-35 mm long.

The gap probably reflects the situation in the population. In the late summer and fall, most individuals are adult and spawning, or getting ready to spawn. They will probably spawn over a relatively short period and die soon after spawning. The population of H. hygomi in winter will consist predominantly of young individuals. Data presented by Taning (1918) are sufficient to show an increase in size from January (12-17 mm) to April (15-24 mm).

Vertical Distribution.

Daytime depths of occurrence of 9 adults and one juvenile at stations 1, 3, 4, and 5, were 600-750 m, with highest

concentrations apparently at 600 m. At station 2, no strictly daytime samples were taken between 400 m and 800 m during the day and no H. hygomi were collected, but a 3-hour sample at 600 m ending shortly before sunset caught one adult.

Adults and juveniles migrate at night into the upper water layers. Night depths of occurrence of 1 postlarva, 4 juveniles and 6 adults at stations 1, 3, and 5 were from the surface to 235 m, with peak concentrations at 0-80 m. At station 2, one adult was taken in a dawn sample at 25 m and two adults in a dusk sample at 15 m. No night samples were taken at station 4. The single postlarva was taken at 70 m and all adults were caught from the surface to 80 m. Of the 4 juveniles, one was taken at the surface, one at 70 m, and two at 235 m. No specimens were collected deeper than 235 m.

Hygophum benoiti

Appendix 3 Tables 276-290

Distribution and Abundance.

This small species was one of the most abundant in our collections. It was taken at stations 1, 2, 3, and 4, was most abundant at station 2, moderately abundant at stations 1 and 4, and uncommon at station 3.

Depths judged to be near those of maximum concentration of H. benoiti were sampled during the day at each of the four positive stations. The number of specimens caught per hour at these depths was as follows (dash indicates depth of maximum concentration not sampled).

Station	Day-Shallow No./hr.	Depth (m)	Day-Deep No./hr.	Depth (m)
1	17.8	700	12.0	940
2	42.5	800	50.0	1000
3	0.5	750	0.7	1000
4	21.0	700	-	-

The catch rate at station 3 at night was also very low, with a maximum of 2.3/hr. at 750 m.

Growth Stages and Reproductive Condition.

Juveniles of H. benoiti predominate in our collections (411 of 615 staged specimens). The number of specimens of each stage, followed by size range (mm) in parentheses is as follows.

		Subadult		Adult	
Postlarva	Juvenile	Male	Female	Male	Female
77(5-11)	109(9-21)	11(17-29)	13(17-31)	15(34-44)	13(33-44)
36(7-10)	264(9-16)	0	1(25)	2(36-40)	1(44)
1(10)	16(11-20)	9(19-27)	8(19-28)	0	1(35)
0	22(12-17)	10(16-26)	6(17-28)	0	0
114(5-11)	411(9-21)	30(16-29)	28(17-31)	17(34-44)	15(33-44)

In addition, one specimen (21 mm long) of undetermined sex or stage was collected at station 3. The smallest adult female in our collections is 33 mm and the largest subadult female is 31 mm. Males are about the same size as females.

The large numbers of juveniles, moderate numbers of postlarvae, and relatively small numbers of other stages suggest that spawning reaches a peak in the spring and summer, then tapers off and remains at a low level at other times of the year. The adults are probably one year old and probably die soon after spawning. The small number of intermediate-sized specimens, in the large subadult-small adult range, also suggests a one-year life cycle. Of the 616 specimens collected, only 21 are between 25 and 37 mm, a 13 mm range, while 25 are 38-44 m, a 7 mm range. At station 1, the gap is most pronounced; only 8 of the 238 specimens are between 25 and 37 mm, while 23 are 38-44 mm. Taning (1918) reported that his data indicated H. benoiti spawned in the spring, summer and autumn months in the Mediterranean.

The spawning period is apparently earliest at the eastern stations and gradually later to the westward. Approximately equal numbers of juveniles and subadults and lack of postlarvae and adults at stations 3 and 4 indicates that spawning was well

past, that adults had died, and that most of the new year-class had reached the juvenile or subadult stage. At station 2, spawning had been completed and adults had died, but the largest specimens of the new year-class had reached only the juvenile stage. At station 1 spawning was probably still in progress; only at this station were large subadults and adults abundant, while postlarvae formed a larger proportion of the new year-class than at station 2.

Vertical Distribution.

Daytime depths of occurrence at stations 1, 2, 3, and 4, were 100-1000 m with peak concentrations at 700-1000 m. Night depths of occurrence at stations 1 and 3 were 40-400 m and 700-750 m without well defined depths of greatest abundance, and at station 2, 12-100 m and 800-1000 m with greatest abundance at 800 m. At station 4, no samples were taken at night.

At night, H. benoiti was caught between 12-400 m at low to moderate rates (0.3-11.0/hr.) and in deeper layers at a high rate at station 2 (36.9/hr. at 800 m) and lower rates at stations 1 and 3 (6.0/hr. at 700 m and 2.3/hr. at 1000 m, respectively); no night samples were taken at station 4.

Smaller postlarvae (mostly 5-9 mm) occurred at shallow depths both night and day, while larger ones (mostly 9-11 mm) had migrated to greater depths where they remained without migrating vertically. Stations 1 and 2 provided all of the shallow discrete-depth postlarval specimens. Shallow depths occupied by postlarvae at night were 70-235 m at station 1 and 45-100 m at station 2. An hour's sampling at sunset at 25 m at

station 1 produced 22 specimens 5-7 mm long. The only postlarvae taken at shallow levels during the day were from 100 m at station 2 (1.5/hr.). At deeper levels, they were taken at 700-800 m both day and night at stations 1 and 2, and the single postlarva caught at station 3 was from 750 m at night.

That the smaller postlarvae occur at shallow depths and larger ones at greater depths is shown best by two non-discrete samples, both from station 2. One made at night at station 2 for one hour at 45 m plus 8 minutes retrieval time took a total of 88 specimens, all 6-9 mm long. One made during the day at station 2 for two hours at 1000 m and 52 minutes retrieval time took 130 specimens 9-11 mm long, together with many others 11-28 mm.

Juveniles predominated in all discrete depth collections and exhibited marked diel vertical migration. During the day they occurred in about equal concentrations at 700-800 m and at 940-1000 m at each of the stations (1, 2, and 3), although catch rates among stations differed considerably. The following table summarizes these data.

Station	Catch Rate for Juveniles (no./hr.) 700-800 m	940-1000 m
1	10.3	12.0
2	41.5	50.0
3	0.0	0.5

At station 4, a sample at 700 m caught juveniles at the rate of 11.0/hr., comparable to the catch rate at the same depth at station 1, but no samples were made below 700 m. Small numbers of juveniles were taken during the day at 235 m (station 1),

300 m (station 2), and 500 m (station 1).

At night some juveniles remained at their daytime depths while others migrated to shallower levels. There was no evidence that migratory or non-migratory behavior was related to size. The upper levels to which juveniles migrate are not clearly defined. They were taken at 40-235 m at station 1 and 12-45 m at station 2. At station 3, a single specimen was taken at night, at 300 m, but more than 30 were taken in an oblique sample from 25-0 m.

Subadults and adults apparently have vertical distributions and diel migratory behavior similar to those of juveniles, but too few specimens were caught to say this positively.

This species, at night, is probably occurring at a higher density in the shallow layer than is indicated by the night samples. A night tow at 40 m at station 1 caught 4.0/hr. in the first chamber of the sampler, while the succeeding chambers in the transition period, caught 10.0/hr. and 30.0/hr. The latter rate of capture far exceeds those of any other samples in the upper layers and approaches the maximum rate in the deep layer (36.9/hr. at station 2).

Evidence of patchiness is found in our data, and this renders quantitative aspects tentative. As an example, the tow at 800 m at night at station 2, collected 110 juveniles and 1 postlarva at an average rate (for the 3 chambers) of 36.9/hr. The rates for each chamber individually were:

Chamber	No./hr.
A	6.8
B	10.0
C	94.0

At station 3, where H. benoiti was uncommon in discrete-depth samples, a 6-minute oblique sample from 25-0 m at dusk took 57 specimens, more than the combined number taken in all other discrete and non-discrete samples at that station.

Another disturbing factor is that only 5 of the 32 adults taken in discrete-depth samples were taken during the night or day. The remaining 27 were caught during the transition periods. Furthermore, at station 1, the only station where adults were abundant, non-discrete samples with an oblique depth-to-surface component, took 103 adults and only 68 of all other stages. It would seem as if something in the behavior of adult H. benoiti enables them to avoid the net except during the periods when they are migrating vertically or when the net is being retrieved.

Benthosema glaciale

Appendix 3 Tables 291-305

Distribution and Abundance.

This small species was one of the most abundant in our collections. It was taken at stations 1, 2, 3, and 4, was most abundant at stations 1 and 2, moderately abundant at station 3 and uncommon at station 4.

Depths judged to be near those of maximum concentration of B. glaciale were sampled either day or night (or both) at stations 1, 2, 3, and 4. The number of specimens caught per hour at these depths is as follows (dash indicates depth of maximum concentration not sampled).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	168.0	500	50.0	70
2	-		84.5	45
3	2.3	600	11.1	50
4	2.0	700	-	

The night samples indicate B. glaciale may have been more abundant at station 2 than at station 1. No day samples were made at station 2 between 400 m and 800 m that could have been compared with day samples from stations 1, 3, and 4.

Growth Stages and Reproductive Condition.

Juvenile and subadult stages predominate in our collections (826 of 876 staged specimens). Relatively few adults and only

11 postlarvae were taken. The number of specimens of each stage, followed by size range (mm) in parentheses, is as follows:

		Subadult		Adult	
Postlarva	Juvenile	Male	Female	Male	Female
11(8-11)	361(10-23)	29(16-31)	165(16-35)	9(32-36)	7(31-37)
0	70(12-20)	74(14-30)	85(17-35)	19(32-41)	3(32-36)
0	23(17-23)	3(20-22)	10(19-28)	0	0
0	1(21)	3(21-22)	2(22-22)	0	0
11(8-11)	455(10-23)	109(14-31)	262(16-35)	28(32-41)	10(31-37)

In addition, one unsexable adult, 40 mm long, was collected at station 2, and four specimens (17-30 mm) of undetermined sex and stage were taken at station 1, and two (20-21 mm) at station 2. The smallest adult females in our collections are 31 mm, and all females over 35 mm are adult. The broad overlap in sizes of large subadult females and adult females (based on egg sizes) and the small number of adults indicates a postspawning condition. Spawning probably peaks in the late spring and summer, after which the adults die.

At station 2, the principal spawning period appears to have been earlier than at station 1. At station 1, most specimens caught were juveniles and a few postlarvae were collected. More subadults than juveniles and no postlarvae were collected at station 2. The subadult females were also slightly larger at station 2: 20.7 mm at station 1 (165 specimens) and 21.5 mm at station 2 (85 specimens). An east to west progression in spawning time is further indicated by the minimum sizes of juveniles caught, as shown in the following table.

Station	Minimum Size of Juveniles (mm)
1	10
2	12
3	17
4	21

Vertical Distribution.

Daytime depths of occurrence were 375-800 m (2 specimens at 100 m at station 2) with peak concentrations at 500-700 m. Night depths of occurrence were from 12 to 200 m and 600-800 m, with peak concentrations at 70 m at station 1 and 45-50 m at stations 2 and 3; no samples were taken at night at station 4. No specimens were collected at station 5.

A degree of size stratification during the day is indicated by the data.

At station 1, specimens captured during the day at 500 m are juveniles (108.0/hr.) and subadults (59.5/hr.) with a size range of 12-27 mm. Of these, more than 95% are between 13 and 21 mm. At 700 m, specimens captured range from 9 to 37 mm; all stages, including adults and postlarvae, are represented and no size group predominates. Specimens taken during the day at station 2 (800 m) are subadults and adults; no samples were made between 400 and 800 m. At stations 3 (600 m) and 4 (700 m), juveniles and subadults were taken with neither stage predominating. At stations 3 and 4, shallower tows, comparable to the 500 m sample at station 1, did not catch any B. glaciale. Adults appear to inhabit the 700-800 m layer, together with all other stages, but not the 500-600 m layer, where most of the juveniles and subadults were found.

At night, this species migrated up to higher levels at stations 2 and 3 than at station 1, and at each of the three stations a deep, non-migrating component was present at night. The highest rate of capture at station 1 was at 70 m (50.0/hr.), while at stations 2 and 3 the highest rates were shallower, at 45 m (84.5/hr.) and 50 m (11.1/hr.), respectively. The sample from 40 m at station 1, in contrast, caught 1 specimen (1.0/hr.).

The vertical distribution of B. glaciale at night in the upper layers does not appear to be marked by size stratification. Each of the stages present in our collections was most concentrated at the same level at each station, with smaller numbers taken at other depths. The deeper layer, however, appears to be marked by size stratification at night similar to that in the daytime. At stations 2 and 3, the few specimens taken at 600 m were smaller than 23 mm, while those taken at 800 m and 750 m were longer than 23 mm. At station 1, specimens taken at 700 m were 9-36 mm with no size groups predominating.

The deep layer at night was composed of juveniles, subadults, and adults that did not migrate (plus postlarvae at station 1). Each of the three stages was represented in the shallow layers at concentrations that were usually much greater than those in the deep layer (adults at station 1 were present at about equal concentration in the two layers).

Diogenichthys atlanticus

One postlarva, 12 mm, was taken at station 1 at 700 m between 1340-1441 hrs. This species, widespread in the Atlantic, presumably occurs in the Mediterranean only as a rare transient. It has not previously been recorded from the Mediterranean.

Myctophum punctatum

Appendix 3 Tables 306-317

Distribution and Abundance.

This moderate-sized species occurred at stations 1, 2, and 3, was probably most abundant at station 1, and progressively less abundant to the east at stations 2 and 3. It was the most abundant species in our surface (neuston) samples from stations 2 and 3.

Depths below the surface judged to be near those of maximum concentration of M. punctatum were sampled both day and night at stations 1, 2, and 3. The number of specimens caught per hour at these depths is as follows.

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	7.0	700	28.0	40
2	1.0	800	6.0	45
3	1.0	750	0.0	50

Growth Stages and Reproductive Condition.

Most of the specimens collected were subadults (257 of 348 staged specimens); juveniles (81 specimens) and postlarvae (10 specimens) made up the remainder of the staged specimens. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

		Subadult			
Postlarva	Juvenile	Male	Female	Unsexed	Undesignated
8(10-15)	38(15-23)	36(20-50)	40(20-50)	2(28-34)	2(22-25)
0	33(15-24)	49(22-65)	62(21-64)	2(36-50)	1(24)
2(8-11)	10(17-27)	29(25-47)	33(24-44)	4(29-37)	2(23-26)
10(8-15)	81(15-27)	114(20-65)	135(20-64)	8(28-50)	5(22-26)

Subadult males and females were about the same size. None of the females had eggs large enough to indicate maturity, although Taning (1918) reported females 51, 52, and 61 mm as mature.

The large number of subadults may have resulted from a period of maximum spawning intensity in the winter or spring. The presence of moderate numbers of juveniles and a few postlarvae suggests that spawning continued at a low level through the summer. Taning (1918) reported peak concentrations of M. punctatum postlarvae in the Mediterranean in June.

Vertical Distribution.

Daytime depths of occurrence at stations 1, 2, and 3, were 100-150 m and 700-1000 m with peak concentrations at 700-800 m. Night depths of occurrence at stations 1, 2, and 3 were from the surface to 190 m, and at stations 1 and 2 a few were caught at 700-800 m. Greatest abundance was at the surface at all 3 stations (assumed for station 1) with a secondary peak at 40-45 m at stations 1 and 2.

Postlarvae occurred at 70-150 m day and night. The only postlarva collected during the day came from 100 m (8 mm, station 3). Postlarvae were taken at night at station 1 at 70 m (1.0/hr.) and 150 m (1.7/hr.).

Most juveniles and subadults were taken at 700-800 m during the day (25 of 30 specimens). The 5 specimens caught outside of the 700-800 m interval do not suggest size or stage stratification with depth.

At night, stage stratification with depth is not indicated by the data, but size stratification is suggested, with smaller individuals living deeper. The following table lists the maximum sizes of subadults at stations 1 and 2 at each depth positive for subadults at night.

Maximum size of subadults

Station 1		Station 2	
Depth (m)	Size (mm)	Depth (m)	Size (mm)
25	30(1 specimen)	surface	65
40	44	12	32(1 specimen)
70	33(1 specimen)	45	51
100	30	150	48
700	21	800	24

The depth interval between the surface and about 40 m appears to be sparsely populated with M. punctatum compared with the 40-45 m interval, where 16 specimens were taken at station 1 and 7 at station 2 (no subadults were caught at 50 m at station 3), and the surface, where 116 specimens were taken in 24 neuston samples at station 2, and 70 in 58 samples at station 3. No subadults were taken below the surface at station 3. The single subadult at 25 m at station 1 and the one at 12 m at station 2 were both considerably smaller than the maximum size of those living deeper or shallower (at least at station 2).

At night, juveniles of M. punctatum were distributed in a pattern similar to that of the subadults, with peak concentrations

at the surface and at 40-45 m, and with smaller numbers taken at other depths.

Symbolophorus veranyi

Appendix 3 Tables 318-329

Distribution and Abundance.

This large species was relatively uncommon in our collections. It was most abundant at station 2 and uncommon at stations 1 and 3; it was not taken at stations 4 and 5. The maximum catch rate at station 1 was 2.0/hr. (40 m at night), and at station 3, 1.0/hr. (100 m at night), while at station 2, the maximum rate was 7.5/hr. (at 45 m at night).

Growth Stages and Reproductive Condition.

About half of our specimens of this species were subadults, followed in order of dominance by postlarvae, juveniles, and adults. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

		Subadult		Adult	
Postlarva	Juvenile	Male	Female	Male	Female
0	3(20-22)	0	2(50-64)	0	0
15(6-14)	7(22-28)	20(29-78)	8(42-75)	4(81-96)	3(84-114)
5(9-10)	3(23-31)	3(66-78)	0	0	0
20(6-14)	13(20-31)	23(29-78)	10(42-75)	4(81-96)	3(84-114)

There was no overlap in sizes of subadult and adult females in our collections. Males were about the same size as females.

Our data on size at maturity coincide well with data presented by Taning (1918), who recorded an 82 mm female, collected in August, with numerous large eggs (0.38 mm), and another, 87 mm collected in January, that had eggs 0.25 mm, but also contained numerous smaller eggs.

Spawning evidently takes place in the summer, at least at a low level. No period of maximum spawning intensity is suggested by our data; the large number of subadults compared to juveniles is a reflection of the larger size range of subadults: 29-78 mm (a 49 mm range) as compared to 20-31 mm (11 mm range) for juveniles. The size frequency distribution for specimens collected at station 2 does not have even weak peaks, but shows a rather even, although intermittent, distribution. This appears to confirm data presented by Taning (1918) for postlarval Mediterranean S. veranyi suggesting that spawning occurs at a low level during most of the year. The following table summarizes his table of size frequencies for three seasons of the year, and includes the average number caught per hour of trawling, calculated on the basis of all trawls positive for S. veranyi.

Size Interval (mm)	No. of Specimens Dec. - Feb.	June - July	Aug. - Sept.
15-20	5	1	1
10-15	27	26	14
7-10	41	59	17
7	1	7	1
Total Number	74	93	33
No./Hour	3.1	7.0	4.7

Catch rates were similar, and low, at each of the seasons represented. Our catch rate of 5.0/hr. at 45 m at station 2 compares well with the rate of 4.7/nr. for Aug. - Sept. calculated from Taning's data.

Vertical Distribution.

Daytime depths of occurrence were at 100 m at station 3 and 700-800 m at stations 1 and 2. Night depths of occurrence were at 40 m at station 1, and from the surface to 150 m at stations 2 and 3, with peak abundances at station 2 at the surface and at 45 m and no well-defined depth of greatest concentration at station 3. No specimens were captured at stations 4 and 5.

Postlarvae were taken during the day only at 100 m at station 3. At night they were taken only at station 2, at 45 m and 150 m. They apparently inhabit these shallow depths at all times, migrating downward to deeper levels either before or shortly after metamorphosis. Diel migratory behavior appears to begin with the juvenile stage.

Juveniles, subadults, and adults occupy deeper depths during the day. Three juveniles (1.0/hr.) were taken during the day at 700 m at station 1 and one subadult (0.5/hr.) at 800 m at station 2. No adults were taken during the day. The very small daytime catches, particularly at station 2, suggest that the depth of maximum abundance of S. veranyi juveniles through adults was not sampled. This species is either living deeper than 1000 m during the day (our maximum sampling depth), is concentrated within a relatively narrow depth interval that we did not sample, or is avoiding the net.

Size and stage stratification with depth is evident at night with small subadults being deeper than large subadults and adults;

juveniles were not concentrated at any depth. At station 2, subadults were caught at 2.5/hr. at 45 m and at the surface in neuston tows at 1.4/hr; a single specimen was captured at 12 m (0.7/hr.). Subadults taken at 45 m were 37-47 mm long, those at the surface 49-78 mm. The subadult from 12 m was 29 mm long, only slightly larger than juveniles; the smallest subadults may behave as the juveniles, which were scattered between the surface and 100 m. Of the six adults captured, five were taken at the surface and one at 150 m.

Gonichthys cocco

Appendix 3 Tables 330-339

Distribution and Abundance.

This small species was the most abundant lanternfish taken in the eastern Mediterranean, and occurred only rarely in the western Mediterranean. It was taken in small numbers by trawls at stations 3, 4, and 5 and was abundant in surface (neuston) samples taken at station 5 (48.8/hr.), rare in those taken at station 3 (0.1/hr.). No neuston tows were made at station 4. The highest catch rate for any IKMT sample was 2.0/hr. at 80 m at station 5.

Growth Stages and Reproductive Condition.

Subadult and juvenile stages of G. cocco predominated in our collections (244 and 156 respectively of 401 specimens). One postlarva was taken and no adults. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

Station	Postlarva	Juvenile	Subadult Male	Subadult Female
3	0	1(28)	0	1(38)
4	0	1(14)	0	0
5	1(10)	154(14-28)	118(19-37)	125(19-39)
3-5	1(10)	156(14-28)	118(19-37)	126(19-39)

None of the specimens were adults (as based on egg sizes). Males were about the same size as females.

The large number of juveniles and of subadults only slightly larger than the juveniles, together with the small number of postlarvae, suggest that this species spawns in the spring and early summer in the eastern Mediterranean and that adults probably die soon after spawning. At station 5, of the 154 juveniles captured, 97% were 16-19 mm, while of the 243 subadults, 87% were 19-22 mm. The species presumably does not spawn in the western Mediterranean.

Vertical Distribution.

Daytime depths of occurrence at stations 4 and 5, were 500-675 m; no specimens were taken during the day at station 3. Night depths of occurrence at stations 3 and 5 were from the surface to 135 m; no night samples were taken at station 4.

During the day, a juvenile, 14 mm, was captured at 500 m at station 4, and 2 subadults, 29 and 38 mm, were captured at 675 m at station 5.

At night, two subadults, 28 and 38 mm, were captured in surface neuston tows at station 3. At station 5, 391 of the 394 specimens taken at night were captured in neuston tows; the single postlarva and a subadult (24 mm) were taken at 80 m and a juvenile (16 mm) at 135 m.

Lobianchia dofleini

Appendix 3 Tables 340-357

Distribution and Abundance.

This small species was one of the most abundant in our collections. It was taken at all five stations, was most abundant at station 1, moderately abundant at stations 2 and 4, and uncommon at stations 3 and 5.

Depths judged to be near those of maximum concentration of L. dofleini were sampled either day or night (or both) at all stations. The number of specimens caught per hour at these depths is as follows (dash indicates depth of maximum concentration not sampled).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	26.5	500	61.0	70
2	-		12.5	45
3	1.7	500	2.3	150
4	17.0	500	-	
5	0	495	2.0	80

Clearly, L. dofleini was most abundant at station 1. The day catch rate at station 4 exceeds the night rate at station 2, indicating that this species was more abundant at station 4 than at station 2. Abundances at stations 3 and 5 were very low.

Growth Stages and Reproductive Condition.

Adult and subadult stages of L. dofleini predominated in our collections (375 of 421 specimens). Few juveniles and only one

postlarva were present. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

			Subadult		Adult	
a.	Postlarva	Juvenile	Male	Female	Male	Female
	0(	27(12-20)	85(18-26)	80(15-28)	70(27-38)	57(27-42)
	1(16)	9(10-16)	18(17-26)	4(23-27)	3(32-35)	4(29-39)
	1(7)	5(12-16)	5(16-26)	11(17-28)	6(30-35)	5(33-38)
	0	3(15-18)	10(18-26)	12(16-28)	1(27)	0
	0	0	3(23-25)	0	1(27)	0
5	2(7-16)	44(10-20)	121(16-26)	107(15-28)	81(27-38)	66(27-42)

In addition, one unsexable subadult, 25 mm long, was collected at station 1. The smallest adult females in our collections were 27 mm long, and all females longer than 28 mm were adult. Males were about the same size as females. The largest specimen was 42 mm.

The small numbers of postlarvae and juveniles and large numbers of subadults and adults suggest that spawning is at a low level during the summer. Taning (1918) reported that L. dofleini in the Mediterranean spawns mainly from February to June, with lower levels of spawning during the rest of the year. By late August - early September, then, the population is composed primarily of mature and maturing individuals.

Vertical Distribution.

Daytime depths of occurrence at stations 1, 2, 3, and 4 were 375-600 m with peak concentrations at 375-500 m; no specimens were taken during the day at station 5. Night depths of occurrence at station 2 were 45-400 m with greatest abundance at 45-100 m and at stations 1, 3, and 5, from 27 to 300 m, with peak concentrations

at 70-150 m. At station 4, no samples were taken at night.

Size stratification with depth is apparent during daytime, with medium-sized individuals predominant at shallower depths, and all sizes present at deeper levels. At station 1, specimens captured at 375 m were 17-33 mm, while specimens taken at 500 m were 12-42 mm and include all sizes represented at 375 m. The catch rate at 500 m was more than 3 times that at 375 m (26.5/hr. vs. 8.3/hr.), the higher rate being attributable mostly to adults, which were taken at 500 m at a rate more than 6 times that at 375 m (13.0 vs. 2.0). Juveniles were taken at 3 times the shallower rate (3.0 vs. 1.0), and subadults at only about 2 times the shallower rate (10.5 vs. 5.3). At stations 2, 3, and 4, the data are too sparse to allow observations on size differences with depth and at station 5, no specimens were collected.

This species migrated up to higher levels at night at station 2 than at stations 1, 3, or 5. The highest rate of capture at station 2 was at 45 m (12.5/hr.), while in samples from similar depths at station 1 (40 m), 3 (50 m), and 5 (50 m), catches were negative (stations 1 and 5) or neglibible (0.9/hr. at station 3). This depth was in the middle of the thermocline at station 2. At stations 1 and 3, L. dofleini concentrated at depths of 70 m and 100 m respectively, both depths below the bottom of the thermocline.

The vertical distribution of L. dofleini at night is also marked by size stratification. At stations 1, 2, and 3, adults larger than 33 mm were taken from 50 m to 355 m deeper than the

peak concentrations of juveniles, subadults, and adults smaller than 34 mm. The mean sizes of adults captured at night increases with depth as indicated in the following table.

Depths Sampled (m)	Mean Sizes of Adults Station 1	Station 2	Station 3
45		29.0	
70	28.7		
100		29.0	33.0
150	31.7	32.0	34.6
190	35.0		
200		39.0	

Two adults were captured below 200 m; one, 35 mm at 400 m at station 2, and one, 30 mm at 300 m at station 3. At station 5, only 2 specimens (subadults) were taken, and no night samples were taken at station 4.

Diaphus rafinesquei

Appendix 3 Tables 358-376

Distribution and Abundance.

This moderate-sized species was uncommon at all stations, and most abundant at station 1.

Depths judged to be near those of maximum concentration were sampled during the day at stations 1, 3, 4, and 5. The number of specimens caught per hour at these depths was as follows.

Station	Day No./hr. - Depth (m)	
1	6.5	500
3	2.3	500 and 600
4	2.0	500
5	1.5	675

The maximum catch rate at station 2 was 2.0/hr. at 45 m at night; no day samples were taken between 400 and 800 m, but a 3-hour sample from 1512-1818 hours at 600 m caught 6 specimens, indicating a depth of maximum daytime concentration similar to that at the other stations.

Growth Stages and Reproductive Condition.

Adult and subadult stages predominated in our collections (45 and 50, respectively of 100 specimens). Three postlarvae and two juveniles were collected. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

ta.	Postlarvae	Juveniles	Subadult Males	Subadult Females	Adult Males	Adult Females
1	0	0	9(34-46)	3(32-41)	1(58)	7(57-64)
2	0	0	17(34-52)	0	0	1(70)
3	0	2(13-14)	10(32-44)	8(27-45)	9(53-69)	23(54-78)
4	1(11)	0	1(40)	0	0	1(59)
5	2(11-11)	0	0	2(32-46)	1(60)	2(66-74)
-5	3(11-11)	2(13-14)	37(32-52)	13(27-46)	11(53-69)	34(54-78)

The advanced stage of development (and large size) of most of the specimens indicates that spawning occurs primarily during the fall and winter and is at a very low level during the summer. Data presented by Taning (1918) indicated that postlarvae and juveniles enter the population in December, and no recruitment seems to take place between January and September.

Vertical Distribution.

Daytime depths of occurrence were 400-675 m with peak concentrations at 500-675 m. Night depths of occurrence at stations 1, 2, 3, and 5 were from the surface to 600 m, with subadults occupying mainly the 45-200 m depth interval, and adults the 300-600 m interval; no night samples were taken at station 4.

During the day at stations 1, 2, 4, and 5, all specimens captured at each station were taken at one depth: 500 m at stations 1 and 4, 400 m at station 2, and 675 m at station 5. At station 3, at 500 m, subadults and adults were taken in about equal abundances (1.3/hr. and 1.0/hr., respectively), while at 600 m, only adults were taken and at a higher rate (2.3/hr.) than at 500 m, suggesting stage stratification with depth. Approximately equal concentrations

of subadults and adults at 500 m were also noted at stations 1 and 4. The catch rates at 500 m for these 3 stations are as follows.

Station	Day - 500 m (No./hr.) Subadult	Adult
1	3.0	3.5
3	1.3	1.0
4	1.0	1.0

No specimens were taken at 500 m at station 5.

The night depths of distribution indicate strong stage and size stratification with depth in this species. Of the 20 subadults collected, only 3 were caught below 200 m; and of the 21 adults, only 3 were taken above 300 m (1 of them in a surface sample).

