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P. Tardent and R. Tardent, editors

REPRODUCTION SEASONS AND DAY/NIGHT BATHYMETRIC DISTRIBUTION OF THREE SPECIES OF DIPHYINAE (SIPHONOPHORAE), OFF CALIFORNIA AND BAJA CALIFORNIA

ANGELES ALVARIÑO

INTRODUCTION

Muggiaea atlantica, *Chelophyes appendiculata* and *Eudoxoides spiralis* are abundant off California and Baja California. Published works [1,2,3,4,5,6,7,8,9] included information on the species, and in [7] are studies as predators of *Engraulis mordax* larvae. Previous works [10,11] on day/night bathymetric distribution are not based on continuous series of hauls at same locations and depths, and no works are available on polygastric and eudoxid stages through the seasons.

MATERIALS AND METHODS

Plankton analyzed were seasonal cruises of 1969 California Cooperative Oceanic Fisheries Investigations (CalCOFI) for winter (Feb-Mar, 6902-03), spring (May-June, 6905-06), summer (Aug-Sep, 6908-09), fall (Nov-Dec, 6911-12). Paired open-closing bongo nets were used in oblique hauls, calibrated by speed and length of stratum to strain 1000m^3 of water. Sampling covered CalCOFI region grid (stations on lines 70, 90, 120), roughly off Monterey, San Diego, Punta Eugenia; with tows at each station and depth stratum around noon and midnight (about 12 hours time difference at same location and depth from daylight to night hauls). Strata sampled: 600-475m, 475-350m, 350-225m, 225-100m, 100-75m, 75-50m, 50-25m, 25-0m depth.

The entire plankton samples from both paired nets were examined from each haul. No fraction of samples was taken.

Physico-chemical data obtained during the cruises are used in the discussion.

Standardization of counts of specimens in strata above and below 100-m layer to quantitatively compare data to 1000m^3 water for each 25-m depth, was obtained by the formula: $N = n \frac{(\text{opening depth} - \text{closing depth})}{25}$

N = standardized number of specimens

n = number of specimens counted in both paired nets.

The difficulty in quantitative determination of siphonophores was solved in Diphyinae by counting superior and inferior nectophores, bracts and gonophores, and the highest number of either part was applied to the respective polygastric and eudoxid population.

RESULTS

Muggiaea atlantica Cunningham 1892, *Chelophyes appendiculata* Eschscholtz 1829, *Eudoxoides spiralis* Bigelow 1911, are the most abundant siphonophores, together with some species of *Lensia*, in the California and Baja California regions.

M. atlantica inhabits neritic waters of those regions. Polygastric stages extended from 0 to 225 m in winter, spring and summer, and to 100m in the fall. Highest abundance of eudoxids was at upper 75 m in winter and 50 upper m in spring, and absent in summer and fall, probably due to development of benthic stage, as stated[12] for *M. kochi* (closest related to *M. atlantica*) (Table 1).

Polygastric population obtained at daylight was 5 times that at night, and daylight eudoxid population was more than 12 times that obtained at night.

Reproduction may occur late in winter and spring.

M. atlantica inhabited layers above thermocline, and greatest concentrations occurred at 32.98-34.0 ‰ salinity, 9.0°C-20.99°C temperature, and 4.38-6.1 ml/L oxygen.

Ch. appendiculata, the most abundant siphonophore in these regions, was present in all stations covered by 1969 cruises. It was more abundant off San Diego and Punta Eugenia than off Monterey. Polygastric population peaks were respectively at daylight and night, at 0-25m, 50-75m in winter and fall, and 0-25m and 25-50m in spring and summer. Polygastric population was more abundant in daylight hauls of spring, followed by day/night hauls of summer, fall and winter.

Eudoxid population presented peaks at 0-25 and 50-75m depth, respectively, at daylight and night, in winter and spring, and in summer and fall were scattered through the depth strata.

Daylight average abundance of polygastric population was about 1.2 of night, and daylight eudoxid population was 20 times that of night. Polygastric and eudoxid populations were highest in spring. Polygastric population was lowest in winter, and eudoxid population in the fall. Reproduction appears to be continuous through the seasons, with peaks in spring and summer (Table 2).

Highest concentration of *Ch. appendiculata* occurred at 32.22-33.67 ‰ salinity, 9.14-20.75°C temperature, and 4.38-6.2 ml/L oxygen. It was found at the thermocline and above and below this structure.

Day/night changes did not agree with [10,11].