Among subadults, the depths reached at night are increasingly less shallow as the individuals increase in size. At station 2, subadults taken at 45 m were 34-37 mm long, at 100 m a 38 mm specimen was taken, and at 200 m subadults were 39-47 mm. At station 3, subadults caught at 50 m were 32-39 mm, at 100 m 1 specimen 37 mm long was taken, and at 150 m a 45 mm subadult was collected. Subadults of D. rafinesquei apparently do not migrate to as high a level at station 1 as they do at stations 2 and 3.

At stations 2 and 3, subadults were most abundant at night at 45 m (2.0/hr.) and 50 m (3.7/hr.), respectively, but at station 1, samples made at 27 m, 40 m, 70 m, and 150 m were all negative. Indeed, 2 of the 3 subadults taken below 200 m

were caught at station 1, and the only other subadult collected at station 1 came from 190 m. No night samples were taken at station 4, and no subadults were collected at station 5.

The level reached at night by adults also becomes less shallow with size until the largest apparently do not migrate vertically. Adults were taken at night at stations 1 (1 at 400 m), 3 (18 at 0-600 m), and 5 (2 at 510 m). At station 3, size stratification with depth is quite evident. The following table summarizes this trend.

Depth (m)	No. Males	Size mm	No. Females	Size mm Mean	Range
0	1	53			
150	1	53			
200	1	63			
300	1	61	3	60.0	54-69
400			7	60.1	56-74
500			1	70.0	70
600	1	69	1	76.0	76

These data from station 3 suggest also that adult males occur shallower than adult females at night. Of the 5 adult males, 4 were taken at or shallower than 300 m, while all 13 females were taken at or deeper than 300 m.

Diaphus holti

Appendix 3 Tables 377-395

Distribution and Abundance.

This moderate-sized species was uncommon at stations 1 and 5, and rare at stations 2, 3, and 4.

Depths judged to be near those of maximum concentration of D. holti were sampled either day or night (or both) at all stations. The number of specimens caught per hour at these depths was as follows (dash indicates depth of maximum concentration not sampled).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	2.5	500	9.0	190
2	-		2.0	100
3	2.7	600	3.0	100
4	1.0	500	-	
5	1.0	675	9.0	155

The large day-night differences in catch rates at stations 1 and 5 may be related to ontogenetic changes in vertical distribution and will be discussed later.

Growth Stages and Reproductive Condition.

Adults and juveniles predominated and were of about equal abundance in our collections (54 and 45 respectively of 103 specimens). The other four specimens were postlarvae; no subadults were taken. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

ta.	Postlarva	Juvenile	Subadult	Adult Male	Adult Female
1	1(9)	9(12-14)	0	24(30-41)	25(30-42)
2	3(6-11)	1(12)	0	1(33)	1(35)
3	0	16(10-15)	0	3(33-39)	0
4	0	2(13-14)	0	0	0
5	0	17(11-17)	0	0	0
-5	4(6-11)	45(10-17)	0	28(30-41)	26(30-42)

The presence of juveniles and adults, together with the lack of subadults (no specimens 18-29 mm) suggests that spawning occurs in summer and that adults die soon after spawning.

An east to west progression in spawning times is indicated by the data. At station 1, adults were more abundant than juveniles; 49 adults to 9 juveniles. The juveniles had just begun to enter the population, while adults had not yet died and were still relatively common. At station 3, spawning had occurred earlier than at station 1; 16 juveniles and only 3 adults were taken. Most of the adults had died. Spawning occurred earliest at station 5; 17 juveniles and no adults were collected.

Data presented by Taning (1918) indicated that in August-September in the Mediterranean, D. holti were mostly postlarvae and juveniles. An increase in size through the winter was apparent, and by June, the population was composed almost exclusively of adults (31-40 mm).

Vertical Distribution.

Daytime depths of occurrence were 100-235 m, and 500-675 m with peak abundance at 500-675 m. Night depths of occurrence were 80-235 m and 400-600 m with greatest abundance at 100-200 m. At station 4, no samples were taken at night.

Two postlarvae were taken, both during daytime at 100 m at station 2. Probably the postlarvae occupy this and adjacent depths both day and night, until they approach metamorphosis, near which time they migrate to the deep layer.

Juveniles occurred in the deep layer (500-675 m) during the day. At night, the smaller juveniles remained at these depths (400-600 m) while the larger ones migrated into the shallow layer (80-235 m). The following table indicates this night size-depth relationship.

	Shallow		Deep	
ta.	No./hr.	Size range mm	No./hr.	Size range mm
1	0.3	13	0.7	12-13
3	2.0	11-15	0.3	10
5	5.0	12-16	1.0	11

It is possible that larger juveniles change their vertical migratory pattern by moving into the shallow layer, where they remain as subadults and adults. This is suggested by the capture during the day of a single large juvenile (17 mm, the largest juvenile in the collections) at 160 m at station 5 and of an adult (40 mm) at 235 m at station 1. No other adults were taken during the day, while all 30 adults taken at night were also in the shallow layer, at 100-190 m.

Diaphus metopoclampus

One specimen, an adult female 67 mm long, was taken in a non-discrete sample at station 3 from 500-0 m between 2030-2330 hrs. D. metopoclampus occurs in the northern North Atlantic, and is probably most abundant in the eastern North Atlantic (Nafpaktitis, 1968). It may occur in the Mediterranean only as a stray, although its presence as an adult in the Tyrrhenian Sea and the Strait of Messina (Mazzarelli, 1909) suggest that it could be a rare resident.

Lampanyctus crocodilus

Appendix 3 Tables 396-409

Distribution and Abundance.

This large species was moderately abundant to rare in our collections. It was taken at all five stations, was moderately abundant at stations 1 and 2, uncommon at station 3, and rare at stations 4 and 5.

Depths judged to be near those of maximum concentration of L. crocodilus were sampled day and night at stations 1, 2, and 3. The number of specimens caught per hour at these depths was as follows.

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	22.1	700	4.0	70
2	10.5	800	10.5	45
3	6.0	750	1.0	100

At station 4, one specimen was taken and at station 5, eight; all were taken in oblique or transitional period samples.

Growth Stages and Reproductive Condition.

Juveniles of L. crocodilus predominated in our collections (175 of 212 specimens). Most of the rest were postlarvae (24 specimens); 13 subadults and no adults were taken. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows:

Sta.	Postlarva	Juvenile	Subadult Male	Subadult Female
1	4(8-9)	80(13-75)	1(133)	1(125)
2	17(6-12)	56(17-73)	0	5(83-178)
3	3(8-8)	30(14-45)	4(79-129)	2(124-128)
4	0	1(20)	0	0
5	0	8(18-31)	0	0
1-5	24(6-12)	175(13-75)	5(79-133)	8(83-178)

The smallest subadult female is 83 mm long, and the largest female, 178 mm, is a subadult based on egg sizes. Males are about the same size as females.

The high proportion of juveniles, particularly of those in the 21-25 mm range, and relatively large numbers of postlarvae suggest that L. crocodilus spawns in the spring and summer. The large size of the species and the lack of dominant sizes in the subadult category indicate that this species lives more than 1 year, and probably lives several years.

Vertical Distribution.

Daytime depths of occurrence were 100-200 m and 700-1000 m, with peak concentrations at 700-800 m; no specimens were taken during the day at stations 4 and 5. Night depths of capture were 45-150 m and 400-1000 m, with greatest abundance at 45-100 m and a smaller secondary peak of abundance at 700-800 m; at station 4, no night samples were taken, and at station 5 no L. crocodilus were collected at night.

Postlarvae were taken only at night: at 150 m at station 1 and at 45 m and 150 m at station 2. Probably they inhabit similar shallow depths both day and night.

Beginning around the time of metamorphosis, L. crocodilus moves downward to deeper water. Small juveniles migrate at night to shallow depths, but large juveniles and subadults cease this diel vertical migration and remain at depth, although some of these large juveniles may move into the upper part of the deep layer at night. The following table gives the catch rates for juveniles and subadults (no./hr.) in the deep layers.

	700-800 m					
	Small Juveniles		Large Juveniles		Subadults	
Station	Day	Night	Day	Night	Day	Night
1	22.0	0.9	0	0.9	0.3	0.3
2	10.0	0.3	0.5	2.1	0	0.3
3	5.0	0.3	0.5	0.7	0.5	0.3
	940-1000 m					
1	0	-	0.6	-	0	-
2	0	0	1.0	0.3	1.0	0.9
3	0	-	0.4	-	0.2	-

Small juveniles (13-33 mm) occurred almost exclusively at 700-800 m during the day (96 of 103 specimens) and migrated into shallow layers at night. The seven specimens not taken at 700-800 m during the day were taken at 100-200 m; none were taken at 940-1000 m. At night, a few small juveniles remained at the daytime depth, but the striking differences between their day and night catch rates here indicate that most of them migrated. At shallower depths at night most were taken at 45-150 m, and they were most abundant at 45 m (station 2, 4.5/hr.) and 70 m (station 1, 4.0/hr.). A few were taken at 400-600 m.

Juveniles larger than 33 mm and subadults were caught during the day both at 700-800 m and 940-1000 m, where most of them

remained at night. Only 4 larger specimens were taken shallower than 700 m at night: 1 (36 mm) at 45 m and 1 (44 mm) at 100 m at station 2; 1 (79 mm) at 400 m and 1 (37 mm) at 600 m at station 3. The catch rate for large juveniles at 700-800 m is slightly higher at night than during the day, suggesting that some of those at 940-1000 m migrate into the 700-800 m layer at night. There is no evidence of migration in subadults.

Lampanyctus pusillus

Appendix 3 Tables 410-428

Distribution and Abundance.

This small myctophid was abundant in our collections. It was taken at all five stations, was most abundant at station 1 and moderately abundant at the other four stations.

Depths judged to be near those of maximum concentration of L. pusillus were sampled either day or night (or both) at all stations. The number of specimens caught per hour at these depths was as follows (dash indicates depth of maximum concentration not sampled).

Station	Day		Night	
	No./hr.	Depth (m)	No./hr.	Depth (m)
1	19.2	700	38.0	70
2	-		13.0	45
3	17.1	600	5.0	100
4	13.0	700	-	
5	2.0	675	17.0	80

The day catch rates for stations 1, 3, and 4 were similar, with the highest rate at station 1. The night catch rates at stations 2 and 5 were moderately high and similar to the day rates at stations 3 and 4. The highest catch rates, both day and night, occurred at station 1, and moderate rates occurred either day or night at the other four stations.

Growth Stages and Reproductive Condition.

Adults of L. pusillus were more numerous in our collections than subadults and juveniles, largely due to their abundance at

station 1, but the numbers of specimens of each stage were not widely divergent (171, 133, and 106 respectively). Only 2 postlarvae were collected. The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

			Subadult		Adult	
a.	Postlarva	Juvenile	Male	Female	Male	Female
	0	14(15-20)	36(22-32)	33(17-39)	32(33-38)	106(32-39)
	2(7-7)	11(13-22)	11(17-32)	10(18-32)	8(34-37)	7(32-39)
	0	51(15-22)	10(25-32)	6(20-29)	9(33-37)	5(32-37)
	0	14(16-22)	9(23-31)	7(23-26)	0	0
	0	16(16-21)	5(24-32)	6(23-38)	0	4(33-39)
5	2(7-7)	106(13-22)	71(17-32)	62(17-39)	49(33-38)	122(32-39)

Subadult females in our collections were 17-39 mm; adult females were 32-39 mm, overlapping the largest subadults. Our main criterion for distinguishing these two stages was development of large eggs; thus, maturation of eggs must occur rapidly in subadults that have reached near-maximum size. Large males were about the same size as large females.

Our data suggest that spawning occurs in the late summer and fall, and generally progresses chronologically from east to west in the Mediterranean.

The following table gives for stations 1, 2, 3, and 5 the percentage of the total catch represented by juveniles, subadults, and adults. Station 4 was inadequately sampled.

Station	Juvenile %	Subadult %	Adult %
1	6.3	31.2	62.4
2	23.4	44.7	31.9
3	63.0	19.8	17.3
5	51.6	35.5	12.9

The population at station 1 was probably at a spawning peak, with a majority of adults, many subadults, and few juveniles. At station 3, the spawning peak was probably past, with most adults having died and a large population of juveniles. Latitudinally between stations 1 and 3, station 2 produced fewer specimens than either 1 or 3, and the size-frequency distribution shows no peaks. This suggests that spawning has occurred, most adults have died, and few of the most recently produced age-class have reached the juvenile stage; thus the situation would be intermediate between stations 1 and 3. The population at station 5 was strongly skewed toward juveniles, but had a greater percent of subadults than adults, indicating an approach toward a future spawning peak that would be earlier than that at station 3.

Possible evidence for multiple spawning periods in L. pusillus is found in Taning's (1918) catch data for the Alboran and Balearic Seas during February, June and September, with August included in our data. In February (see above) a late spawning period was indicated by the presence of abundant juveniles and moderate numbers of subadults and adults. In June a declining period of spawning seems apparent from the presence of many adults and juveniles, but very few subadults. Our August data (see above) have been interpreted as showing a spawning peak. Taning's September data show almost no subadults, but both adults and juveniles common, again indicating the decline of spawning. At least three spawning periods are thus indicated by the combined data for the Balearic-Alboran region, the peaks occurring approximately in January, May, and August.

Vertical Distribution.

Daytime depths of occurrence were 500-1000 m (1 specimen was taken at 160 m) with peak concentrations at 600-700 m. Night depths of occurrence at station 2 were 45-150 m and 800 m with greatest abundance at 45-100 m, and at stations 1, 3, and 5 from 50-150 m and 325 m with peak concentrations at 70-100 m. At station 4, no samples were taken at night.

Stratification by size during the day was indicated by the combined catch data for all stations, although no single station was sampled adequately to show this. Juveniles were taken in greatest abundance at 600 m at station 3; this depth was not sampled at any other station. Lesser concentrations of juveniles were indicated at 500, 675, and 700 m at the other four stations. Adults and large subadults, on the other hand, were most abundant at 700 m (stations 1 and 4) and were taken in smaller numbers at 750, 800, 940, and 1000 m. The largest specimen taken shallower than 700 m was 27 mm.

Size stratification at night is not pronounced, but the data for stations 1 and 2 suggest that some large individuals do not migrate upward as far as the main body of the population. At station 1, all five specimens (1.7/hr.) taken at 150 m, 80 m below the depth of highest concentration, were adults larger than 34 mm (adults were caught at 70 m at a rate of 20.0/hr.). At station 2, 9 specimens out of 10 collected at 55 m to 105 m deeper than the depth of main concentration at 45 m were larger than 24 mm; 5(5.0/hr.) adults were taken at 100 m (adults were captured at 45 m at a rate of only 1.0/hr.).

At night, juvenile and subadult L. pusillus moved up to higher levels at station 2 than at stations 1, 3 or 5 (no night samples were obtained at station 4). The rate of capture at station 2 was highest at 45 m (13.0/hr.), while in samples from similar depths at stations 1 (40 m), 3 (50 m), and 5 (50 m), catches were negative (station 1) or negligible (0.9 at station 3, and 1.0 at station 5). This depth was in the middle of the thermocline at station 2. At stations 1 and 3, this species concentrated at depths of 70 m and 100 m respectively, both depths below the bottom of the thermocline.

Ceratoscopelus maderensis

Appendix 3 Tables 429-446

Distribution and Abundance.

This moderate-sized lanternfish was one of the most abundant in our collections. It was very abundant at stations 1, 2, 3, and 5, and moderately abundant at station 4.

Depths judged to be near those of maximum concentration of C. maderensis were sampled either day or night at all stations. The number of specimens caught per hour at these depths is shown in the table below.

Station	No./Hr.	Depth (m)	Diel Period
1	105.0	700	Day
2	94.1	12	Night
3	72.0	750	Day
4	10.0	700	Day
5	45.0	80	Night

The catch rate was very high at stations 1, 2, 3, and 5, as compared with the low catch rate at station 4; the rate at station 1 was more than ten times that at station 4 at the same depth (700 m) during the day.

Growth Stages and Reproductive Condition.

Juveniles predominated in our collections (1023 of 1188 staged specimens). The number of staged specimens followed by size range (mm) in parentheses was as follows.

ta.	Postlarva	Juvenile	Subadult Male	Subadult Female	Adult Male	Adult Female
1	26(6-15)	400(13-26)	0	0	63(39-50)	31(38-47)
2	9(8-15)	285(11-26)	0	0	7(42-68)	4(44-58)
3	8(12-16)	267(14-28)	3(27-29)	1(30)	1(58)	3(47-50)
4	0	14(18-20)	0	0	0	0
5	1(13)	57(18-27)	1(34)	2(28-29)	2(42-45)	3(50-56)
-5	44(6-16)	1023(11-28)	4(27-34)	3(28-30)	73(39-68)	41(38-58)

In addition, five specimens, 18-23 mm long, of undesignated sex and stage were taken at station 2, and two, 28-29 mm, at station 3. Of all specimens collected, only one individual was between the sizes of 30 and 38 mm. All specimens 38 mm and larger were adults. The preponderance of juveniles suggests that C. maderensis spawns in the spring and summer, while the lack of large subadults and/or small adults (31-37 mm) indicates a one-year life cycle, with adults dying in the fall and winter following spawning. Taning (1918) reported that C. maderensis in the Mediterranean spawned principally in the summer months, then died. He showed that the young increased in size during the winter months, and by June the population consisted almost entirely of adults.

Our data further indicate a difference in spawning times at the various localities. Spawning occurred earliest at station 5, where most of the adults had died by September; less than 2% of the postlarva-juvenile catch was made up of postlarvae, and a few of the young had progressed to the subadult stage. At the other extreme, spawning occurred latest at station 1, where many adults were still present, more than 6% of the postlarva-juvenile catch was made up of postlarvae, and none of the young

had progressed to the subadult stage. Stations 2 and 3 were intermediate between stations 1 and 5, with no subadults at station 2, and subadults present at station 3. The mean sizes of juveniles and subadults further substantiate an east-west trend in spawning time. The mean sizes increase from west to east (stations 1 to 5), as shown in the following table.

Station	Mean Sl (mm)
1	16.9
2	19.2
3	19.8
5	22.1

The 14 specimens collected at station 4 were all juveniles and did not fit into the pattern presented above.

Vertical Distribution.

Daytime depths of occurrence were 100-1000 m with peak concentrations at 700-800 m; no specimens were taken during the day at station 5. Night depths of occurrence were in two strata, 12-300 m with greatest abundance at 12-150 m, and 600-800 m with peak concentrations at 700-800 m. At station 4, no samples were taken at night, and at station 5, no samples were taken below 510 m.

Postlarvae were taken mostly either at shallow depths (12-80 m) or at 700-940 m. A few were caught at 150-400 m. The shallow depths were sampled only during the night except at station 3, where a daytime sample was made at 50 m and took no postlarvae.

Probably postlarvae inhabit the shallow stratum at all times during their early development, later moving prior to metamorphosis to the deep layers, where they were taken both day and night.

Juveniles were strongly concentrated during the day in the 700-800 m interval, with relatively few taken at other depths. At night, most of the juvenile population migrated into the upper 300 m. although part remained at the 700-800 m interval. The following table gives the day and night catch rates (no./hr.) for juveniles at 700-800 m at stations 1, 2, and 3.

	No./hr.	
Station (Depth)	Day	Night
1 (700 m)	103.7	11.0
2 (800 m)	18.0	3.3.
3 (750 m)	72.0	9.1

About 11-18% of the juveniles remained at depth while the rest migrated. At station 5, juveniles occurred in the upper 135 m, but no samples were made below 510 m, where more juveniles might have been expected. The migrating juveniles were larger than the non-migrants, 16-26 mm long, as opposed to 11-19 mm (one of 23 mm), for the non-migrants. The non-migrants were probably recently metamphosed individuals that must undergo further development before they begin diel vertical migrations.

The migrant juveniles at stations 1, 2, and 3 probably migrated into the upper 20 m, but did not reach the surface (all neuston samples were negative for C. maderensis).

The night depth of maximum concentration of migrating juvenile C. maderensis at stations 1, 2, and 3, was probably

approached only at station 2, where they were caught at the rate of 93.6/hr. at 12 m. At stations 1 and 3 no samples were taken above 25 m. The maximum catch rates for migrant juveniles at these stations were: 8.5/hr. at 25 m (station 1) and 1.8/hr. at 50 m (station 3). These rates were substantially lower than the maximum daytime rates of 103.7/hr. and 72.0/hr. respectively, indicating that the night depth of maximum concentration was not sampled.

No night samples were taken at station 4, but at station 5, migrant juveniles appeared not to reach depths as shallow at night as at stations 1, 2, and 3. Migrant juveniles at station 5 were caught at 8.0/hr. at 50 m, 36.0/hr. at 80 m, and 7.0/hr. at 135 m. At stations in the western Mediterranean, captures at similar depths below 50 m were negative for migrant juveniles (station 1, 70 m and 150 m; station 2, 100 m; station 3, 150 m), or at low rates (station 2, 150 m, 2.3/hr.; station 3, 100 m, 1.0/hr.).

Subadults were taken in the western Mediterranean only at station 3: one at 1000 m during the day, one at 300 m at night, and two in transitional period samples. All subadults collected in the eastern Mediterranean (3 specimens) were taken in a night sample at station 5, where they occurred at the depth of maximum concentration of migrating juveniles (80 m).

Adults were taken during the day at 940-1000 m at stations 1 and 3, but not at 700-750 m. At station 2, one adult was taken at 800 m, none at 1000 m. This suggests that adults

generally inhabit greater depths during the day than juveniles. At night, all adults had migrated into the upper 300 m. The following table gives the maximum catch rate for adults and the depth of this maximum rate.

Sta.	Depth (m)	No./hr.
1	70	10.0
2	45	4.5
3	50	3.6
5	80	5.0

At stations 1, 2, and 3 adults were concentrated below the depths of greatest juvenile abundance (12-25 m), while at station 5 adults and juveniles were most abundant at the same depth.

Notoscopelus kroyeri

Appendix 3 Tables 447-455

Distribution and Abundance.

This large species was of low to moderate abundance at stations 1, 2, and 3; none were taken at stations 4 and 5.

Depths judged to be near those of maximum concentration of N. kroyeri were sampled at night at stations 1, 2, and 3. The number of specimens caught per hour at these depths was as follows.

Station	Night No./hr.	Depth (m)
1	8.0	40
2	7.5	45
3	3.7	50

Growth Stages and Reproductive Condition.

Subadults predominated in our collections (53 of 69 staged specimens), followed in order of abundance by juveniles (10) and adults (6). The number of specimens of each stage, followed by size range (mm) in parentheses, was as follows.

		Subadult			Adult	
Sta.	Juvenile	Male	Female	Unsexed	Male	Female
1	6(20-27)	8(28-54)	5(40-53)	1(43)	2(83-87)	2(84-91)
2	4(24-36)	14(34-59)	0	1(40)	0	0
3	0	8(48-71)	16(43-63)	0	2(81-96)	0
1-3	10(20-36)	30(28-71)	21(40-63)	2(40-43)	4(81-96)	2(84-91)

Three postlarvae, 8.5, 14, and 15 mm long, were taken at station 1 and one, 12 mm, at station 2; these were tentatively identified

as N. kroyeri, and were not included in the tabular data summaries. In addition, one specimen, 28 mm long, of undetermined sex and stage was taken at station 1. The large proportion of subadults and smaller numbers of juveniles suggest that N. kroyeri spawns in late winter and spring. The adults, the smallest of which was 18 mm longer than the largest subadult, were probably at least two years old.

Vertical Distribution.

One postlarva, 12 mm long, was taken during the day at 100 m at station 2; no other specimens were caught during the day. Night depths of occurrence were 12-200 m (three specimens from 700 m) with peak concentrations at 45-50 m. Only subadults were collected in the 40-50 m depth interval. One subadult was taken outside of this range (25 m, station 1). Two juveniles were taken, 1 at 700 m at station 1 and 1 at 12 m at station 2. The adults were taken deeper than subadults, and adult males appeared to live deeper than adult females. An adult female was taken at 70 m at station 1. Adult males were caught at 150 m (1 at station 1 and 1 at station 3), and at 200 m (1 at station 3). Two postlarvae, 14-15 mm long, were taken at 700 m at station 1.

There is some indication that the subadults may segregate by sex at night. At station 2, 15 of the 19 specimens of N. kroyeri collected were taken in a single 2 hour sample, and all 15 were males.

The only clue to the depths inhabited by N. kroyeri during the day is from non-discrete samples (all with an oblique component from depth to surface). Although every trawl produced

one such sample, the only ones positive for N. kroyeri during the day were two made at 1000 m. One of these, at station 2, spent two hours at depth and took two specimens (27 and 48 mm); the other, an oblique sample at station 3, took one specimen (51 mm). This suggests that 1000 m may be the upper limit of the daytime population and that the majority lives deeper than 1000 m.

Notoscopelus elongatus

Distribution and Abundance.

This large species was uncommon at station 2 and rare at stations 1 and 3; it was not collected at stations 4 and 5. The maximum catch rate at station 2 was 3.0/hr. (day - 1000 m), at station 1, 1.5/hr. (day - 500 m), and at station 3, 1.0/hr. (night - 100 m).

Growth Stages and Reproductive Condition.

All of the 18 specimens collected were subadults. The number of subadults, followed by size range (mm) in parentheses, was as follows.

Station	Male	Female
1	3(36-63)	2(48-49)
2	6(42-98)	6(37-106)
3	1(34)	0
1-3	10(34-98)	8(37-106)

The lack of juveniles, which would probably have been captured if present, indicates that N. elongatus spawns in winter and perhaps spring. The young grow rapidly and by fall are at least 34 mm long. The large individuals may be 2 or more years old.

This species is endemic in the Mediterranean Sea (Nafpaktitis, personal communication), which rules out the possibility that the presence of large individuals only is due to expatriation from the Atlantic.

Vertical Distribution.

Daytime depths of occurrence at stations 1 and 2 were 375-1000 m, with peak concentrations at 500 m at station 1 and 1000 m at station 2; none were taken during the day at station 3. At night, N. elongatus occurred from 45 to 150 m at stations 2 and 3, with greatest abundance at 45-100 m; none were collected at night at station 1.

During the day, at station 1, 1 specimen (48 mm) was caught at 375 m and 3 (36-54 mm) at 500 m. At station 2, the 3 specimens (37-47 mm) were taken at 1000 m. There is no apparent reason why this species was taken at 375 m and 500 m at station 1 but not at 400 m at station 2, and at 1000 m at station 2 but not at 940 m at station 1. The size ranges of specimens collected at each station were similar. They may occur throughout the 400-1000 m depth range during the day, but in such small numbers that limited sampling can not elucidate their distribution pattern.

At night, six specimens were taken at station 2 at 45-150 m: 4 (59-72 mm) at 45 m, 1 (42 mm) at 100 m, and 1 (65 mm) at 150 m. The one specimen (34 mm) taken at station 3 was captured at 100 m.

Nemichthys scolopaceus

One specimen, 520 mm, was taken at station 3 at 100 m between 0305-0405 hrs. This species occurs in the North Atlantic, where it is among the most common of bathypelagic eels. It is apparently a stray into the Mediterranean.

Paravocettinops trilinearis

One specimen, 523 mm long, of undetermined sex and stage, was collected at station 2, at 600 m, at 1512-1818 hours. This species previously had not been recorded in the Mediterranean Sea.

Zu cristatus

One specimen, 90 mm long, of undetermined sex and stage, was collected at station 3, from 0-25 m at 0306-0506 hours. This broadly ranging fish is generally rare in collections.

Summary

Appendix 3 Tables 466-474

Geographic Distribution and Abundance.

The numbers of species caught, and total abundances were higher at stations in the western than in the eastern Mediterranean. Each of the 36 species of midwater fishes was represented in samples from stations 1, 2, or 3, while at stations 4 and 5, only 23 species were taken (Table 16). To some extent, the difference in species diversity may be the result of fishing effort. Nine species were represented by fewer than 10 specimens among the five stations, and of these 9, 7 were collected only in the western Mediterranean, where fishing effort was greatest. Even excluding these rare species, more species were caught in the western than in the eastern Mediterranean: 27 vs. 21.

Abundances were higher in the western than the eastern Mediterranean, in terms of catch rates both for all species combined and for each species individually. Table 15 summarizes the maximum catch rates and their depths for all species combined for each station, day and night. The catch rates reflect, in large part, the catch rates for Cyclothone, which comprised more than 80% of the rate listed for station 4.

Examination of maximum catch rates for each species among the five stations similarly shows that abundances were highest in the western Mediterranean (Table 16). Only one species,

Gonichthys cocco, occurred at higher concentrations in the eastern than in the western Mediterranean, while two species, Lestidiops sphyrenoides and Diaphus holti, occurred at concentrations in the eastern Mediterranean that were matched by those in the western Mediterranean.

Striking differences in the concentrations of various species were noted among the three stations in the western Mediterranean. At station 1, 11 species occurred at higher concentrations than at stations 2 and 3; all eleven species were myctophids. At station 2, 17 species occurred at highest concentrations among the three stations, and the composition was quite diverse: 4 species of gonostomatids, the sternoptychid, the melanostomatid, the stomatid, the 4 paralepidids, the evermannellid, one of the nemichthyids, and 4 myctophids. The least number of species (7) were most concentrated at station 3: one of the nemichthyids, 3 gonostomatids, the chauliodontid, 1 myctophid, and the trachipterid.

Table 15. Maximum catch rates for all species combined for each station, day and night, and depth of maximum rate.

Station	Day		Night	
	Max. Catch Rate (No./hr.)	Depth (m)	Max. Catch Rate (No./hr.)	Depth (m)
1	701.0	500	191.0	400
2	694.0	800	600.0	600
3	521.3	500	343.7	500
4	447.0	500		
5	48.0	675	130.0	425

Table 16. Maximum catch rate for each species at each station, day or night. Rates underlined are those which were largest among the five stations for each species.

Species	Maximum Catch Rate (No./hr.) Station 1	2	3	4	5
C. pygmaea	228.1	500.0	47.0	42.0	18.0
C. braueri	484.5	564.0	499.0	367.0	107.0
G. denudatum	-	0.3	2.0	-	-
I. ovatus	-	0.7	1.0	-	-
M. muelleri	-	2.0	-	-	-
V. attenuata	5.0	44.0	9.0	7.0	6.0
V. poweriae	-	-	12.0	6.0	7.0
A. hemigymnus	12.3	17.5	9.5	2.0	15.0
B. nigerrimus	-	0.5	0.3	-	-
S. boa boa	3.0	4.5	3.6	-	2.0
C. sloani	0.7	1.5	4.6	2.0	2.0
L. jayakari	-	6.3	1.0	-	2.0
L. sphyrenoides	-	1.0	-	1.0	-
N. rissoi	1.0	20.0	4.5	-	1.0
P. coregonoides	3.3	14.0	7.6	-	1.0
E. balbo	-	0.5	0.2	-	-
E. rissoi	2.3	4.0	3.5	-	-
H. hygomi	2.0	-	1.3	1.0	1.5
H. benoiti	17.8	50.0	2.3	21.0	-
B. glaciale	168.0	84.5	11.1	2.0	-
D. atlanticus	0.3	-	-	-	-
M. punctatum	38.0	10.0*	2.3*	-	-
S. veranyi	2.0	7.5	1.0	-	-
G. cocco	-	-	0.1*	1.0	48.8*
L. dofleini	61.0	12.5	2.3	17.0	2.0
D. rafinesquei	6.5	2.0	3.7	2.0	2.0
D. metopoclampus	-	-	-	-	-
D. holti	9.0	2.0	3.0	1.0	9.0
L. crocodilus	22.1	10.5	6.0	-	-
L. pusillus	38.0	13.0	17.1	13.0	17.0
C. maderensis	105.0	94.1	72.0	10.0	45.0
N. kroyeri	8.0	7.5	3.7	-	-
N. elongatus	1.5	3.0	1.0	-	-
N. scolopaceus	-	-	1.0	-	-
P. trilinearis	-	0.3	-	-	-

* surface neuston sample

Growth Stages and Reproduction.

Most of the Mediterranean midwater fishes appeared to have one-year life cycles, with a more or less pronounced spawning peak, after which the adults died. Some of the species live at least two years, and probably live several years; included in this category are the larger species such as Stomias boa boa, Chauliodus sloani, the paralepidids, and Lampanyctus crocodilus. For some of the species, pronounced spawning peaks were not evident (Symbolophorus veranyi) or could not be determined because of the paucity of data (Nemichthys scolopaceus, Paravocettinops trilinearis, Maurolicus muelleri, Bathophilus nigerrimus, Evermannella balbo, Diaphus metopoclampus, and Zu cristatus), or because of poor representation of large specimens which were probably successfully avoiding the net (Stomias boa boa, Chauliodus sloani, the four paralepidids).

The species of Mediterranean midwater fishes spawn at various seasons of the year in a manner that presumably reduces competition for available space and food resources (Table 17). Nevertheless, most species spawn at periods that allow them to take advantage of the productive spring and summer months. These months mark the period of peak spawning activity for 10 of the 20 species for which we have been able to determine breeding season: four species of Gonostomatidae and six of Myctophidae. The breeding seasons of eight species overlap the spring-summer months: the sternoptychid and 3 myctophids spawn in summer-fall and 4 myctophids in winter-spring. Only one species, a myctophid,

Table 17. Periods of peak spawning activity and the species of Mediterranean midwater fishes in each category.

Period of Peak Spawning Activity	Species
Summer - fall	A. hemigymnus
	E. rissoi
	H. hygomi
	L. pusillus
Fall - winter	D. rafinesquei
Winter - spring	M. punctatum
	L. dofleini
	N. kroyeri
	N. elongatus
Spring - summer	G. denudatum
	I. ovatus
	V. attenuata
	V. poweriae
	H. benoiti
	B. glaciale
	G. cocco
	D. holti
	L. crocodilus
	C. maderensis
none well defined	S. veranyi

spawned predominantly in the fall and winter. Thus, at any specified time of year, the species of midwater fishes would be at various stages in their life cycles.

An examination of the spawning seasons, together with the patterns of vertical distribution of some of the more abundant myctophids at station 1 further emphasizes the way in which competition is reduced.

At station 1, six species of myctophids accounted for more than 90% of the myctophids captured at that station. The species are listed in Table 18 along with their respective periods of peak spawning activity and main depth of occurrence during both day and night. Where several species were concentrated together (700 m, day, and 70 m, night), each species spawned at a different time of the year. Two of the species, L. dofleini and B. glaciale, shared depths of abundance both day and night, and each spawned at a different time of the year. As a result, the size frequency distributions of the two species complemented one another in such a way that the two species could utilize different sizes, and perhaps kinds, of food at any given time (Fig. 18).

Fig. 18. Size frequency distributions, as a per cent of total catch, for two of the more abundant myctophids at station 1.

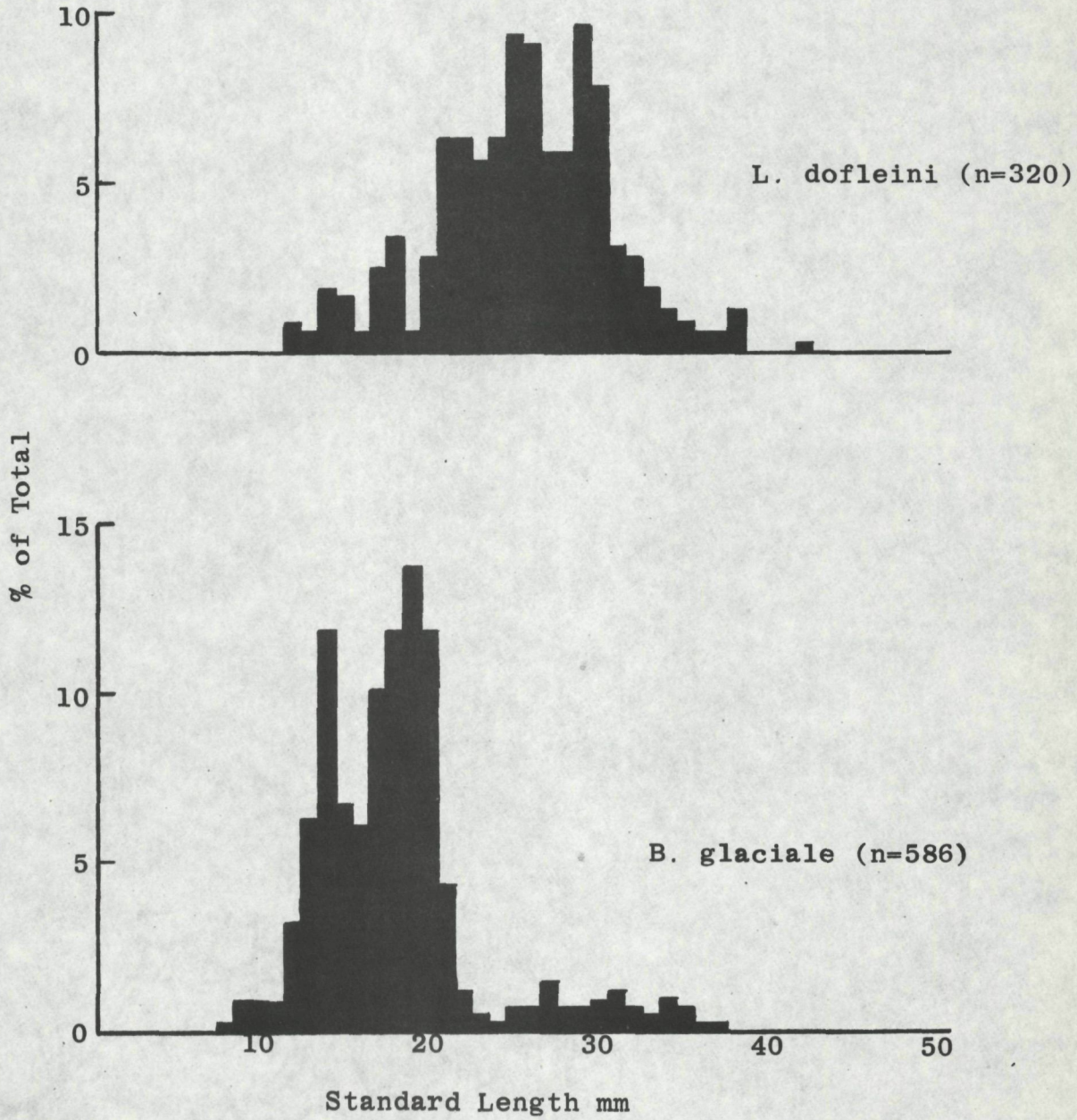


Table 18. Breeding season and depth of main concentration, day and night, for six most abundant myctophids at station 1.

Depth (m)	Dominant species	Breeding season
	Day	
500	L. dofleini	winter-spring
	B. glaciale	spring-summer
700	M. punctatum	winter-spring
	C. maderensis	spring-summer
	L. pusillus	summer-fal
700-940	H. benoiti	spring-summer
	Night	
0-40	M. punctatum	winter-spring
25-70	C. maderensis	spring-summer
70	L. dofleini	winter-spring
	B. glaciale	spring-summer
	L. pusillus	summer-fall
40-235	H. benoiti	spring-summer

Vertical Distribution.

Most midwater fishes in the Mediterranean occupy the upper 1000 m, and we have circumstantial evidence that a few species live, at least during part of the diel period, below 1000 m (Figs. 19-22). During the day, midwater fishes were caught between 100 m and 1000 m (but not from the surface to 60 m), with peak concentrations of the species at various levels from 375-1000 m. At night, catches were from the surface to 1000 m, with greatest species abundances at 0-100 m and 400-800 m.

During the day, the 100-250 m depth interval was occupied by postlarvae of gonostomatids, paralepidids, and myctophids, and by juveniles of Stomias and Chauliodus. At 300-500 m, juveniles, subadults, and adults of C. braueri, V. attenuata, V. poweriae, A. hemigymnus, and L. dofleini predominated. At 500-700 m juveniles, subadults, and adults of G. denudatum, I. ovatus, B. nigerrimus, S. boa boa, C. sloani, H. hygomi, B. glaciale, G. cocco, D. rafinesquei, D. holti, and L. pusillus were most common. At 700-1000 m, postlarvae of gonostomatids, paralepidids, and myctophids were concentrated, as well as juveniles, subadults, and adults of C. pygmaea, M. punctatum, S. veranyi, L. crocodilus, C. maderensis, N. kroyeri, and N. elongatus. Five species could not be identified with a depth stratum.

At night, most species migrated to the upper water layers, with three species, M. punctatum, S. veranyi, and G. cocco, regularly migrating to the surface. Two species that occurred

Fig. 19. Station 1. Day and night depth distribution and abundance of midwater fishes. Black bars and solid lines = night samples. Open bars and dotted lines = day samples. Length of bars proportional to catch rate, except catch rates over 40 per hour shown by numbers in blocks. Depths shown at left are those actually sampled. Open circles indicate samples made during the day, dots indicate samples made at night.


Depth (M)
Day
Night
C. BRAUERI
C. PYGMAEA
V. ATTENUATA
A. HEMIGYMNUS
S. BOA BOA
C. SLOANI
N. RISSOI
P. COREGONOIDES
E. RISSOI
H. HYGOMI
H. BENOITI
B. GLACIALE
D. ATLANTICUS
M. PUNCTATUM
S. VERANYI
L. DOFLEINI
D. RAFINESQUEI
D. HOLTI
L. CROCODILUS
L. PUSILLUS
C. MADERENSIS
N. KROYERI
N. ELONGATUS
Number per hour
0 10 20 30 40 50
25
40
70
150
190
235
375
400
500
700
940
181.7
178.7
484.5
96.2
81.0
228.1
55.3
50.0
168.0
61.0
105.0

Fig. 20. Station 2. Day and night depth distribution and abundance of midwater fishes. For explanation see Fig. 19.

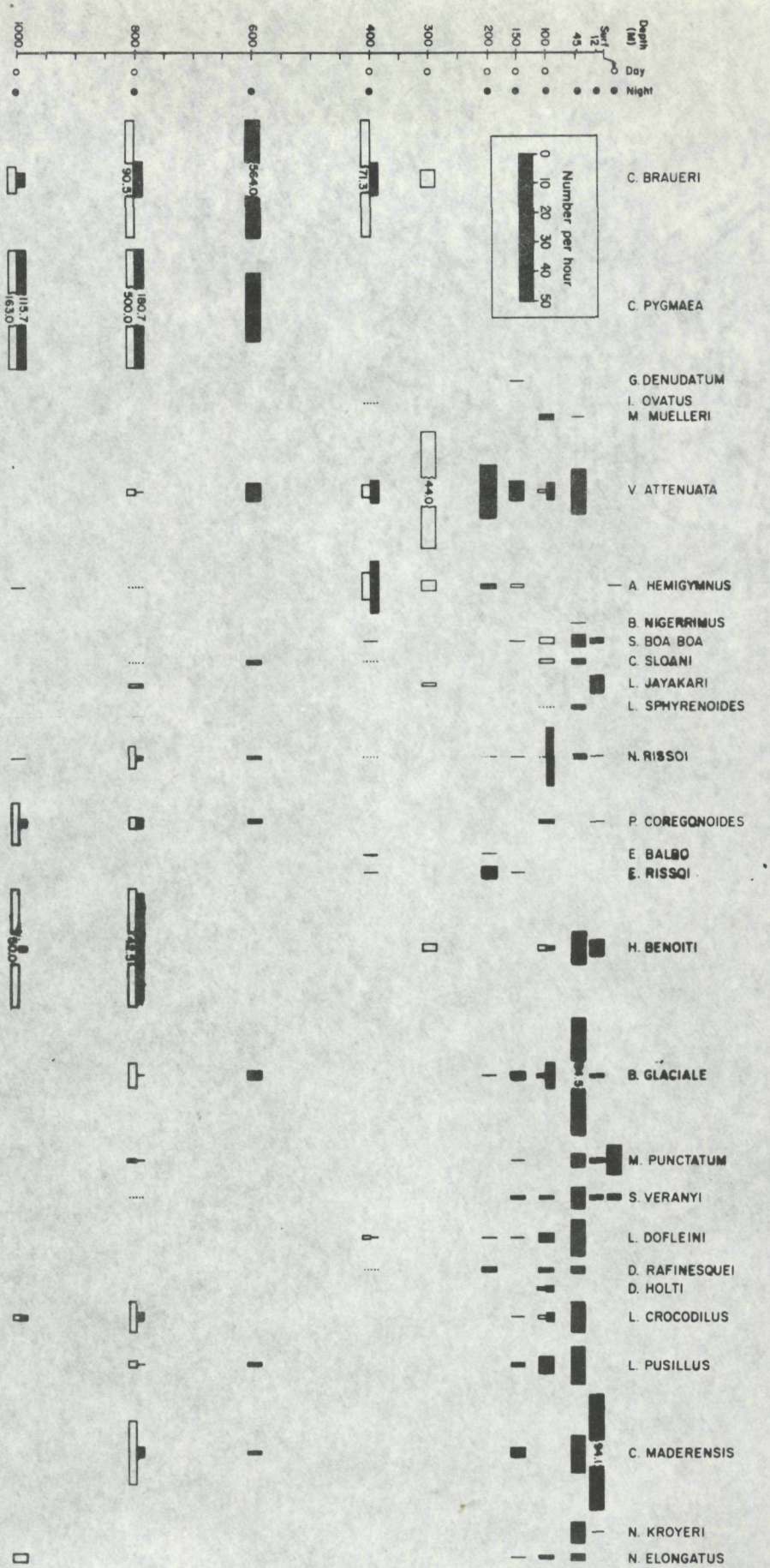

Depth (M)
1000
800
600
400
300
200
150
100
45
Surf
12
Day
Night
Number per hour
0 10 20 30 40 50
90.3
564.0
71.3
115.7
163.0
180.7
500.0
44.0
C. BRAUERI
C. PYGMAEA
G. DENUDATUM
I. OVATUS
M. MUELLERI
V. ATTENUATA
A. HEMIGYMNUS
B. NIGERRIMUS
S. BOA BOA
C. SLOANI
L. JAYAKARI
L. SPHYRENOIDES
N. RISSOI
P. COREGONOIDES
E. BALBO
E. RISSOI
H. BENOITI
B. GLACIALE
M. PUNCTATUM
S. VERANYI
L. DOFLEINI
D. RAFINESQUEI
D. HOLTI
L. CROCODILUS
L. PUSILLUS
C. MADERENSIS
N. KROYERI
N. ELONGATUS

Fig. 21. Station 3. Day and night depth distribution and abundance of midwater fishes. For explanation see Fig. 19.

Depth (M)
Surf
50
100
150
200
300
400
500
600
750
1000
Day
Night
N. SCOLOPACEUS
C. BRAUERI
C. PYGMAEA
G. DENUDATUM
I. OVATUS
V. ATTENUATA
V. POWERIAE
A. HEMIGYMNUS
B. NIGERRIMUS
S. BOA BOA
C. SLOANI
L. JAYAKARI
N. RISSOI
P. COREGONOIDES
E. BALBO
E. RISSOI
H. HYGOMI
H. BENOITI
B. GLACIALE
M. PUNCTATUM
S. VERANYI
G. COCCO
L. DOFLEINI
D. RAFINESQUEI
D. HOLTI
L. CROCODILUS
L. PUSILLUS
C. MADERENSIS
N. KROYERI
N. ELONGATUS
Number per hour
0 10 20 30 40 50
61.0
145.0
149.3
332.7
499.0
47.0
43.4
72.0

Fig. 22. Station 5. Day and night depth distribution and abundance of midwater fishes. For explanation see Fig. 19.

Depth (M)
Surf
50
80
135
155
160
250
325
340
410
425
495
510
675
Day
Night
Number per hour
0 10 20 30 40 50
93.0
107.0
48.8
45.0
C. BRAUERI
C. PYGMAEA
V. ATTENUATA
V. POWERIAE
A. HEMIGYMNUS
S. BOA BOA
C. SLOANI
L. JAYAKARI
N. RISSOI
P. COREGONOIDES
H. HYGOMI
G. COCCO
L. DOFLEINI
D. RAFINESQUEI
D. HOLTI
L. PUSILLUS
C. MADERENSIS

n the intermediate layer (300-500 m) during the day, V. attenuata
nd A. hemigymnus, undertook only limited vertical migrations
nich involved mainly the larger sizes. In the deep layer,
500-1000 m), postlarvae and juveniles of many gonostomatids,
aralepidids, and myctophids did not migrate, while the two
pecies of Cyclothone and post-juvenile stages of C. sloani
nd L. crocodilus remained at or near their respecitive daytime
epths.

Size stratification with depth was evident in most species,
oth day and night, and can be divided into two categories:
) broad scale, involving distinct and widely separated depths,
nd 2) narrow scale, involving continuous distributions,
sually of limited depth. Postlarvae and juveniles exhibited
road-scale size stratification with depth. Small postlarvae
f gonostomatids and myctophids occurred in the shallow layer
nd large postlarvae, those approaching metamorphosis, occurred
n the deep layer (Table 19 for postlarval myctophids). After
etamorphosis, the small juveniles remained in the deep layer at
ight while the larger juveniles migrated into the shallow layer
e.g. C. maderensis, Table 20).

Narrow-scale size stratification involves depth ranges of
sually 100-200 m, but may be as large as 600 m; in all cases
he distribution of the species was continuous throughout the
epth range in which size stratification occurred. The general
attern found was that larger fishes, particularly larger adults,
ived deeper than the main concentration of juveniles, subadults

Table 19. Vertical distribution of myctophid postlarvae; samples from all stations, day and night combined.

Species	No. of Postlarvae Captured		
	Shallow (12-250 m)	Intermediate (300-600 m)	Deep (675-1000 m)
E. rissoi	2		2
H. hygomi	1		
H. benoiti	45	1	33
B. glaciale	6		5
D. atlanticus			1
M. punctatum	7		
S. veranyi	16		
G. cocco	1		
L. dofleini	1		
D. rafinesquei			2
D. holti	2		
L. crocodilus	15		
L. pusillus	2		
C. maderensis	14	2	18
Notoscopelus	1		2
Total no. of postlarvae	113	3	63
Hours of collecting	60.7	53.2	28.0
No./hour	1.9	0.1	2.3

Table 20. Vertical distribution of *Ceratoscopelus maderensis*, Station 1: Night

Size (mm)	Number of Juveniles Caught	
	Shallow (25-40 m)	Deep (700 m)
13		1
14		5
15		6
16	1	10
17	4	10
18	4	1
19	2	
20	1	
21	2	
22	1	
23	1	
24		
25		
26	1	
Mean Size	19.2	15.8

and adults. This trend reached its maximum expression in O. rafinesquei, in which the smaller adults migrated extensively, but the larger the adult the less extensive the migration became, and the largest adults did not migrate at all.

Two of the species that regularly migrated to the surface at night, M. punctatum and S. veranyi, had a unique vertical distribution pattern at night, in which many of the smaller subadults tended to remain as much as 50 m below the surface, although all sizes reached the surface.

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PART 4

SWIMBLADDER STRUCTURE OF MEDITERRANEAN MIDWATER FISHES AND A METHOD OF COMPARING SWIMBLADDER DATA WITH ACOUSTIC PROFILES

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Introduction

Inasmuch as swimbladders have been strongly implicated as the main source of resonant sound scattering in the oceanic midwaters, we undertook a survey of swimbladder structure in all species of midwater fishes in our Mediterranean collections. This survey demonstrated a wide variety of swimbladder shapes and sizes that were different from species to species and, to a considerable extent, showed different forms within a species. Such differences largely invalidate any estimates of sound scattering that are based on population densities of fishes of selected sizes without considering species composition. The reverse approach, estimation of fish sizes and densities from acoustic measurements, also must take these differences into account.

Our observations indicate, furthermore, that accumulations of fatty material associated with the swimbladder do not represent obstructions of the lumen (as already shown by Marshall, 1960; Capen, 1967; and Zahuranec and Pugh, 1971), and that the "cottony" material that has been described in the lumen (Capen, 1967) is a result of swimbladder contraction, not of any obstructing growth.

This paper gives the results of our investigations of the gross morphology and dimensions of the swimbladders of Mediterranean midwater fishes, presents information derived

from studies of the histology of one species (Myctophum punctatum), and combines swimbladder data to obtain hypothesized profiles of acoustic reverberation.

Materials and Methods

Gear. All fish specimens were collected using either a 10-foot (3-m) Isaacs-Kidd midwater trawl (IKMT) equipped with a cod-end discrete-depth sampler (Aron, et al., 1964; Bourbeau, et al., 1966) at depths below the surface or a 1-m ring net at the surface-air interface. Station data are given in Appendix 1 in Part 1 of this report.

Species. Thirty-six species of midwater fishes were caught, of which 32 species were examined for this study. The four that were not examined were two deepsea eels, Nemichthys scolopoceus and Paravocettinops trilinearis, a trachypterid, Zu cristatus, and a myctophid, Diogenichthys atlanticus, that was represented by a single larva. Swimbladders were absent in nine species: Bathophilus nigerrimus (Melanostomiatidae); Stomias boa boa, (Stomiatidae); Chauliodus sloani (Chauliodontidae); Lestidiops jayakari, L. sphyraenoides, Notolepis rissoi, and Paralepis coregonoides (Paralepididae); Evermannella balbo (Evermannellidae); and Gonichthys cocco (Myctophidae). The remaining 23 species, all of which were examined, belong to the three families that dominate the midwater ichthyofauna, Gonostomatidae, Sternoptychidae, and Myctophidae.

Gonostomatidae

Cyclothone braueri

C. pygmaea

Gonostoma denudatum

Ichthyococcus ovatus

Maurolicus muelleri

Vinciguerria attenuata

V. poweriae

Sternoptychidae

Argyropelecus hemigymnus

Myctophidae

Electrona rissoi

Hygophum hygomi

H. benoiti

Benthosema glaciale

Myctophum punctatum

Symbolophorus veranyi

Lobianchia dofleini

Diaphus rafinesquei

D. holti

D. metopoclampus

Lampanyctus crocodilus

L. pusillus

Ceratoscopelus maderensis

Notoscopelus kroyeri

N. elongatus

The only species of any of these three families that had been recorded from the Mediterranean, but which we did not catch, was the myctophid *Lobianchia gemellari*. This species, *Diogenichthys atlanticus*, and *Diaphus metopoclampus*, the latter two each represented in our collections by a single specimen, are apparently very rare in the Mediterranean.

Methods. All specimens examined were fixed in 10% formalin (4% formaldehyde solution) and later soaked in water and transferred through an increasing series of steps to 70% ethyl alcohol. A series of each species, including most of the

size range available, was dissected under a low-power microscope, details of swimbladder morphology were observed and recorded or drawn, and measurements of bladder dimensions were made with an ocular micrometer. Specimens chosen for this study all had relatively intact swimbladders.

Measurements used in this study were the following:

Standard length (SL) - snout tip to caudal base (end of hypural plate), measured with dial calipers and recorded to the nearest mm.

Fish volume - wet volume ml, measured by immersing the specimen in water in a graduated cylinder.

Bladder length - the anterior-posterior length of the external swimbladder wall, not including rete mirabile that often extend beyond the wall.

Bladder width - the greatest width of the external bladder wall.

Bladder volume - calculated using the bladder length and width in a formula for the volume of a prolate spheroid ($V = 4/3\pi ab^2$, where a and b are the major and minor semiaxes).

Anatomical Differences

The three families of midwater fishes with swimbladders - Myctophidae, Gonostomatidae, and Sternoptychidae - are considerably different in fundamental swimbladder anatomy. The Gonostomatidae and Sternoptychidae are closely related phylogenetically, and their swimbladders are fairly similar to one another and very different from those of the Myctophidae (Marshall, 1960). In the Myctophidae, the vascular supply to and from the gas glands is through three unipolar retia mirabilia located at the anterior end of the swimbladder; the resorptive area is organized as an oval that is capable of being shut off by a sphincter-like arrangement of smooth muscles, and the venous vascular return from the oval is separate from that of the gas glands. In the Gonostomatidae and Sternoptychidae, the gas glands are supplied by a single, bipolar rete mirabile located at the posterior end of the swimbladder; the resorptive area is not organized, being merely a well-vascularized area of the bladder wall, and the venous vascular return through the rete.

These anatomical differences and the physiological differences that are associated with them may account for the high frequency in specimens examined by us, of ruptured swimbladders in the Gonostomatidae and Sternoptychidae, as opposed to the paucity of ruptured bladders in Myctophidae. In all 8 Mediterranean species of Gonostomatidae unruptured swimbladders were difficult to find. Often the bladders were so badly fragmented that we were hard pressed for specimens to measure, and we could find

none at all of Maurolicus muelleri. The diel vertical migrations of Gonostomatids and Sternoptychids (in the Mediterranean and elsewhere as well) tend to be limited in extent compared to those of most Myctophidae, and most of the species occur in intermediate depths both day and night, whereas most myctophids are found deeper during the day and shallower at night than gonostomatids and sternoptychids. The relative lack of organization of the swimbladder resorptive area in these two families is probably related to their habits of undergoing little or no vertical migration and could account for the abundance of ruptured bladders in trawl-caught specimens.

A phenomenon that has been observed among many species of Myctophidae but not in Gonostomatidae or Sternoptychidae, and which may be common to all species of Myctophidae when more evidence is gathered, is the apparent ability of the swimbladder to contract (become shorter) toward its anterior end within the covering layer of peritoneum. In this study, we observed both fully-inflated and contracted bladders in 8 of the 15 myctophid species examined in numbers. Only inflated bladders (not contracted) were seen in the other 7. Contracted bladders were not correlated with depth of capture and were, for example, almost as common as inflated bladders in the abundant specimens of Myctophum punctatum caught at the surface. Contraction, however, may be correlated with fish size. This appears to be the case in the small samples examined of most species, and it is definitely the case in surface samples of Myctophum punctatum from station 2. Of 63 specimens of M. punctatum, 16 to 42 mm SL

in these samples, 60 have inflated bladders; of 43 specimens 48 to 65 mm SL, 39 have contracted bladders. Those specimens 43 to 47 mm include 11 with contracted bladders and seven with inflated bladders, indicating that the basic change in bladder condition occurs mainly in this size range.

Fat-investment of Swimbladders

Accumulations of fat or oil in or around the swimbladder would certainly have an effect on sound-scattering by the bladder. Although several workers have suggested the presence of fatty material within the swimbladder lumen (Ray, 1950; Jollie, 1954; Barham, 1957), recent evidence indicates that any fat associated with the swimbladder is not within the lumen or walls of the bladder proper, but invests the bladder or accumulates near it. Marshall (1960) reported fat-invested swimbladders in several species of midwater fishes, notably Cyclothone braueri, C. livida, and Gonostoma elongatum, and demonstrated that the fatty material was between the peritoneum and the outer wall (tunica externa) of the bladder. Capen (1967) and Zahuranec and Pugh (1971) have confirmed this situation.

None of the Mediterranean midwater fishes that we examined had accumulations of fat between the peritoneum and the swimbladder. A thin layer of oil droplets was observed on the coelomic side of the peritoneum in some specimens of Myctophum punctatum. This layer was especially visible in specimens with contracted bladders, which left a loose fold of peritoneum posterior to

the bladder. Small amounts of oil were found in the body cavity of some specimens of Symbolophorus veranyi, Lobianchia dofleini, Ceratoscopelus maderensis, Lampanyctus pusillus, and Notoscopelus elongatus. Large specimens of Benthosema glaciale, Hygophum hygomi, and the two species of Cyclothone had extensive accumulations of oil droplets within the body cavity. The numerous specimens of several species with contracted bladders, however, failed to show the pattern of fatty investment described by Marshall (1960), Capen (1967), and Zahuranec and Pugh (1971).

"Cottony Tissue" in the Lumen

Whitish material was found in almost all Mediterranean myctophid swimbladders that were contracted: in Hygophum hygomi, Myctophum punctatum, Symbolophorus veranyi, Lobianchia dofleini, Ceratascopelus maderensis, Notoscopelus elongatus, and N. kroyeri. No white material was observed in contracted bladders of Benthosema glaciale or in one contracted bladder of Lobianchia dofleini, and no such material was seen in inflated bladders of any species.

Capen (1967) reported bladders filled with a "cottony tissue" out-growth from the gas glands in large specimens of the Pacific myctophid species Stenobrachius leucopsarus, Triphoturus mexicanus, Lampanyctus parvicauda, Diaphus theta, and Myctophum aurolaternatum. This "cottony tissue" is presumably the same as the white material that we observed in Mediterranean myctophids.