E. spiralis was mainly abundant in warm waters of southernmost and offshore locations under the influence of warm currents. Polygastric population was highest in winter, followed by summer and fall, with minima in spring. Eudoxids started to increase in winter, with a peak in spring, diminishing through summer and fall. Polygastric and eudoxid populations marked the rhythm of alternation of genera-

tions, maximum polygastric of winter was followed by maximum eudoxid of spring, which may be responsible for the increase of summer polygastric population. Reproduction appears continuous through the year. Polygastric population was more abundant in daylight hauls of winter, summer and fall, and night hauls of spring. Eudoxid population was more abundant at uppermost layers during night hauls of winter, and daylight hauls of spring, summer and fall (Table 3).

Daylight polygastric population was 1.2 of the night population. The eudoxids collected at daylight were 4 times those at night.

Maximum concentration of *E. spiralis* concurred with 32.8-34.01 ‰ salinity, 13.1-20.75°C temperature, 5.2-6.3 ml/L oxygen. It was mainly present above the thermocline.

The total polygastric population of *M. atlantica* during 1969 was 35,815 specimens, an average of 78 per haul, and the eudoxid population amounted to 6,260 (average of 13 specimens per haul). Total polygastric population of *Ch. appendiculata* was 16,897 (average of 37 specimens per haul), and the euxoxid population was 9,327 specimens (average of 20 per haul). Total polygastric population of *E. spiralis* was 8,888 (19 specimens per haul), and 17,864 eudoxids (average of 39 per haul).

Highest concentrations of polygastric and eudoxids occurred always during daylight hauls, for *M. atlantica* in winter, *Ch. appendiculata* in spring, and *E. spiralis* in winter and spring, respectively.

These species are active predators on fish larvae and found[7] inversely related to concentrations of anchovy larvae. *M. atlantica* was abundant in "anchovy water"[7], rich in small calanoid copepods, and in 1969 was also present with anchovy larvae.

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Table 1. Seasonal day/night bathymetric distribution of *Muggiaea atlantica* (polygastric and eudoxid stages) during 1969.

Sta. / Depth	70.60 D	70.60 N	70.75 D	70.75 N	70.90 D	70.90 N	70.110 D	70.110 N	90.45 D	90.45 N	90.60 D	90.60 N	90.90 D	90.90 N	120.45 D	120.45 N	120.55 D	120.55 N	120.70 D	120.70 N	120.90 D	120.90 N	Total Average Day Poly.	Day Eudox.	Night Poly.	Night Eudox.
6902-03																										
25- 0	0	0	17	0	-	-	-	-	638 + 3335*	0	508 + 31*	16 + 16*	-	-	14978	94	617	211	8	0	0	0	2095	420	40	2
50- 25	-	0	0	0	-	-	-	-	165 + 510*	0 + 36*	790 + 1231*	0	-	-	2404	392	-	98	0	8	0	0	559	600	62	4
75- 50	20	-	0	-	-	-	-	-	0	148 + 48*	51 + 273*	0	-	-	31	0	-	98	0	0	-	-	17	45	49	9
100- 75	16	-	0	-	-	-	-	-	0	140	51	0	-	-	78	156	7	0	0	0	0	0	12	0	49	0
225-100	-	-	0	-	-	-	-	-	0	-	0	-	-	-	11	-	-	0	-	0	0	0	2	0	0	0
350-225	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	0	-	-
475-350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
600-475	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
																							2685	1065	191	15
															Polygastric average D/N total: 2776/2 =								1388			
															Eudoxid average D/N total: 1080/2 =								540			
6905-06																										
25- 0	1	0	50	0	0	4	0	0	-	76 + 740*	0	0	0	0	0	0	70	0	480	0	0	0	60	0	7	67
50- 25	0	2	6	0	0	0	-	0	-	0 + 40*	0	0	0	0	0	42	1	44	456	0	-	0	66	0	8	3
75- 50	8	0	10	0	0	0	-	0	-	0	18	0	16	0	0	0	0	75	27	0	0	0	8	0	6	0
100- 75	0	0	0	0	0	0	-	0	-	0	1	0	-	0	0	0	-	5	-	0	-	0	0.2	0	0.4	0
225-100	0	0	0	0	0	0	0	0	-	40	0	0	-	0	0	0	96	0	0	0	-	0	12	0	3	0
350-225	-	0	0	0	0	0	0	0	-	0	0	0	-	-	0	0	0	0	0	-	-	0	0	0	0	0
475-350	0	0	0	0	0	0	0	0	-	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0
600-475	0	0	0	0	0	0	-	0	-	0	0	0	-	0	0	0	0	-	0	0	-	0	0	0	0	0
																							146	0	24	70
															Polygastric average D/N total: 170/2 =								85			
															Eudoxid average D/N total: 70/2 =								35			
6908-09																										
25- 0	-	-	-	1022	-	82	-	2	0	0	184	0	0	0	510	90	0	0	30	0	0	0	103	0	119	0
50- 25	-	-	-	117	1944	82	18	196	0	0	66	0	0	0	225	1005	-	0	0	0	0	0	281	0	140	0
75- 50	-	-	-	0	1863	138	191	308	90	0	-	2	0	0	465	0	0	-	0	0	0	0	326	0	49	0
100- 75	-	-	-	0	710	4	148	-	0	0	2	45	0	0	0	0	0	0	15	0	0	0	97	0	5	0
225-100	0	-	0	0	5	-	760	1195	-	0	535	45	0	0	0	0	0	0	0	0	0	0	130	0	137	0
350-225	0	-	0	0	0	0	0	0	-	-	0	0	-	-	-	0	0	-	0	0	0	0	0	0	0	0
475-350	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
600-475	0	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
																							937	0	450	0
															Polygastric average D/N total: 1387/2 =								693			
															Eudoxid average D/N total:								0			
6911-12																										
25- 0	0	0	248	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0
50- 25	0	0	15	-	-	-	-	-	0	-	0	0	0	-	0	0	-	0	0	0	0	0	1	0	0	0
75- 50	0	0	92	-	-	-	-	-	-	-	0	0	0	-	0	0	0	-	0	0	0	0	11	0	0	0
100- 75	0	-	87	-	-	-	-	-	0	0	0	-	-	-	-	0	-	0	0	0	0	0	14	0	0	0
225-100	-	0	0	-	-	-	-	-	-	-	0	-	-	-	0	0	-	0	0	-	0	0	0	0	0	0
350-225	0	0	0	-	-	-	-	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	0	0	0	0
475-350	0	0	0	-	-	-	-	-	-	-	0	0	-	-	0	0	0	0	0	-	0	0	0	0	0	0
600-475	0	0	0	-	-	-	-	-	-	-	-	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0
																							53	0	0	0
															Polygastric average D/N total: 53/2 =								26			
															Eudoxid average D/N total:								0			