In order to investigate the nature of the white material, we sectioned and stained with H and E a contracted swimbladder from a 46 mm specimen of Myctophum punctatum. Before it was

removed, this bladder, like all contracted bladders, appeared as a dorsoventrally flattened, oblong structure, located anteriorly within a much longer peritoneal fold. This peritoneal fold closely invests all but the dorsal surface of expanded bladders, but an unoccupied extraperitoneal space is left posterior to a contracted bladder. The peritoneum is easily removed from a contracted bladder to expose the outermost tissue layer (tunica externa), composed of dense connective tissue and showing no sign of folding. Upon teasing away the tunica externa, the middle layer (submucosa) is revealed, consisting of a reticulum of loose collagenous fibers within a gelatinous matrix. The thickness of the submucosa varies considerably in a contracted bladder, generally becoming thicker posteriorly, but also being quite thick in the region of the gas glands. The innermost layer (mucosa) is a pavement of epithelium except where it is modified to form the gas glands. In contracted bladders the gas glands are greatly thickened and folded, considerably obstructing the already small lumen. Posterior to the gas glands the epithelium also shows small folds, and the lumen extends only a short distance toward the posterior end, which is composed entirely of the fibrous submucosa and the tunica externa.

Study of the stained sections emphasizes the thickness of the apparently expanded submucosa. The gas glands are thickened and folded, and the submucosa underlying them forms a thickened hump that occupies a sizable portion of what would be the lumen in an inflated bladder (Fig. 23). Posterior to the gas glands,



Fig. 23 . Cross section through anterior part of contracted swimbladder of Myctophum punctatum (about 160 X). Expanded submucosa fills much of lumen and is capped by large cells of gas gland. Mucosa shows folds. Rete mirabile seen in lower right side.

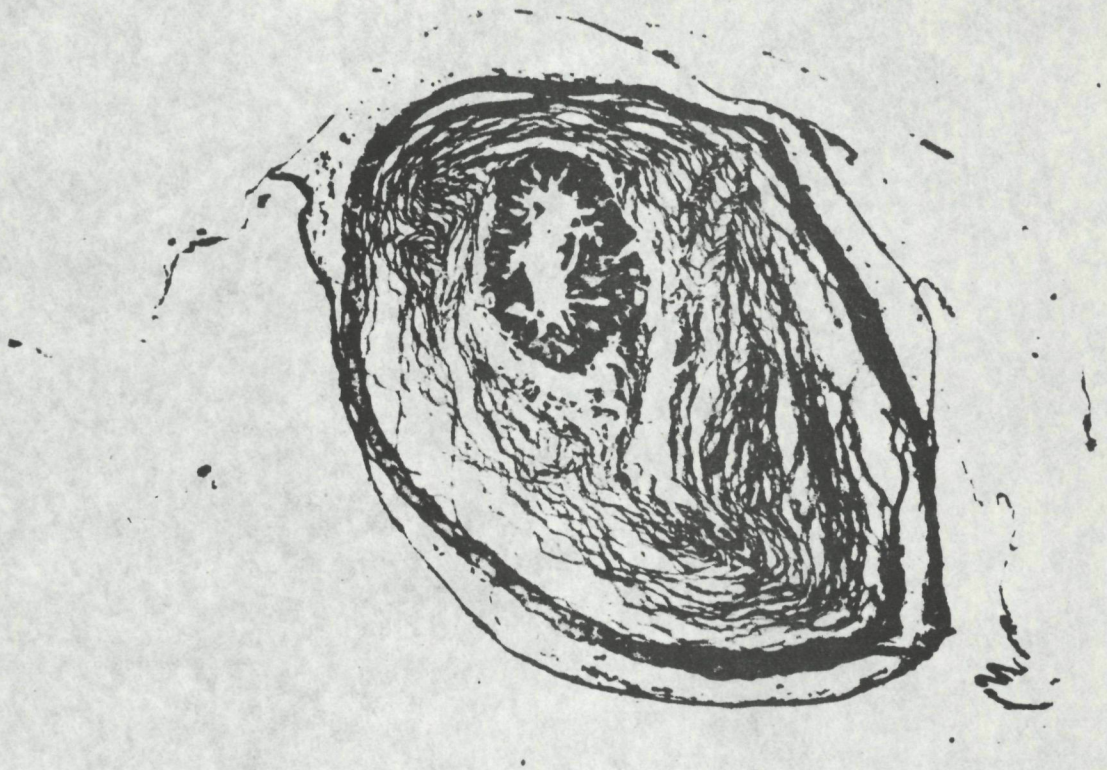


Fig. 24 . Cross section through posterior middle part of contracted swimbladder of Myctophum punctatum, (about 160 X). Expanded submucosa fills most of space. Lumen much reduced, with thick, folded mucosa.



Fig. 25 . Cross section through posterior part of contracted swimbladder of Myctophum punctatum (about 160 X). Expanded submucosa fills entire space. No lumen is present.

the submucosa appears almost to squeeze the lumen out of existence (Fig. 24), and the posterior one-third of the bladder has no lumen at all, only a mass of fibrous submucosa (Fig. 25).

We are convinced that the cottony tissue "outgrowth from the gas glands" described by Capen (1967) is the same as the white material that we have described. This material, therefore, is not an outgrowth from the gas glands but is the greatly expanded, fibrous submucosa within the relatively thin mucosa. We have observed this phenomenon only in contracted swimbladders, and we believe it will prove to be characteristic only of these.

Capen's (1967) specimens of S. leucopsarus, T. mexicanus, and D. theta presumably also had contracted bladders, for their bladder lengths and widths are comparable with those of Mediterranean species with contracted bladders. However, Capen's specimens of L. parvicauda and M. aurolaternatum, again judging from their listed dimensions (Capen, 1967:17), apparently had inflated swimbladders, yet their lumens were described as being packed with "cottony" tissue. Because we have not observed the white material in any specimens with inflated bladders, we examined 4 specimens of M. aurolaternatum from the eastern tropical Pacific. All of these were close in size to Capen's two largest specimens. All 4 had contracted swimbladders that were about as wide, but only half as long, as those reported by Capen. However, if the loose fold of peritoneum behind the contracted bladder were included, the bladder lengths would approximate those listed for Capen's specimens. We believe,

then, that Capen's M. aurolaternatum, and probably his L. parvicauda, actually had contracted swimbladders and that Capen included the fold of peritoneum behind the swimbladders in his length measurement.

What the functional significance of swimbladder contraction may be, we cannot say with certainty. In those species in which contracted bladders have been observed, it has been the larger specimens that most often had such bladders. Depth of capture does not seem to be correlated with contraction; for example, both contracted and inflated bladders have been observed in specimens of Symbolophorus veranyi taken at night at the surface as well as those taken at 700-800 m. (Table 21). Possibly what we are calling contraction is actually a permanent degeneration of the swimbladder, but if so, it is difficult to understand why the retia and gas glands do not degenerate. The whole appearance of the organ suggests that it has actively shortened. Our conclusion is that swimbladder contraction is an adaptation that lessens the restrictions imposed by an inflated swimbladder on vertical movement.

Barham (1971) suggested that certain species tend to display lethargy at their daytime depths of occurrence, hanging motionless, almost vertical in the water. These species were termed the "inactive" type, and were characterized as having atrophied swimbladders, among other characteristics. Examples included the eastern Pacific myctophids Stenobrachius leucopsarus and Triphoturus mexicanus. They were opposed to the "active"

type, characterized by either large, gas-filled swimbladders or none at all, and examples included Myctophum aurolaternatum, Benthosema panamense, and, perhaps, Ceratoscopelus maderensis. From our study, it seems clear that swimbladder structure is not a distinguishing characteristic of the two behavioral types. Some of the other characters mentioned by Barham, however, may be more pertinent, especially the lipid content of the organs. Probably the two kinds of behavior are related to the density of the fish as a whole, involving mainly the muscles and skeleton, which seem on gross observation to be heavier in his "active" type than in his "inactive" type. Assuming that the swimbladder contribution to density is the same in both categories, the denser fish would have to be more "active" in order to remain at a given depth.

Assuming the "active" type of fish to have denser tissues than an "inactive" type, the swimbladder would have to have a larger volume in order to keep the "active" fish neutrally buoyant. Such a situation, particulary in a large specimen, might well be a hindrance to extensive vertical migrations, as are carried out by species such as M. punctatum and S. veranyi, both of which reach the surface at night from a daytime depth of 700 m or more. It may be easier to maintain depth without a large swimbladder than to counteract its affects on the way up.

Swimbladder Volumes

Swimbladder volumes of Mediterranean midwater fishes relative to fish length and fish volume vary greatly from species to species (Figs. 26 and 27). Volumes also vary according to patterns among individuals of a given species, where both contracted and inflated bladders may be present at all sizes or may be size-dependent.

Inflated swimbladders, but no contracted ones, were observed in 13 Mediterranean midwater species (Fig. 26): 5 gonostomatids, the one sternoptychid, and 7 myctophids. The maximum size of these species ranges from small (30 mm or less) to large (Lampanyctus crocodilus may be more than 200 mm SL). The increase of bladder volume relative to fish length in these species is quite variable; for example, a specimen of Electrona rissoi 35 mm long (Fig. 26) may have a swimbladder volume equal to that of an 85 mm Lampanyctus crocodilus (Fig. 26).

Both inflated and either regressed or contracted swimbladders were found in another 10 Mediterranean species (Fig. 26): the two species of Cyclothone and 8 myctophids. In 6 of these, no large bladders were observed, even when the bladders were inflated, and the largest specimens of each species had regressed (Cyclothone) or contracted (myctophids) swimbladders in which the presence of an effective lumen was highly doubtful. In the remaining 4 species, all myctophids, inflated swimbladders were observed in some large specimens, (including the largest volume observed by us, in a 59 mm Hygophum hygomi), but most

Fig. 26 . Swimbladder volumes as a function of standard length for 20 species of Mediterranean midwater fishes. Open circles = inflated bladders; dots = contracted or regressed bladders. Species with contracted bladders are grouped in the left column, those in which only contracted bladders were observed are in the middle and right columns. (The specimen of Argyropelecus hemigymnus represented by a dot had an inflated, but abnormal bladder).

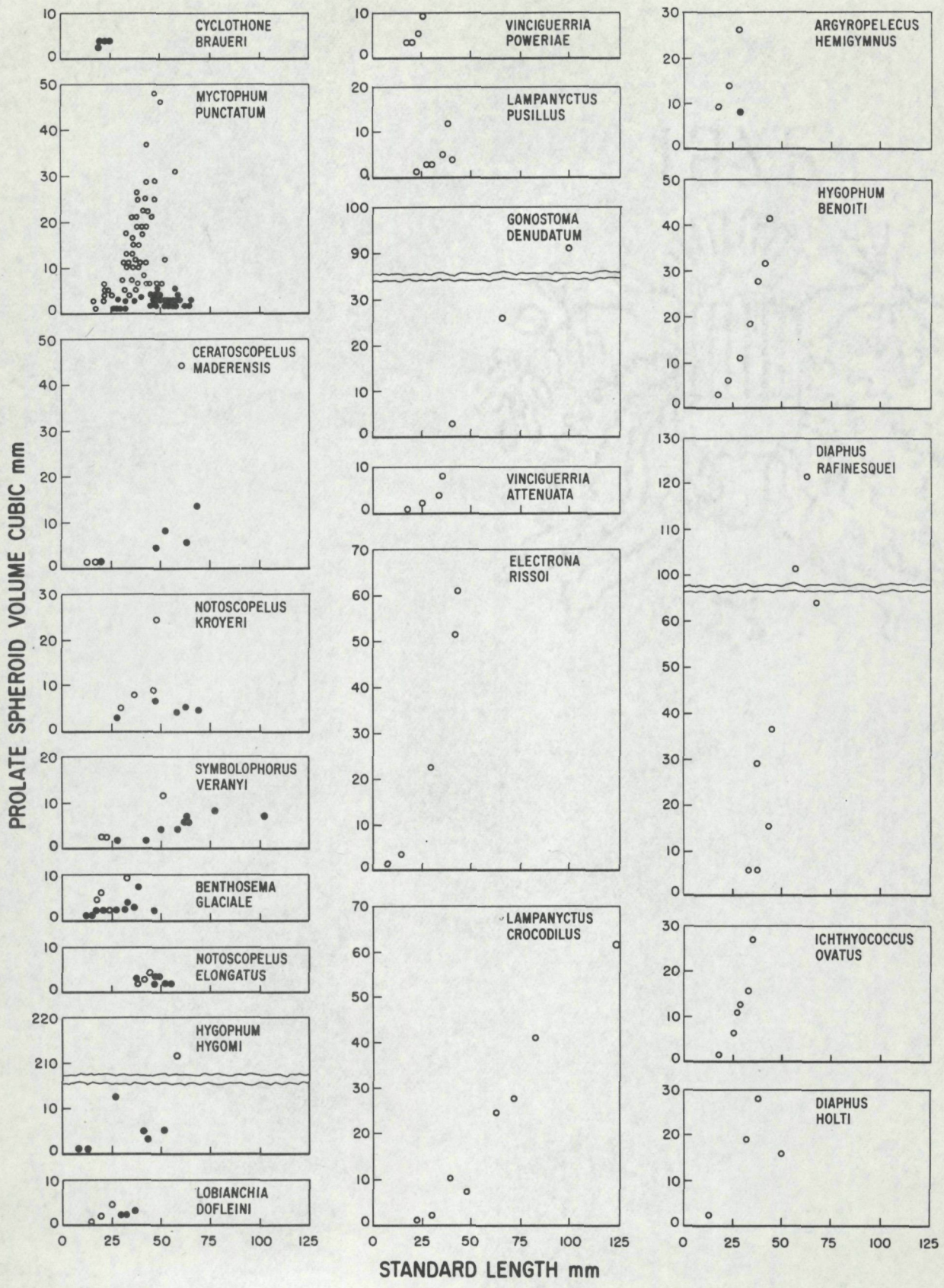
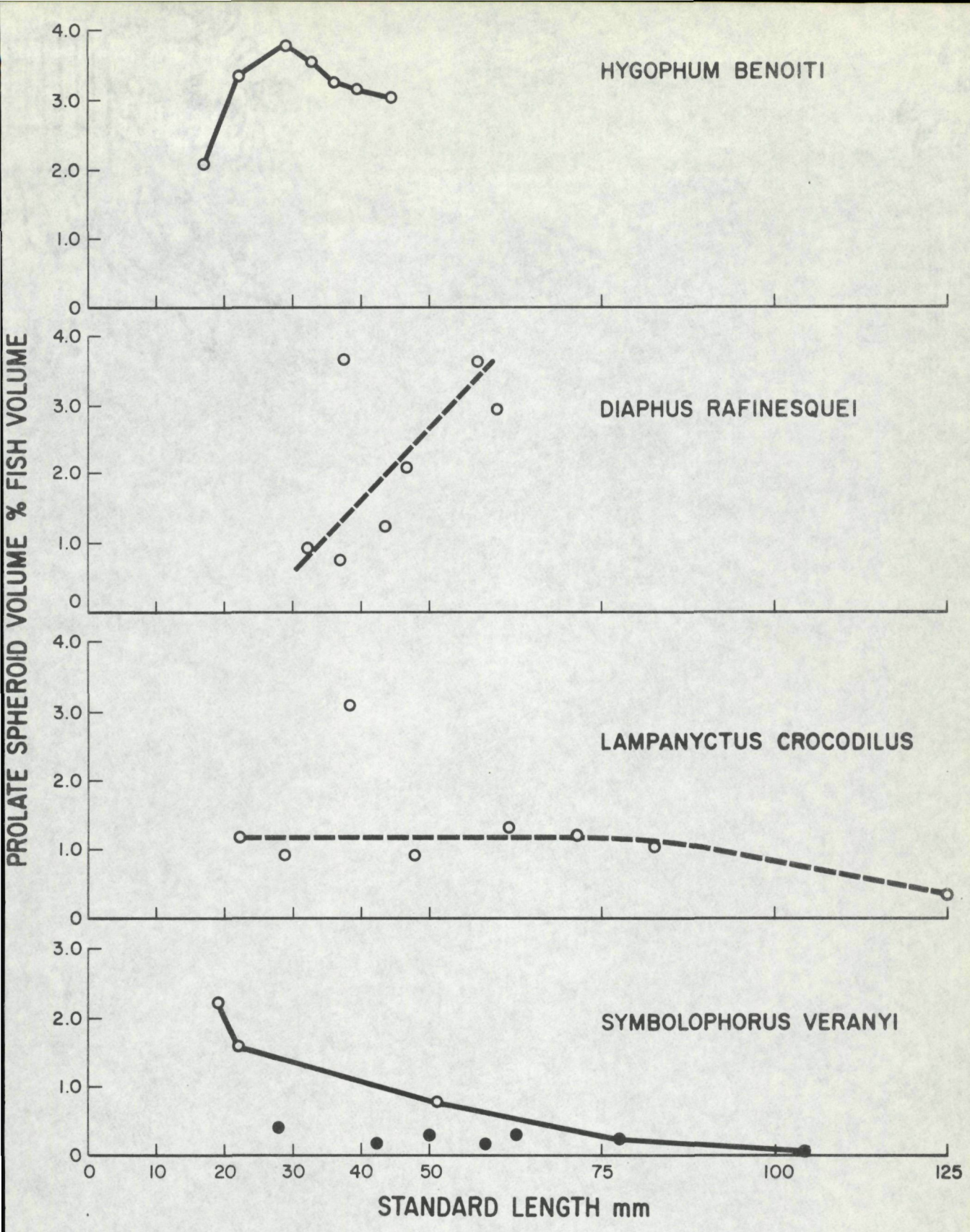

CYCLOTHONE BRAUERI
MYCTOPHUM PUNCTATUM
CERATOSCOPELUS MADERENSIS
NOTOSCOPELUS KROYERI
SYMBOLOPHORUS VERANYI
BENTHOSEMA GLACIALE
NOTOSCOPELUS ELONGATUS
HYGOPHUM HYGOMI
LOBIANCHIA DOFLEINI
VINCIGUERRIA POWERIAE
LAMPANYCTUS PUSILLUS
GONOSTOMA DENUDATUM
VINCIGUERRIA ATTENUATA
ELECTRONA RISSOI
LAMPANYCTUS CROCODILUS
ARGYROPELECUS HEMIGYMNUS
HYGOPHUM BENOITI
DIAPHUS RAFINESQUEI
ICHTHYOCOCCUS OVATUS
DIAPHUS HOLTI
PROLATE SPHEROID VOLUME CUBIC mm
STANDARD LENGTH mm

Fig. 27 . The four patterns of growth changes in the relationship of swimbladder volume to fish volume. Open circles = inflated bladders; dots = contracted bladders.


HYGOPHUM BENOITI
DIAPHUS RAFINESQUEI
LAMPANYCTUS CROCODILUS
SYMBOLOPHORUS VERANYI
PROLATE SPHEROID VOLUME % FISH VOLUME
STANDARD LENGTH mm
0
1.0
2.0
3.0
4.0
10
20
30
40
50
75
100
125

of the large specimens and many small ones had contracted bladders. In those specimens with inflated bladders, the increase in volume relative to fish length appears to be widely variable; at about 50 mm SL, Hygophum hygomi would be estimated to have a swimbladder volume five times that of a similar-sized Notoscopelus kroyeri.

The assumption that swimbladder volume of a fish approximates 5 percent of the fish volume, often applied in equations using numbers and lengths of fishes to determine sound-scattering strengths, is contradicted by our studies, which agree with the findings of some other workers (e.g. Capen, 1967). Our estimates of swimbladder volumes (Tables 21 and 22), using the external length and width in a formula for the volume of a prolate spheroid, are likely to be liberal, for the bladder wall may be quite thick in some places, and the gas glands often impinge considerably into the lumen. Nevertheless, a swimbladder volume exceeding 5 percent of fish volume was found in only one specimen, a fairly large Hygophum hygomi (7.08 percent), and the 5 percent figure was approached only by two other species, Myctophum punctatum, with a maximum of 4.49 percent and Argyropelecus hemigymnus, with a maximum of 4.47 percent. Both myctophid species with maximum percent volumes characteristically have contracted bladders in large specimens.

Maximum percent volumes range from 1.60 to 4.47 in 10 of the 13 species in which only inflated bladders have been observed

(fish volumes were not obtained for Vinciguerria poweriae or the two species of Cyclothone). The data for 4 of these (Argyropelecus hemigymnus, Electrona rissoi, Hygophum benoiti, Diaphus holti) indicate that the maximum percent volume of the swimbladder is reached at an intermediate fish length and is followed by a decline (Fig. 27 top). In 5 others (Vinciguerria attenuata, Gonostoma denudatum, Ichthyococcus ovatus, Diaphus rafinesquei and Lampanyctus pusillus), the swimbladder volume appears to increase continously with fish length (Fig. 27 upper middle), and in one (Lampanyctus crocodilus) the percent volume may remain relative constant with increasing fish length (Fig. 27 lower middle).

Of the remaining 10 species in which regressed or contracted bladders were observed, data for inflated swimbladder volume relative to fish volume are available for 7. In 3 species (Benthosema glaciale, Myctophum punctatum and Notoscopelus kroyeri), the maximum percent volume occurs at an intermediate fish length; in 3 (Hygophum hygomi, Lobianchia dofleini and Ceratoscopelus maderensis) the percent volume appears to increase continously with fish length; and in one (Symbolophorus veranyi) the data suggest a continuous decrease in percent volume relative to fish length (Fig. 27 bottom). The maximum values observed in the 5 species not previously mentioned range from 1.19 to 2.21 percent.

TABLE 21.

SWIMBLADDER AND FISH MEASUREMENTS FOR MEDITERRANEAN MIDWATER FISHES.

Swimbladder States: R = regressed, I = inflated, C = contracted.
Volume calculated as a prolate spheroid.

Standard Length mm	Fish Volume cm^3	Bladder State	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
			Cyclothone braueri				
19	--	R	2.0	0.7	0.51	--	0-500
20	--	R	2.0	0.8	0.67	--	0-500
20	--	R	2.0	0.8	0.67	--	0-500
21	--	R	2.4	1.0	1.26	--	0-500
23	--	R	2.5	1.0	1.31	--	0-500
24	--	R	2.2	0.8	0.74	--	0-500
			Cyclothone pygmaea				
19	--	R	1.0	0.4	0.42	--	0-750
20	--	R	1.0	0.4	0.42	--	0-1000
21	--	R	0.8	0.5	0.42	--	0-1000
			Gonostoma denudatum				
40	0.30	I	5.4	1.0	2.83	0.94	500
66	1.40	I	13.5	1.9	25.52	1.82	500
97	4.50	I	22.7	2.8	93.18	2.07	600
			Ichthyococcus ovatus				
17	--	I	2.0	1.0	1.05	--	0-200
25	--	I	3.1	1.9	5.86	--	0-200
28	--	I	5.0	2.0	10.47	--	0-600
29	0.50	I	4.7	2.2	11.91	2.38	400
33	0.60	I	6.5	2.1	15.01	2.50	0-1000
35	0.80	I	6.8	2.7	25.96	3.24	400
			Vinciguerria attenuata				
18	0.04	I	2.1	0.7	0.54	1.35	100
25	0.15	I	3.1	0.9	1.31	0.88	100
33	0.37	I	4.5	1.3	3.98	1.08	100
35	0.42	I	5.0	1.6	6.70	1.60	100

Standard Length mm	Fish Volume cm^3	Bladder State	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
			Vinciguerria poweriae				
19	--	I	3.0	1.1	1.90	--	0-50
20	--	I	2.8	1.2	2.11	--	0-50
23	--	I	3.0	1.4	3.08	--	0-50
25	--	I	4.7	1.9	8.88	--	0-50
			Argyropelecus hemigymnus				
18	0.2	I	3.4	2.2	8.62	4.31	400
22	0.3	I	4.1	2.5	13.42	4.47	400
28	0.7	I	4.9	3.2	26.27	3.75	600
29	0.8	?	3.7	1.9	6.99	0.87	0
			Electrona rissoi				
12	0.05	I	1.7	0.8	0.57	1.14	200
18	0.10	I	3.9	1.0	2.04	2.04	200
29	0.55	I	7.8	2.3	21.60	3.93	200
40	1.60	I	8.4	3.4	50.84	3.18	400
42	2.40	I	11.2	3.2	60.05	2.50	400
			Hygophum hygomi				
09	--	I	0.9	0.2	0.02	--	0-600
27	--	I	5.6	2.1	12.93	--	235
41	1.30	C	3.7	1.3	3.27	0.25	0-600
44	1.40	C	2.6	1.2	1.96	1.40	25
53	2.60	C	4.1	1.2	3.09	1.19	0
59	3.0	I	15.0	5.2	212.37	7.08	0
			Hygophum benoiti				
18	0.10	I	2.7	1.2	2.04	2.04	40
22	0.15	I	3.7	1.6	4.96	3.31	40
29	0.30	I	6.0	1.9	11.34	3.78	40
34	0.50	I	6.3	2.3	17.45	3.49	40
37	0.85	I	8.4	2.5	27.49	3.23	40
40	1.00	I	8.8	2.6	31.15	3.12	40
44	1.40	I	10.3	2.8	42.28	3.02	40

Standard Length mm	Fish Volume cm^3	Bladder State	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
			Benthosema glaciale				
13	--	C	1.8	0.4	0.15	--	0-600
15	0.07	C	2.1	0.6	0.40	0.57	100
17	--	C	2.1	1.0	1.10	--	0-600
18	--	I	3.9	1.3	3.45	--	0-600
20	--	I	4.5	1.5	5.30	--	0-600
21	--	C	2.8	0.9	1.19	1.19	100
23	--	C	2.9	0.9	1.23	--	0-600
26	0.15	C	3.3	1.0	1.73	1.15	800
31	--	C	3.3	0.9	1.40	--	0-600
32	0.40	C	3.5	1.4	3.59	0.89	100
33	--	I	6.0	1.6	8.04	--	0-600
35	0.50	C	3.0	1.3	2.65	0.53	800
38	0.65	C	4.6	1.5	5.42	0.83	800
41	1.00	C	3.6	0.9	1.53	0.15	100
			Symbolophorus veranyi				
20	0.10	I	2.5	1.3	2.21	2.21	700
22	0.13	I	2.6	1.2	1.96	1.51	0
28	0.25	C	2.3	0.9	0.98	0.39	800
43	0.80	C	3.2	0.9	1.36	0.17	45
50	1.40	C	4.4	1.2	3.32	0.24	40
51	1.50	I	6.0	1.9	11.34	0.75	0
59	1.80	C	4.8	1.1	3.04	0.16	0
63	--	C	5.2	1.4	5.34	--	600
64	2.00	C	5.5	1.5	6.48	0.32	40
65	--	C	4.5	1.5	5.30	--	600
78	2.80	C	5.5	1.6	7.37	0.26	0
104	15.50	C	6.5	1.3	5.75	0.04	150
			Lobianchia dofleini				
15	0.06	I	1.9	0.6	0.36	0.60	70
20	0.15	I	3.0	0.7	0.77	0.51	70
25	0.20	I	4.0	1.2	3.02	1.51	70
30	0.45	C	3.1	0.7	0.80	0.17	70
32	0.55	C	3.2	0.7	0.82	0.15	70
36	0.80	C	2.7	1.2	2.04	0.25	70

Standard Length mm	Fish Volume cm^3	Bladder State	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
			Diaphus rafinesquei				
32	0.50	I	5.8	1.2	4.37	0.88	70
36	0.65	I	7.1	1.2	5.35	0.82	500
37	0.80	I	7.7	2.7	29.39	3.67	500
44	1.25	I	7.7	1.9	14.55	1.16	500
45	1.70	I	9.5	2.7	36.26	2.13	190
56	2.90	I	12.3	4.0	103.04	3.55	500
63	4.20	I	14.5	4.0	121.48	2.89	500
66	--	I	13.4	3.0	63.15	--	0-600
			Diaphus holti				
14	0.06	I	2.2	0.9	0.93	1.56	190
31	0.50	I	7.8	2.2	19.77	3.95	190
37	0.80	I	9.9	2.3	27.42	3.43	190
50	1.90	I	9.9	1.8	16.79	0.88	235
			Diaphus metopoclampus				
67	--	I*	16.2	3.5	59.25	--	0-500
			* Bladder badly ruptured, measurements approximate				
			Lampanyctus crocodilus				
22	0.05	I	2.3	0.7	0.59	1.18	800
29	0.20	I	3.4	1.0	1.78	0.89	800
38	0.30	I	4.0	2.1	9.24	3.08	800
47	0.70	I	6.2	1.4	6.36	0.91	800
62	1.80	I	9.5	2.2	24.08	1.34	940
71	2.40	I	9.9	2.3	27.42	1.14	1000
83	3.80	I	14.3	2.3	39.61	1.04	1000
124	19.00	I	17.3	2.6	61.23	0.32	1000
			Lampanyctus pusillus				
23	0.10	I	3.0	0.5	0.39	0.39	70
27	0.15	I	3.4	1.0	1.78	1.19	70
30	0.20	I	4.1	0.9	1.74	0.87	70
35	0.35	I	6.3	1.1	3.99	1.14	70
38	0.40	I	6.3	1.8	10.69	2.67	70
40	0.55	I	5.8	0.8	1.94	0.35	70

Standard Length mm	Fish Volume cm^3	Bladder State	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
			Ceratoscopelus maderensis				
13	--	I	1.3	0.5	0.17	--	0-40
17	0.04	I	1.8	0.6	0.34	0.85	235
20	0.10	C	1.5	0.6	0.28	0.28	235
43	0.90	C	4.4	0.9	1.87	0.21	235
51	1.70	C	4.1	1.9	7.75	0.45	235
60	3.00	I	11.4	2.7	43.51	1.45	0-235
62	2.90	C	6.2	1.1	3.93	0.14	235
67	3.80	C	7.8	1.7	11.80	0.31	235
			Notoscopelus kroyeri				
28	0.25	C	3.4	0.8	1.14	0.46	40
30	--	C	6.0	1.0	3.14	--	0-70
36	0.45	I	5.0	1.5	5.89	1.31	40
46	--	I	8.4	1.3	7.43	--	0-50
47	--	C	5.6	1.2	4.22	--	0-50
48	--	I	9.7	2.2	24.58	--	0-50
58	2.10	C	3.3	1.0	2.09	0.10	45
63	--	C	5.4	1.1	3.42	--	0-50
70	3.50	C	5.2	1.0	2.72	0.07	45
			Notoscopelus elongatus				
37	--	C	3.5	1.2	2.64	--	0-70
39	0.60	I	3.2	0.9	1.36	0.23	45
41	--	I	4.0	1.1	2.53	--	0-45
44	--	I	4.5	1.2	3.39	--	0-70
47	--	C	4.0	0.9	1.70	--	0.45
48	--	C	4.0	1.0	2.09	--	0-600
49	1.10	C	3.7	1.0	1.94	0.18	6000
52	--	C	3.0	0.7	0.77	--	0-600
55	--	C	2.8	1.0	1.47	--	0-45

TABLE 22 . SWIMBLADDER AND FISH MEASUREMENTS FOR MEDITERRANEAN MYCTOPHUM PUNCTATUM.

Swimbladder States: I = Inflated, C = Contracted
Volume calculated as a prolate spheroid

Standard Length mm	Fish Volume cm^3	Bladder Stage	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
16	0.05	I	1.9	0.7	0.49	0.98	0
17	0.06	I	1.9	0.7	0.49	0.81	0
17	0.06	I	2.3	0.7	0.59	0.98	0
17	0.06	I	2.3	0.6	0.43	0.72	0
17	0.06	I	2.5	0.9	1.06	1.77	0
18	0.07	I	2.8	0.8	0.94	1.34	0
18	0.07	I	2.3	0.7	0.59	0.84	0
18	0.06	I	2.3	1.0	1.20	2.01	0
19	0.08	I	3.0	1.0	1.57	1.96	0
19	0.08	I	2.6	0.8	0.87	1.09	0
20	0.10	I	2.3	1.2	1.73	1.73	70
20	0.07	I	2.5	0.8	0.84	1.20	0
21	0.12	I	2.5	0.7	0.64	0.54	40
21	0.10	I	2.7	1.0	1.41	1.41	0
21	0.10	I	2.1	0.8	0.70	0.70	0
22	0.12	I	2.8	0.8	0.94	0.78	0
22	0.12	I	2.8	1.2	2.11	1.76	0
23	0.13	I	3.4	1.6	4.56	3.51	0
23	0.13	I	3.0	1.5	3.53	2.72	0
24	0.14	I	3.9	1.4	4.00	2.86	0
25	0.17	I	3.9	1.0	2.04	1.20	0
30	0.28	I	4.4	1.8	7.46	2.67	0
31	0.31	I	5.2	1.4	5.34	1.72	0
31	0.30	I	4.8	2.1	11.08	3.70	0
32	0.35	I	5.2	1.7	7.87	2.25	0
32	0.35	I	4.8	1.6	6.43	1.84	0
32	0.36	I	4.3	1.7	6.51	1.81	0
32	0.34	I	4.2	1.9	7.94	2.34	0
33	0.39	I	5.2	2.3	14.40	3.69	0
33	0.39	I	5.0	1.9	9.45	2.42	0
33	0.39	I	5.8	2.4	17.49	4.49	0
34	0.46	I	4.0	1.4	4.11	0.89	0
34	0.46	I	4.5	2.1	10.39	2.26	0
34	0.41	I	4.2	2.3	11.63	2.84	0
34	0.46	I	5.5	2.0	11.52	2.50	0
35	0.49	I	4.7	1.9	8.88	1.81	0
35	0.49	I	6.1	2.3	16.90	3.45	0
35	0.49	I	4.8	1.9	9.07	1.85	0

Standard Length mm	Fish Volume cm^3	Bladder Stage	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
35	0.50	I	6.1	2.5	19.96	3.99	0
35	0.50	I	5.8	2.2	14.70	2.94	0
35	0.50	I	5.2	1.7	7.87	1.57	0
36	0.53	I	4.1	1.9	7.75	1.46	0
37	0.67	I	5.5	2.7	20.99	3.13	0
37	0.60	I	6.3	2.2	15.97	2.66	0
37	0.60	I	7.1	2.3	19.67	3.28	0
37	0.60	I	7.1	1.9	13.42	2.24	0
38	0.66	I	7.3	1.3	6.46	0.98	0
38	0.64	I	5.7	1.8	9.67	1.51	0
39	0.69	I	5.5	1.9	10.40	1.51	0
39	0.69	I	5.2	2.4	15.68	2.27	0
39	0.69	I	7.0	2.7	26.72	3.87	0
39	0.69	I	6.5	2.7	24.81	3.60	0
40	0.75	I	5.5	2.6	19.47	2.60	0
40	0.76	I	5.9	1.9	11.15	1.47	0
40	0.76	I	6.5	2.3	18.00	2.37	0
41	0.79	I	6.8	2.3	18.83	2.38	0
41	0.83	I	5.3	2.0	11.10	1.34	0
42	0.90	I	4.8	1.8	8.14	0.91	0
43	1.00	I	4.2	1.6	5.63	0.56	0
43	1.03	I	6.8	3.2	36.46	3.54	0
43	0.97	I	7.1	2.6	25.13	2.59	0
43	0.97	I	6.1	2.6	21.59	2.23	0
44	1.00	I	7.1	2.4	21.41	2.14	0
44	1.00	I	8.1	2.6	28.67	2.87	0
45	1.11	I	7.2	2.3	19.94	1.80	0
47	1.26	I	8.0	3.4	48.42	3.84	0
47	1.30	I	8.0	2.6	28.32	2.18	0
47	1.30	I	7.2	2.6	25.48	1.96	0
49	1.46	I	5.8	1.4	5.95	0.41	0
50	1.60	I	8.4	3.2	45.04	2.82	0
52	1.83	I	5.8	2.1	13.39	0.73	0
57	2.70	I	8.4	2.6	29.73	1.10	0
16	0.05	C	1.4	0.4	0.12	0.24	0
25	0.20	C	1.6	0.8	0.54	0.27	40
27	0.30	C	1.7	0.8	0.57	0.19	45
28	0.27	C	1.9	0.5	0.25	0.09	0
29	0.30	C	2.0	0.8	0.67	0.22	40
33	0.40	C	1.4	1.2	1.06	0.26	40
33	0.43	C	2.5	0.5	0.33	0.07	0
37	0.60	C	3.6	1.6	4.83	0.80	0
37	0.60	C	3.0	1.0	1.57	0.26	0
40	0.70	C	1.9	1.6	2.55	0.36	40
43	0.95	C	2.3	1.4	2.36	0.25	0
43	0.97	C	2.4	1.2	1.81	0.19	0
45	1.10	C	4.6	1.6	6.17	0.56	0

Standard Length mm	Fish Volume cm^3	Bladder Stage	Bladder Length mm	Bladder Width mm	Bladder Volume mm^3	Bladder Volume % Fish Volume	Depth of Capture m
46	1.20	C	2.5	1.0	1.31	0.11	0
46	1.29	C	1.7	1.2	1.28	0.10	0
46	1.29	C	3.2	1.4	3.28	0.26	0
47	1.30	C	2.1	1.1	1.33	0.10	0
48	1.30	C	2.3	1.2	1.73	0.13	150
48	1.36	C	2.6	1.6	3.49	0.26	0
48	1.36	C	2.7	1.4	2.77	0.20	0
48	1.36	C	2.3	1.2	1.73	0.13	0
48	1.36	C	1.7	1.4	1.74	0.13	0
49	1.50	C	2.5	1.4	2.57	0.17	0
49	1.46	C	2.6	1.8	4.41	0.30	0
49	1.46	C	2.6	1.1	1.65	0.11	0
50	1.60	C	1.9	1.4	1.95	0.12	0
50	1.60	C	2.0	1.3	1.77	0.11	0
50	1.60	C	2.3	1.6	3.08	0.19	0
51	1.70	C	2.5	1.3	2.21	0.13	45
51	1.66	C	3.0	1.3	2.65	0.16	0
51	1.66	C	3.0	1.7	4.54	0.27	0
51	1.63	C	2.6	1.3	2.30	0.14	0
51	1.66	C	2.6	1.9	4.91	0.30	0
51	1.69	C	2.4	1.2	1.81	0.11	0
51	1.69	C	3.9	1.7	5.90	0.35	0
51	1.69	C	2.5	1.1	1.58	0.09	0
52	1.83	C	2.5	0.9	1.06	0.06	0
52	1.83	C	2.1	1.1	1.33	0.07	0
52	1.83	C	2.1	1.3	1.86	0.10	0
53	1.97	C	2.9	1.3	2.57	0.13	0
54	2.10	C	3.0	1.1	1.90	0.09	0
54	2.10	C	2.5	1.0	1.31	0.06	0
54	2.10	C	2.5	1.2	1.88	0.09	0
55	2.23	C	2.5	1.5	2.95	0.13	0
56	2.36	C	2.0	1.2	1.51	0.06	0
56	2.39	C	2.4	1.5	2.83	0.12	0
57	2.56	C	2.1	1.0	1.10	0.04	0
58	2.69	C	3.0	1.8	5.09	0.19	0
58	2.69	C	2.3	1.4	2.36	0.09	0
59	2.90	C	2.8	1.6	3.75	0.13	0
59	2.90	C	2.3	1.2	1.73	0.06	0
59	2.90	C	2.3	1.1	1.46	0.05	0
60	3.30	C	2.6	1.2	1.96	0.06	0
62	3.80	C	2.6	1.2	1.96	0.05	0
62	3.80	C	2.5	1.2	1.88	0.05	0
62	3.80	C	2.3	1.2	1.73	0.05	0
64	4.30	C	1.9	1.0	0.99	0.05	0
65	4.50	C	2.3	1.5	2.71	0.06	0

A Method for Comparing Biological Data With Acoustical Data

Having summarized the complexity of the relationship of swimbladder volume to fish length, we now offer a first attempt at relating number and size of fishes, swimbladder volumes, and acoustical profiles.

Because of the curvilinear relationship of swimbladder volume as a function of fish standard length, and because of the complication arising from the presence of both inflated and contracted swimbladders in the same species of fish, we have chosen not to use swimbladder volumes as such in our calculations. Rather, we have used the regression of bladder length on standard length, and bladder width on standard length individually, because these more closely approach a rectilinear relationship with fish standard length. For each species, a formula of the type $Y = a + bX$ has been calculated by computer for length and for width of swimbladder as a function of standard length. This information given in Tables 23 and 24, and summaries of the measurements are given in Tables 25 and 26. A single formula has been developed for each species, even though both inflated and contracted swimbladders may be present. Such a procedure doubtless results in considerable error, but we regard a single formula as a good first approximation to reality until much more extensive studies are made.

Using the regression statistics for length and for width of swimbladder for each species, we constructed a computer

TABLE 23. SWIMBLADDER LENGTH VS. STANDARD LENGTH:

Linear Regression Statistics by Least Squares Method.
X = Standard Length mm, Y = Swimbladder Length mm

Species	Regression Equation	Correlation Coefficient	Number of Observations
Cyclothone braueri	Y = 0.6 + 0.08X	0.655	6
Gonostoma denudatum	Y = -6.7 + 0.30X	1.000	3
Ichthyococcus ovatus	Y = -3.2 + 0.28X	0.969	6
Vinciguerria attenuata	Y = -1.0 + 0.17X	0.997	4
Vinciguerria poweriae	Y = -2.2 + 0.26X	0.801	4
Argyropelecus hemigymnus	Y = 2.4 + 0.07X	0.541	4
Electrona rissoi	Y = -1.2 + 0.28X	0.965	5
Hygophum hygomi	Y = -1.2 + 0.17X	0.678	7
Hygophum benoiti	Y = -2.6 + 0.29X	0.988	7
Benthosema glaciale	Y = 1.6 + 0.07X	0.550	14
Myctophum punctatum	Y = 3.8 + 0.00X	0.006	130
Symbolophorus veranyi	Y = 1.6 + 0.05X	0.882	12
Lobianchia dofleini	Y = 2.2 + 0.03X	0.361	6
Diaphus rafinesquei	Y = -1.9 + 0.25X	0.974	8
Diaphus holti	Y = 0.0 + 0.22X	0.923	4
Lampanyctus crocodilus	Y = -1.1 + 0.16X	0.980	8
Lampanyctus pusillus	Y = -2.0 + 0.21X	0.931	6
Ceratoscopelus maderensis	Y = -0.9 + 0.14X	0.855	8
Notoscopelus kroyeri	Y = 5.6 + 0.00X	0.019	9
Notoscopelus elongatus	Y = 5.1 + -0.03X	0.350	9

TABLE 24. SWIMBLADDER WIDTH VS. STANDARD LENGTH:

Linear Regression Statistics by Least Squares Method.
X = Standard Length mm, Y = Swimbladder Width mm

Species	Regression Equation	Correlation Coefficient	Number of Observations
yclothone braueri	Y = 0.2 + 0.03X	0.463	6
onostoma denudatum	Y = -0.2 + 0.03X	0.999	3
chthyococcus ovatus	Y = -0.3 + 0.08X	0.948	6
inciguerria attenuata	Y = -0.3 + 0.05X	0.967	4
inciguerria poweriae	Y = -1.3 + 0.12X	0.952	4
rgyropelecus hemigymnus	Y = 2.0 + 0.02X	0.190	4
lectrona rissoi	Y = -0.4 + 0.09X	0.988	5
ygophum hygomi	Y = -0.4 + 0.06X	0.673	7
ygophum benoiti	Y = 0.2 + 0.06X	0.994	7
enthosema glaciale	Y = 0.6 + 0.02X	0.500	14
yctophum punctatum	Y = 1.1 + 0.01X	0.218	130
ymbolophorus veranyi	Y = 1.1 + 0.00X	0.364	12
obianchia dofleini	Y = 0.4 + 0.02X	0.492	6
iaphus rafinesquei	Y = -0.7 + 0.07X	0.806	8
iaphus holti	Y = 0.9 + 0.03X	0.640	4
ampanyctus crocodilus	Y = 0.8 + 0.02X	0.825	8
ampanyctus pusillus	Y = -0.2 + 0.04X	0.568	6
eratoscopelus maderensis	Y = 0.1 + 0.03X	0.766	8
otoscopelus kroyeri	Y = 1.2 + 0.00X	0.025	9
otoscopelus elongatus	Y = 1.6 + -0.01X	0.513	9

TABLE 25. RANGES OF SWIMBLADDER LENGTH, STANDARD LENGTH, AND SWIMBLADDER LENGTH AS PERCENT OF STANDARD LENGTH IN 20 SPECIES OF MEDITERRANEAN MIDWATER FISHES.

Species	Number of Specimens	Standard Length-mm	Swimbladder Length-mm	Swimbladder Length % SL
Cyclothone braueri	6	19- 24	2.0- 2.5	9.2- 11.4
Cyclothone pygmaea	3	19- 21	0.8- 1.0	3.8- 5.3
Gonostoma denudatum	3	40- 97	5.4- 22.7	13.5- 23.4
Ichthyococcus ovatus	6	17- 35	2.0- 6.8	11.8- 19.7
Vinciguerria attenuata	4	18- 35	2.1- 5.0	11.7- 14.3
Vinciguerria poweriae	4	19- 25	2.8- 4.7	13.0- 18.8
Argyropelecus hemigymnus	4	18- 29	3.4- 4.9	12.8- 18.9
Electrona rissoi	5	12- 42	1.7- 11.2	14.2- 26.9
Hygophum hygomi	7	9- 59	0.9- 15.0	5.9- 25.4
Hygophum benoiti	7	18- 44	2.7- 10.3	15.0- 23.4
Benthosema glaciale	14	13- 41	1.8- 6.0	8.6- 22.5
Myctophum punctatum	130	16- 65	1.4- 8.4	3.0- 19.2
Symbolophorus veranyi	12	20- 104	2.3- 6.5	6.3- 12.5
Lobianchia dofleini	6	15- 36	1.9- 4.0	7.5- 16.0
Diaphus rafinesquei	8	32- 66	5.8- 14.5	17.5- 23.0
Diaphus holti	4	14- 50	2.2- 9.9	15.7- 26.8
Diaphus metopoclampus	1	67-	16.2-	24.3-
Lampanyctus crocodilus	8	22- 124	2.3- 17.3	10.5- 17.2
Lampanyctus pusillus	6	23- 40	3.0- 6.3	12.6- 18.0
Ceratoscopelus maderensis	8	13- 67	1.3- 11.4	7.5- 19.0
Notoscopelus kroyeri	9	28- 70	3.3- 9.7	5.7- 20.0
Notoscopelus elongatus	9	37- 55	2.8- 4.5	5.1- 10.2

TABLE 26. RANGES OF SWIMBLADDER WIDTH, STANDARD LENGTH, AND SWIMBLADDER WIDTH AS PERCENT OF STANDARD LENGTH IN 20 SPECIES OF MEDITERRANEAN MIDWATER FISHES.

Species	Number of Specimens	Standard Length-mm	Swimbladder Width-mm	Swimbladder Width % SL
Cyclothone braueri	6	19- 24	0.7- 1.0	3.3- 4.8
Cyclothone pygmaea	3	19- 21	0.4- 0.5	2.0- 2.4
Gonostoma denudatum	3	40- 97	1.0- 2.8	2.5- 2.9
Ichthyococcus ovatus	6	17- 35	1.0- 2.7	5.9- 7.7
Vinciguerria attenuata	4	18- 35	0.7- 1.6	3.6- 4.6
Vinciguerria poweriae	4	19- 25	1.1- 1.9	5.8- 7.6
Argyropelecus hemigymnus	4	18- 29	1.9- 3.2	6.6- 12.2
Electrona rissoi	5	12- 42	0.8- 3.4	5.6- 8.5
Hygophum hygomi	7	9- 59	0.2- 5.2	2.2- 8.8
Hygophum benoiti	7	18- 44	1.2- 2.8	6.4- 7.3
Benthosema glaciale	14	13- 41	0.4- 1.6	2.2- 7.5
Myctophum punctatum	130	16- 65	0.4- 3.4	1.5- 7.4
Symbolophorus veranyi	12	20- 104	0.9- 1.9	1.2- 6.5
Lobianchia dofleini	6	15- 36	0.6- 1.2	2.2- 4.8
Diaphus rafinesquei	8	32- 66	1.2- 4.0	3.3- 7.3
Diaphus holti	4	14- 50	0.9- 2.3	3.6- 7.1
Diaphus metopoclampus	1	67-	3.5-	5.2-
Lampanyctus crocodilus	8	22- 124	0.7- 2.6	2.1- 5.5
Lampanyctus pusillus	6	23- 40	0.5- 1.8	2.0- 4.7
Ceratoscopelus maderensis	8	13- 67	0.5- 2.7	1.8- 4.5
Notoscopelus kroyeri	9	28- 70	0.8- 2.2	1.4- 4.6
Notoscopelus elongatus	9	37- 55	0.7- 1.2	1.3- 3.2

program that converts the standard length of each specimen of a given species to a swimbladder (prolate spheriod) volume. Having created a new file of swimbladder volumes replacing standard lengths, these data were then tabulated in the same way that standard lengths were tabulated in the fish accounts (Appendices). The results for night collections for stations 1, 2, and 3 are depicted graphically in Figs. 28, 29, and 30, and are tabulated for both night and day collections from all stations in Tables 27-32.

Because we have not had access to the acoustical data collected, we have chosen not to refine our calculations further. We predict, however, that for each frequency of sound for which profiles are available, taking into consideration depth and attenuation,the range of swimbladder volumes responsible for reverberation at each depth at that frequency may be selected and their abundance found to correspond closely to the intensity of sound at the source of reception.

Finally, the data in Tables 27-32 were tabulated by species (Appendix 4, Tables 475-613). Using these tables, the species responsible for reverberation may be identified.

This static approach, treating a relatively short time span, may be expanded into a year-round model. The necessary ingredients are knowledge of the changes in swimbladder structure with growth, together with the kinds of observations on life-history patterns that are given in Part 3 of this report, but with better seasonal coverage.

Fig. 28 Station 1, Night: Number of swimbladders per hour in discrete-depth samples. Samples within 1.5 hours of sunrise or sunset excluded.

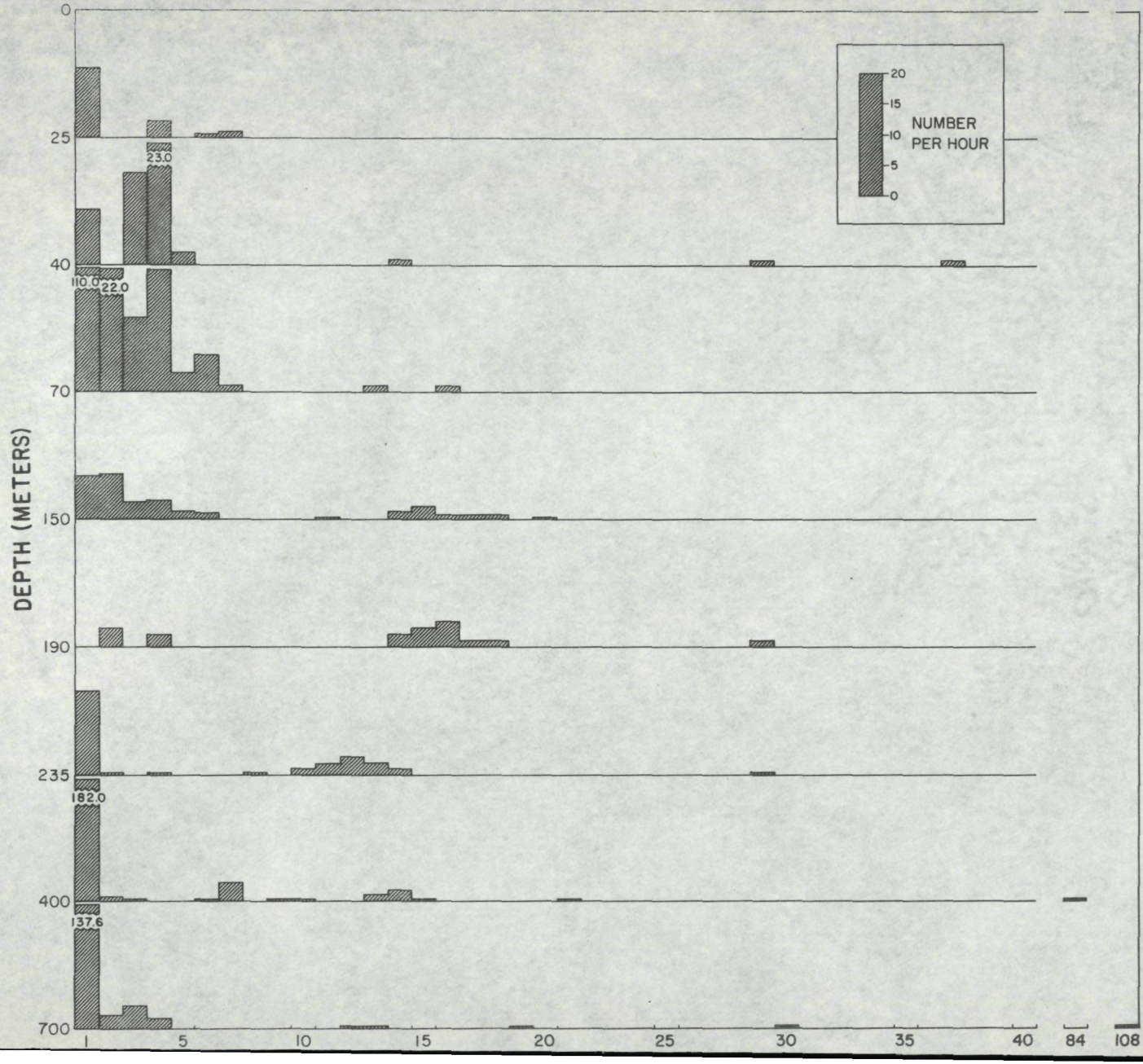

DEPTH (METERS)
0
25
40
70
150
190
235
400
700
23.0
110.0
22.0
182.0
137.6
NUMBER PER HOUR
20
15
10
5
0
1
5
10
15
20
25
30
35
40
84
108

Fig. 29 Station 2, Night: Number of swimbladders per hour in discrete-depth samples. Samples within 1.5 hours of sunrise or sunset excluded.

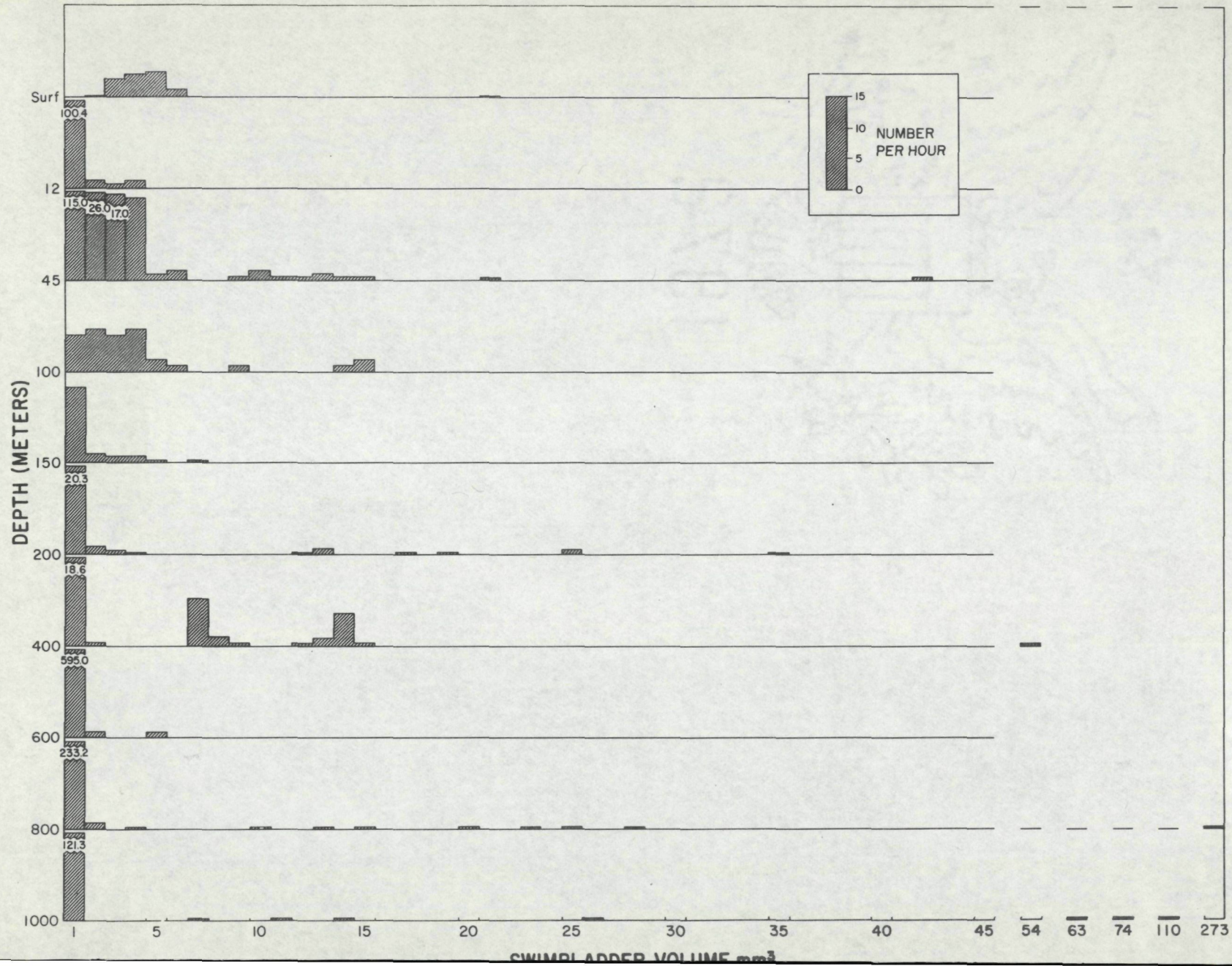

Surf
12
45
100
150
200
400
600
800
1000
DEPTH (METERS)
100.4
115.0
26.0
17.0
20.3
18.6
595.0
233.2
121.3
15
10
5
0
NUMBER PER HOUR
1
5
10
15
20
25
30
35
40
45
54
63
74
110
273
SWIMBLADDER VOLUME mm³

Fig. 30 Station 3, Night: Number of swimbladders per hour in discrete-depth samples. Samples within 1.5 hours of sunrise or sunset excluded.

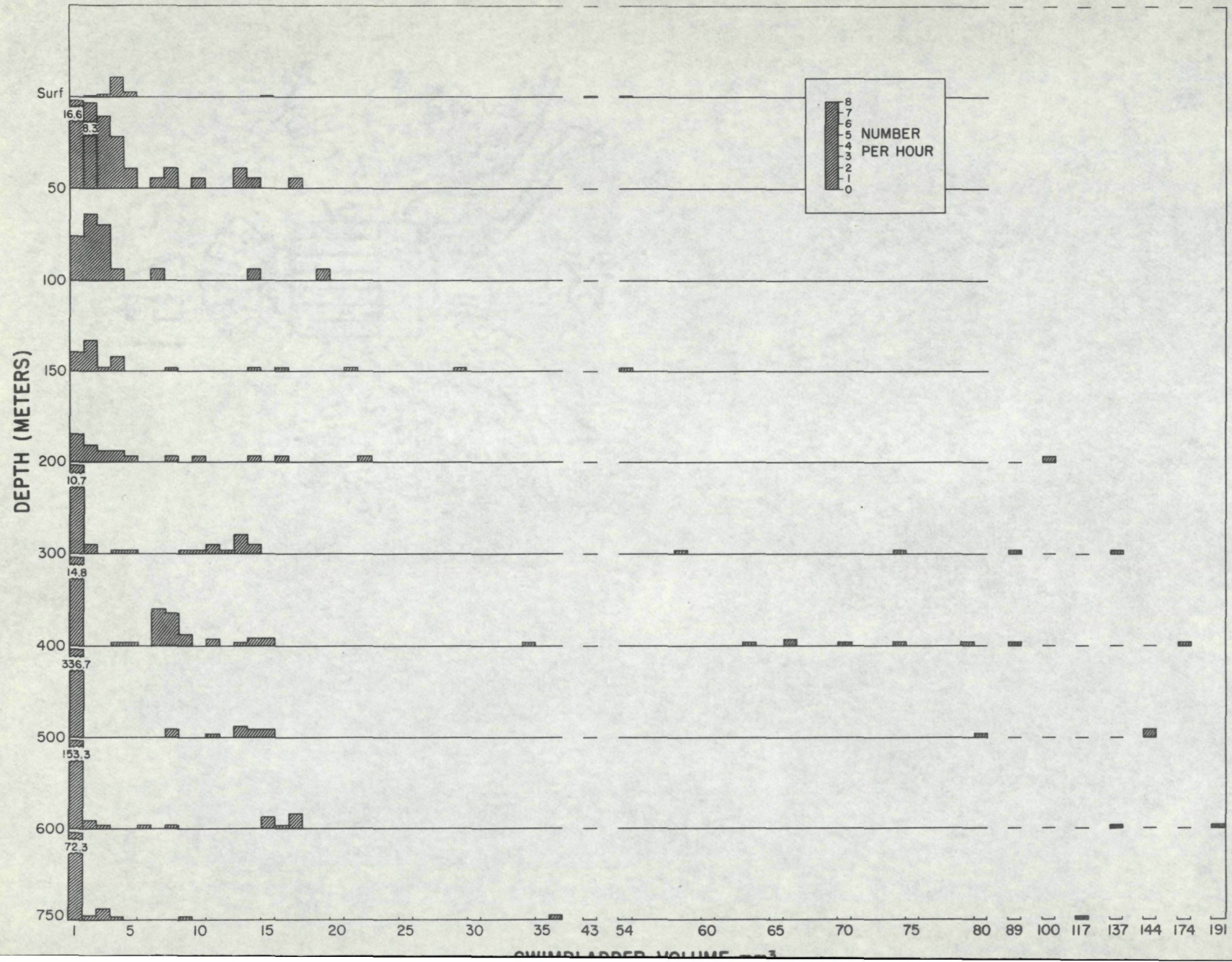

DEPTH (METERS)
Surf
50
100
150
200
300
400
500
600
750
16.6
8.3
10.7
14.8
336.7
153.3
72.3
NUMBER PER HOUR
0
1
2
3
4
5
6
7
8
1
5
10
15
20
25
30
35
43
54
60
65
70
75
80
89
100
117
137
144
174
191

TABLE 27. STATION 1, DAY: NUMBER OF SWIMBLADDERS PER HOUR IN DISCRETE-DEPTH SAMPLES. SAMPLES WITHIN 1.5 HOURS OF SUNRISE OR SUNSET EXCLUDED.