* Eudoxid

Table 2. Seasonal day/night bathymetric distribution of *Chelophyes appendiculata* (polygastric and eudoxid* stages) during 1969.

Sta. / Depth	70.60 D	70.60 N	70.75 D	70.75 N	70.90 D	70.90 N	70.110 D	70.110 N	90.45 D	90.45 N	90.60 D	90.60 N	90.90 D	90.90 N	120.45 D	120.45 N	120.55 D	120.55 N	120.70 D	120.70 N	120.90 D	120.90 N
6902-03																						
25- 0	32	154 + 34*	89	3	-	-	-	-	8	2	49 + 208*	21	-	+	0	2	51 + 58*	115 + 48*	46	90	14	83
50- 25	-	207	104	6	-	-	-	-	120*	18	38 + 35*	62	-	-	0	0	-	54	14	36	8*	7
75- 50	16	-	89 + 74*	-	-	-	-	-	5 + 5*	92*	43	30	-	-	0	0	-	3	28	8	-	-
100- 75	10	-	0	-	-	-	-	-	0	1 + 183*	24 + 35*	8	-	-	0	0	0	42	7	7	16	29
225-100	-	-	80	-	-	-	-	-	25	-	123	-	-	-	116	-	-	0	-	0	85 + 21*	134
350-225	-	-	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
475-350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
600-475	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Polygastric average D/N total: 187
Eudoxid average D/N total: 61

Sta. / Depth	70.60 D	70.60 N	70.75 D	70.75 N	70.90 D	70.90 N	70.110 D	70.110 N	90.45 D	90.45 N	90.60 D	90.60 N	90.90 D	90.90 N	120.45 D	120.45 N	120.55 D	120.55 N	120.70 D	120.70 N	120.90 D	120.90 N
6905-06																						
25- 0	1	26	120	81	40	5	8 + 2326*	83 + 416*	-	20	42	97	40 + 1000*	30 + 706*	19	80	76 + 9*	45	218 + 102*	59	3	1
50- 25	0	5	8	40	52	225	-	0	-	2	116	141	293 + 3244*	85	4	20	1	23	2	14	-	0
75- 50	1	0	8 + 16*	2	1 + 1*	2	-	2	-	2	101	26	1540	2	4	2	1	10	0	1	0	0
100- 75	11	0	11	1	2	0	-	24 + 30*	-	5	12	5	-	70 + 302*	14	18	-	180	-	12	-	0
225-100	0	115	0	0	100	40	50	5	-	45	50	10	-	30	10	0	10	70	10	0	-	0
350-225	-	0	0	0	60	5	15	0	-	25	84	75	-	-	5	0	0	0	30	-	-	0
475-350	0	0	0	0	0	0	5.	0	-	0	15	5	-	115	60	0	0	0	0	0	0	0
600-475	0	0	0	0	0	0	-	0	-	0	0	0	-	5	0	15	0	-	0	0	-	0