Volume mm^3	Depths Sampled (m)					
	150	235	375	500	700	940
1	0.7	1.5	190.3	637.5	457.3	67.7
2			1.7	51.0	32.6	0.3
3				1.0	17.3	0.3
4	0.3				11.2	4.0
5				0.5	2.7	0.7
6				0.5		0.3
7			4.0	1.0		
8			0.3			
9						
10			0.7	0.5		
11			1.0	0.5		
12	0.3		3.0	1.0	0.7	
13			1.7			
14			1.0	1.5	0.3	
15			0.7	0.5		
16						
17				0.5		
18						
19						0.3
20		0.5				
--						
27				0.5		0.3
--						
70				0.5		
--						
74				0.5		
--						
94				1.0		
--						
100				1.0		
--						
105				0.5		
--						
126					0.3	
No./Hour	1.3	2.0	204.3	700.0	522.4	74.0
No. Hours	3.0	2.0	3.0	2.0	3.0	3.0
No. Specimens	4	4	613	1400	1576	222
No. Samples	3	2	3	2	3	3

TABLE 28. STATION 1, NIGHT: NUMBER OF SWIMBLADDERS PER HOUR IN DISCRETE-DEPTH SAMPLES. SAMPLES WITHIN 1.5 HOURS OF SUNRISE OR SUNSET EXCLUDED.

Volume mm^3	Depths Sampled (m)							
	25	40	70	150	190	235	400	700
1	11.5	9.0	110.0	7.0		13.7	182.0	137.6
2			22.0	7.3	3.0	0.3	0.7	2.3
3		15.0	12.0	2.7			0.3	3.7
4	2.8	23.0	20.0	3.0	2.0	0.3		1.7
5		2.0	3.0	1.3				
6	0.8		6.0	1.0			0.3	
7	1.0		1.0				3.0	
8						0.3		
9							0.3	
10						1.0	0.3	
11				0.3		1.7		
12						3.0		0.3
13			1.0			2.0	1.0	0.3
14		1.0		1.3	2.0	1.0	1.7	
15				2.0	2.3		0.3	
16			1.0	4.0				
17				0.7	1.0			
18				0.7	1.0			
19								0.3
20				0.3				
21							0.3	
--								
29		1.0			1.0	0.3		
30								0.3
--								
37		1.0						
--								
84							0.3	
--								
108								0.3
No./Hour	16.1	52.0	176.0	28.3	17.0	23.7	190.7	146.9
No. Hours	1.1	1.0	1.0	3.0	1.0	3.0	3.0	3.0
No. Specimens	17	52	176	85	17	71	572	444
No. Samples	2	1	1	3	1	3	3	3

TABLE 29 . STATION 2, DAY: NUMBER OF SWIMBLADDERS PER HOUR IN DISCRETE-DEPTH SAMPLES. SAMPLES WITHIN 1.5 HOURS OF SUNRISE OR SUNSET EXCLUDED.

olume mm^3	Depths Sampled (m)							
	Surf	100	150	200	300	400	800	1000
1		2.0			52.5	76.0	657.5	222.0
2		1.5				0.3	11.0	1.0
3		2.0				0.3	6.5	2.0
4						0.3	2.0	
5							1.0	
6							1.0	
7					1.0	2.0		
8					3.0	1.0	0.5	
9						0.3		
10			1.0					
11						0.3		
12						1.0		
13						2.3		
14						2.0		
15						0.3		
16						0.3		
--								
23							0.5	
24						0.3		
25								1.0
--								
27						0.3		
--								
39								1.0
No./Hour	0.0	5.5	1.0	0.0	56.5	87.3	680.0	227.0
No. Hours	2.0	2.0	1.0	2.0	2.0	3.0	2.0	1.0
No. Specimens	0	11	1	0	113	262	1360	227
No. Samples	2	2	1	2	2	3	1	1

TABLE 30 . STATION 2, NIGHT: NUMBER OF SWIMBLADDERS PER HOUR IN DISCRETE-DEPTH SAMPLES. SAMPLES WITHIN 1.5 HOURS OF SUNRISE OR SUNSET EXCLUDED.

Volume mm^3	Depths Sampled (m)									
	Surf	12	45	100	150	200	400	600	800	1000
1		100.4	115.0	6.0	12.6	20.3	18.6	595.0	233.2	121.3
2	0.08	1.3	26.0	7.0	1.3	1.3	0.5	1.0	1.0	
3	2.9	0.7	17.0	6.0	1.0	0.7				
4	3.7	1.3	13.5	7.0	1.0	0.3			0.3	
5	4.1		1.0	2.0	0.3			1.0		
6	1.2		1.5	1.0						
7					0.3		7.8			0.3
8							1.5			
9			0.5	1.0			0.5			
10			1.5						0.3	
11			0.5							0.3
12			0.5			0.3	0.5			
13			1.0			1.0	1.4		0.3	
14			0.5	1.0			5.4			0.3
15			0.5	2.0			0.5		0.3	
16										
17						0.3				
18										
19						0.3				
20									0.3	
21	0.08		0.5							
22										
23									0.3	
24										
25						0.7			0.3	
26										0.3
27										
28									0.3	
--										
35						0.3				
--										
43			0.5							
--										
54							0.5			
--										
63										0.3
--										
74										0.3
--										
110										0.3
--										
273									0.3	
No./Hour	12.0	103.8	180.0	33.0	16.6	25.7	37.2	597.0	237.2	123.7
No. Hours	11.9	1.5	2.0	1.0	3.0	3.0	2.1	1.0	3.0	3.0
No. Specimens	140	147	360	33	50	77	76	597	713	371
No. Samples	24	3	1	1	3	3	2	1	3	3

TABLE 31 . STATION 3, DAY: NUMBER OF SWIMBLADDERS PER HOUR IN DISCRETE-DEPTH SAMPLES. SAMPLES WITHIN 1.5 HOURS OF SUNRISE OR SUNSET EXCLUDED.

Volume mm^3	Depths Sampled (m)									
	50	100	150	200	300	400	500	600	750	1000
1		4.5	1.0	1.2	65.5	25.7	511.0	183.7	123.5	47.6
2				0.3		0.3	0.7	4.0	2.5	
3		0.2		0.2			0.3		2.0	0.2
4									2.5	0.7
5										
6										
7						0.7	0.3			0.2
8					0.5		0.7	0.3	0.5	0.2
9									1.0	0.2
10						1.0				0.2
11								0.3		
12					0.5	0.3	1.3			
13						0.7	0.7			
14						1.3	1.0			
15							0.3	0.3		
16										
17							0.3			
18								0.3		
19										
20										
21							0.3			
22										
23							0.3			
24								0.3		
--										
32						0.3				
--										
58								0.3		
--										
70							0.3	0.7		
--										
86								0.3		
--										
94								0.7		
--										
100							0.3			
--										
106									0.5	
--										
115										0.2
--										
137								0.3		
--										
159							0.3			
--										
209								0.3		
No./Hour	0.0	4.7	1.0	1.7	66.5	30.3	518.3	192.0	132.5	49.8
No. Hours	2.0	6.0	2.0	6.0	2.0	3.0	3.0	3.0	2.0	3.0
No. Specimens	0	28	2	10	133	91	1555	581	265	158
No. Samples	2	6	2	6	2	3	3	3	2	2

TABLE 32. STATION 3, NIGHT: NUMBER OF SWIMBLADDERS PER HOUR IN DISCRETE-DEPTH SAMPLES. SAMPLES WITHIN 1.5 HOURS OF SUNRISE OR SUNSET EXCLUDED.

Volume mm^3	Depths Sampled (m)									
	Surf	50	100	150	200	300	400	500	600	750
1		16.6	4.0	1.7	2.5	10.7	14.8	336.7	153.3	72.3
2	0.03	8.3	6.0	2.7	1.5	0.7			0.7	0.4
3	0.2	6.5	5.0	0.3	1.0				0.3	1.0
4	1.8	4.6	1.0	1.3	1.0	0.3	0.3			0.3
5	0.4	1.8			0.5	0.3	0.3			
6									0.3	
7		0.9	1.0				3.3			
8		1.8		0.3	0.5		2.9	0.7	0.3	
9						0.3	1.0			0.3
10		0.9			0.5	0.3				
11						0.7	0.6	0.3		
12						0.3				
13		1.8				1.7	0.3	1.0		
14		0.9	1.0	0.3	0.5	0.7	0.7	0.7		
15	0.03						0.7	0.7	1.0	
16				0.3	0.5				0.3	
17		0.9							1.3	
18										
19			1.0							
20										
21				0.3						
22					0.5					
--										
29				0.3						
--										
34							0.3			
--										
36										0.4
--										
43	0.03									
--										
54	0.04			0.3						
--										
58						0.3				
--										
63							0.3			
--										
66							0.6			
--										
70							0.3			
--										
74						0.3	0.3			
--										
79							0.3			
80								0.3		
--										
89						0.3	0.3			
--										
100					0.5					
--										
117										0.3
--										
137						0.3			0.3	
--										
144								0.7		
--										
174							0.3			
--										
191									0.3	
No./Hour	2.5	45.2	19.0	8.0	9.5	17.3	27.9	341.0	158.3	75.0
No. Hours	29.0	1.1	1.0	3.0	2.0	3.0	3.1	3.0	3.0	3.0
No. Specimens	74	49	19	24	19	52	85	1023	475	226
No. Samples	58	1	1	3	2	3	3	3	3	3

Acknowledgments

Computer programs for plotting scatter diagrams of swimbladder data and for computing regression statistics were developed by Richard H. Goodyear. The program for transforming standard lengths to swimbladder volumes was developed by the Information Systems Division of the Smithsonian Institution. Ivy R. Kneeland of the Department of Zoology, University of Rhode Island, aided in the preparation of photomicrographs.

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PART 5

ECOLOGY AND VERTICAL DISTRIBUTION OF MEDITERRANEAN PELAGIC CEPHALOPODS

Clyde F. E. Roper

Smithsonian Institution

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Cephalopoda

The cephalopods collected during the program comprised 15 species in 12 families; a total of 326 specimens was captured. Table 33 lists the species, stations of capture and number of specimens. None of the species represented in the collections is restricted in distribution to the Mediterranean Sea.

The major portion of the cephalopods captured were juvenile and larval specimens, so analyses of life histories is not possible for all species. Distributional analyses, however, are possible as it has been shown that juveniles of many species of pelagic cephalopods exhibit the vertical distributional patterns of the adults (Roper and Young, in press).

The data for each species will be presented, followed by a summary of captures by station. All closing-net captures are discussed, but captures within 1.5 hours each side of sunrise and sunset are excluded from analyses of discrete-depth samples. Sample sizes are so small for most species, however, that all captures are taken into account where possible.

1. Heteroteuthis dispar (Tables 34-39, Fig. 31)

Heteroteuthis dispar, a small sepiolid squid, was the second most abundant cephalopod captured. Of the total of 78 specimens, (closing - and open-net captures), 44 were taken at station 3, 31 at station 2, and 3 at station 5; the species

Table 33 . Cephalopod species and numbers of specimens captured in Mediterranean stations 1 - 5.

Species	Med 1	Med 2	Med 3	Med 4	Med 5	Total
piolidae						
Heteroteuthis dispar	0	31	44	0	3	78
oploteuthidae						
Abraliopsis pfefferi	3	3	22	0	1	29
Thelidioteuthis alessandrinii	1	0	0	0	0	1
Pyroteuthis margaritifera	0	0	18	0	4	22
ychoteuthidae						
Onychoteuthis banksii	3	21	57	1	16	98
stioteuthidae						
Histioteuthis reversa	7	6	0	0	0	13
enopterygidae						
Ctenopteryx sicula	1	2	18	0	0	21
achioteuthidae						
Brachioteuthis riisei	8	0	0	0	0	8
mastrephidae						
Ommastrephes sp.	0	2	7	0	7	16
Todarodes sagittatus	2	0	7	0	7	9
ysanoteuthidae						
Thysanoteuthis rhombus	0	0	1	0	0	1
iroteuthidae						
Chiroteuthis veranyi	1	1	2	0	0	4
anchiidae						
Galiteuthis armata	2	6	0	1	0	9
topodidae						
Octopod sp. A.	0	4	1	0	0	5
gonautidae						
Argonauta argo	0	0	11	0	1	12
Total	28	76	188	2	32	326

was absent in catches from stations 1 and 4. It was the most abundant cephalopod at station 2, and at station 3 it was exceeded in numbers only by Onychoteuthis banksii.

Distribution: Thirty-eight of the 78 specimens captured were taken in discrete samples, the remainder in open nets. At station 2 during the day one specimen of H. dispar (5 mm ML - Mantle Length) was captured at 200 m and 8 specimens (6-10 mm ML) were captured at 400 m. At night 8 specimens (5-9 mm ML) were captured at 45 m (4/hr.). Although sampling at station 2 was somewhat patchy, there appears to be an indication of diel vertical movement.

Ten specimens were captured at station 3; during the day 3 specimens (3-8 mm ML) were taken at 150, 200 and 300 m, while at night 7 specimens (6-14 mm ML) were captured over a range of 50-300 m, one each at 50 and 100 m and 5 at 150-300 m. The shallowest daytime catch (150 m) is also the smallest specimen (3 mm ML), possibly too small to have begun to display a diel migratory behavior. Evidence for diel migration is not strong at station 3; six samples between 400 and 500 m during the day produced one specimen, while the same effort there at night yielded no material.

Only two specimens of H. dispar were taken at station 5, both during the day; one (3 mm ML) was captured at 250 m and the other (2 mm ML) at 410 m.

An analysis of non-closing net captures by individual station adds little concerning distribution.

When all stations at which H. dispar was captured in discrete tows (2, 3 and 5) are plotted together, an indication of diel vertical movement is noted (Table 34). In addition, total sampling effort is shown with negative captures indicated by zeros. The range of the daytime per hour captures extends from 150 to 500 m with a peak in concentration at 400-425 m. At night the captures occurred from 50 to 300 m. Rather than exhibiting a distinct vertical migration H. dispar is considered to undergo a diel vertical shift where most specimens occur below 200 m during the day and above 200 m at night with a zone of overlap between 150 and 300 m. H. dispar does not occur at the surface; over 50 hours of sampling at the surface at night on stations 2, 3 and 5 failed to yield specimens.

Non-closing net data (M, P, and N samples) for all stations combined is shown in Figure 31 . During daytime at 200 m a peak of captures occurs of 4 specimens per hour. Fewer than one specimen/hour were taken at 150 m and no specimens were captured at 100 m. Daytime captures plotted at 500-800 m probably represent contamination from the upper layers. At night the large majority of captures was made at 45-150 m, especially at 45-50 m where nearly 12 specimens per hour were captured. The specimens recorded below 150 m, one each at 300, 500 and 600 m, easily could be contaminants from the upper layer of abundance. Although no samples are available from 50 m during the day, it appears that open-net samples also indicate a diel vertical shift of H. dispar in the Mediterranean.

TABLE 34

HETEROTEUTHIS DISPAR NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 1 2 3 4 5
NUMBER OF SAMPLES 292 NUMBER OF SPECIMENS 38

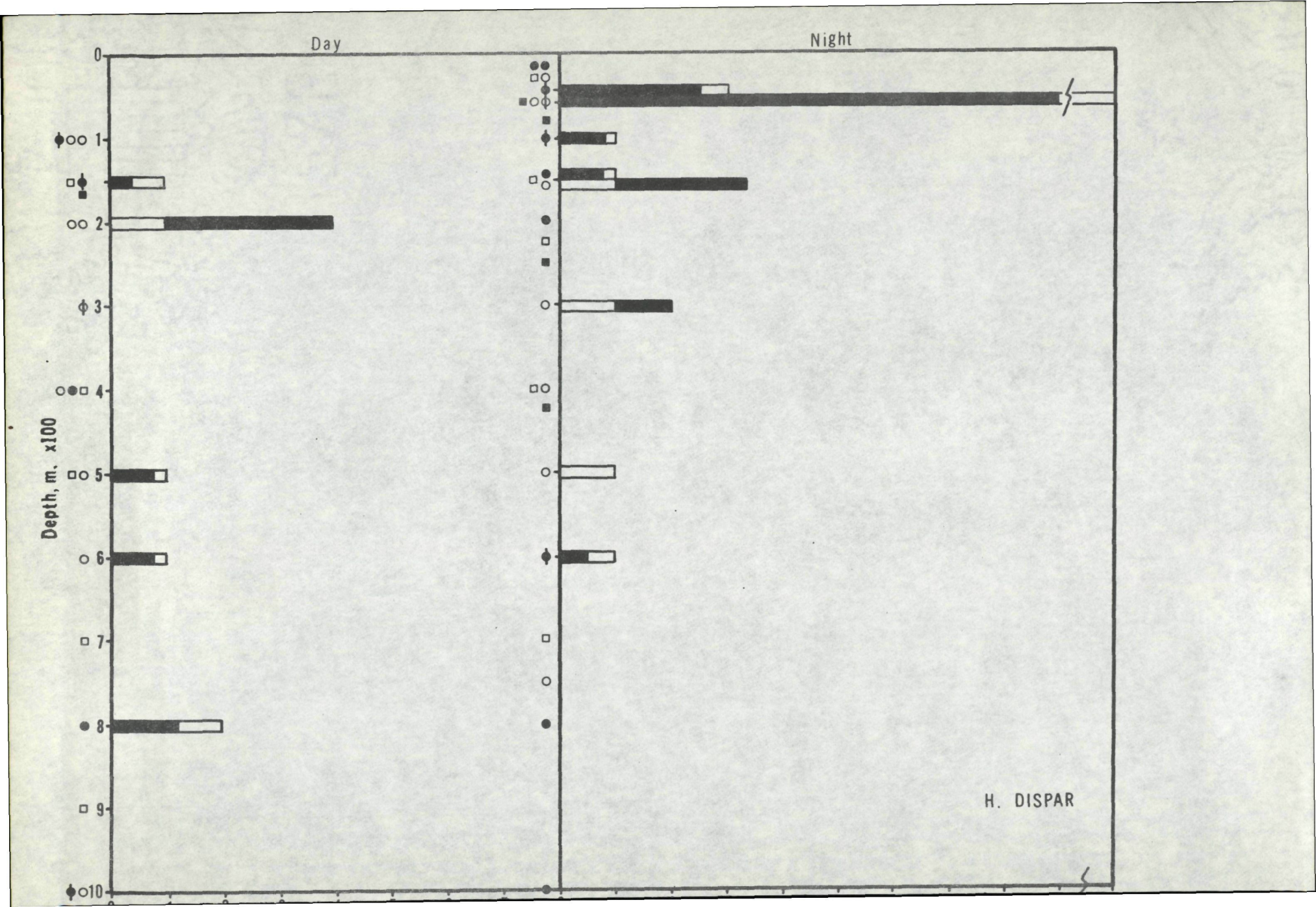
LOCAL STANDARD TIME

	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	2:00	4:00
NEUSTON			0 0					0	0 0 0	0 0 0	0 0	0 0
25							0 0	<1	0 0 0		0	0 2
50						0 0	0 1	0		2	0	0 0
75									0		0	0 0
100				0 0	0 0	0			0 0		0 <1	3 1
125												
150					0 0 0	<1 0	0		0 1 0	<1 0		
175					0					0		
200		0 0	1	0 0	0 0 0	0 1			0 0	0	1 0	<1 0
225												
250						<1	0 0		0	0 0		
275												
300					0 0	0 0	0		0	1 1		
325									0			
350					0							
375			0	0 0								
400	0	0 0			0 7	1			0 0 0		0 0 0	0
425			1							0		
450												
475									0			
500	0	<1 0				0 0			0	0 0		
525							0		0			
550												
575												
600			0 0	0		0 0			0 0		0 0 0	
625												
650												
675						0 0						
700					0	0 0				0 0	0	
725												
750						0 0	0		0	0 0		
775												
800			0						0	0 0		
825												
850												
875												
900												
925												
950			0	0 0								
975												
1000			0	0					0	0 0		

Fig. 31 Heteroteuthis dispar. Day-night vertical distribution of non-discrete (open-net) captures. Symbols used are as follows:

Station	Non-discrete (M,N,P)	Discrete (A,B,C)
1	□	△
2	●	▲
3	○	▽
5	■	▼

Symbol(s) closest to bar is the station(s) at which the capture was made. "P" sample is represented by a " | ", eg. ⧫ . Black portion of bar = number of specimens per hour. White portion of bar = number of specimens. Solid white bar indicates no. specimens/hr. = no. specimens.


Day
Night
Depth, m. x100
0
1
2
3
4
5
6
7
8
9
10
H. DISPAR

Size and Stage of Maturity: The size of all specimens of H. dispar captured in the Mediterranean ranged from 2 mm ML to 25 mm ML. Table 35 presents the size frequency distribution by stage of maturity. Over 97% (74) of the specimens are larvae (sex not detectable) or juveniles. The only 2 adults are males of 22 and 25 mm ML. Thirty percent of the specimens are 6-7 mm ML and 80% of the total is included in the 5-12 mm ML size range.

Closing-net data on stage of maturity vs. depth show no differences between stages, possibly because no fully adult specimens are present (Table 36). The data do show that during the daytime more specimens (2.4/hr.) are caught at greater depths (400-500 m) than at shallower depths, eg., 0.8 specimens/hr. at 150-250 m, whereas at night the reverse appears to be the case, although not as pronounced: 2.1 specimens/hr. at 50-150 m and 0.9 specimens/hr. at 200-300 m. No major differences in depth distribution by sex (Table 37) are noted during the day (200-500 m); at night the only males (1.14 specimens/hr.) were taken at 50 m; whereas females (1.9 specimens/hr.) were taken over the range of 50-300 m. The slight differences in distribution by sex and size noted above probably are a result of the small size of the sample.

In closing nets (Table 38) at station 2 during the day the smallest specimen (5 mm ML) was captured at 200 m, while the 8 remaining specimens (6-10 mm ML) were taken at 400 m. At night 8 specimens (5-9 mm ML) were captured at 45 m. Daytime

SAMPLES, MED 1 2 3 4 5

MM SIZE	LARVAE	JUVENILE FEMALES	JUVENILE MALES	ADULT MALES	UNDESIGNATED	TOTALS
2	1					1
3	4				1	5
4	1		1			2
5	3	5	3			11
6		7	4			11
7		6	5			11
8		3	4			7
9		5	3			8
10		2	6			8
--						
12		2	4			6
13		1				1
14		1	1			2
--						
16		1				1
17			2			2
--						
22				1		1
--						
25				1		1
TOTALS	9	33	33	2	1	78

TABLE 36

HETEROTEUTHIS DISPAR

NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 1 2 3 4 5
SAMPLES WITHIN 1.50 HOURS OF SUNRISE OR SUNSET EXCLUDED

DEPTH M	DAY TOTAL HOURS	DAY NUMBER PER HOUR LARVA	DAY NUMBER PER HOUR JUVENILE	DAY NUMBER PER HOUR SUBADULT	DAY NUMBER PER HOUR ADULT	DAY NUMBER OF SAMP.	DAY NUMBER OF INDIV.	NIGHT TOTAL HOURS	NIGHT NUMBER PER HOUR LARVA	NIGHT NUMBER PER HOUR JUVENILE	NIGHT NUMBER PER HOUR SUBADULT	NIGHT NUMBER PER HOUR ADULT	NIGHT NUMBER OF SAMP.	NIGHT NUMBER OF INDIV.
SURF	2.0	0.0	0.0	0.0	0.0	2	0	48.7	0.0	0.0	0.0	0.0	97	0
25								2.6	0.0	0.0	0.0	0.0	5	0
50	2.0	0.0	0.0	0.0	0.0	2	0	4.1	0.0	1.6	0.0	0.0	3	9
75								2.0	0.0	0.0	0.0	0.0	2	0
100	8.0	0.0	0.0	0.0	0.0	8	0	3.0	0.0	0.3	0.0	0.0	3	1
125														
150	6.0	0.2	0.0	0.0	0.0	6	1	10.0	0.0	0.2	0.0	0.0	10	2
175	1.0	0.0	0.0	0.0	0.0	1	0	1.0	0.0	0.0	0.0	0.0	1	0
200	8.0	0.0	0.3	0.0	0.0	8	2	6.0	0.0	0.2	0.0	0.0	6	1
225														
250	3.0	0.3	0.0	0.0	0.0	3	1	4.0	0.0	0.0	0.0	0.0	4	0
275														
300	4.0	0.0	0.0	0.0	0.0	4	0	3.0	0.0	0.7	0.0	0.0	3	2
325								1.0	0.0	0.0	0.0	0.0	1	0
350	1.0	0.0	0.0	0.0	0.0	1	0							
375	3.0	0.0	0.0	0.0	0.0	3	0							
400	6.0	0.0	1.3	0.0	0.0	6	8	8.1	0.0	0.0	0.0	0.0	8	0
425	1.0	1.0	0.0	0.0	0.0	1	1	1.0	0.0	0.0	0.0	0.0	1	0
450														
475														
500	7.0	0.0	0.1	0.0	0.0	7	1	3.0	0.0	0.0	0.0	0.0	3	0
525								1.0	0.0	0.0	0.0	0.0	1	0
550														
575														
600	3.0	0.0	0.0	0.0	0.0	3	0	4.0	0.0	0.0	0.0	0.0	4	0
625														
650														
675	2.0	0.0	0.0	0.0	0.0	2	0							
700	4.0	0.0	0.0	0.0	0.0	4	0	3.0	0.0	0.0	0.0	0.0	3	0
725														
750	2.0	0.0	0.0	0.0	0.0	2	0	3.0	0.0	0.0	0.0	0.0	3	0
775														
800	2.0	0.0	0.0	0.0	0.0	1	0	3.0	0.0	0.0	0.0	0.0	3	0
825														
850														
875														
900														
925														
950	3.0	0.0	0.0	0.0	0.0	3	0							
975														
1000	4.0	0.0	0.0	0.0	0.0	3	0	3.0	0.0	0.0	0.0	0.0	3	0

SAMPLES WITHIN 1.50 HOURS OF SUNRISE OR SUNSET EXCLUDED

	DAY						NIGHT					
	JM	JF	SM	SF	AM	AF	JM	JF	SM	SF	AM	AF
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	1.14	0.50	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.33	0.0	0.0	0.0	0.0
125	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0	0.0
175	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.13	0.13	0.0	0.0	0.0	0.0	0.0	0.17	0.0	0.0	0.0	0.0
225	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
250	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
275	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.67	0.0	0.0	0.0	0.0
325	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
350	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
375	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.50	0.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
425	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
450	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
475	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
525	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
550	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
575	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
625	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
650	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
675	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
725	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
775	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
825	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
850	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
875	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
925	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
950	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 38

HETEROTEUTHIS DISPAR
DAY

NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 2
SAMPLES WITHIN 1.50 HOURS OF SUNRISE OR SUNSET EXCLUDED

SIZE MM	DEPTHS SAMPLED (M)							
	SURF	100	150	200	300	400	800	1000
5				0.5				
6						0.7		
7						0.3		
8						0.3		
9						1.0		
10						0.3		
NO./HOUR	0.0	0.0	0.0	0.5	0.0	2.7	0.0	0.0
NO. HOURS	2.0	2.0	1.0	2.0	2.0	3.0	2.0	1.0
NO. SPEC.	0	0	0	1	0	8	0	0
NO. SAMPLES	2	2	1	2	2	3	1	1

NIGHT

SIZE MM	DEPTHS SAMPLED (M)									
	SURF	12	45	100	150	200	400	600	800	1000
5			1.5							
6			0.5							
7			0.5							
8			1.0							
9			0.5							
NO./HOUR	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO. HOURS	11.9	1.5	2.0	1.0	3.0	3.0	2.1	1.0	3.0	3.0
NO. SPEC.	0	0	8	0	0	0	0	0	0	0
NO. SAMPLES	24	3	1	1	3	3	2	1	3	3

TABLE 39

HETEROTEUTHIS DISPAR — NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 3
DAY — SAMPLES WITHIN 1.50 HOURS OF SUNRISE OR SUNSET EXCLUDED

SIZE MM	DEPTHS SAMPLED (M)									
	50	100	150	200	300	400	500	600	750	1000
3			0.5							
4										
5										
6				0.2						
7										
8							0.3			
NO./HOUR	0.0	0.0	0.5	0.2	0.0	0.0	0.3	0.0	0.0	0.0
NO. HOURS	2.0	6.0	2.0	6.0	2.0	3.0	3.0	3.0	2.0	3.0
NO. SPEC.	0	0	1	1	0	0	1	0	0	0
NO. SAMPLES	2	6	2	6	2	3	3	3	2	2

NIGHT

SIZE MM	DEPTHS SAMPLED (M)									
	SURF	50	100	150	200	300	400	500	600	750
6			1.0							
7				0.3						
8										
9				0.3	0.5					
10		0.9								
11										
12										
13						0.3				
14						0.3				
NO./HOUR	0.0	0.9	1.0	0.7	0.5	0.7	0.0	0.0	0.0	0.0
NO. HOURS	29.0	1.1	1.0	3.0	2.0	3.0	3.1	3.0	3.0	3.0
NO. SPEC.	0	1	1	2	1	2	0	0	0	0
NO. SAMPLES	58	1	1	3	2	3	3	3	3	3

captures at station 3 (Table 39) consisted of specimens of 3 mm ML (150 m), 6 mm ML (200 m), and 8 mm ML (500 m), while nighttime captures included specimens of 10 mm ML (50 m), 6 mm ML (100 m), 7 and 9 mm ML (150 m), 9 mm ML (200 m), and 13 and 14 mm ML (300 m). At station 5 during the day specimens of 2 and 3 mm ML were taken at 410 m and 250 m respectively; no specimens were taken at night.

The largest specimens captured during the program were taken in open nets, so precise information of depths of capture is lacking. Specimens of 25 and 17 mm ML were taken at 800-0 m, 22 mm ML at 600-0 m, 17 mm ML at 100-0 m, 16 mm ML at 200-0 m, and 14 mm ML at 500-0 m. Any tendency that may appear to exist for larger specimens to occur at deeper depths cannot be verified with existing material.

2. Abraliopsis pfefferi (Table 40, Fig. 32)

A. pfefferi was the third most abundant cephalopod in the collections with a total of 29 specimens. Three specimens each were captured at stations 1 and 2, 22 at station 3, none at station 4, and one at station 5.

Distribution: Only 9 of the 29 specimens of A. pfefferi were captured in discrete-depth samples. At station 1 a single specimen (20 mm ML) was taken at 375 m during the day in a closing chamber. A second specimen (21 mm ML) was taken in the M chamber of the same tow. One specimen (36 mm ML) was taken during the dawn migration period at 70-0 m. No specimens were captured at night.

One specimen (17 mm ML) was taken at station 2 in a closing net at night at 45 m. Two specimens were taken in open nets: one (21 mm ML) at 100-0 m during the day and one (36 mm ML) (equivalent to 3 specimens/hr.) at 200-0 m at night.

At station 3, 5 specimens were taken in closing nets: 1 (10 mm ML) at 100 m during the day; 1 (10 mm ML) at 600 m at night; 3 (10, 15, 18 mm ML) at 50 m during the evening migration period. Open net samples include specimens from 1000-0 m (16 mm ML) and 600-0 m (12, 14, 17 mm ML) during the day, from 750-0 m (36 mm ML), 200-0 m (14 mm ML), 150-0 m (18 mm ML), 50-0 m (13, 15 mm ML) and 25-0 m (7 and 6 mm ML) during the night, and from 150-0 m (19 and 6 mm ML), and 50-0 m (9 mm ML) during the evening migration. Two specimens from a discrete tow were eliminated because of their very poor condition, indicating that they had been captured during a previous tow.

In station 5 a single specimen of 23 mm ML was taken in a closing net at 675 m during the day.

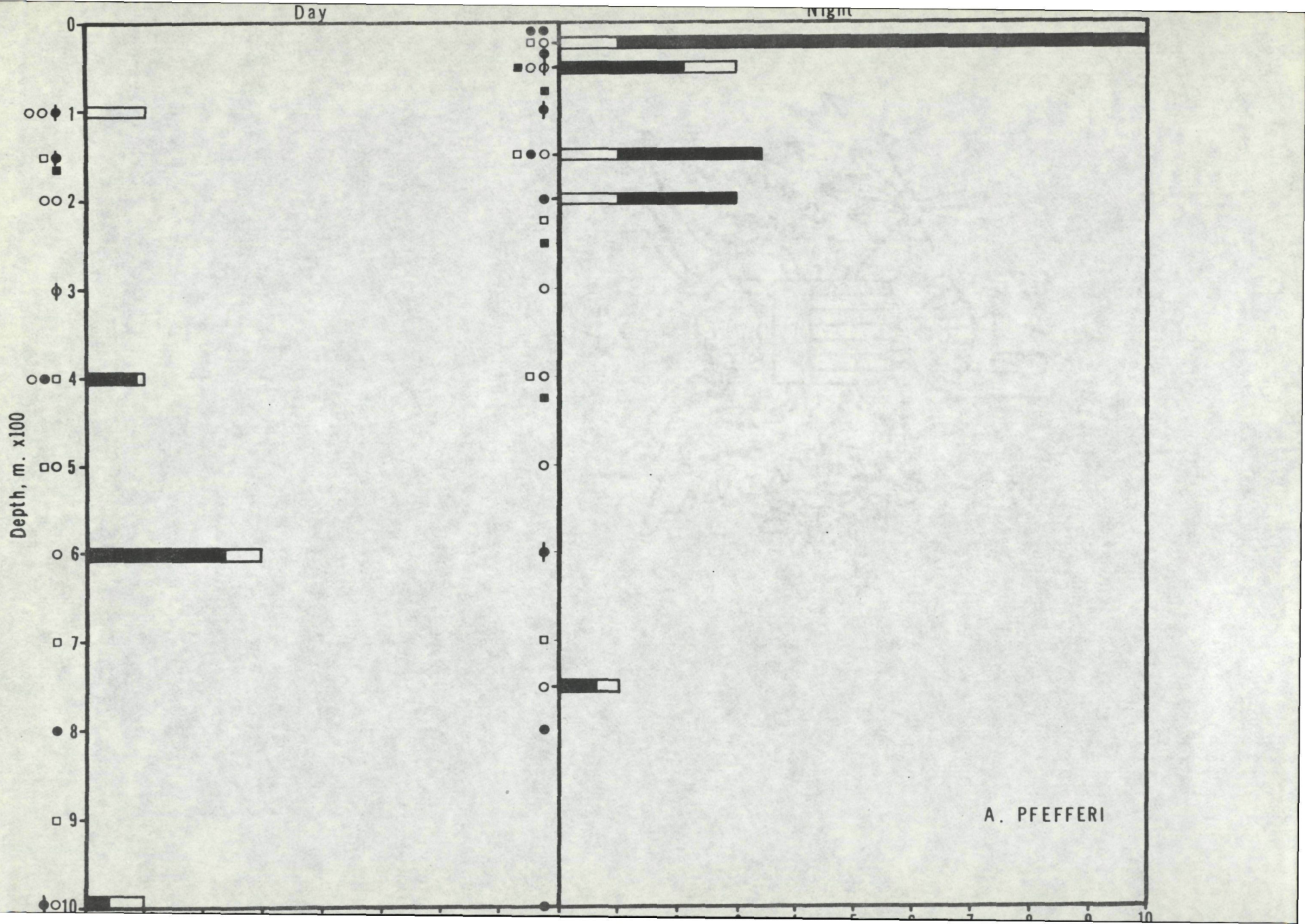
The number of discrete-depth captures is so few for individual stations that little can be determined concerning diel vertical distribution. Even with all stations combined (Table 40) no well-defined pattern emerges. The distribution appears to extend from 100-675 m during the day and from 45-600 m at night. Fig. 32 presents a plot of all open net captures. Daytime captures are spread through-out the water column from 100-1000 m with a "peak" at 600 m. Night captures are heavily concentrated in the upper 200 m; a peak occurs at 25 m where 10 specimens/hr. were taken and at 50 m where 2 specimens/hr.

NUMBER OF SAMPLES 292 NUMBER OF SPECIMENS

LOCAL STANDARD TIME

	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	2:00	4:00
NEUSTON			0 0					0	0 0 0 0	0 0	0 0	0 0
25							0 0	0	0 0 0		0	0 0
50						0 0	0 0	[2]			[<1] 0	0 0
75									0		0	0 0
100				0 0	[<1] 0	0			0 0		0 0	0 0
125												
150				0	0 0	0 0	0		0 0 0	0 0		
175				0							0	
200		0	0 0 0	0 0	0 0	0 0			0 0 0		0 0	0 0
225												
250						0	0 0		0 0 0			
275												
300					0 0	0 0	0		0 0 0			
325									0			
350					0							
375			0 0	0 [2]								
400	0 0 0				0 0	0		0	0 0 0		0 0 0	0
425			0							0		
450												
475									0			
500	0 0 0					0 0			0	0 0		
525							0		0			
550												
575												
600			0 0 0			0 0			0 0		[1] 0 0	
625												
650												
675						0 [<1]						
700					0	0 0				0 0	0	
725												
750						0 0	0		0	0 0		
775												
800			0						0	0 0		
825												
850												
875												
900												
925												
950			0	0 0								
975												
1000			0	0					0	0 0		

Figure 32. Abraliopsis pfefferi. Day-night vertical distribution of non-discrete (open-net) captures. Symbols as in Fig. 31.


Day
Night
Depth, m. x100
0
1
2
3
4
5
6
7
8
9
10
A. PFEFFERI

were captured. (Tows at such shallow depths may be considered "discrete" in that the excursion of the trawl is limited to 25-50 m). Concentrations of 3 and 3.5 specimens/hr. occur at 150 and 200 m respectively. The single capture at 775 m probably represents contamination from shallower depths, but the possibility that it actually came from that depth zone cannot be eliminated entirely since a discrete capture was made at 600 m at night.

The combination of closing net and open net data indicates that A. pfefferi is predominant at 375-675 m during the day and at 25-200 m at night. Scattered individuals may occur shallower in the daytime and deeper at night. Data on this species from the Sargasso Sea (Ocean Acre) also indicate a vertical diel migration from about 600-650 m during the day to about 50-100 m at night. Other species of Abraliopsis also undergo strong diel vertical migrations (Roper and Young, in press).

Size and Stage of Maturity: Specimens of A. pfefferi ranged from 6 mm to 36 mm ML. The three largest specimens, 25, 36 and 36 mm ML, were the only adult females; all other specimens were less than 24 mm ML. Adult males ranged from 17-23 mm ML; the remaining specimens were larvae and juveniles of 6-16 mm ML. Just over one-third of the specimens were in the 14-18 mm ML size group which is comprised primarily of juveniles with a few adult males. One-third of the specimens are adults.

The scanty data for depth of capture vs. size (ML) and stage of maturity (discrete samples; 1.5 hours each side of

sunrise and sunset excluded), may indicate a trend for adult specimens to occur deeper than larval specimens during the day (375-675 m vs. 100 m).

3. Thelidioteuthis alessandrinii.

A single specimen of T. alessandrinii was caught in station 1 and no specimens were caught in station 2-5. The specimen was a larva (22 mmML) that was captured at night in the M chamber at 225-0 m. In the Sargasso Sea juveniles of the species are known to occur at night in the upper 125 m.

4. Pyroteuthis margaritifera. (Tables 41-42)

P. margaritifera was fourth in abundance in the collections with a total of 22 specimens. Eighteen specimens were taken at station 3 and 4 at station 5, while none were captured at stations 1, 2, and 4.

Distribution: Fourteen of the 22 specimens were captured in closing nets. At station 3 during the day two specimens (10 and 19 mm ML) were taken at 400 m, and one each at 500 m (23 mm ML) and 600 m (26 mm ML). At night one specimen (24 mm ML) was taken at 150 m, 4 (22, 27, 28 mm ML; 1 with damaged mantle) at 200 m, and one (26 mm ML) at 750 m. One specimen (20 mm ML) was captured at 50 m during the evening crepuscular period. A diel vertical migration is evidenced at station 3 where specimens occur from 400-600 m during the day and from 150-200 m at night (with one exception at 750 m, possibly a contaminant).

At station 5, two specimens (19, 23 mm ML) were captured at 155 m and one (26 mm ML) at 250 m at night. The remaining specimen (28 mm ML) was taken at 505 m very early in the evening migration period. Although sampling certainly was inadequate at station 5, these captures seem to reflect the trend shown at night at station 3.

The closing net data from stations 3 and 5 are combined in Table 41 to show that P. margaritifera occurs primarily from 400-600 m during the day and from 150-250 m at night. Open net captures (M and P) serve to further indicate this pattern as they yielded 7 specimens from station 3: 2 (26, 24 mm ML) from 600-0 m, one (24 mm ML) from 500-0 m and one (no ML) from 300-0 m during the day and 3 (24, 24, 25 mm ML) from 200-0 m at night. A large quantity of material from the Sargasso Sea Ocean Acre Program shows that this species inhabits primarily 375 to 500 m during the day and migrates to 75-175 m during the night.

Size and Stage of Maturity: The size range represented in the samples extends from 10 to 28 mm ML (Table 42). One specimen was 10 mm ML and the 2 next smallest specimens were 19 mm ML. Twelve (60%) of the 20 measurable specimens were in the 23-26 mm size range.

Males mature at about 19 mm ML, judging from 2 specimens of that size, one of which was mature and the other juvenile. Females begin to mature at 22 mm ML, but some are not matured at 26 mmML. Table 42 summarizes size frequency by stage of maturity.

TABLE 41

PYROTEUTHIS MARGARITIFERA NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 1 2 3 4 5
NUMBER OF SAMPLES 292 NUMBER OF SPECIMENS 14

LOCAL STANDARD TIME

	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	2:00	4:00
NEUSTON			0 0					0	0 0 0	0 0	0 0	0 0
25							0 0	0	0 0 0			0 0 0
50						0 0	0 0	[<1]			0	0 0 0
75									0			0 0 0
100				0 0	0 0	0			0 0		0	0 0 0
125												
150				0	0 0	0 0	0		0 0 [<1]	0 0		
175				0							[2]	
200		0	0 0	0 0	0 0	0 0			0 0 0		[2] [1]	0 0
225												
250						0	0 0		0	[1] 0		
275												
300					0 0	0 0	0		0	0 0		
325									0			
350					0							
375			0	0 0								
400		[1] [1]	0		0 0	0			0 0 0		0 0 0	0
425			0							0		
450												
475									0			
500		0 [<1]	0			0 0			0	0 0		
525							[1]		0			
550												
575												
600			0 [1]	0		0 0			0 0		0 0 0	
625												
650												
675						0 0						
700					0	0 0				0	0 0	
725												
750						0 0	0		0	0 [1]		
775												
800			0						0	0 0		
825												
850												
875												
900												
925												
950			0	0 0								
975												
1000			0	0					0	0 0		

MM SIZE	JUVENILE FEMALES	JUVENILE MALES	ADULT FEMALES	ADULT MALES	TOTALS
10		1			1
--					
19		1		1	2
20				1	1
--					
22			1		1
23	1		1		2
24			2	3	5
25				1	1
26	1			3	4
27				1	1
28			1	1	2
TOTAL	2	2	5	11	20

The closing net data for size vs. depth may indicate a tendency for larger specimens to occur somewhat deeper in the water column than smaller specimens. This is also indicated on the stage of maturity vs. depth plot for day on station 3: the juveniles occur at 400 m while adults occur at 500 and 600 m. Stages appear to be more integrated at night. No discrimination by sex is apparent. A good deal more data are required before these trends can be verified or rejected.

5. Onychoteuthis banksii. (Tables 43-44, Fig. 33)

O. banksii, widely distributed in warm waters of the world, was the most abundantly caught cephalopod during the program. A total of 98 specimens were captured; 3 specimens were taken at station 1, 21 at station 2, 57 at station 3, 1 at station 4, and 16 at station 5. O. banksii was the most abundant cephalopod captured at stations 3 and 5 and second in abundance to Heteroteuthis dispar in station 2. It was one of the two specimens of cephalopods captured at station 4.

Distribution: Fifty of the 98 specimens were captured in closing nets. All specimens were immature and even juveniles of this species may not reflect the adult distribution. At station 1 two specimens (10 and 12 mm ML) were taken in consecutive closing-net samples at 40 m at night. The larger specimen is excluded from analyses because it was caught in a tow that extended into the morning migration period (1.5 hours before sunrise). No daytime captures were made.

During the day at station 2 one specimen (16 mm ML) was captured at 100 m. Two specimens (13 and 20 mm ML) were recorded from 800 m, but the very poor condition of the specimens indicates that they were contaminants that had been caught by their tentacular hooks in the webbing during a previous shallow trawl. At night one specimen of 75 mm ML was taken at the surface, 7 specimens (5-8 mm ML) were captured at 12 m, and one specimen (13 mm ML) was taken at 45 m. Two specimens were caught at dawn at 12 m. While insufficient data are available at station 2 concerning vertical movements, it does seem clear that specimens occur in abundance in the near-surface waters at night.

Four specimens were captured at station 3 during the day: 2 (8 and 18 mm ML) at 50 m and 2 (12 and 13 mm ML) at 100 m. At night 3 specimens were captured at 50 m (10 mm ML), 100 m (15 mm ML), and 300 m (8 mm ML). Twelve specimens (8-22 mm ML) were taken during the evening crepuscular period at 25 m and one (8 mm ML) at 50 m, and 5 (11-20 mm ML) were taken at 100 m during the morning migration period. A larva of 8 mm ML was taken at 750 m during the evening. Again, at station 3 most specimens occur in the upper 100 m.

The sole specimen (22 mm ML) captured at station 4 came from a closing net that fished at 600 m during the day. No specimens were captured in closing nets during the day at station 5. But at night, 8 specimens (2 at 5 mm, 5 at 6 mm, and one at 15 mm ML) were caught at 50 m and 5 (5-11 mm ML) were caught at 80 m.

The time-depth distribution for all stations combined summarizes the data from closing nets (Table 43). The vast majority of specimens occur in the upper 100 m both day and night and there is no indication of a diel vertical movement. It is difficult to interpret the few deep captures; the specimens from 800 m very probably are contaminants (based on poor condition and previous shallow tows), but the ones from 600 and 750 m are not so easily explained.

A summary of open net captures exhibits a distribution similar to that demonstrated by closing nets (Fig. 33). The vast majority of specimens captured on a per-effort basis comes from the upper 100 m at night; the scattered specimens below 100 m could be contaminants. Daytime catches per hour predominate at 100 m with only scattered catches deeper than that.

Size and Stage of Maturity: The size of specimens of O. banksii ranges from 5 mm to 75 mm ML (Table 44). All except the specimen of 75 mm ML were less than 23 mm ML. Fifty-seven percent of the specimens are in the 5-10 mm ML size category. All specimens captured, including the largest, are juveniles and larvae. Specimens are larvae generally until they reach 16-20 mm ML. A few males are identifiable as juveniles at 13 mm ML but most specimens are 17-18 mm ML before sex can be determined. Altogether, 83% of the specimens are larvae (including the undesignated which fall within the size range of larvae). Data are insufficient to indicate a segregation by size in the depth of distribution.

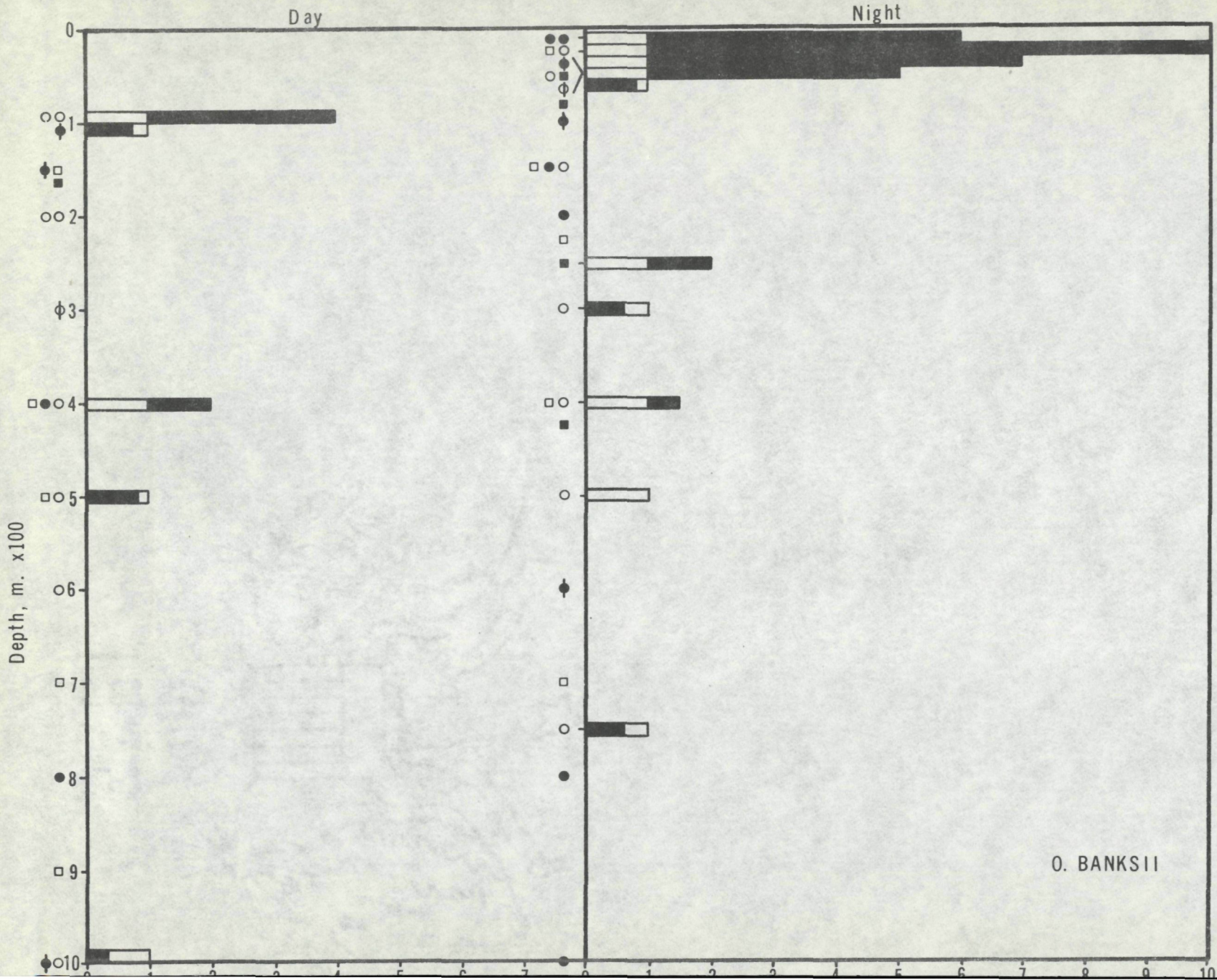
ONYCHOTEUTHIS BANKSII

NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 1 2 3 4 5
NUMBER OF SAMPLES 292 NUMBER OF SPECIMENS 58

LOCAL STANDARD TIME

	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	2:00	4:00	
NEUSTON			0 0					0	0 0 [<1]	0 0	0 0	0 0	0 0
25							[3] 0	2	0 0 0			[9] [4]	0
50						[3] 0	0 0	[<1]			[1]	[2] [2]	0
75									[8]			0 0	0
100				0 [<1]	0 [2]	0			4 0		[1]	[1] [3]	[1]
125													
150				0	0 0	0 0	0		0 0 0	0 0			
175				0							0		
200	0	0 0	0 0	0	0 0	0 0			0 0	0	0	0 0	
225													
250						0	0 0		0	0 0			
275													
300					0 0	0 0	0		[1]	0 0			
325									0				
350					0								
375			0	0 0									
400	0	0 0			0	0 0			0 0 0		0	0 0	0
425			0							0			
450													
475									0				
500	0	0 0				0	0		0	0 0			
525							0		0				
550													
575													
600			0	0 0		[<1]	0		0 0		0	0 0	
625													
650													
675						0	0						
700					0	0	0			0	0		
725													
750						0	0 [1]		0	0	0		
775													
800			[1]						0	0	0		
825													
850													
875													
900													
925													
950			0	0 0									
975													
1000			0	0					0	0	0		

Fig. 33 Onychoteuthis banksii. Day-night vertical distribution of non-discrete (open-net) captures. Symbols as in Fig. 31.


Day
Night
Depth, m. x100
0
1
2
3
4
5
6
7
8
9
10
O. BANKSII

SAMPLES, MED 1 2 3 4 5

MM SIZE	LARVAE	JUVENILE FEMALES	JUVENILE MALES	UNDESIGNATED	TOTALS
5	5				5
6	14			1	15
7	10				10
8	12			1	13
9	11				11
10	5				5
11	2				2
12	4				4
13	4		2		6
14	2				2
15	3			1	4
16	1				1
17	1		1		2
18	2	1	1	1	5
19		2	1		3
20	1	1	1		3
21		1			1
22		1	1		2
23		1			1
--					
75		1			1
TOTAL	77	8	7	4	96

Since all specimens are larvae and juveniles nothing can be stated from this data about adult distributions. Adult O. banksii are known, however, to inhabit the surface waters at night and they are commonly caught at a night-light or are found on decks of ships (Rees, 1949). Since adults are good swimmers they probably are capable of deep excursions during the daytime.

6. Histioteuthis reversa. (Fig. 34)

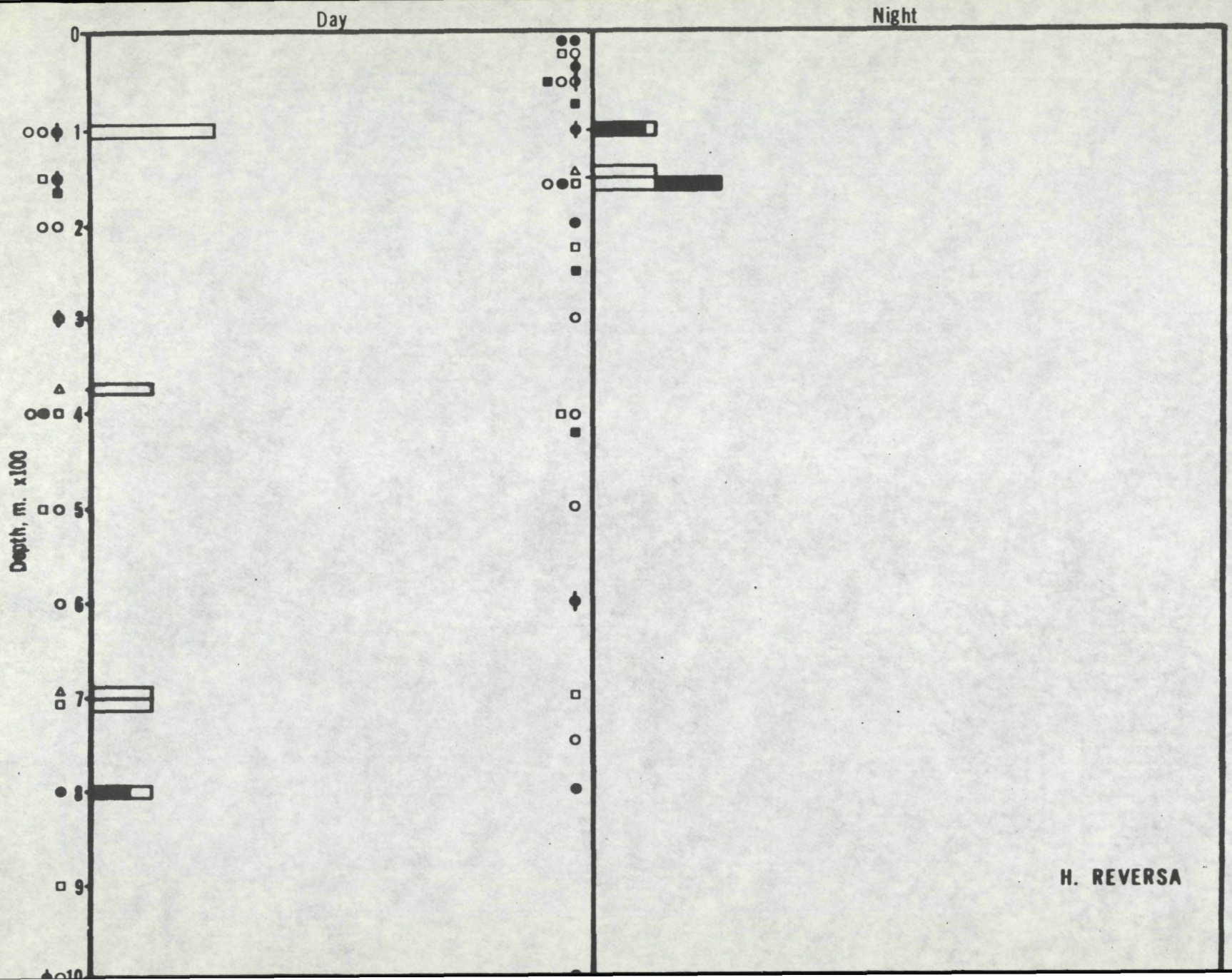
Thirteen juvenile specimens of H. reversa were taken during the sampling program: 7 specimens at station 1 and 6 at station 2. None were taken at station 3-5.

Distribution: Only 3 specimens were captured in closing nets, all at station 1. One specimen (17 mm ML) was taken at 700 m and one (14 mm ML) at 375 m during the day, while one (20 mm ML) was captured at 250 m during the night. Open net captures included specimens from 70-0 m (15 and 16 mm ML) during the morning migration period, 150-0 m (22 mm ML) at night, and 700-0 m (16 mm ML) during the day.

The specimens at station 2, all from open nets, came from 100-0 m (19 mm ML) at night, 100-0 m (20 and 25 mm ML) during the morning migration period.

While the closing net captures seem to indicate a diel vertical movement from 375-700 m to shallower levels at night, data are too few to verify this. Fig. 34 plots both closing and open net captures. Daytime captures are spread throughout

Fig. 34 Histioteuthis reversa. Day-night vertical distribution of non-discrete (open-net) and discrete captures. Symbols as in Fig. 31.


Day
Night
Depth, m. x100
0
1
2
3
4
5
6
7
8
9
10
H. REVERSA

the water column while nighttime captures are limited to the upper 150 m. If the juveniles reflect the behavior of adults, during the day specimens may disperse over a broad range and at night congregate in the upper layers.

Other species of Histioteuthis appear to occur at about 500-700 m during the day and to migrate to 50-400 m at night (Roper and Young, in press).

Size and Stage of Maturity: The size range of specimens of H. reversa extends from 14 to 36 mm ML. All specimens are juveniles, about evenly divided by sex, and all but 3 are between 14 and 20 mm ML.

7. Ctenopteryx sicula. (Table 45)

Twenty-one specimens of C. sicula were taken at stations 1 through 3 and none at stations 4 and 5. One specimen was captured at station 1, 2 at station 2, and 18 at station 3. All but 4 of the specimens are larvae, which makes an interpretation of distribution difficult.

Fifteen specimens were taken in closing nets. At station 1 one specimen (25 mm ML) was taken at 190-0 m in an open net during the dawn crepuscular period. At station 2, no specimens were caught during the day in a closing net, but one (35 mm ML) was caught at night at 150 m. The second specimen (10 mm ML) was taken at station 2 at 100-0 m at night in an open net. The majority of captures came from station 3 where 14 specimens were taken in closing nets: 4 specimens (5, 6, 7 and 9 mm ML)

at 100 m and 3 (9, 12, 12 mm ML) at 150 m during the day; 1 (7 mm ML) at 50 m and 4 (5, 6, 8 and 19 mm ML) at 100 m at night and 2 (5 and 9 mm ML) at 100 m during the early morning migration. Open net samples came from 100-0 m (10 mm ML) and 150-0 m (6 mm ML) during the day, from 500-0 m (5 mm ML) at night and from 50-0 m (13 mm ML) during the evening migration.