Polygastric average D/N total: 533/2 = 267
Eudoxid average D/N total: 1690/2 = 845

Sta. / Depth	70.60 D	70.60 N	70.75 D	70.75 N	70.90 D	70.90 N	70.110 D	70.110 N	90.45 D	90.45 N	90.60 D	90.60 N	90.90 D	90.90 N	120.45 D	120.45 N	120.55 D	120.55 N	120.70 D	120.70 N	120.90 D	120.90 N
6908-09																						
25- 0	-	-	-	6	-	2	-	85	0	1	16	102	385	110	0	5	19 + 81*	8	1	256	62	36
50- 25	-	-	-	4	16	2	3	475	0	1	10	61	186	411 + 1*	0	4	-	13	24	370	0	4
75- 50	-	-	-	0	61	2	195	0	0	0	-	2	9	74	0	2	61	-	1	9	2	0
100- 75	-	-	-	0	6	0	12	-	2	2	11	0	0	52	0	0	2	30	1	6	0	0
225-100	15	-	40	0	15	-	565	60	-	5	50	10	285	420	330	0	130	15	40	30	20	10
350-225	15	-	10	40	0	0	355	5	-	-	45	0	-	-	-	0	10	-	380	20	15 + 5*	30
475-350	0	-	0	0	0	0	0	0	0	0	0	0	0	30	0	75 + 75*	0	0	0	15	0	0
600-475	0	-	-	-	-	-	-	-	0	0	0	0	0	0	0	165	0	0	0	0	0	0

Polygastric average D/N total: 628/2 = 314
Eudoxid average D/N total: 18/2 = 9

Sta. / Depth	70.60 D	70.60 N	70.75 D	70.75 N	70.90 D	70.90 N	70.110 D	70.110 N	90.45 D	90.45 N	90.60 D	90.60 N	90.90 D	90.90 N	120.45 D	120.45 N	120.55 D	120.55 N	120.70 D	120.70 N	120.90 D	120.90 N
6911-12																						
25- 0	4	13	15	-	-	-	-	+	3	140	32	84	76	3	0	0	90*	50	0	0	38	95
50- 25	1	0	0	-	-	-	-	-	3	-	62	174	5	-	0	0	-	91	0	2	53	75
75- 50	20	0	2	-	-	-	-	-	-	-	56 + 1*	288	6	-	0	3	4	-	0	1	0	11
100- 75	2	-	56	-	-	-	-	+	0	18	4	-	-	-	-	1	-	0	4	0	1	3
225-100	-	0	30	-	-	-	-	-	-	-	260	-	460	75	30	30	-	5	20	-	20	20
350-225	0	0	0	-	-	-	-	-	-	-	145	120	-	-	0	35	0	0	20	0	-	0
475-350	0	0	0	-	-	-	-	-	-	-	80	0	10	-	0	0	0	0	0	-	0	0
600-475	0	0	0	-	-	-	-	-	-	-	-	10	0	-	-	0	0	0	0	0	0	0

Polygastric average D/N total: 443/2 = 221
Eudoxid average D/N total: 10/2 = 5

Total Average	Day Poly.	Day Eudox.	Night Poly.	Night Eudox.
6902-03	201	81	174	41
6905-06	553	1650	181	42
6908-09	305	11.6	526	7.1
6911-12	223	10.1	220	0

Table 3. Seasonal day/night bathymetric distribution of *Eudoxoides spiralis* (polygastric and eudoxid stages) during 1969.