Ctenopteryx sicula in the Mediterranean appears to be a shallow-living squid that lives in the upper 150 m both day and night as shown in the plot (Table 45). Discrete-depth captures are at 100 and 150 m during the day and at 50-150 m at night. The 3 juvenile and one adult specimens appear to live in the same zone as the larvae. No significant vertical movement is indicated by the data. The one specimen from greater than 150 m was taken in an open net (500-0 m) and probably is a contaminant. In Ocean Acre specimens have been captured in closing nets at 100 m and less at night and at 350 m during the day. Data from all sources are too meagre to enable one to judge definitely the vertical distributional pattern of this species.

The size distribution, as noted, is composed primarily of larvae from 5-12 mm ML; 81% of the total are in this size group. The other specimens are juvenile males of 13, 19, and 25 mm ML and an adult male of 35 mm ML. Evidence for a stratification of depth of capture by size does not exist for daytime captures, but at night the single adult was caught at 100 m, the juveniles at 100 m, and the larvae at 50 and 100 m. This "trend" must be verified by a greater amount of material.

TABLE 45

CTENOPTERYX SICULA

NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 1 2 3 4 5
NUMBER OF SAMPLES 292 NUMBER OF SPECIMENS **15**

LOCAL STANDARD TIME

	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	24:00	2:00	4:00		
NEUSTON			0	0				0	0	0	0	0	0	0
25							0	0	0	0	0	0	0	0
50						0	0	0	0	0	<1	0	0	0
75									0			0	0	0
100				0	0	<1	3	0	0	0	0	2	2	0
125														
150					0	0	0	<1	2	0	0	0	0	<1
175					0						0			
200		0	0	0	0	0	0	0	0	0	0	0	0	0
225														
250							0	0	0	0	0	0	0	0
275														
300					0	0	0	0	0	0	0	0	0	0
325									0					
350						0								
375				0	0	0								
400		0	0	0	0	0	0	0	0	0	0	0	0	0
425				0						0				
450														
475									0					
500		0	0	0		0	0		0	0	0			
525							0		0					
550														
575														
600			0	0	0	0	0		0	0	0	0	0	
625														
650														
675						0	0							
700					0	0	0			0	0	0		
725														
750						0	0	0	0	0	0			
775														
800				0					0	0	0			
825														
850														
875														
900														
925														
950				0	0	0								
975														
1000			0		0				0	0	0			

8. Brachioteuthis riisei. (Fig. 35)

Eight specimens of B. riisei were captured, all at station 1. Four specimens were captured in closing nets: 3 specimens (34, 35, 65 mm ML) at 150 m at night and one (26 mm ML) at 40 m during the morning crepuscular period. The 4 open net captures were made at 40-0 m (no ML) and 70-0 m (31 mm ML) during morning migration period, at 150-0 m (20 mm ML) and 400-0 m (21 mm ML) during the day.

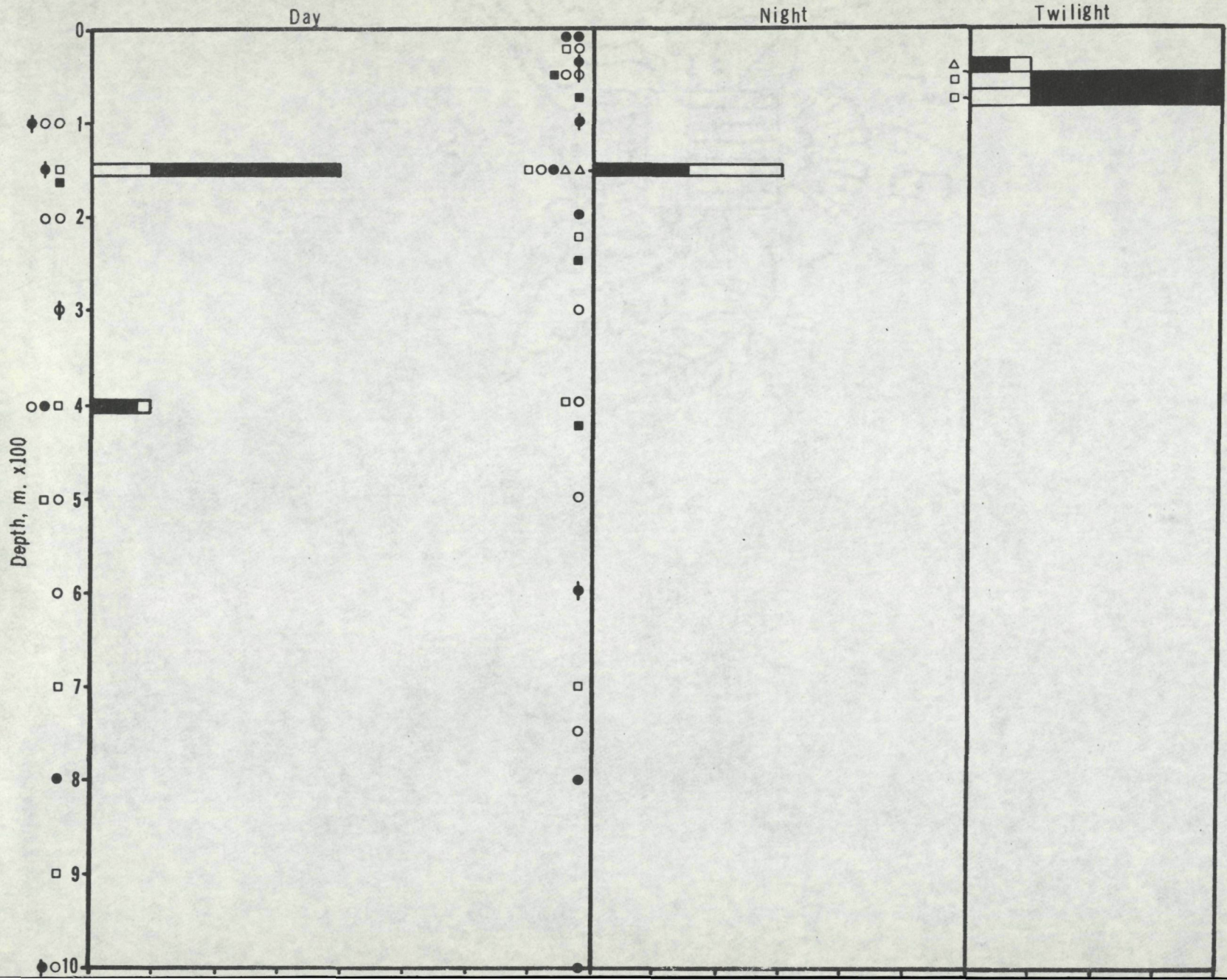
All captures are plotted on Fig. 35 . The distribution of B. riisei appears to be limited primarily to the upper 150 m (the single specimen from 400 m could very well be a contaminant in the open net). All specimens, however, are juveniles and these young animals may be restricted to the upper levels of the sea. Adults are large, relatively powerful swimmers and evidence exists that they live in deep water. Species of Brachioteuthis inhabit deep water during the day (900-1000 m) and ascend into the upper 200 m at night; apparently this is the only cephalopod genus that exhibits such a strong diel vertical migration from great depths (Roper and Young, in press).

The size range is 20-63 mm ML; most specimens are juvenile males, one specimen is unsexable at 34 mm ML, and the largest, 63 mm ML is a juvenile female.

9. Ommastrephes sp.

Sixteen larval specimens of a species of Ommastrephes were taken at stations 2, 3 and 5: 2 specimens at station 2,

Fig. 35 Brachioteuthis riisei. Day-night vertical distribution of non-discrete (open-net) and discrete captures. Symbols as in Fig. 31.


Day
Night
Twilight
Depth, m. x100
0
1
2
3
4
5
6
7
8
9
10

7 at station 3, and 7 at station 5. All but one specimen was taken either in closing nets or at the surface, so all these captures are considered as discrete-depth samples. Both specimens from station 2 were caught in closing nets, 1 (7 mm ML) at 45 m and the other (11 mm ML) at 12 m at night. At station 3, 2 specimens (14 mm ML) were captured at 750 m at twilight, as was one (7 mm ML) at 50 m; 3 specimens (9, 7, 13 mm ML) were taken at the surface in the early morning migration period. All seven specimens (9-12 mm ML) captured at station 5 were taken at the surface at night.

Except for the perplexing capture in 750 m, it appears as though these larval ommastrephids inhabit the upper 50 m. Adults of species of Ommastrephes are known to wander over a great range of depths (Roper and Young, in press).

The size of the larvae ranged from 7-14 mm ML with 73% of the specimens in the 7-11 mm size group.

10. Todarodes sagittatus.

Nine larval and juvenile specimens of T. sagittatus were taken; 2 at station 1 and 7 at station 3. Only one specimen was taken in a closing net - an immature female of 206 mm ML at station 1 from a depth of 150 m at night. The second specimen from station 1 came from an open net at night from 700 m; it was a male of 181 mm ML. All 7 specimens (8-18 mm ML) from station 3 were taken in an open net that fished at 500-0 m at night. Because of the near absence of closing net data, little can be said concerning

the distribution of T. sagittatus except that it occurs in pelagic waters at night, probably within 150 m of the surface. Mangold (1963) gives the distribution of adults of the species in the Catalane Sea as 200-1000 m, mostly 400-700 m. Clarke (1966) reports that this species occurs at the surface at night and is caught at 70-800 m during the day.

11. Thysanoteuthis rhombus.

A single specimen of the rarely captured squid, Thysanoteuthis rhombus, was taken at station 3 in a closing net that fished at 25 m during the twilight period. The specimen is a larva, 8 mm in mantle length. Very little is known about the vertical or geographic distribution of this species which attains a large size (800 mm ML).

12. Chiroteuthis veranyi.

Chiroteuthis veranyi is represented in the collections by 4 larval and juvenile specimens. One specimen (52 mm ML) was captured in a closing net at 400 m at night at station 1. A second specimen (no ML) was taken in an open net at night that fished from 150-0 m at station 2. Two specimens (40, 48 mm ML) were captured at station 3 in an open net that fished at night from 750-0 m. Based on this data alone little can be said about the vertical distribution of this species in the Mediterranean. Other species of the genus, however, are known to undergo ontogenetic descent and limited diel vertical migrations (Roper and Young, in press).

13. Galiteuthis armata.

A total of 9 larval specimens of G. armata was captured: 2 specimens from station 1, 6 from station 2, and one from station 4. None were caught at station 3 and 5. At station 1, 2 specimens were taken in open nets during the day, 1 from 400-0 m (182 mm ML), the other from 900-0 m (90 mm ML). At station 2 one specimen (34 mm ML) was taken at night in a closing net at 400 m and a second (25 mm ML) at 25 m during the morning migration period. Four specimens were taken in open nets at station 2: 1 (43+ mm ML) at 400-0 m during morning migrations, 1 (13 mm ML) at 800-0 m during the day; 1 (10 mm ML) at 200-0 m during the evening; 1 (31 mm ML) at 1000-0 m at night. At station 4 a single specimen (12 mm ML) was taken in a closing net at 600 m during the day. The closing and open net captures of specimens from the Mediterranean suggest that G. armata is widespread throughout the water column. With such small specimens to work with, however, it is impossible to delineate its distribution.

The size of specimens ranges from 10-182 mm ML; all are either larvae or unsexable.

Other species of Galiteuthis that have been studied exhibit ontogenetic descent into deep water (800-1200 m) and a diel dispersal of adults into the 400-800 m zone (Roper and Young, in press).

14. Octopod species A.

Five specimens of an unidentified species of octopod

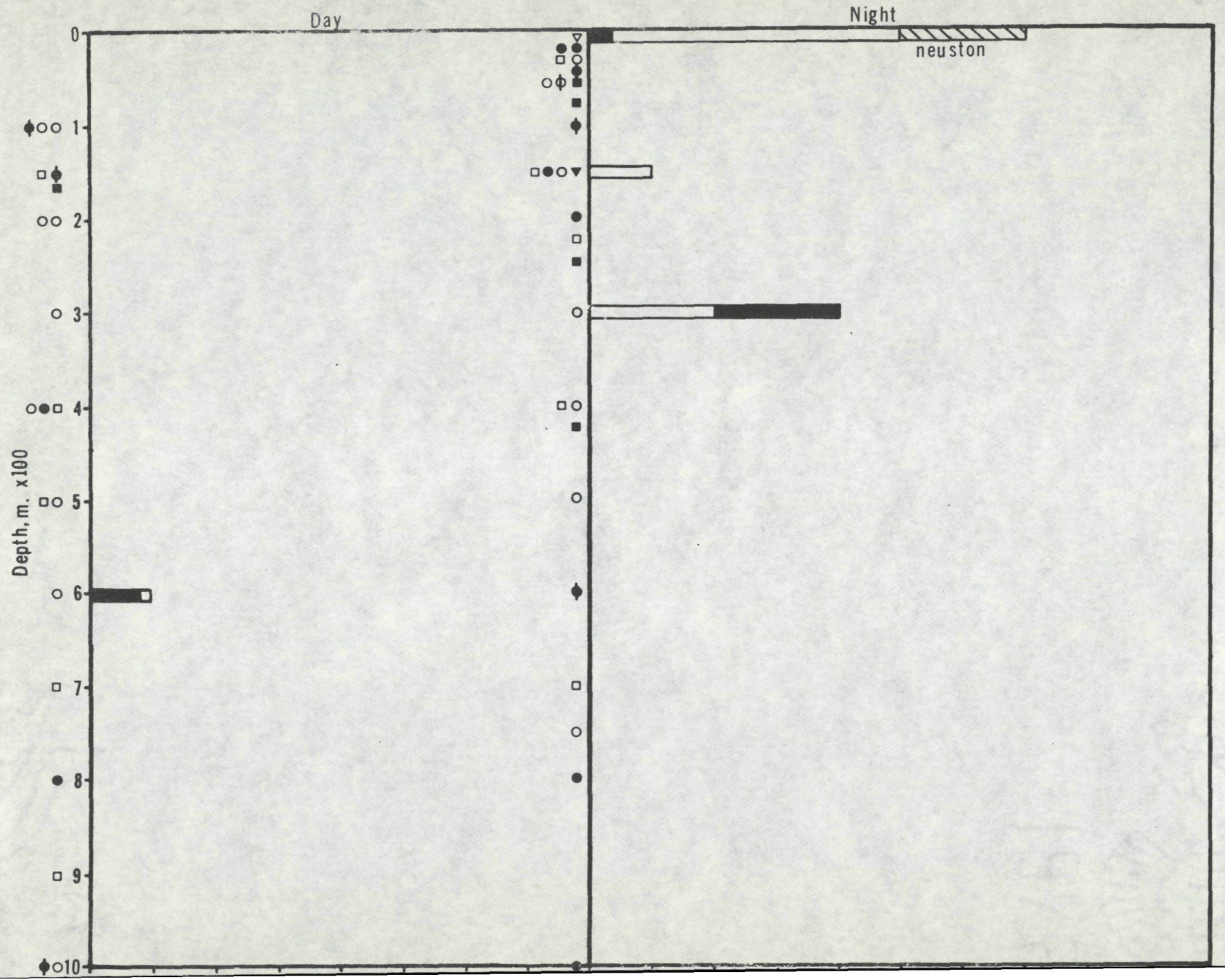
ere captured, 4 in station 2 and one in station 3. All pecimens are larvae or juveniles of 11-15 mm ML. Larvae f a number of shallow water species of octopods are pelagic, nd it is suspected that the specimens belong to one of these pecies. The specimens at station 2 were captured in a closing et at 600 m (11 mm ML) during the day, and in 200-0 m (11, 13 m ML) at night. The specimen (15 mm ML) from station 3 was aptured in an open net at 200-0 m during the night.

15. Argonauta argo. (Fig. 36)

Twelve specimens of the common, near-surface pelagic ctopod were taken in the collections. Females possess calcarious xternal shells in which is trapped a bubble of gas. Eleven pecimens are from station 3 and one from station 5 (Fig. 36). t station 3, 7 specimens (5-71 mm ML) were taken at the surface n neuston nets at night. Three open net captures at station 3 ielded: 1 (5 mm ML) from 600-0 m in the daytime, 1 (6 mm ML) 00-0 m during morning migration periods, and 2(5, 7 mm ML) from 00-0 m at night. At station 5 the lone specimen (6 mm ML) was aken in a closing net at 155 m at night.

A. argo certainly is common at or near the surface and the pen net captures may very well be contaminants from upper levels. he species is not restricted to the surface, however, as videnced by the closing net capture at 155 m. Specimens from he Ocean Acre area have been taken in closing nets at 50-200 m. he species probably is capable of considerable vertical movement,

Fig. 36 Argonauta argo. Day-night vertical distribution of non-discrete (open-net), discrete and neuston captures. Symbols as in Fig. 31


Day
Night
neuston
Depth, m. x100
0
1
2
3
4
5
6
7
8
9
10

as is indicated by its total absence from surface catches during the day. Thus, a diel vertical migration of some sort seems to exist, but the extent is not known.

Comparison by station: A comparison of stations shows that station 3 in the Tyrrhenian Sea produced the greatest number of cephalopods - 188 specimens or 58% of the total catch. Seventy-six specimens, or 20%, were captured at station 3, while 32 specimens (10%) and 28 specimens (8%) were captured at stations 5 and 1 respectively. So little trawling was done at station 4 that a proper comparison can not be made.

Station 3 also produced the largest number of species - 11 of the 15. Stations 1 and 2 each had 9 species, station 5 had 6 species, and station 4 had 2 species.

Only one species. Onychoteuthis banksii, was captured at all 5 stations; it also was the most abundant species, comprising 33% of the total cephalopod catch. This is consistent with its presumed world-wide distribution in warm waters. Abraliopsis pfefferi was taken at 4 stations, absent only from the sparcely sampled station 4. Five species were taken at 3 stations. Heteroteuthis dispar and Ommastrephes sp. were present at stations 2, 3 and 5; Ctenopteryx sicula and Chiroteuthis veranyi were both taken at the western-most stations, stations 1, 2 and 3, and Galiteuthis armata was taken at stations 1, 2 and 4. Pyroteuthis margaritifera and Argonauta argo, both very widely

distributed cephalopods in the Atlantic and Pacific Oceans, were taken at station 3 and 5. Histioteuthis reversa, another widely distributed species, was moderately abundant at stations 1 and 2 but absent from the others.

Abundance: Figs. 37-40, record the six most abundant species on a per-hour basis for closing nets at each station (1-3, 5) respectively. At station 1 (Fig. 37) captures and abundance were relatively low with only 0.3 specimens/hr. of Abraliopsis pfefferi and Histioteuthis reversa caught during the day at 375 m. At night one specimen/hr. of Onychoteuthis banksii was caught at 40 m but no daytime captures were made. No A. pfefferi were caught at night, but .3 specimens/hr. of H. reversa, the same abundance as during the day, were captured. The remaining captures at station 1 were night captures of Branchioteuthis riisei (1 specimen/hr.) and Todarodes sagitattus (.3 specimens/hr) at 150 m and Chiroteuthis veranyi (.3 specimens/hr.) at 400 m.

At station 2 (Fig. 38) Heteroteuthis dispar was the most abundantly caught species during the day with 3 specimens/hr. at 400 m and 5 specimens/hr. at 200 m; 4 specimens/hr. were taken at night at 45 m, an indication of vertical migration. Onychoteuthis banksii was taken at 100 m during the day (.5 specimens/hr) and in great abundance, nearly 6 specimens/hr. from the surface to 45 m at night. All remaining captures were

Fig. 37 Station 1. Day-night abundance (number of specimens per hour) with depth of the six most commonly captured cephalopod species.

940
700
500
400
375
235
190
150
70
40
25
Depth (M)
Day
Night
A. PFEFFERI
O. BANKSII
H. REVERSA
B. RIISEI
T. SAGITTATUS
C. VERANYI
Number per hour
0
1
2
3
4
5

Fig. 38 Station 2. Day-night abundance (number of specimens per hour) with depth of the six most commonly captured cephalopod species.

Depth (M)
Surf
12
45
100
150
200
300
400
600
800
1000
Day
Night
H. DISPAR
A. PFEFFERI
O. BANKSII
C. SICULA
OMMASTREPHES
G. ARMATA
Number per hour
0
1
2
3
4
5

at night in the upper 150 m (ca. 2.3 specimens/hr.) and at 400 m (.5 specimens/hr. for G. armata).

The greatest number of specimens was captured at station 3 (Figure 39) and this number is reflected in the per-hour captures. Small numbers of H. dispar were taken at 150-500 m (1.1 specimens/hr.) during the day; at night about 4 specimens/hr. were captured at 50-100 m. Pyroteuthis margaritifera was taken at 400-600 m (1.3 specimens/hr.) during the day and at 150-200 m (1.8 specimens/hr.) during the night. Day and night captures of O. banksii were evenly mixed at 50-100 m, while Ctenopteryx sicula occurred at 50-100 m during the day (5 specimens/hr.) and at 100-150 m at night (2.2 specimens/hr.).

At station 5 (Figure 40), H. dispar was caught only during the day with 1 specimen/hr. each at 250 and 410 m. A. pfefferi occurred at 675 m during the day (.5 specimens/hr.). The remaining captures were at night: P. margaritifera (2 specimens/hr.) at 155 m; O. banksii at 50 m (8 specimens/hr.) and 80 m (1 specimen/hr.); Ommastrephes larvae at the surface (1 specimen/hr.) and A. argo (1 specimen/hr.) at 135 m.

In summary, nighttime captures far exceeded daytime captures at all stations and the peak abundance of these night captures occurred at shallow depths (25-175 m) while day catches were concentrated below 250 m.

Relation with Hydrography: An analysis of distribution in relation to hydrographic features for all cephalopod species

Fig. 39 Station 3. Day-night abundance (number of specimens per hour) with depth of the six most commonly captured cephalopod species.

Depth (M)
Surf
50
100
150
200
300
400
500
600
750
Day
Night
H. DISPAR
A. PFEFFERI
P. MARGARITIFERA
O. BANKSII
C. SICULA
A. ARGO
Number per hour
0
1
2
3
4
5

Fig. 40 Station 5. Day-night abundance (number of specimens per hour) with depth of the six most commonly captured cephalopod species.

Depth (M)
Surf
50
80
135
155
160
250
325
340
410
425
495
510
675
Day
Night
H. DISPAR
A. PFEFFERI
P. MARGARITIFERA
O. BANKSII
OMMASTREPHES SP.
A. ARGO
Number per hour
0
1
2
3
4
5

is not feasible, since so few specimens were captured. Only the most abundantly caught species and only the specimens caught in discrete-depth samples are discussed. Details concerning oceanographic features are found in the section on Hydrography.

Heteroteuthis dispar was captured over the range of 150-500 m during the day and 45-300 m at night (stations 2, 3, 5). The range of temperatures extended from about 13-16°C during the day and about 13-20°C at night. The species appears to occur chiefly in the lower surface and the intermediate water masses. The captures in the thermocline layer occurred at night at station 2 to 45 m (ca. 18-20°C), whereas all other captures were below the thermocline.

Abraliopsis pfefferi (stations 1-3, 5) occurred from 100-600 m during the day and from 25-600 m at night. As a probable migratory species, specimens may pass from waters as cold as about 13°C to as warm as about 25°C, and through the salinity maximum to the salinity minimum.

Pyroteuthis margaritifera (stations 3, 4) occurs at 400-600 m during the day and at primarily 150-250 m at night, (with a record to 50 m during migration period). The temperature range for the species in the Mediterranean would extend from about 13°C to about 17°C (the 50 m capture). Although other parameters may more dominantly control the vertical distribution of P. margaritifera, the species does appear to be stenothermal in the range of 13-17°C.

Onychoteuthis banksii (stations 1-5), only larvae and juveniles of which were captured, occurs overwhelmingly in the upper 100 m both day and night. (Specimens from 600 and 750 exist). The range of temperatures at various stations in the upper 100 m extends from about 13°C to 26°C, so the species is clearly able to survive a broad range of temperatures.

Specimens of Ctenopteryx sicula were caught at 50-150 m (stations 1-3) over a temperature range of 13-17°C. Although shallow-living, it appears to shun the upper 50 m.

In summary, the cephalopods captured in the Mediterranean inhabit primarily the zone of the surface to 750 m (recognizing that too little sampling was possible below 750 m), a zone that includes the Surface Water and Intermediate Water masses. Some species occur almost exclusively in cool Intermediate Water, eg., Pyroteuthis margaritifera ascends to 150-250 m at night, but few specimens penetrate the thermocline layer. On the other hand, species may range into very warm Surface Waters (26°C) while tolerating colder waters, eg. O. banksii. The thermocline zone, therefore, appears not to be a barrier for some species, but it may contribute to an avoidance of the near-surface waters by others.

The factors of salinity and oxygen encountered during the program appear not to be limiting cephalopod distributions in any detectable manner.

Summary

A summary of the time-depth distribution for all cephalopods caught in closing nets (specimens per hour) is presented in Table 46. The distribution of captures during the day extends from 100-750 m but the abundance is relatively low in all but two samples; "peaks" in abundance occur at 100-200 m and at 400-600 m. Absence of cephalopods in the upper 100 m may be partially a reflection of low sampling effort as well as real distribution. At night captures extend from the surface to 750 m but an overwhelming majority occur in the upper 200 m. Considerable sampling effort at night below 400 m yielded negligible catches.

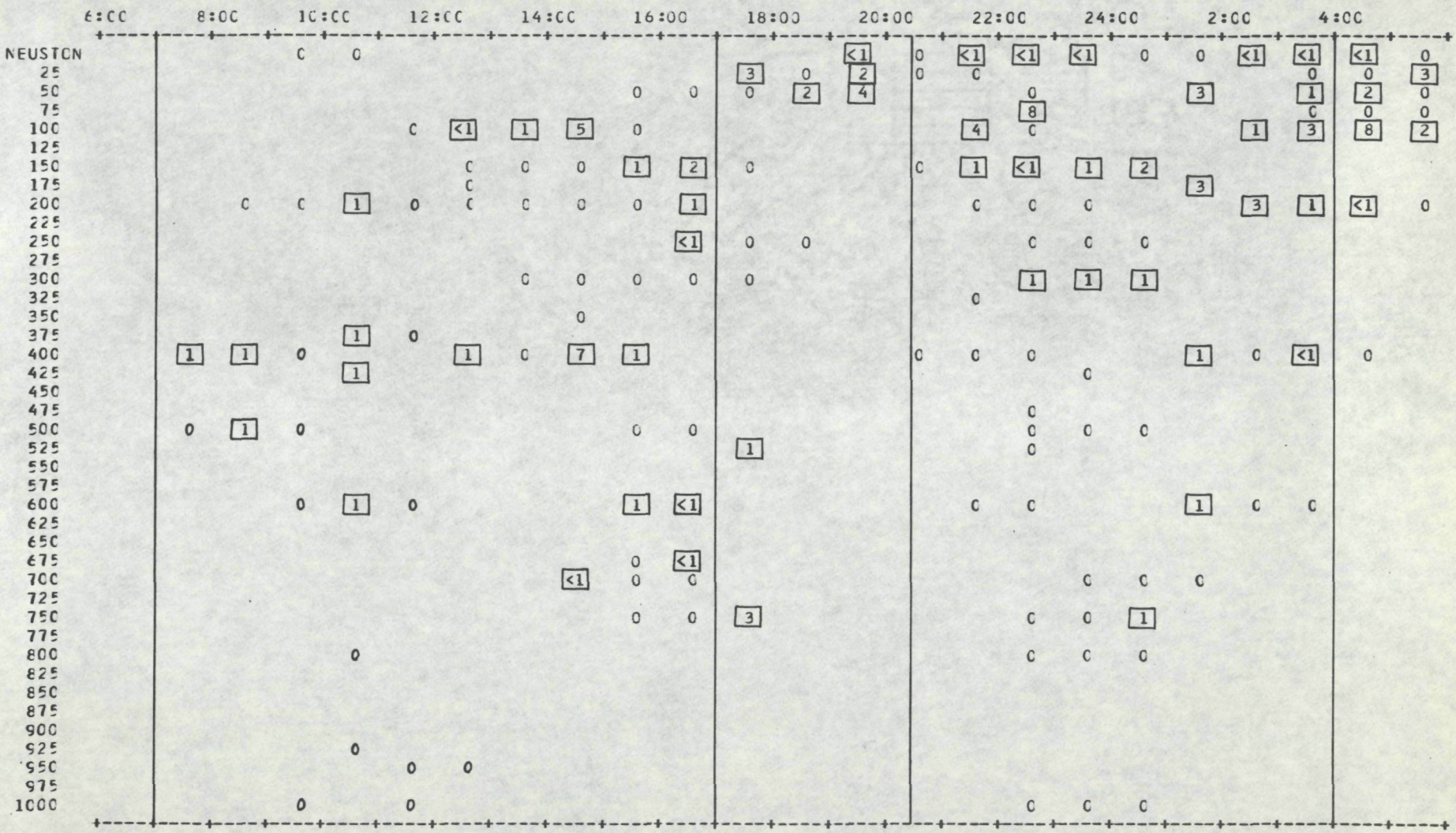
In spite of the known bias of the sampling gear in favor of small specimens, of the probability of net-avoidance, and the relatively low numbers of specimens captured, useful information concerning the vertical distributions of cephalopod species was gained during the investigation. Clearly, several species exhibit diel vertical migrations to varying degrees (eg. H. dispar, P. margaritifera, A. pfefferi), and a general trend for the cephalopod population to shift upwards at night is apparent (Table 46). Some species do not migrate daily as such, but remain in more or less well-defined depth zones (eg. C. sicula) or in near-surface waters with individuals wandering throughout the water column (eg. O. banksii).

While cephalopods do not possess gas-filled swimbladders, as many fish do, most of them have a dense chitinous skeletal rod that may very well reflect sound. In addition, one species

TABLE 46
ALL SPECIES COMBINED.

NUMBER OF SPECIMENS PER HOUR IN DISCRETE DEPTH SAMPLES FROM MED 1 2 3 4 5
NUMBER OF SAMPLES 292 NUMBER OF SPECIMENS 162

LOCAL STANDARD TIME



Argonauta argo, possesses a large, hard calcarious shell that serves as an egg case for the female; a bubble of gas is normally trapped near the apex of the shell. Since discrete-depth data indicate that A. argo may undergo a vertical movement from around 150-200 m to the surface, this species, distributed world-wide in warm waters, may very well contribute to the sound scattering phenomenon.

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