Sta. / Depth	70.60 D	70.60 N	70.75 D	70.75 N	70.90 D	70.90 N	70..10 D	70..10 N	90.45 D	90.45 N	90.60 D	90.60 N	90.90 D	90.90 N	120.45 D	120.45 N	120.53 D	120.53 N	120.70 D	120.70 N	* 120.90 D	* 120.90 N	Total Average Day Poly.	Total Average Day Eudox.	Total Average Night Poly.	Total Average Night Eudox.
6902-03																										
25- 0	0	0	0	17*	-	-	-	-	0	0	0	0	-	-	0	9	117 19*	170 359*	535 265*	596 323*	28 20*	278 133*	60	38	168	108
50- 25	-	0	0	0	-	-	-	-	0	9	0	0	-	-	0	0	- -	197 84*	1518 252*	530 186*	42 21*	78 50*	260	42	101	40
75- 50	0	-	0	-	-	-	-	-	0	0	0	0	-	-	0	0	- -	78 60*	392 1404*	348 40*	-	-	65	24	93	21
100- 75	0	-	0	-	-	-	-	-	0	0	0	0	-	-	0	0	0 -	65 48*	45 24*	43 50*	10	54 35*	9	2	27	22
225-100	-	-	0	-	-	-	-	-	0	-	0	-	-	-	0	-	- -	0 -	- -	33* -	133 165*	0 -	33	41	0	0
350-225	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	-	-
475-350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
600-475	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
															Polygastric average D/N total: 815/2 =								426	147	389	191
															Eudoxid average D/N total: 348/2 =											
																							407			
																							174			
6905-06																										
25- 0	0	0	0	0	0	0	0	184 385*	-	0	0	2	0	16 384*	0	1	0	0	0	33 24*	30+ 134*	16*	3	13	21	55
50- 75	0	0	0	0	0	0	-	408 418*	-	0	0	0	9264*	30 45*	0	0	1 -	58* -	0 5*	16* -	-	33 6*	0.5	1158	42	49
75 -50	0	0	0	0	0	0	-	180	-	0	0	0	216 1078*	106*	0	0	0	0	0	0	1	0	24	118	16	9
100- 75	0	0	0	0	0	0	-	6	-	0	0	0	-	0	0	2	-	0	-	5 8*	-	0	0	0	1	0
225-100	0	0	0	0	0	0	0	5	-	0	0	0	-	0	0	0	0	0	0	0	-	0	0	0	0.4	0
350-275	-	0	0	0	0	0	0	5	-	0	0	0	-	-	0	0	0	0	0	-	-	0	0	0	0.5	0
475-350	0	0	0	0	0	0	0	5	-	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0.4	0
600-475	0	0	0	0	0	0	-	0	-	0	0	0	-	0	0	0	0	0	0	0	-	0	0	0	0	0
															Polygastric average D/N total: 108/2 =								27	1200	81.3	113
															Eudoxid average D/N total: 1402/2 =											
																							54			
																							701			
6908-09																										
25- 0	-	-	-	0	-	0	-	2	0	0	50 60	0	423 . 375*	45 15*	0	0	15 16*	0	45*	105			78	82	16	1
50- 25	-	-	-	0	0	0	0	0	0	0	31	1	165 . 168*	340 325*	0	0	- -	0 -	132 16*	91 -			46	26	50	56
75- 50	-	-	-	0	15	0	0	0	0	0	-	0	8	45	0	0	14 14*	-	1	0			4	2	9	0
100- 75	-	-	-	0	0	0	0	-	0	0	0	1	0	0	0	0	0	15	0	0			0	0	2	0
225-100	0	-	0	0	0	-	0	5 300*	-	0	0	0	0	0	0	0	0	0	0	70			0	0	9	37
350-225	0	-	0	0	0	0	0	5	-	-	0	0	-	-	-	0	0	-	0	0			0	0	0	0
475-350	0	-	0	0	0	5	0	0	0	0	0	0	5	10	0	0	0	0	0	0			0	0	1	0
600-475	0	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0
															Polygastric average D/N total: 215/2 =								126	110	87	74
															Eudoxid average D/N total: 184/2 =											
																							107			
																							92			
6911-12																										
25- 0	0	0	15	-	-	-	-	-	0	0	30*	0	236 . 360*	90 30*	0	0	0	0	0	0	15	45 60	29	43	16	11
50- 75	0	0	0	-	-	-	-	-	0	-	0	76	81 90*	-	0	0	- -	0 -	0	0	16	0	12	11	12	0
75- 50	2	0	0	-	-	-	-	-	-	-	1	0	31	-	0	0	0	-	0	0	0	0	4	0	0	0
100- 75	0	-	0	-	-	-	-	-	0	0	2	-	-	-	-	0	-	0	0	0	0	0	0	0	0	0
225-100	-	0	0	-	-	-	-	-	-	-	0	-	530 675*	0	0	0	-	0	0	-	0	0	88	112	0	0
350-225	0	0	0	-	-	-	-	-	-	-	0	0	-	-	0	0	0	0	0	0	-	0	0	0	0	0
475-350	0	0	0	-	-	-	-	-	-	-	0	0	0	-	0	0	0	0	0	-	0	0	0	0	0	0
600-475	0	0	0	-	-	-	-	-	-	-	-	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0
															Polygastric average D/N total: 161/2 =								155	164	78	11
															Eudoxid average D/N total: 177/2 =											
																							60			
																							88			

* Eudoxid stage